The Information Society: Technological, socio-economic and cultural aspects

Prolegomena for a sustainability-oriented ethics of ICT

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Abstract *This thesis studies the enabling properties of ICT and their effects and potential for social change, and prepares the ground for a sustainability-oriented ethico-political assessment of this technology. It primarily builds on interdisciplinary scholarship to describe and explain the multifaceted co-evolution between the global deployment of ICTs and the emergence of the Information Society, understood as a socio-economic restructuring of capitalism. Beyond the role of ICTs in this regime transition, the thesis delivers other philosophical insights about crucial aspects of ICT development, applications and management. These include arguments about how we should conceptualize ICTs on the basis of their different roles in extending human communication and in performing or facilitating the remote control of humans and animals, machines and systems operations; about the entanglement between telecommunications, transport networks, urban development and work and organization; and about the relations between ICTs, culture and human values. Examples are offered to illustrate the potential that these empirical and philosophical lessons may hold for the construction of a framework for the ethico-political assessment of ICTs.*

Keywords Information & Communication Technology; AI; Internet; Information Society; Industrial Society; innovation; capitalism; rationalization; digitalization; automation; socio-economic restructuring; philosophy of information; philosophy of computing; philosophy of media.

Acknowledgments *To Cristina, her family and our little baby monster. To the University of Twente, for having granted me a unique professional opportunity. To uncountable contacts and trolls from my Facebook echo chamber, for the discussions, arguments and evidence with which they have anonymously contributed to the development of this thesis.*

Summary of contents

Introduction and Plan of the Thesis

Information and Communication Technologies (ICTs) are converging technologies that, beginning in the 60s and 70s, have had a worldwide diffusion to penetrate all social fields: business, government, consumer markets and, therefore, the daily life of billions. As a result, ICTs have deeply transformed our societies and cultures to an extent that, in recent times, is perhaps only paralleled by the massive diffusion of electricity, cars and telephony since the early 20th century (Gordon 2012). The breadth and scope of the changes induced by ICTs has been so overwhelming as to elicit the view that they have brought about a transition from the Industrial Society toward the Information Society[1].

This thesis is an enquiry about the ways in which ICTs and the Information Society have co-shaped one another, and an attempt to describe and grasp the relations between the major technical, socio-political and cultural trends that have emerged in the process.

But the piece is also conceived and organized as a preliminary background research that would be necessary to undertake a broader philosophical project about the impact of ICTs on sustainability and other values. More specifically, the guiding aim of that broader project, whose urgency I have defended somewhere else[2], is to develop an analytical framework for the ethico-political assessment of ICTs, such that it enables researchers to grapple with the value tradeoffs and conflicts that are likely to surface in ICT-enabled strategies for sustainability.

This has immediate consequences for the present text. One is that, since it belongs to a broader project that aims to understand and assess the ways in which ICTs impact on the value of sustainability, the reader may notice, at times, an emphasis on problems and discussions that are primarily relevant to that specific issue. On the other hand, this text forms a coherent unity of discourse whose significance is by no means limited to lessons

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[1]The use of the singular and capitals to speak of the Industrial Society or the Information Society needs a brief commentary, since many authors would only speak of "societies", in lower case and plural. In particular, while some hold that societies can only arise from nation states, others make societies coincide with cultural nations; further, one might also regard some indigenous tribes, or clans thereof, as societies that are semi-independent from any nation. My use of the singular thus evokes the fact that the Industrial Society and the Information Society presuppose a large degree of global integration of nations, states and cultures to give raise to a world system whose properties and functioning cannot be understood by reference to any single 'geographical' society and, more controversially perhaps, not even to inter-national relations. On the other hand, the functioning of this global system is reflected, to a greater or lesser degree, in realities or vectors of transformation that are progressively impinging upon the geographically and historically distinct societies –in whatever meaning of the term. This is a basic lesson that can be drawn from more exhaustive investigations on Modernity, capitalism or the Information Society, and that I assume all throughout the text (Marx 1959, 1976; Giddens 1990; Castells 1996).

[2]See my PhD proposal (annex I).

about the impact of ICTs on sustainability. In fact, the link of many findings of the thesis with practical ethico-political questions is often unapparent, and awaits further work.

This gives me occasion to remark that, due to obvious limitations of space and time, this work cannot be an exhaustive analysis of all the relations about ICTs and society, let alone a disclosure of the origin and type of all the ethico-political challenges that emerge from the deployment and use of ICTs. However, it synthesizes many of the fruitful conceptual or empirical insights found in the literature about ICTs and the Information Society, and interprets them with philosophical rigor. Sometimes, direct ethico-political implications of those phenomena and trends are suggested; in other places, the text engages in conceptual or methodological discussions with the aim to shed a light onto the groundwork necessary to formulate ethico-political issues properly. Therefore, the method and inspiration of the thesis is clearly materialist at least in the two following senses: first, it tries to derive dominant societal values and potential factors of ethico-political conflict directly from trends whose existence and character is supported by the best science available to the author; second, this evidence is interpreted in a way that presents a potential for further conceptual and empirical revision.

Delving more closely into matters of method, I have sought to describe the characteristic patterns of the Information Society by placing a special emphasis on the interplay between its technological basis –that is, ICTs- and its broader socio-economic, political and cultural context. Although this sharp distinction between technology and society may be controversial to some, there are reasons to abide by it.

Firstly, a seminal book on the Information Society, *The Network Society* (Castells 1996), has similarly portrayed the rise of this society as involving the emergence of a new technological system, based on ICTs, coupled with many other socio-economic, institutional and cultural changes. In fact, a crucial passage of this book advances a causal account of this process, according to which, although ICTs arose from an "autonomous dynamics of technological discovery and diffusion", their applications were "decisively shaped by the historical context in which [they] expanded" (ibid, 51ss). This context was the industrial capitalism of the 70s, which featured cultural, socio-economic and ecological crises whose resolution would come about in the 80s through a radical socioeconomic restructuring. More importantly still: although aspects of this restructuring had been setting in Western countries since the 50s, Castells contends that, once the established uses of ICTs gained momentum and diffused in the 70s and 80s, they were instrumental for advancing and accelerating that restructuring.

Further, this account of the interplay between ICTs and the essential trends of the Information Society is not only largely supported by other major assessments of the topic (Sassen 1991; Graham & Marvin 1996; van Dijk 2006); in addition, it agrees well with long-standing and empirically well-seated theories that, in the last decades, have guided research in philosophy of technology and STS, as well as practices of technology assessment. In these traditions, a basic methodological tenet has it that two types of forces commonly interact in the transformation of modern societies and technological development itself. On the one hand, some forces are embedded in already existing technology. This technology may be so entrenched in society that it comes to constitute further societal processes, or at least has a large influence upon them. To the extent that such influence exists, dominant social values or subsequent social transformations can be said to be path-dependent on, or locked-in by, that technology (Collingridge 1980). There are, therefore, purely *technological forces* acting upon individuals and societies. Yet there are also extra-technological, or broadly *social forces,* that bear importantly upon the development of any emerging technology, and thus upon society too –though this time, insofar as technology is concerned, this sort of influence is indirect. The two forces can be seen to interact and compound in the following way: while social interests and structures influence and shape new technological developments and applications, these, once entrenched, come to shape society in turn.

In consequence, the distinctions between technology and society, and technological and social forces, are theoretically sound. Further, the distinction between technological and social forces has practical relevance for technology assessment (TA) insofar as it clarifies the scope and limits of this practice *while also offering insights to guide its coordination with other policy-oriented practices* where, although technology may be the end-point of reform, other institutional, cultural or economic factors have to enter the picture as well, *in order for reforms to be effective -and assessments practical*.

These reasons have led me to take Castells' remarks as methodological cues to organize the plan of the thesis. Consequently, in the first chapter I address the central features of ICTs and the synergistic techno-scientific developments that led to them. Then, in the second, I describe an array of socio-economic and cultural trends that can be provisionally considered as intrinsic implications of the deployment and use of ICTs, as these technologies were described in the first chapter. Now, since the Information Society is primarily characterized by a worldwide, large scale diffusion and use of ICTs, such trends can be safely regarded as essential and irreversible patterns of the Information Society…as well as of future societies that are yet to come.

Chapters three and four will dissipate the impression of technological determinism aroused by chapter two, by highlighting several ways in which the development of ICTs has been affected by the confluence of different causes of social import. To this effect, the approach in these two sections will involve the critical scrutiny of pieces of research in the intersection of a variety of disciplines from the social sciences, such as political economy, sociology, urban theory or STS. In chapter three, I rely on the work of prominent authors such as Marx (1959; 1976) or Beniger (1986) to present and discuss the distinctive features and tendencies of industrial capitalism, and thus of the Industrial Society. Then, in chapter four, I examine the main processes involved in the socio-economic restructuring of capitalism in the 70s and 80s. This allows me to compare the Industrial Society and the Information Society, in order to specify both their differences and similarities. In this regard, of course, special attention is paid to the interplay between ICTs (or their predecessors) and the broader social forces that have shaped, and been shaped by, these technologies.

I conclude with a brief chapter that recapitulates the main findings of the thesis and some of their implications. Here I will also highlight a few important challenges that these findings pose for a rigorous ethico-political assessment of ICTs and information. The reader may understand these remarks as suggestions for future research.

1. ICTs as the technical basis of the Information Society.

ICTs are the synergistic outcome of techno-scientific innovations with two basic roots: applied physics (solid-state physics, electronics, optics) and engineering fields adjacent to the formal sciences (logic, cybernetics, computer science, information theory). This chapter follows these developments by directly comparing ICTs with the technologies they transformed or replaced. To this effect, I first present concepts of media theory that have been used to compare ICTs with their predecessors (1.1.). Then I address the technical trends leading from these media to ICTs: electronics (1.2), digitization (1.3), computerization (1.4), and a layered organization of infrastructure and equipment (1.5).

1.1. Media theory and communication technologies

ICTs are often understood as media technology. In this widespread functional view, media *technologies* are those *used to bridge space or time in human communication.* One of its proponents is van Dijk (2006), who offers a detailed set of categories to compare the contributions of different media. Here I briefly present its most interesting aspects.

First, he identifies four *traffic patterns* which differ in the source of determination of the time, speed, content and subject matter of communication (Fig. 1.1). Each of these patterns is typically embodied by concrete media and sustained by specific social structures, which it tends to reinforce.

- In *consultation*, local units request information from a central source that accumulates information. They have the freedom to choose from a limited variety of messages, and to interpret them at their convenience.
- In *registration*, central sources ask local units for information. This enables data accumulation and enhanced consultation activities, but also monitoring or control. This pattern is often related to the membership of units to social organizations.
- In *allocution*, a central source issues standard messages (norms, commands…) to a mass of isolated local units, themselves standardized by the source.
- In *conversation,* units address a shared medium that becomes the true source of

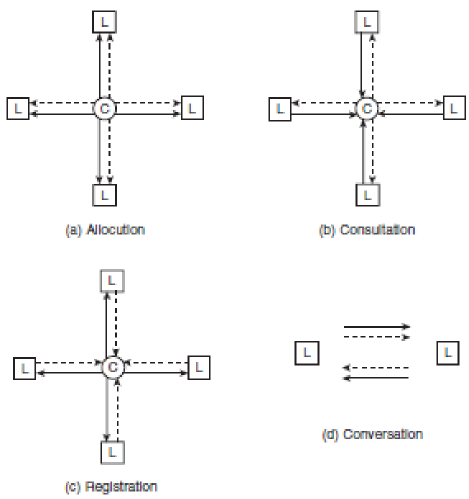

Fig 1.1. van Dijk's four kinds of traffic patterns

information in substitution of any central organ[3]. This point-to-point or end-to-end pattern sharply contrasts with other traffic patterns, which are point-multipoint.

Second, *artificial memories* need to be distinguished from *transmission links* in that, while the former are "offline media" that enable humans to bridge time, the latter are "online media" for bridging space (Fig.1.2). These are the defining capabilities of media, by virtue of which they can replace or complement face-to-face communication.

Artificial memories store information in durable materials which, in being fixed to places, create a place-bound shared medium that persists across generations: think of inscriptions in edifices. Artificial memories are offline media because the information-related tasks they afford (i) are fixed to place, and (ii) endure beyond communication. They enable consultation (libraries) or registration (statistics).

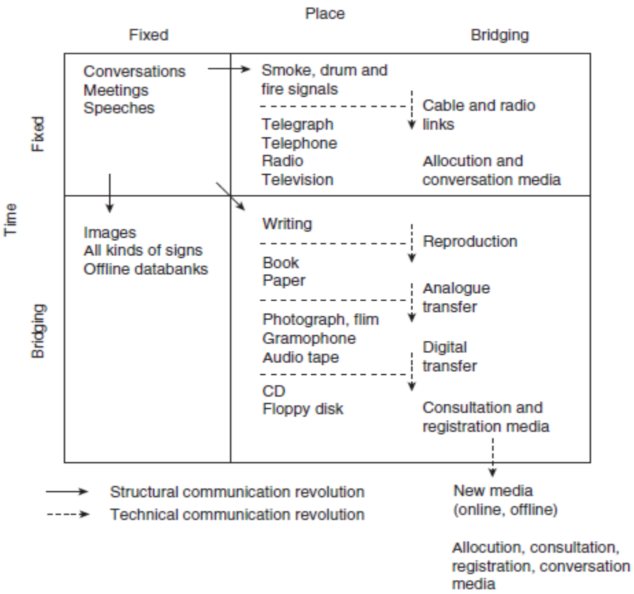

Fig 1.2. van Dijk's functional chronogram of media

In contrast, *transmission links* [4] bridge space through the transmission of signals across distant places. This demands a smart use of natural channels (fire signals) or deploying new ones (telephony). They are online media because the informational tasks they involve emerge from the act of distance communication itself: they are time- rather than place-bound.

Finally, media like books, coins or maps[5] enjoy features of both artificial memories and transmission links because they are easy to circulate, which allows a quick diffusion of signals, almost amounting to online activity. Then, as they endure across generations, and can be accumulated and used in solitude (offline), they bridge both space and time. This is why the invention of writing

[3]Standard codes aid end-to-end interpretation and are, thus, also necessary to build shared media. In fire signals, for instance, meanings have to be agreed upon beforehand; and telephony also entails the use of a common language. Coding may affect details of both content and form. Famously, Charlemagne established the Carolingian type in writing, in order to ease the governance of his empire (Burke 1985).

[4]"Transmission link" must not be understood as standing merely for a *physical link* like, for instance, the electric circuit. In addition to links, distance communication also requires a shared code (see note 3).

[5]Consider Giddens' circulating *tokens* (1990) or Latour's *immutable mobiles* (1983).

was a structural communications revolution (van Dijk 2006)[6]. However, not even these media can circulate on their own, and therefore the long-distance circulation of the information they convey was only possible either by physically transporting the information device together with a carrier (e.g. shipping books), or having the receiver of information carried to the source (e.g. visiting galleries or libraries). Time constraints are of course critical in these contexts, since the non-availability of transmission links raises delays, message corruption and related issues. For this reason, the need to overcome time constraints always constituted, for pre-modern and early modern civilizations, a constant pressure to develop large urban nodes and networks of cities connected by short-sea shipping and river transport, so that many different material substrates and carriers of information could circulate through reliable and appropriate channels. This close coupling between transport, cities and media is why all three can be labeled as *communication technologies*.

A third way of classifying media addresses their mode of production. Pre-modern media extended communication by *craft* (painting, paper). Modern *mechanical media* enabled mass reproduction (print, videotapes, cinema rolls, phonograph), thus granting more availability of copies and greater freedom of choice in consultation. In turn, *electric media* (Brey 1999) were the first transmission links working at national, transnational and transcontinental (i.e. global) scales, yielding three communication modes: data exchange, (voice) telecommunications (voice) and broadcast media (radio, TV).

1.2. Electronics and other material changes in telecommunications

With regards to the material basis of infrastructure and equipment, an identifiable trend starts with manual data handling and transmission; the progressive mechanization of this process, up to fully electrified electromechanical devices; and, finally, a transition toward electronic and optic-electronic equipment. Circuit switching in basic telephony exemplifies this trend. First performed manually, switching was automated in successive waves of innovation: from mechanical *rotary* switches it turned to electromechanical *relays*; finally, in the 80s, it was fully digitized and computerized. In broadcast media the latter transition took place later, at the turn of the 21st century (van Dijk 2006).

Since the 60s, the advances in the microelectronics of silicon semi-conductors have been huge, leading to microprocessors of astounding speeds and memories of huge

[6] However, the same could be said of money or scientific cartography.

storage capacities. These advances are epitomized by Moore's Law, which predicts a doubling of the number of transistors in integrated circuits approximately every 18/24 months, meaning that computer power would double every two years (Moore 1965). The effects of the continued compliance of this law will be examined below[7].

Other advances, not reducible to electronics, have enhanced the capacity and other features of transmission links, yielding high-speed *broadband* networks. A landmark here is the world-wide provision of *fiber optics*. Cupper twisted pairs always were the cheapest technology for short-distance links, and still today they are the typical solution in subscriber branches or customer premises; for instance, they still dominate in Local Area Networks (LANs). In telecommunications and data communications[8], twisted pairs were complementary to coaxial links serving as high-capacity distribution trunks for Metropolitan Area Networks (MANs) or between them (in Wide Area Networks, WANs). Yet, coaxial trunks could not satisfy a thriving demand for broadband connections –as patent in the growing numbers of TV channels (van Dijk 2006, 50). Fiber optics satisfied that demand by massively boosting the capacity (bandwidth) of trunks and distribution lines, due to its low attenuation in long distances[9]. This enabled real-time transmission of audio and video, which contributed to integrate broadcast with other flows by cable. As a result, fiber optics has simultaneously relegated coaxial links and air transmission.

1.3. Digitization

Digitization[10]or *digitizing* involves changes in signal processing techniques, but also in infrastructure and equipment. Analogue data or signals vary continuously, for they are mechanical reproductions or measurements of physical things or events which vary smoothly too (Floridi 2010). In analogue systems like the Plain Old Telephone Service (POTS) or early radio, codification was not required in addition to electromechanical signal processing: the only codes were the social conventions about how to interpret the contents of an exchange. In contrast, digital signals vary discretely, entailing the ongoing and deliberate use of a code, as well as *sampling* and *quantization* techniques.

[7]Though Moore's Law is usually understood as a quasi-natural law, in fact it has often had a constructive or prospective role in building the R&D agenda in the field of microelectronics (Rip 1998).

[8]Broadcast transmission was done by air -through electromagnetic waves.

[9]Increases in bandwidth are captured by *Guilder's Law,* which holds that communication power doubles every 6 months, thus growing three times as fast as computer power in Moore's predictions (ibid)

[10]Digitization must be distinguished from *digitalization*, which has a broader meaning (see 4.2.4).

The model for the digitization of all media came from data networks, where *digital transmission* was already used both in telegraphy (Morse code) and its successor the telex (working over a variety of codes). Although telegraphy used digital transmission, however, the operation of the system required the intervention of Morse experts. Instead, the teleprinters used in telex automated the coding and decoding between terminals. Yet, still then, the exchange and printing of telex data required manual pre-formatting: a teleprinter expert had to punch cards and feed teleprinters with them[11].

Digital signal processing poses an important shift from digital transmission, aided by manual or electromechanical processing and/or encoding, to systems where digital inputs are produced either directly, from peripherals connected to computers; or from analogue inputs, processed in automatic analog/digital (A/D) conversions[12]. Our first claim can now be qualified to hold that the material basis of digital signal processing is electronic technology *operating with binary digital coding*. A keystone of this innovation was Boole's algebra, a formalism for describing logical relations predating mathematical logic. This system expresses the outcomes of calculation in bivalent variables -taking the values '0' and '1'. Yet, digital signal processing became technically possible only when Shannon (1938) found out that certain electrical (*electronic*) circuits behaved like the calculations of Boole's algebra. This invited the physical realization of Boole's algebra in automatic machines. Today, Boolean logic is a standard for most computer architectures, machine code, high-order programming languages and assembly languages alike[13].

Since multi-valued digital electronics was equally possible, the widespread adoption of binary digital codes needs explanation. At least two reasons can be given. First, each *bit* divides probability spaces in two equiprobable spaces, and it appears that sequences of questions with predefined possible answers satisfying this pattern provide the most efficient way -with the least number of computations, given a maximum error threshold- for structuring decision-making problems (Shannon & Weaver 1949; Hilbert 2015). A second reason, related to the first, also explains why digital circuits outperform analogue ones: because they were superior in discriminating signals, they were a more

[11]Telex is a switched network of teleprinters evolved from the telegraph. Though it could support both point-to-point and point-to-multipoint data exchange, the broadcasting potential (allocution) of telex was seldom realized, in favor of commercial and administrative uses. Further, it also differed from telephony in that the latter reached not only offices, but also households.

[12]The short life of teleprinters was thus parallel to that of their expert operators. Automatic digital processing (i.e. computers) made them both obsolete.

[13]Assembly languages translate high-level programming languages to machine code.

efficient and reliable transmission method in the face of interference and noise -a crucial aspect in communication (van Dijk 2006). Thus, digitization made signal transmission and processing more flexible and reliable. This had manifold advantages. For instance, it facilitated the implementation of new switching techniques such as *packet switching* and *cell switching*[14]. It also became possible to aggregate channels in compound signals, as in Cable TV; or to combine different kinds of service (telephony, internet) or traffic (audio, video or text) upon the same carrier signal, as in Voice over IP (VoIP) or Cable TV. Finally, a long-standing obstacle in the digitization of audiovisual contents had been the need to attain high fidelity after decoding, in order to retrieve the smoothness of original signals –a problem which was solved by advances in microelectronics, aided by new compression and decompression techniques. Altogether, these changes allowed the mass production of digital *multimedia* devices and services, which made compatible, and indeed merged, the production, transmission and use of text, audio and video.

1.4. Computerization

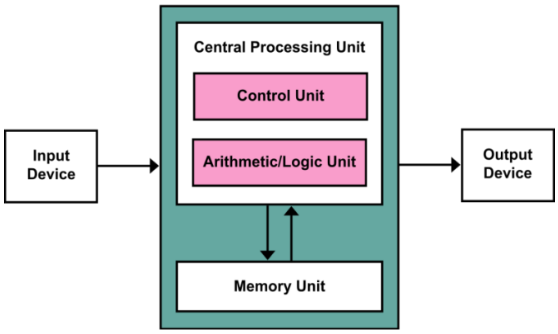

Fig. 1.3. Von Neumann's computer architecture

Computerization refers to the growing presence of computers in infrastructure and equipment, including a variety of mass-marketed devices –from cars to watches. The Turing Machine is often referred to as the most influential abstract description of a digital computer. Computers can be understood as automated digital signal processing machines, as implicitly defined above, but an alternative view, more akin to Turing's concept, could be "[machines that] can process information in accordance with lists of instructions" (Brey & Søraker 2009). Though a Turing machine may handle analogue inputs, both its internal instructions and its outputs use binary digits. Its basic operation is as follows: a head or processor can move along a (potentially) infinitely long tape of external memory where it reads '0's and '1's; its successive operations (read, write, erase or move forward-backward) are determined by the readings of the head and by a (finite) internal list of transition functions. This concept of computation turned out to be

[14]The Asynchronous Transfer Mode (ATM), a subtype of the latter, merits some attention. ATM divides messages in tiny packages tagged with addresses; then sends them through networks, where their small size allows them to cross even the most congested links; in destination, they lie on wait until the rest of packages comprising the original message are received; once this is the case, the original messages are retrieved and reproduced. The ATM method massively improves the efficiency of network capacity use.

powerful and flexible enough to become a paradigm for research and development in computer science. Closely connected was Von Neumann's contribution, a general architecture of computers capable of implementing any Turing Machine (Fig 1.3).

Computers, however, did not result directly from *digital electronics*. Instead, they followed the step-wise trends above referred: from analogue to digital signals, from mechanical to electronic devices. In fact, until 1940 they were analogue and mechanical, and most of them only executed pre-programmed operations. Programmable computers were developed in the 50s, firstly electromechanical (with relays, 1st generation); then all-electric and digital (with vacuum tubes, 2nd), later with discrete transistors (3rd) and, finally, with integrated circuits made of ever-increasing numbers of transistors (4th). This culminated in personal computers (PCs) and the general computerization of communications infrastructure, enabling more recent services such as cloud computing.

1.5. Architecture or layered organization in computers and computer networks

The emergence of advanced computers and computer networks –including the Internet-, required key innovations along a fourth aspect: the general *architecture of computers and computer networks*, or their *layered organization*. In networks, I discuss two related trends: the *integration* of devices in networks and the *interoperability*-driven *convergence* of technology, processing techniques, services and contents. In computers, I discuss the hardware/software distinction. I conclude by analyzing how memories and software are organized through nesting or recursivity to allow the programming of intelligent tasks, or artificial intelligence (AI).

Network architecture: the OSI model.

Networks can be minimally organized in three layers (infrastructure, transport and operation) but often feature the seven layers of the Open Systems Interconnection model (OSI): physical, data-link, network, transport, session, presentation and application. Based on recommendations made by the International Organization for Standardization (ISO), OSI is, today, tacitly or explicitly accepted by service providers, programmers and users alike. OSI is a

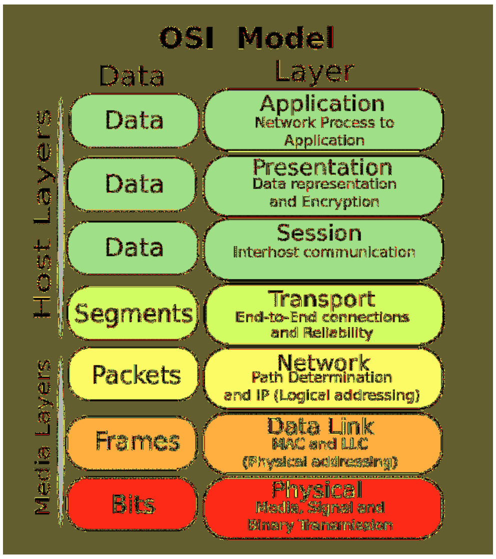

Fig. 1.4. The OSI model

neat expression of layered organization in integrated systems and, consequently, of the socio-technical advantages and problems of standardization and hierarchy (Fig 1.4)[15].

On the one hand, OSI is just an abstract model by which computers are “horizontally integrated” in networks through vertical integration (the conceptual hierarchy); so that computers can not only connect with one another, but also share resources, provide joint services or handle multiple data formats. OSI underlies the interactions between servers or between users and servers, allowing users to upload, download or process information by accessing virtual environments that generate out of the communication between local and remote applications. In this regard, Van Dijk highlights the relevance of the *store and forward principle*, by which contents stored in electronic memories and databases are also accessible by software programs or remote applications.

On the other hand, the successful operation of applications demands coordinating the exchange of frames, establishing reliable logical links, and so on. This, in turn, entails the need for the other side of OSI: the adoption of a common set of conventions by all parties networked, thus turning OSI’s conceptual hierarchy into an operational standard: for instance, OSI regulates end-to-end information exchange between user and server nodes with a decentralized routing of messages through TCP/IP (van Dijk 2006) – see Fig 1.4. Although often phrased as a choice of standard protocols, this also involves choices of standard technology. From this latter standpoint, the central phenomenon is less one of integration than one of *convergence* for the sake of *interoperability*.

Computer architecture: the hardware/software distinction

Now consider the layered organization used in computers and software. In computer science, there is a classic distinction between physical components, or hardware; and the virtual systems that they instantiate, or software. This distinction, however, has some problems. First, it disregards the difference between memories and programs – software properly so called; while, for Turing and Von Neumann, these held external relations to one another. Another way to put this is that data are *factual* or *instructional*. Factual data are *representations* of worldly facts, but also facts about the hardware or about internal or online applications; while, in contrast, programs are made of instructional data. In a different sense, however, both memories and programs are constituted by *primary data*, that is, ‘0’s and ‘1’s that are stored in physical computer

[15] https://www.lifewire.com/osi-model-reference-guide-816289

memory, i.e. hardware[16]. Summing up, the concepts "memory" and "software" can be interpreted so as to not fit sharply into the hardware/software dichotomy.

Second, this dichotomy makes no sense from Turing's own view, where hardware and software do not exist separately because a computer is intrinsically a physical system that handles lists of instructions. This close relationship between hardware and software is apparent, for instance, in *firmware*, a type of software that may often be permanently installed in a ROM (read-only memory); so that, when firmware fails, some integrated circuits may need replacement[17].

Still, the hardware/software distinction has pragmatic value insofar as it allows us to distinguish layers of computer organization. At the basis lies the *operating system* (OS), needed to run all other programs and that can act upon any of them, except for firmware. Nowadays, OSs are often totally virtual systems, i.e. their operation can be emulated by different computer hardware. Moreover, rather than being embedded in physical circuits that realize their preprogrammed functions automatically, OSs run on random-access memory (RAM) and thus they can be updated or replaced. At still higher levels, programs operate by calling the functions of OSs, and even other programs. Still, these programs may elicit hardware requirements in terms of speed or computational power, memory, graphic quality and the like. In this context, the hardware/software distinction is made to shed light on compatibility issues –where this concept highlights similar, but not identical phenomena as the concept of interoperability.

Layered organization in electronic memories

The differences between physical memories lie on their being modifiable (RAM) or not (ROM), and on how they are instantiated. Many ROM functions trigger merely by pushing a button that starts the computer, but normal use requires booting the OS (often automatically) plus starting programs by clicking or typing commands, i.e. manually. Other applications even need Internet connection to run. This, in turn, demands the coordination of numerous -largely automatic- local and remote operations through OSI.

Memories are hierarchically organized, but their hierarchy has a defining feature: its transparency. Computer, software and network architectures are often *opaque* to users, meaning that their customization or maintenance requires expert skills. In contrast,

[16]See Floridi (2010) for a more elaborate typology of data.

[17]Sophisticated computing is actually possible only since motherboards came to integrate many circuits of considerable complexity.

memory is not organized in a totally automatic or pre-programmed way. Further, it is represented at the *interface* level, thus being *transparent* to users, who can change most of it at will[18]. More specifically, memories organize in self-similar directories that may include several other virtual objects: programs, documents or other directories. This is called *nesting*, a type of layered organization also used by individual programs for creating or managing electronic memories like *databases*, *knowledge bases* or *ontologies*.

Insofar as virtual objects are available for many users, publicly or otherwise, the problems they raise resemble the interoperability issues that led to adopting OSI. Having been labeled as "Tower of Babel" problems (Brey & Soraker 2009), they have motivated the creation of software such as Database Management Systems (DMS). The urgency of pressures toward convergence; not of technology here, but rather of concepts and tags; is especially clear in attempts to build "domain- and application-independent ontologies […] that can be shared by different data models in different domains". This purpose has had a general interest for data mining, particularly in activities such as "natural language translation, mechanical engineering, electronic commerce, geographic information systems [or GIS], legal information systems and […] biomedicine" (ibid, 21-22).

Organization in software, and Artificial Intelligence (AI)

In a simple definition, programming languages can be regarded as "virtual machines" with prototyped functions that call on simpler computer functions. A source code uses those functions to generate, out of them, even more complex ones. When a code is compiled and executed successfully, a program is realized. Programs may serve two basic goals. They can access to peripherals, inner memories or online environments in order to retrieve and modify existing representations (stored data) and forward them – to other networking nodes, or to peripherals. Or they can build upon those data, or constructs of them, to run *simulations*: virtual courses of action that offer the tools for monitoring both the developing process and the resulting product.

Nesting crucially grounds these capabilities for navigating memories and networks, as well as simulating. Nesting is achieved in creating (self-similar) recursive structures whereby control functions can be placed into one another, thus resulting in cumulative logical hierarchies with complexity gains from one level to another. This complexity can

[18]This applies to software and configuration. Most computer users can navigate the Internet in the search for the software updates that better satisfy their needs. This shows that digital skills and the training needed to master them are a matter of degree (more on this on 4.4).

then be easily conferred to databanks, rapidly diffused to similar programs, or embedded in "intelligent systems" or artificial intelligence (AI).

Here I shall merely illustrate some strands of AI research and techniques, aiming to gain an insight about their implications. Brey and Søraker (ibid) distinguish three concepts of AI. The aim of *strong AI* is to study human intelligence by replicating it in algorithms or programs, which entails a second aim: to endow programs with an *Artificial General Intelligence* (AGI). Many contend that such controversial aims and tenets are doomed to fail (Dreyfus 1972). Proponents of weak AI defend a more cautious approach: while being equally committed to building automata capable of intelligent tasks, and even *Artificial Super Intelligence* (ASI), they deny that such programs would resemble human intelligence. Lastly, the *engineering approach* assumes that all programs capable of intelligent tasks qualify as AI. The goal here is to apply AI techniques in "areas such as data mining, ontological engineering, computer networking, agent technology, robotics, computer vision, human-computer interaction, ubiquitous computing and embedded systems" (ibid, 30). Clearly, this broader concept of AI can be interpreted so as to encompass computer functions as simple as the automatic translation of symbols from/to binary code–since homologue tasks were once executed by intelligent (human) telegraph operators. Yet, one needs not go this far to admit that many software applications perform intelligent tasks, and can thus qualify as AI. Therefore, with the stated reservation, I will subsequently stick to this concept of AI.

Among the most prominent advances in AI, some deserve a closer look.

Expert systems belong to *symbolic AI*, the first generation of AI. Entirely designed by human hand, they codify sets of explicit rules for acting upon a knowledge base to return "reliable and accurate answers in response to non-experts' queries" (ibid, 30). Some of these rules are built-in by *ad hoc* methods in order to fix when and how other rules will be applied, thus solving the so-called *infinite regress problem of applying rules* (Dreyfus 1972). Though an initial aim of their developers was to automate expert labor in various domains, the scope of such substitution has been limited. A reason may be that human experts often make "intuitive and holistic judgments" upon the basis of tacit knowledge that cannot be made explicit and encoded in programs (ibid; Brey & Søraker 2009, 30).

A second generation of AI drew on an alternative paradigm, *connectionism* or *neural nets*, in order to overcome the alluded limits of symbolic AI. Neural nets solve difficult tasks without rules or representations that are directly programmed by human hand, by recursively applying closed-loop models that are continuously simulated and compared with desired performance targets. Errors, or deviations from stated expectations, are measured and fed back into the models (Clark 2013); then these are slightly changed with the aid of statistical techniques, thus yielding more accurate performances –that is why they are said to learn. Three basic regimes of training can be identified (Thomas et al. 2016), each aimed at developing greater levels of autonomy in the AI. In *supervised methods*, training materials are collected and processed by engineers. In *semi-supervised methods,* the AI is placed in certain chosen virtual environments in computer networks, like Internet forums or social networks, where it can interact with human users or other AI and learn from them, though in relatively "expected" and controlled ways. Finally, in the more radical but as yet largely unfeasible approach of *unsupervised training*, the AI is literally "freed" on the Internet, so that it can seek the materials for its own training (Schuller 2015; Thomas et al. 2016). Lines of automata with "emotional capabilities" devised in affective computing (Picard 1997) and famous applications such as AlphaGo[19] belong to this class of AI, often labeled as *machine learning.*

These advances have allowed the development of *artificial agents*, often through technological mixtures of symbolic and connectionist AI. For AIs to qualify as artificial agent, they must have four properties (Brey & Søraker 2009, 37). The first, i.e. their *situatedness* in environments they can change, is arguably shared with virtual systems such as expert systems, and even with the most rudimentary videogame characters. The other three, however, distinguish artificial agents from the latter: these are *adaptivity* (through machine learning techniques), *autonomy* (especially in semi-supervised or unsupervised AI) and *sociability* (enabled by advances in affective computing and human-computer interaction). Together with internet connection, these features allow artificial agents not just to interact with humans and other AI, but also to learn from them and even to act upon remote virtual-physical systems out of specifications which may not be strictly designed by a concrete human developer.

[19]In 2016 AlphaGo became the world champion of Go, whose computational complexity had so far been unassailable to programs. This showed the potential of machine-learning for complex problem-solving. (https://aibusiness.com/deepminds-alpha-go-defeats-worlds-best-go-player-three-match-series/)

2. The intrinsic implications of ICTs.

Once the basic trends of development of ICTs have been examined, it is worthwhile to ask what they entail. This chapter is such an attempt to review the phenomena that result from the deployment of ICTs. While some can be seen to almost logically follow from the previously detected trends, others are intricately connected to broader social phenomena, and thus they will be reappraised throughout the essay. These are:

- Integration and convergence: multimedia, telematics and multi-functionality.
- Ubiquitous connectivity and ubiquitous computing.
- Self-reinforcing growth in the volume and complexity of information.
- Self-reinforcing polarization in networks.
- Pressures toward concentration of capital and centralization of management.
- Virtualization and virtual commodities.
- A structural revolution in control and communications.

2.1. Integration and convergence.

Van Dijk (2006) has insisted in the fact that ICTs promote a process of integration and convergence at all levels: infrastructure, signal transmission, management, services and types of traffic. Since the previous chapter offers abundant examples of convergence and integration, here I focus on multimedia, telematics and the multi-functionality of devices, due to their relevance for understanding other features of the Information Society.

Multimedia, itself resulting from a convergence toward digitization and electronics, stands for the integration of different types of traffic and data (text, audio and text). Though the integration takes place already in carrier signals, it becomes transparent to users in many ways. One can, for instance, navigate online environments through hyperlinks containing audio, video, text or blends of them. Further, multimedia services have allowed telecommunications, data exchanges and mass communications to merge.

At the level of disciplines or techniques, *telematics* is a neologism that conveys the integration of TELEcommunications and inforMATICS. It must be distinguished from the closely related *telemetry* in that, while the latter involves measuring and monitoring of objects at distance, the former also includes control at distance both through distributed methods such as the TCP/IP protocol, or strategies of Dynamic Model Predictive Control (DMPC); and centralized methods like ATM or Central Model Predictive Control (CMPC).

Processes of convergence and integration are responsible for the emergence of highly multi-functional devices. Recent applications of industrial ecology approaches to the analysis of household electronics have developed "functional profiles" of U.S. average households that depict their evolution over time (Ryen et al. 2014; 2015) (Fig 2.2). One of the findings of these studies is that the typical US household has seen an increase in the functions provided both by single devices, and by electronic profiles as a whole. This tendency toward multi-functionality in devices, especially mobile ones (Fig 2.1),is partly explained by the intense competition in consumer electronics, but also by the fact that computers are, inherently, general-purpose machines. The authors of the study praise the trend as an opportunity to foster more sustainable lifestyles in consumer electronics, without necessarily having users renounce to the enjoyment of any function at all.

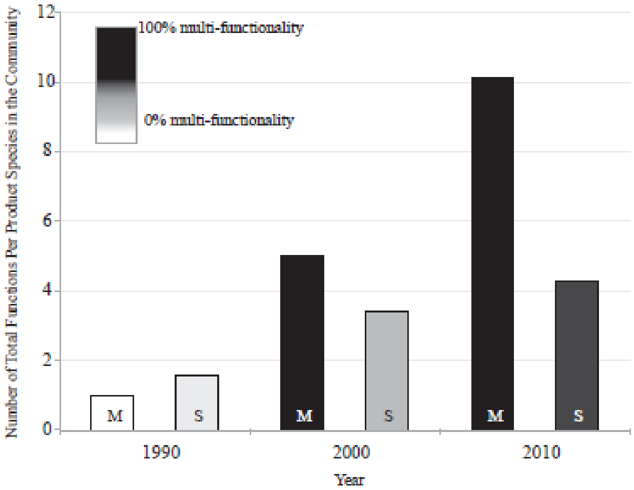

Fig. 2.1. Evolution in the multi-functionality of mobile (M) and stationary (S) household electronic devices, 1990-2010.

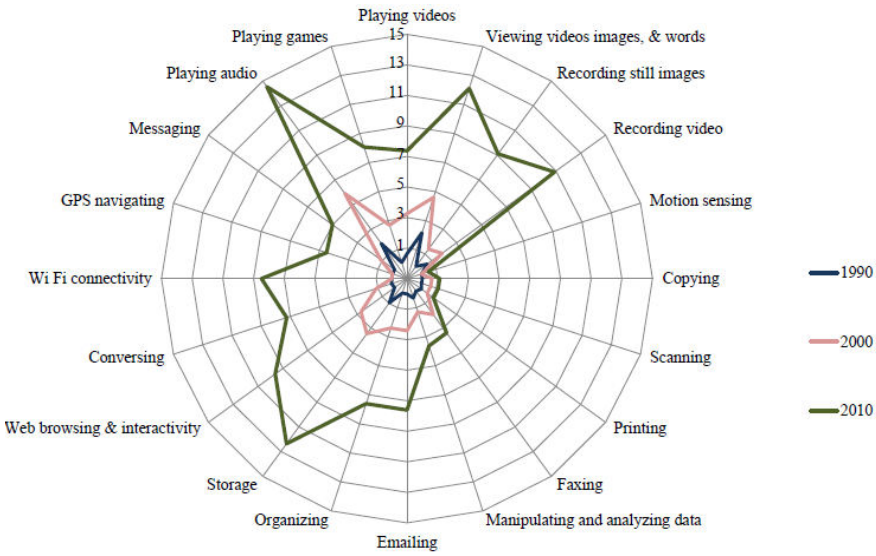

Fig. 2.2. Electronic "functional profiles", measuring the evolution in the number of devices per function and househould in U.S., 1990-2010 (Ryen et al. 2014, 9).

2.2. Ubiquitous connectivity and ubiquitous computing.

The continued compliance with Moore's Law has signaled a trend towards the cost-effective *miniaturization* of equipment, which has granted a mass market for computing devices, notably personal computers; but also to cheaper and smarter sensors and actuators, as well as mobile phone terminals operating with wireless cell switching. In fact, as mobile telephony offers connectivity or coverage across entire territories with relatively small infrastructure investments, it has often been a preferred solution for poor and sparsely populated areas in developing countries (van Dijk 2006).

In this way, parallel decentralizations of computer power and communication bandwidths have taken place[20], thus pushing a joint trend toward *greater mobility*, *personalization, ubiquitous connectivity* and *ubiquitous computing*. Two phenomena deserve mention in this regard. First, the increasing *personalization* of digital devices is coupled with a highly segmented consumer electronics demand, as well as a greater flexibility in forms of communication. A rapid co-evolution between computing devices, personal lifestyles and socially accepted habits has occurred, involving "the extension of use from homes and workplaces to uses in transport and in leisure time" (van Dijk 2006, 59). Second, an astounding variety of telematic systems has been or will be soon implemented across all kinds of processes. To name but a few:

1. Transactional devices such as cards and microchips, ready to use with physical systems connected to computer networks, such as ATM points.
2. Embedded systems (i.e. "smart" home appliances like washing machines or fridges with computing capabilities)
3. Radical paradigms such as domotics (interconnected smart home appliances) ambient intelligence (urban furniture provided with extra control features), the Internet of Things (IoT), computerized agriculture and cyber-physical systems.
4. Computer Integrated Manufacturing (CIM) technologies enable the monitoring and controlling of production processes, thus securing increased precision in the fabrication and assembly of components. This allows higher levels of automation with reduced coordination costs (Castells 1996; Graham & Marvin 1999).

[20] See note 9.

2.3. Self-reinforcing growth in the volume and complexity of information.

Currently we live in the "exabyte era" (10^{18}) and quickly approaching the "zettabyte era" (10^{21}) in terms of the total volume of stored information (Floridi 2010). Though most of this information comes from digital devices -specifically from personal computers and gaming consoles (Hilbert 2015), the advent of the Internet has shaped the trend as a logistic or exponential growth curve. This *information explosion* raises the concern that we may be facing an information overload, or *data deluge*, meaning that societies may be creating more information than they can handle while also preserving their complexity.

These concerns are not new. Already in the 60s, Herbert Simon (1969) argued that the huge growth of information taking place in his time would soon dramatically boost the social relevance of abilities for processing and filtering valuable information. Then, in a historical analysis of the Information Economy, Godin (2008) traces the concept back to 1965, when the OECD Ad Hoc Group on Information Policy detects governmental challenges stemming from an information explosion that could be traced back to the 50s, in a dramatic increase in the number of scientific publications -mainly applied science in R&D contexts. This evidence shows the growing awareness of scholars and politicians about (i) the economic impacts of innovation; (ii) the fact that information had turned into a commodity[21] whose mass production required government control; (iii) that this control might be impossible due to the very dimensions of the information flood.

Thus, mass consumer electronics and the Internet are not the only causes of the information explosion. An equally credible hypothesis could trace these problems to the 50s and, perhaps, even to the 19th century control crisis studied by Beniger (1986)[22]. In any case, the evidence supports the existence of a self-reinforcing process whereby information creation, processing and storage are mutually boosting one another; while digitization, computerization and advances in microelectronics can be seen both as stimulants of this crisis and products of its earlier stages. This does not entail that the related innovations arrived to the mass market by necessity; but it entails that processes of information production and management in the 50s and 60s had created problems whose solution would require, in time, huge increases in the social capacities for handling information, as well as corresponding organizational changes.

[21] More on this below, 2.6 and elsewhere in chapter 4.

[22] More on this below, 3.2 and 4.3.

Another side of this dynamics is a self-reinforcing complexity of software and data. Since Turing's and Shannon's works, information is conceptualized as structured masses of binary digits sent as inputs to information systems, and whose computation requires a certain amount and kind of resources. The aforementioned challenges can thus be understood as needs for increased computational power and increased efficiency in its management. These needs have only multiplied ever since 60s, continuously demanding improved software and larger electronic memories. As a result, the joint self-reinforcing trend encompasses data explosion, software complexity[23] and hardware improvements.

Here I merely offer a preliminary argument for the existence of these trends, leaving a more detailed defense as a challenge for further research. Such research should also address seemingly related dynamics. For instance, while interoperability pressures at a given level motivate the development of convergent technologies and techniques, once invented these tend to spread and diversify, thus scaling-up interoperability issues. Consider, as an example, the paradox that "the very success of ontologies", as a method for unifying the vocabulary of different databases, "has led to a proliferation of different ontologies" (Brey & Søraker 2009, 22). This suggests that data production and data management are engaged in a self-reinforcing dynamics too: while programming affords tools for the efficient management of ever higher volumes of increasingly complex and diverse data, it also boosts the complexity and volume of both software and databanks.

2.4. Self-reinforcing polarization in networks.

Networks have consolidated as the dominant form of association since the 70 (Castells 1996; van Dijk 2006). In computer networks, two trends stand out as extremely relevant for understanding other network dynamics in the Information Society.

The first one is an accelerating *connectivity,* which triggers once a *critical mass of users* is connected to a network or service. About one third of the potential users of a given network are required to trigger acceleration; once attained this figure, however, the medium rapidly diffuses "until all potential users are connected". The reason is that networks with so many connections are "both less expensive and more effective" (ibid, 78). Contingent upon ubiquitous connectivity, this trend applies to the Internet in general, but also to specific services or environments such as social networks or email. It

[23] Brey and Søraker (2009) identify two meanings of *complexity* regarding software. A technical one has a mathematical expression, coming from computer science. However, this concept is hard to apply to most programs, for their astounding complexity arises from the requirements that customization imposes on programming. This second meaning of complexity demands a more qualitative analysis.

explains why certain services or software become very popular in a short time-span, but also why companies are keen to bet high entry investments on them: they seek to reach this critical mass of connected users, then to see massive returns on their investments.

A second trend is still more fundamental. As opposed to *random networks*, where everyone is connected and enjoys a similar number of links to other users, computer networks are *scale-free networks* that, in lacking an "inherent scale for the number of links" (ibid, 183), promote patterns of self-reinforcing polarization. Polarization, here, stands for a dual tendency toward increased agglomeration between highly connected users, coupled with parallel exclusionary pressures toward the poorly connected. It arises from the "preferential attachment" (ibid, 184) of users to actors who are tacitly identified as best-connected "hubs" capable to offer the best services or information.

Individual users can identify hub-actors and cluster around them through a well-known process of reputation-building mediated by machine-learning algorithms. In the World Wide Web, one's reputation is measurable by the amount of one's positive interactions with other users: the number of visits or clicks received, or the number of hyperlinks from other pages. Search engines then use these data to rank pages. Google, for instance, uses the algorithm PageRank to detect reputed and clustered users. While these are made easily visible and accessible, the rest is automatically ranked down (Page et al. 1999). This competition for visibility is one where an extremely scarce resource is at stake: the attention of all connected users, including potential customers. Polarization thus raises winner-takes-all situations in which one can either establish oneself as a hub-actor, or quickly become totally irrelevant. In Facebook, a similar algorithm rewards visibility to those most interacted with, and fosters frequent contact between those already interacting often. Indeed, many accuse social networks of being "echo chambers" that promote hypes and mood agglomeration, reinforce prejudices, spread hoaxes, and create online ghettoes (Del Vicario et al. 2016; Davies 2016).

Thus, reputation often emerges from a quasi-infinite regress where, in reaching a critical point, one's reputation is indefinitely self-reinforced with the aid of the codes of service providers. Clearly, this dynamics has provided fair opportunities for many who, starting from near-zero capital investment, achieve visibility by accumulating links, clicks or citations, i.e. reputation; then to capitalize this visibility through pay-per-view formulae or, more generally, through their increased chances for recruiting resources by means like crowdfunding. While these polarization dynamics are programmed by service providers, they are, too, seemingly naturalized and even praised by users.

Yet, more or less legal methods exist for “hacking” the reputation-based “allocation of visibility”. To start, powerful organizations may acquire the services of entire armies of advanced bots (AI agents) to ensure extra boosts to their reputation. These bots may just visit the organization’s website or click on its hyperlinks; and they may create user accounts in social networks, from which to click on the posts of its owner or contribute to spread its contents in other ways. Such actions are performed quickly and in a large scale, thus multiplying the reputation of the bot-owner in a very short time. In this way, the owner is ranked up and its visibility to humans, dramatically boosted. A more familiar method comes from the advertisement opportunities that Internet companies offer customarily to other companies. These pay for receiving a preferential treatment by algorithms, thus becoming more popular by means other than their own ability[24].

A clear outcome of these strategies for adulterating reputation-based mechanisms of “attention allocation” is that networks stop being spheres where more or less fair competition takes place. Instead, they become scenarios for the ongoing staging of ever cruder versions of the “Matthew effect”, by which the rich get richer only for being rich, while the poor get poorer just because they are already poor. Yet, the Matthew effect arguably arises not just in relation to these AI strategies, but also to the possession of digital skills. Van Dijk (2006, 183ss.) shows how one’s economic resources and political influence are decisive in securing better digital skills for oneself and one’s kin or closest contacts. Then those skills become cognitive advantages that add up to positional or personal differences to determine one’s chances to attain influence or economic position through computer networks. Therefore, problems like the oft-mentioned *digital divide* involve not just network polarization, but also other entangled and complex causes.

2.5. Pressures towards concentration of capital and centralization of management.

Though choices between distributed and centralized methods of networking and control are quite significant[25], they may mask the fact that integrated communication systems always require the interoperability of devices and infrastructure, while this in turn demands, among other things, convergent management strategies. As was advanced, the

[24] Thus, although networks indeed induce polarization by virtue of their intrinsic dynamics; the ongoing commercialization of the Web adds distinct extrinsic factors of specifically economic nature.

[25] See van Dijk (ibid) for a review of the socially sensitive issues involved in these choices.

world-wide adoption of OSI was essential to achieve the integration and interoperability of multimedia and telematic services over computer networks. Evidence suggests that decisions taken in this process favored manufacturers with already well-established positions in the ICT sector, promoting, ever since, horizontal and vertical mergers, with the requisite economic concentrations (van Dijk 2006). In sum: while convergence and integration were needed to achieve interoperability so that highly demanded services could be commercialized, achieving these capabilities involves concentrations of capital and centralizations of management. For van Dijk, this is in fact an intrinsic property of interoperable systems, since these (i) involve network dynamics such as an accelerating connectivity when a critical mass of users is achieved (2.4), and (ii) promote integrated solutions that place on users “high switching costs in cases where [they] want to change systems as products” (ibid, 78). On the other hand, this pressure may not be exclusive of ICTs, since communication networks –and, more generally, infrastructures- are often deployed in a large scale and involving high entry costs; and, consequently, they can be considered natural monopolies too. In other words: although ICT services and networks need not be monopolistic, they place strong pressures for oligopolistic management and exploitation.

2.6. Virtualization and virtual commodities.

ICTs have enabled the creation of a large amount and variety of natively digital virtual entities and systems, many of which are directly treated as commodities. At the same time, many pre-existing physical goods and services are being digitized and treated as virtual commodities too. A widely held argument states that this *commodification* of the virtual world is only part of a broader two-way process of massive expansion of market relations, in which market relations were first extended to online environments; while, afterwards, virtual entities and processes, shaped as commodities or market procedures, came to reshape aspects of everyday, non-virtual life (Castells 2006; Graham & Marvin 2006). Here I address the first part of this process, leaving the second for chapter 4.

Consider, first, the virtualization of pre-existing goods and services. Two important socioeconomic trends arise here: *dematerialization*, and *zero marginal cost* (and *value)*.

The fact that many virtual entities and events formally resemble their non-virtual counterparts has allowed them to replace or complement those counterparts (Brey & Søraker 2009). Online communities, for example, can both replace or complement locally embedded activities of all sorts, and many virtual interactions have become fully legal alternatives of socially sanctioned institutions: examples abound of virtual marriages and other signed agreements which have been granted real-world validity as virtual transactions or contracts (ibid). *Dematerialization takes place when virtual goods or services replace their non-virtual counterparts, rather than complementing them.* This often occurs, for instance, with the digitized copies of educational and cultural contents, such as specialized magazines, films, songs or academic papers. Likewise, artifacts like calendars, clocks, calculators or maps have been virtualized and integrated in programs or even in the OSs of electronic devices such as personal computers, often coming to replace their non-virtual counterparts. Since the multi-functionality of ICTs (2.1) is what allows the effective substitution of these virtual -and thus intangible or immaterial- commodities, this property of ICTs can be said to advance economic dematerialization.

Yet, not only artifacts and goods have become intangible through virtualization; their value is now intangible too. Clocks or maps are sold as parts of a huge package of functionalities provided by OSs in a host device. As a result, they remain very useful but also taken for granted, and it is hard to single out their cost or value. More generally, all virtual systems, including OSs, are made of data that can be copied indefinitely many times, and stored in indefinitely many devices. In other words: once virtual goods are produced, the cost of reproducing them is negligible. This is often captured by the claim that virtual goods or information have low reproduction costs (van Dijk 2006) or zero marginal cost -and, tautologically, zero marginal value[26]. In addition, Floridi (2010) holds that virtual goods have two other intrinsic properties: they are *non-rivalrous* because their being used by someone does not prevent their use by others; and *non-excludable,* because they are easy to disclose and share. Altogether, Floridi concludes, these three properties of virtual goods have raised the idea that information (or virtual goods) is best seen as a public good to which all citizens should have access (ibid).

However, as mentioned, most virtual goods are being commercialized. A reason for virtual goods not to be treated as public goods, but rather as commodities to be exploited by their producers, may be the fact that, although they have low reproduction costs, often they also have *high development costs* and a potential for high profits (van Dijk 2006, 77). This is best seen, perhaps, by shifting the emphasis from digitized goods

[26]Rifkin (2014) takes this cue to affirm that the present explosion of information and software is leading us to a zero marginal cost society. This claim is broader than Floridi's, and it entails the assumption that an ongoing trend of innovation in ICTs will cause the cost of all commodities to shrink to almost zero.

to natively digital virtual systems. Programs and telematic tools can monitor events or processes, extract data and patterns from them; building upon them, they can generate abstract models of systems including predictions about the behavior of many systems and agents -even AI agents, if required; finally, they can use those models to interact with virtual and non-virtual processes and entities, including humans, robots and AI agents. These tools have at least four potentially profitable types of application. First, central computers equipped with sensors and actuators can control and supervise natural or production processes, both on site and at distance. Second, they can generate useful information about the most disparate issues: the goal may be minimal, as in modeling the preferences of typical customers in a given country; or grow in scope and generality, to simulate the dynamics of national and transnational supply chains or the behavior of the entire global economy in a variety of scenarios, each embodying specifications that together compound whole strategies for countries and corporations alike. Third, virtual reality systems allow humans to tele-operate all sorts of robots, from surgical robots to drones. Finally, these capabilities can be applied to developing videogames and educational software. In all these areas, innovative solutions provide an edge to competitors; and innovative solutions involve high development costs.

In this latter regard, however, natively digital services do not necessarily differ from the virtual copies of recently created non-virtual goods: both required a recent creative effort, and both are wanted and, in a sense, unique. This explains why, ultimately, both natively digital and digitized goods and services have come to be widely protected by intellectual property rights, and readily treated as commodities. Since digital goods diffuse as a matter of course once a critical mass of users is attained, this protection involves positive efforts, which amount to the ongoing enforcement of *artificial scarcity*.

How are virtual commodities integrated in the broader material economy? At the basis of this process there is a diffusion of *pay-per formulae*, embedded in a general trend known as the *product-to-service transition*. The “pay-per revolution” is often mentioned to refer to the ICT-enabled trend by which users have to pay to be allowed access to private virtual sites where they can enjoy the most exclusive and varied digital contents. However, forms of telematic conditional access are applied to online purchases of both digital and non-digital goods. In turn, the *product-to-service transition* conveys the fact that producers retain the rights of access to, and use of, electronic goods, in order to commercialize not a good, but merely its use. Finally, both trends presuppose the legalization and regulation of online transactions which, in turn, entails that of electronic money. Indeed, nowadays money is formally nothing else than information, i.e. numbers in a virtual account, stored in databases and that can be retrieved and processed by the computer networks of banks (Giddens 1990).

2.7. A structural revolution in communication and control.

Multimedia and computer networks converge in an integrated system where contents can be processed both locally and remotely; accessed from memories or networks; stored by and forwarded to anyone. This renders obsolete the distinction between offline and online media -between artificial memories and transmission links. Further, as ICTs integrate broadcast, telecommunications and data exchange, they blur the distinctions between the communication forms of the electric era. For these reasons, van Dijk argues, ICTs constitute a structural revolution of media (2006), whose key aspects can be singled out by comparing the "communication capacities" of different media. Fig. 2.3 shows that ICTs, far from merely increasing transmission speed or storage capacity, bring about two essentially new features: *selectivity* and *interactivity*.

The following pages review this argument and supplement it with critical remarks. More specifically, I shall argue that ICTs do not just revolutionize media; indeed, they are not mere media, but also semi-autonomous control systems.

	Old Media				New Media	
Communication capacity	Face-to-face	Print	Broadcasting	Telephone	Computer networks	Multimedia
Speed	Low	Low/ medium	High	High	High	High
Reach (geographical)	Low	Medium	High[1]	High[1]	High[1]	Low
Reach (social)	Low	Medium	High[1]	High[1]	Low	Low
Storage capacity	Low	Medium	Medium	Low	High	High
Accuracy	Low	High	Low/medium	Low	High	High
Selectivity	Low	Low	Low	High	High	High
Interactivity	High	Low	Low	Medium	Medium	Medium
Stimuli richness	High	Low	Medium	Low	Low	Medium
Complexity	High	High	Medium	Medium	Low	Medium
Privacy protection	High	Medium	High	Medium	Low	Medium

[1]In developed countries only.

Fig 2.3. van Dijk's scheme of communication capacities of all media

Selectivity

ICTs afford a flexible, fine-grained *selectivity* of the targets or recipients of information. For example, a mail-list can be designed and updated on an ongoing basis. Telephones could select too, but only one receiver. Instead, online transmissions and publications may be one-to-one or one-to-many, and senders retain control over who receives them.

Of course, many applications that exploit this capacity have economic value. Floridi suggests a few in a game-theoretic interpretation of economic situations of information asymmetry. Though these are often unfair to underinformed players, information-based techniques exist to help fighting them (2010, 53ss.). Incomprehensibly, however, Floridi does not see that those information techniques can receive exactly an opposite use, i.e. to constitute or reinforce information asymmetries. In fact, this kind of application is to be expected often, since network dynamics reinforce polarization (2.5), which, among other effects, creates and reinforces information asymmetries. To see this, recall that PageRank singles out pages to profile and rank them, thus rewarding the very visible with more visibility. Now, increased visibility equals increased interactivity, which, for hub-actors, means enhanced information exchanges. As a result, a hub-company is not only more easily accessible to customers than its rivals; it also has better information about them. Related to Floridi's techniques for reducing information asymmetries are technologies like smart metering, which allow particular users to be targeted, and their consumption and use monitored (Graham & Marvin 1996, 40). These data can be fed into telematic tools that aid the effective *segmentation of the demand* through new marketing techniques, thus furthering the pay-per revolution while spreading both overt and covert forms of citizen surveillance.

Chapter four surveys more telematic applications that exploit this property.

Interactivity

Interactivity became a feature of media when the TV activated parallel flows of information such as teletext, thus giving the audience the opportunity to participate in shows (van Dijk 2006; Fig 2.4). Since then, bidirectional exchanges of all kinds of data grew rapidly. Together with selectivity, this new feature made possible the pay-per revolution and even new forms of action. Today, users can engage in online exchanges of queries and responses with other users or with AI that registers their actions and even learns from them. Courses of action or scripts are programmed, in varying degrees of determination, to unfold upon users' actions. These functions converge to enable the simultaneous participation of users and AI in joint activities that may remain virtual, but also carry a host of non-virtual effects.

This creates a radical shift in traffic patterns. Modernity had traditionally favored a scaling-up of centers specialized in gathering, managing or diffusing data. These centers allowed registration, issued allocutions, or spread mechanical technology that enriched and diversified consultation. A paradigm of modern society would be the mass society, whose broadcasts ensured maximum audiences but afforded few or no opportunities for bidirectional exchange. In contrast, ICTs afford mixed patterns of consultation and conversation where exchanges can be one-to-one, one-to-many or many-to-many, thus securing rich, bidirectional and poly-centric interaction between citizens and consumers on the one side, and governments and corporations on the other. Van Dijk even suggests that the media available to a society determine its dominant traffic patterns, which in turn deeply influence the political culture that prevails in that society. In this vein, the technical features of radio and TV would explain the tendencies of mass societies toward totalitarianism and technocracy, while modern ICTs, instead, are seen to provide the Information Society with a more democratic and participatory culture.

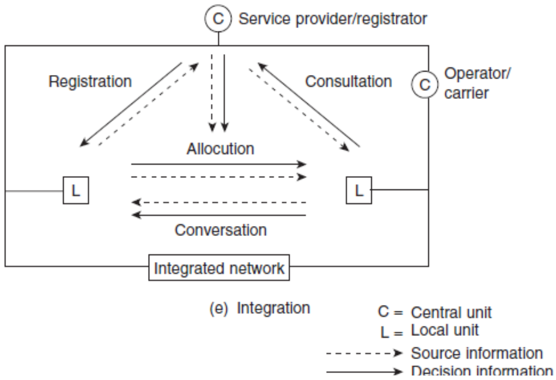

Fig 2.4. Convergence and integration of traffic patterns, with a shift to consultation and conversation (van Dijk).

Indeed, examples abound of the increased demand and provision of “participatory" schemes. Simulation tools like Computer-Aided Design (CAD) have favored a turn to participatory technology design (Schot 2001), and initiatives in participatory healthcare (Martin 2008) or participatory politics have also emerged. Van Dijk also notes an economic transformation which he labels a “reversal of the value chain” (2006, 79), where the demand-side of media, rather than the supply-side, is seen to increasingly determine not just the value of products, but also the commodities to be produced. As consumers can now communicate with each other and with producers, they increasingly

> give the first signals and producers deliver on demand. It also becomes easier for consumers to make large-scale price comparisons […] on the Internet. Moreover, they are able to organize electronically (consumer groups) to push down prices and to command conditions, for example, by means of rating and filtering systems. (ibid 79)

In other words: rather than the “passive” demand of mass societies, the demand of the Information Society would be worthy of the name.

However, as argued, telematic tools afford large public and private organizations improved capabilities for selecting and targeting their audiences, especially when their huge amount of capital and power allows them to use and/or control the best software resources, and even to hack the network logic for reinforcing their power. Van Dijk argues that, although it is true that supply-side views still dominate, both the technical capabilities and the social trends are pushing toward more demand-side determination in production as well as decision-making. The question remains whether the ongoing hegemony of supply-side views is a mere remainder of mass societies, that might be reversed in a further developed Information Society; or whether Van Dijk is simply overstating the implications of interactive ICTs for participation and empowerment.

A revolution in semi-autonomous control

There is another, more crucial sense, in which van Dijk's account of ICTs is not fully satisfactory. This is his assumption that ICTs are mere means for bridging space and/or time in human communication, i.e. *media*. I shall argue that conceptualizing ICTs as mere aids to human communication amounts to disregarding the capabilities of AI.

Computers make possible the semi-autonomous execution of purposeful routines, or sets of intelligent tasks. This autonomy of both networks and AI is jointly boosted by the convergent tendencies toward ubiquitous connectivity and computing, information explosion and higher program complexity to yield functionalities that, from a historical perspective, are entirely new. These can be captured by pointing to the growth of a sphere of increasingly non-intentional control of social processes, including decision-making activities. In this connection, the autonomy of networks was already addressed: it features a host of emergent polarizing effects which, nonetheless, have been largely tackled so far by a status quo which reinforces its power by hacking the codes and, thus, network dynamics as a whole. Here I shall focus on another manifestation of this phenomenon, which is the operation of concrete AI across information systems.

Since Wiener's seminal work (1961), communication and control were assumed to be essentially two faces of the same process. In this conception, human communication can be understood as a co-control loop whereby agents give each other cues in order to change one another's incentive structures. As a result, listeners get ready to enact the intentions expressed by speakers, as negotiated and agreed through communication (Brey 2007). This close tie between human communication, mutual changes in incentive structures and the production of intended real-world effects is what AI contributes to undermine in conjunction with other automatic machines capable to produce worldly effects without the intervention of human action or motivation. To see this, consider that

ICTs generate the cyberspace, which can be defined as an environment or “system of topological relations between virtual objects” (Brey 1999) of “global”, “electronic” and semi-programmed nature. In this space, humans not only interact with one another, but also with entirely virtual non-human beings, like bots; or virtual-physical ones, like networked robots –thus yielding *cyberphysical systems* (Technopolis 2016). Moreover, non-human agents can also interact with one another to produce both virtual and non-virtual events. As a result, entire courses of action arise, which are non-intended and non-initiated by humans.

This raises two disturbing possibilities. On the one hand, human communication and action may be turning out to be increasingly irrelevant for many social purposes. On the other, specialized techniques of human control through communication can be replaced by algorithms for control, whose autonomy grows as they learn. Yet, this crucially means that this technology no longer would act as a “delegate” of its managers and owners, but rather as something else. To this, one might object that all the existing AI is still controlled by powerful but, after all, human agents. Yet, AIs can operate in networks featuring dynamics that cannot be fully hacked by even the most powerful human agents. More to the point, the ongoing improvement of AIs comes hand by hand with their growing unpredictability and increased autonomy, as many experts and policy-makers worldwide assume (Picard 1997; Delvaux 2015; Nevejans 2015). To sum up: the ongoing development of AI has led ICTs to transcend the essence of communication and induce, instead, the growing empire of new forms of non-human autonomous control.

3. ICTs and the industrial order

According to Castells (1996), we are undergoing a transition from industrialism to a new order based on the production of useful information, or “informationalism”. Some, like Toffler (1981), argued that this new, ICT-enabled order, would wipe out capitalism and bring humanity to a whole new age. Yet, this technological deterministic claim has been contested. A dominant response is that informationalism follows the typical dynamics of capitalism, and that, in fact, it is best seen as a socioeconomic restructuring of capitalism resulting from systemic crises that converged in the 1970s. ICTs would have been crucial in shaping this new order (Sassen 1991; Castells 1996; Graham & Marvin 1996).

These remarks lead me to inquire about the basic features of industrial capitalism, including its propensity to crises and the ways in which they are typically overcome, whenever possible. First I shall summarize the core tendencies of industrial capitalism in Marx’s view (1959; 1976). Next I turn to Beniger’s influential argument, which traces the origin of the Information Society in a series of crises arising from the expansion of industrialism and triggering a control revolution (1986). I conclude by sketching a broader picture of the industrial order, with special attention to the national urban systems that resulted from that crisis, and the role that electric media had in them.

3.1. The inner tendencies of capitalism

Historically, economic activity had been about producing culturally fixed use values to be directly consumed by producers, or otherwise appropriated by extractive classes - priests, kings, warlords. In contrast, Marx pointed that capitalism is not aimed at directly obtaining use values, but rather at the accumulation of exchange values, i.e. capital. By 1850, the industrial system had already attained a momentum in value accumulation; yet, for this system to work in a society, a series of conditions are required, which raises the question as to how momentum was gained. Here I abstract from Marx's historical account of the primitive accumulation of capital and related issues, which explain the entrance of Western societies into the industrial system around 1780. Instead, I focus on the factors involved in regular capital accumulation, and the trends thereby promoted.

Capital cycles begin in nature, where natural goods are regarded as *givens* to be directly appropriated by humans: although capitalists may exchange their entitlements to use a particular good, the original entitlement for appropriation is never paid for to nature. Yet, natural goods are not values. Marx follows Ricardo and Smith in arguing that, in capitalism, natural goods are only materials for the valorization of value through work in productive activity: as a result, the value of something can be defined as the *socially necessary labor time* to produce it.

In performing a material processing of natural goods into raw materials, extractive activity (agriculture, mining…) is the first step in transforming natural properties into use values or functions. These pre-processed raw materials then enter factories and are further processed. Insofar as workers perform, control or supervise production, they create value. The final product, i.e. the commodity, embodies more value than all machines, raw materials and auxiliary materials altogether, because it reproduces the value of all those elements, plus that impressed by the working force.

A fraction of value, Marx argues, is extracted by capitalists from workers as follows. A chronic overpopulation of workers must exist to grant (i) that factories will open, and (ii) that competition among workers drops salaries as close as possible to the cost of their basic needs. Workers must be suitable, i.e. specialized if necessary. Since training and capital are required to produce specialists, and these involve a socially necessary labor time, specialists have more value than non-specialists, why is why they tend to receive more than the minimum wage. In any case, once workers sell their working force, they are all made to work more hours than would be required to produce a value-equivalent to the cost of their needs[27]. In other words: their wages pay for less hours of performance than they should. The resultant excess or plus-product is the surplus value.

There are two ways to increase rates of surplus value extraction. First, longer or intensified workdays can be enforced, thus increasing outputs and yielding an extra *absolute surplus value*. Second, the *productivity* of the workflow can be boosted in two ways: either by rationalizing production through scientific methods, or by introducing machines to automate parts of production[28]. If correctly applied, these complementary techniques replace specialists by unskilled workers, thus saving labor costs while

[27]The needs of specialists are assumed to be more sophisticated and thus more costly than the merely reproductive needs of unskilled workers.

[28]The precursors of operations research relied on their historical experience in engaging with complex systems of division of labor in manufacture, which, over time, enabled them to analyze operations in a way that machine tools could be designed and introduced in production to substitute for delicate operations that only skilled workers were able to do before. Thus, since automation presupposes rationalization, the former can be framed as a species of the latter.

increasing outputs per worker-hour[29]. In other words: in boosting productivity, *rationalization* and *automation* generate higher rates of relative surplus value -often, in addition to larger amounts of product in a lesser time, at lower production costs.

The central production unit of industrialism is, therefore, a partly automated factory where live forces are no longer "the prime movers" or energy providers: coal and steam engines do this job. Further, some machines are used for producing other machines and, generally, machines progressively tend to take a more central role across all branches of production. Initially, workers handle them; later on, they merely supervise their tasks; the long term trend being for networked machines to operate in increasingly autonomous ways according to preset goals[30], up to erasing the very basis of value-creation, i.e. work. Since machinery poses huge capital costs, production becomes increasingly capital-intensive, in two ways. First, factories and production areas such as industrial cities tend to concentrate and make cumulative use of machinery (or fixed capital), thus increasing the organic composition of capital–the ratio between the total costs of machinery and labor. Second, there are also pressures to concentrate the amount of money available to invest (mobile capital), which demands sufficient financial liquidity. Production also tends to rely more on the production and diffusion of science and technology to support an ongoing shift from absolute surplus value extraction – longer and intensified workdays- toward relative surplus value extraction, based on rationalizing and automating the highly cognitive, added-value parts of production.

To these tendencies toward automated and rationalized production, one must add tendencies towards *enlarged* and *continuous* production. A firm needs to sell more, faster and more reliably than its competitors not just to increase his capital, but even to survive. This means that firms must offer competitive prices, which forces them to save costs. Among the many formulae for saving costs, a frequent strategy is to scale-up production in order to broaden markets-provided that transport and communication networks make those markets reachable. Scaling-up is not just an opportunity to realize higher sale volumes; since producers thereby commit to make larger orders to suppliers,

[29]See (Noble 1978) for an argument that automation may also, at least occasionally, not be cost-effective and still be carried out just in order to increase the power of managers, corporate owners and, more generally, technocrats over the workforce –through deskilling and other effects.

[30]See Marx's comments on Babbage's analytical engine (1976). Note, though, that our accounts of machine learning AI on 1.5 and 2.7 suggest that future production systems enabled by AI may not even require any human input indicating production targets; since it is theoretically conceivable for some such system to be able to generate these targets by itself through real-time monitoring of, and adjustment to, the demand.

these get reassured with the opportunity to consolidate or even scale-up production themselves. Therefore, suppliers are likely to sell cheaper to huge companies, which helps the latter to dump production costs in a self-reinforcing process. Since –for this and other reasons- competition provides permanent incentives for scaling production up, Marx argued that competition inevitably promotes the concentration of capital and its centralization in few hands, thus making fair concurrency collapse into oligopolies[31].

Continuous production, for its part, is convenient for two reasons. First, machines in disuse are sunken money. Second, it affords an unending replacement of commodities in the market, which allows producers to have their investments quickly returned, so that, dividends aside, this capital can be reused in further value-creation, i.e. production. This circulation process clearly differentiates capitalist accumulation from prior forms of accumulation, like usury[32]. Capitalists know that value is not being created during circulation; in fact, goods depreciate and even damage in store or through transport. Thus, commodities must circulate as fast as possible, in order to grant a fast rotation of capital (*quick capital turnovers*) and therefore its quick, augmented reproduction. This rotation does not conclude, however, until the value of commodities is realized through final sale. For this reason, producers need access to markets with enough power and a predictable will to purchase; otherwise, they risk losses and bankruptcy, while the economy as a whole faces crises of overproduction. New markets can be opened in one of two ways. First, *formally*, by using innovations to create entirely new lines of product; this requires an especially "trained" demand, willing to experiment with new goods. An alternative is *geographic* expansion. This strategy relies on fast and reliable supply chains, and the permanent incentives to realize it entail that capitalism requires and indeed promotes globalization as a means to reproduce and augment itself[33].

Hence, capitals go restlessly from job and machinery markets to production, where workers and machines are set to produce; commodities are constantly shipped through transport networks; their value realized in sale, and a part of it quickly reinvested. As

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[31] Recall, in this connection, our analyses in 2.4 and 2.5.

[32] Marx would call usurers "irrational capitalists" because they kept the money off circulation. In contrast, a capitalist merchant throws his riches into it: for instance, buys some goods and resells them at a higher price. This bears witness to the emergence of a new, specifically capitalist, kind of rationality. On the other hand, unlike producers in subsistence economies, capitalists would no longer have a direct concern with the aim of their activity; instead, they tend to be rational administrators concerned with what, when, where and how much needs to be produced and sold in order to maximize a cost-profit relation.

[33] In modern economics, the terms "economies of scope" and "economies of scale" are often used to convey similar ideas to what Marx understood by, respectively, formal and geographic expansion of markets.

noted, this cycle demands advanced transport and communication networks to secure minimal times of delivery and perfect communication between producers and clients, as well as producers and suppliers. It also requires specialized institutions ensuring the reliability and expediency of transactions (insurance, legal services); advancing capital before production (creditors) or at early stages of circulation (wholesale retailers, shipping agents); and tools boosting the profitability of investments (finance). Although these are management and control needs of the system, Marx argues that they are not productive activities, i.e. they do not create value; rather, they only pose a social cost. Paradoxically, however, Marx argued that, especially during depressions, capitalism fosters a growing autonomy of these activities, i.e. accumulating exchange value *without* production and consumption of use values. The reason is that production costs must be cut in depressions and, consequently, workers' wages and their consumption power diminish. As a result, capitals are led to retreat to financial speculative activity: since the latter is seen as a source of quick profit, it becomes for them a typical way out of crisis.

3.2. Industrial capitalism and its control crises

Marx, like most bourgeois economists of his time, saw capitalism as an organic and purposeful economic system whose processes are law-like and mutually co-dependent. However, each regarded such laws and purposes very differently. Most saw the private accumulation of capital as an endless process that, in the aggregate, promoted the collective growth of riches and, more generally, the unlimited progress of the human race. In contrast, while admitting that capitalism promoted capital accumulation, Marx rendered the "road to progress" to be fraught with crises and contradictions. Most crises could be encompassed by capitalism as opportunities or incentives to reorganize itself by revolutionizing the forces of production with the aid of science, technology[34]and suitable policy. This entails that (i) new approaches to business and management must be constantly devised through a scientific study of the economy; and that (ii) an ongoing pressure exists to engineer and diffuse cost-effective and scalable innovations across the economy. In this way, for example, *business downcycles* (Mandel 1995) can be integrated into the normal functioning of the economy. However, this scientific approach to the

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[34]In Schumpeter's well-known contention, capitalism is a system characterized by ongoing processes of "creative destruction". However, Schumpeter focuses on the role of techno-business entrepreneurs in socio-economic restructuring, but disregards the importance of social conflict or political realignments as the plausible origins of these transformations. For a similar view, see (Korotayev et al. 2011).

economy has unexpected outcomes. On the one hand, since overcoming crises is found to be a useful way to restore high capital accumulation rates, creating crises becomes rational. On the other hand, the system seems unable to handle certain crises. These are *internal contradictions of capitalism*, which in the long run would signal its demise.

This is not the place to engage in a detailed discussion about Marx's views on the unsolvable contradictions of capitalism. What follows, instead, is an interpretation of Beniger's influential analysis of the control crises of industrial capitalism (1986). In principle, control crises are one among the many kinds of crises of capitalism. In Beniger's argument, they are of the solvable kind.

Beniger focuses on strategies and techniques used to control processes within each economic sphere, as well as to efficiently communicate and coordinate different spheres. Note that, for Marx, these activities were part of the sphere of circulation: though they were essential for economic integration, they did not create value and, in fact, they were responsible for indirectly raising production costs. Yet, Beniger wants to account for the growing economic importance of information in the late 20th century, which leads him to somewhat dismiss the centrality of production in Marx's analyses of industrialism, in favor of an informational approach more suited to the informational economy. This approach owes much to Weber's institutional approach to society and the economy.[35]

On the other hand, Beniger, like Marx, directly approaches the capitalist economy as an integrated system of semi-autonomous, networked spheres (extraction, production, transport, services and consumption) seamlessly adjusting their throughputs to one

[35] Although Weber had rejected Marx's materialistic account of the origins of capitalism, he also came to see Western societies as an integrated system with an emergent purpose. This system was not capitalism, however, but Modernity; and its embedded purpose was not the accumulation of capital, but the growing complication of organizational power in private and public sectors alike. Weber identifies three ongoing related trends in modern societies. One was *secularization*, by which authority was untying from local tradition and relations of family, prestige or charisma to become an objective, scalable and improvable system for decision making and management. If an industry conceived a solution for a local problem, for instance, this solution would be scientifically assessed and quickly generalized to be applicable by any agent, public or private, to similar management problems observed in a distant place. A second trend was that of *bureaucratization*. Bureaucracy is an increasingly rational institution of governance through control and information processing. Though Ancient Empires were bureaucratic too, bureaucracy is now deeply entrenched in the organization of corporations and governments, having become an inextricable "iron cage" with five typical features: hierarchy of authority; centralization of decision-making; formalization of rules; standardization of action into tasks; and specialization of tasks (van Dijk 2006, 108). The third trend was *rationalization*, by which growing numbers of societal agents come to see their activities as problems to be solved, and are ready to assume and implement methods for the pursuit of efficiency and the selection of the best solution available in every case. Rationalization involves a positive hegemony of practical reasoning aimed at more efficient results in exchange for less effort, less waste of time, less attention and so forth, and a correlative disregard for any other factors; remarkably, traditional values. Thus, Weberian rationalization takes a slightly broader meaning than Marx's (Giddens 1990).

another within a global functioning that promotes capital accumulation and the formal and geographic expansion of production and the markets. Thus, to some extent, Beniger integrates Marx's and Weber's views on society and the economy. This is apparent in his tenet that the origins of the Information Society can be traced to a Control Revolution taking place by 1890s, as a response to a series of control crises triggered around 1850 by the expansion of the industrial system in the U.S. In this manner, the typically expansive tendencies of the capitalist economy can be seen to trigger the expansion of control functions in society. Finally, another coincidence between Marx and Beniger lies in their similar conceptions of capitalist crises: although capitalist dynamics give rise to periodic crises that may temporarily stop capital accumulation, most of them are solvable and actually constitute incentives for more expansion and growth.

The concept of *bottleneck* helps capturing this dynamics most clearly. Bottlenecks are situations in which a key factor of a process is not available, or does not occur, in the quantity or quality required for this process to take place reliably and at a critical speed. Bottlenecks arise in semi-autonomous, networked processes that exchange certain volumes of materials. For those processes to work coherently, they must adjust to one another and run reliably at a certain speed. Often, however, there is a weak link which has difficulties to adjust to the speeds and throughputs required by other processes in the chain. The throughput of this process may be too high or too low, its speed too fast or too slow. As a result, disruptive events or dynamics in one sphere can quickly have profound repercussions throughout the system. Many of these events, Beniger argues, are due to deficient communication between processes: that is, information bottlenecks.

Consider a factory plant that produces more than it can sell. Such plant is not profitable, and its manager should clearly downscale production. Yet, the existence of such over-dimensioned production process poses incentives for revolutionizing the rest of processes with which this one is interlinked. This led Marx to assume that the state-of-the-art technology is more or less the same across sectors, so that bottlenecks quickly lead to innovations in the underdeveloped processes of the chain. What Beniger (1986) offers is a detailed picture of the difficulties involved in such adjustments. In particular, he shows how the development and expansion of the industrial system in U.S., taking place about 1830-40, triggered a chain reaction of innovations that created information bottlenecks. These, in turn, prompted a Control Revolution in the late XIX century.

This crisis starts in 1830-40. The steam-powered integrated factory, together with cheap anthracite and increases in productivity through the slow but steady diffusion of the American system of interchangeable parts, converged to yield huge outputs in iron, cotton and other agricultural commodities (ibid, 215). Despite commercial relations with many countries had been reopened after U.S. independence, industrialists needed new markets to allocate this production excess, and were led to geographically expand to the West (ibid, 208 ss.). As they did not find fast and reliable means of transportation, they had to develop railway networks through joint initiatives with the government. Since the 40s, railway networks came to develop through ever longer distances and in ever denser patterns. Yet, this created coordination problems in transportation, which can be seen as information bottlenecks: accidents and lags were frequent and arriving times uncertain. This was solved by integrating a standardized signalization system by telegraph to the railway network, in a frantic process which lasted merely eight years and that later would we applied in the control of other infrastructures –like water and energy systems (ibid, 221)[36]. In turn, this raised control needs in distribution, which, in the 1850s, brought the rapid emergence of new commercial figures (ibid, 254 ss.).

Still, the crisis scaled-up in the 50s, a period of strong growth where the American system was applied to producing industrial machines, including specialized machine-tools; most decisively, too, the application of the Bessemer method helped to massively boost the outputs of steel. This created a strong coupling in the growth of the industries of steel, railway and other civil engineering, and telegraph, which led to two new information bottlenecks. First, a crisis of coordination arose in the production of basic materials such as iron, copper, zinc and glass (ibid, 220) to promote two decades of intense innovation in management and control of production. Second, a distribution crisis in supply chains occurred due to problems in handling growing inventories; this had to be tackled in the 60s by creating department stores, managed by large retailers and wholesalers. Soon, however, new crises arose in petroleum industries, which, around 1870, had begun to apply continuous-processing technology to mass production.

[36]The common aspects between telecommunication networks and other infrastructures are at once physical, organizational and regulatory. While early telegraph systems followed the layout of transport or energy infrastructures, this continues to be the case today with cable networks, which tend to follow roads (Graham & Marvin 279ss.). Nowadays, too, deals and partnerships remain frequent between the providers and operators of different infrastructures –transport, water or energy, which constitutes a pressure for the increased concentration of capital and centralization of management in these sectors (2.5), and thus for the reproduction of oligopolies.

The resulting rotation speed of goods and capital was so high that a crisis in the control of demand arose, prompting innovations in marketing and bureaucracy since the late 1880s. Since then, many other innovations in information processing and control followed, often with the aim to secure broadened and more reliable markets in the face of growing competition. These took place in areas as disparate as government census, traffic control (traffic lights, inventories) or control of consumption (public relations, supermarkets, surveys, catalogues, mass advertising). Together, they amounted to a Control Revolution that announced the mass media and mass society of the 20th century. In fact, this revolution involved the use of precedents of modern computers, such as typewriters and punch-card tabulating machines (1889), the latter of which would be later used in the telex service. It is these and similar reasons that move Beniger to claim that the origins of the Information Society can be traced to this period.

To conclude, it is important to note that another way to read Beniger's argument is by highlighting its link with an effect that modern economists know as "rebound effects" or Jevons' paradox (Hilty et al. 2006). A rebound effect happens when increases in the operational efficiency of a process indirectly lead to an expansion of the demand relative to the goods and services whose production or operation was made more efficient. Consider, for example, a highway. Improvements in the efficiency of road use expand the capacity of that highway; then, if prices are set by the market, the increased capacity of the highway translates into a reduction of prices, which acts as an incentive for the expansion of the demand and, consequently, as yet another incentive for expanding the supply through investments in the requisite efficiency improvements. This "virtuous cycle" perfectly captures the dynamics of propagation of bottlenecks that was frequent during the expansion of industrialism. Rebound effects typically arise in relation to vital goods and services, such as energy use, or those primed by better socio-economic opportunities, like transport (Plepys 2002; Hilty et al. 2006). However, as Beniger's argument makes clear, they can be consciously brought about in any sector, provided that a scientific economic assessment is applied to the effective control of the demand. Indeed, that is the reason why the Jevons' paradox has often been acknowledged by industrialists as a true fuel for the ongoing expansion and dynamism of the economy.

3.3. Broader elements of the industrial order

We have discussed some features of industrial capitalism, like its expansionist nature and its related propensity to crises, one of whose outcomes was the Control Revolution.

Many of the technologies and organizational solutions born in this revolution would expand from 1920 to 1970 (van Dijk 2006), and especially in the period of sustained growth starting in 1940 in the U.S. and in 1948 in Europe and Japan (Mandel 1995; Castells 1996; Milanovic 2003; Gordon 2012, 2014), converging to constitute the climax of a coherent social order which has received many labels, such as “industrialism” (Toffler 1981; Castells 1996), the “mass society” (van Dijk 2006) or the “national urban system” (Sassen 1991; Graham & Marvin 1996). Here I describe aspects of the industrial order that, although transcending the economic domain, echo trends that Marx and Beniger had identified in the industrial economy. Some of these parallelisms can be read as path-dependencies that result from technical and organizational choices made during the Control Revolution. In discussing them, I shall place an emphasis on the predecessors of ICTs and their couplings with other subsystems of industrialism.

Consider, first, the world-wide deployment of *electric transmission links.* Broadcast media (radio, TV) sustained the centralized and real-time transmission of contents over wide territories, embodying allocution patterns that, according to van Dijk (2006), shaped the mass culture of industrial societies. Meanwhile, switched networks laid out conversational traffic patterns[37]: while the Public Switched Telephone Networks (PSTN) afforded voice telecommunications, telegraphy and telex allowed instant data exchange.

Yet, we saw that van Dijk tends to dismiss the control functions of ICTs, which leads him to see predecessors of ICTs only among electric media. With Beniger, one can devise a more complete genealogy of the control devices that were invented and used before and until the spread of digital computers (Fig 3.1). Some, like the analytical engine, were true computers; further, limited forms of networking were also possible. In fact, already by 1930

> “offices contain typewriters, copiers, calculators, dictation equipment, and tapes; [and these devices] communicate with each other using telephone switchboards and multiplexers” (Beniger 1986, 398)

[37]In van Dijk’s categories (see 1.1), bidirectional data exchange counts as a conversational pattern.

Year	Desk-top calculating	Digital computing	Analog computing	Punch-card processing
1880				
82				
84	Keyboard			Electric
86	add-subtract			tabulator
88	calculator	Part of		
1890	Multiplier	Analytical		
92		Engine		
94	Four-		Equation	
96	function		solver	
98	calculator		80-element	Automatic
1900			harmonic	bin sorter
02			analyzer	Plug-board
04				tabulator
06				
08				
1910			Gyrocompass	
11			computer	
12			Profile	
13			tracer	
14		End-game	80-input tide	
15		chess machine	predictor	
16			Battle	
17			tracer	
18				
19				Printing
1920		Electro-		tabulator
21		mechanical		
22		calculator		
23				Electric
24	Electric		Product	keypunch
25	printing		integraph	
26	calculator			
27			Electric	
28	Multiple-	Calculators	network	80-column
29	register	linked as	analyzer	punch
1930	cumulating	difference	Differential	card
31	calculator	engines	analyzer	
32				
33		Mechanical		Punch card
34		programmer		accounting
35			Electrical	machines
36			analog	linked for
37			computer	computing
38			Electronic	
39	Electronic	Bell Labs	analog	
	calculator	Model I	computer	

Fig. 3.1. Innovations in information-processing and computing technologies, 1880-1939, from (Beniger 1986)

Although different traffic patterns typically promote distinct interactions and types of organization, all electric networks (telex, telegraphy, telephony, radio and TV) were operated and organized in the model of broadcast companies, thus, working as distribution networks with tree structures where a central source "(the root) uses a transmitter (trunk) to send sounds, images and text through carriers with ever smaller branches until they reach the recipient" (van Dijk 2006, 62 ss.). This explains why public or private monopolies in ownership and management were common (2.4).

Certainly, this kind of organization was not new; in fact, one the first organizational charts in history, that of the New York and Erie Railroad, was also pictured as a tree (Fig. 3.2). This similarity between the organizations of railway and telegraph networks may be unsurprising after Beniger's remarks about the links between communication, transport and other networks; however, it is also true that, in this period, infrastructures were generally regarded as public goods yielding natural monopolies (Graham & Marvin 1996)[38].

That was not uncontroversial, however, since the flows of these vertically integrated and hierarchical organizations –goods and, above all, informational contents- went only in the direction of the smaller branches –i.e. private subscribers[39]. To some, the whole scheme resembled mass production as purely as Fordist factories. Further, since the control of these media often took place at a national level, many came to see culture as an oppressive decision tree where the ends (citizens) are entirely programmed by the

[38] See 2.4; also, note 36.

[39] In analyzing the effects of media in this socio-cultural landscape, however, corporate subscribers and households should be distinguished, since, for example, telex only served the former (see note 11).

root (the state), and little variance was to be expected or tolerated. In this vein, van Dijk (2006, 184ss.) highlights how electric media favored forms of clustering that overlapped with, or reinforced, nationalism or conservative identities of gender, race, family and religion, thus having an overall homogenizing effect. In contrast, others stress how these networks were conceived “as part of the… wider Keynesian welfare state” (Graham & Marvin 1996, 12ss.), in that, in being universally accessible, served as means of redistribution and thus fostered equality.

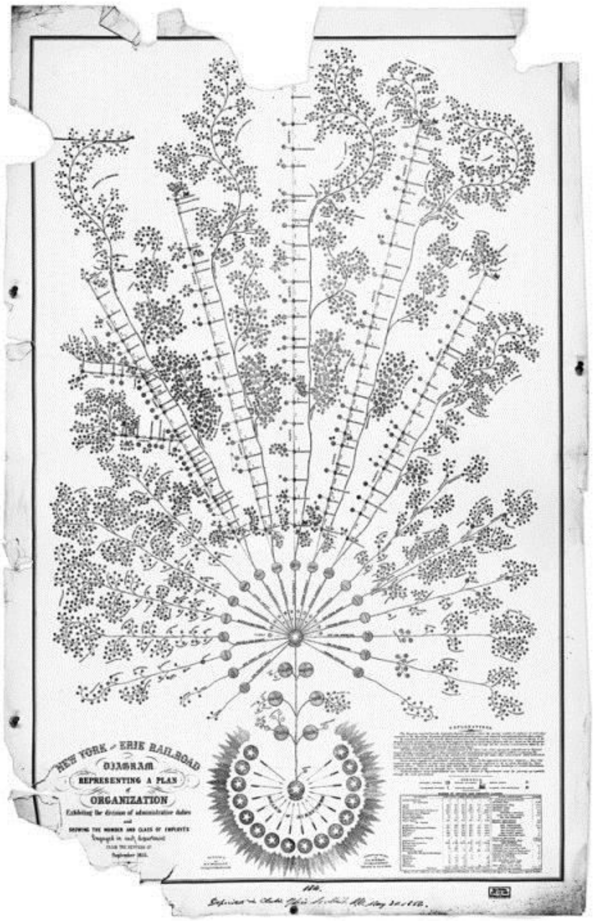

Fig. 3.2. ‘Plan of Organization of New York and Erie Railroad’ by D.C. McCallum (1855). (Lima 2014)

Equally interesting is the seemingly paradoxical role that basic telephony networks (PSTN) have had in urban landscapes. On the one hand, their urban salience was low both for citizens and city authorities, probably due to its national, centralized operation and management. On the other, the industrial city is unconceivable without their impact:

> They integrated national urban systems. They supported the development of central business districts [CBDs] and skyscrapers (as offices could separate from factories and still control them at a distance from central business districts). They allowed social networks to be continued in widely dispersed suburbs. They encouraged the planned zoning of cities, because phone companies came to rely on the predictability that zoning gave their own network expansion plans. (ibid, 12)

In another passage, these authors also highlight how the telephone was essential in establishing the “structured time patterns of the modernist city—with its standard business, leisure, sleep and commuting periods” (ibid, 67).

These remarks suggest the existence of a tetradic relation between communications; transport; organization and work; and land use patterns. In this relation, electric media would promote a polarizing pattern of (geographical and organizational) concentration-dispersal. In turn, this pattern would sustain the growing mobility of goods, information, capital and people both from peripheries to centers, and within urban centers.

First, since the capabilities of telex and telephony for distance communication allow "multi-site organizations or distant markets [to] be controlled over whole territories" (ibid, 129), activities of low added-value could be physically dispersed by creating suburbs, thus saving costs in labor and real estate. As has been observed (ibid; 1.1), cities always were, among other things, centers that controlled and managed their hinterlands by overcoming communicational time constraints through space reduction. In contrast, transmission links like telephony and telex overcome space constraints through synchronization, and for this reason they might be thought to help avoiding urban agglomeration. Yet, the expansion of the hinterlands of industrial cities extended the urban agglomeration of control functions to a qualitatively new level[40]. On the one hand, skyscrapers expanded vertically due to the heightened costs of property in city centers. This raised further control needs, which telex and telephony tackled in allowing an integrated management of these buildings. On the other, asymmetric and synchronic relations dominated the horizontal layout of space, i.e. the relations between CBDs (themselves horizontal agglomerations of skyscrapers) and their hinterlands.

Second, suburbanization could not be sustained merely by media. The labor and real estate costs saved became "externalized" to transport networks, since workers now needed to commute to the city centers, especially to CBDs, which created more traffic of persons both within and around cities.

Third, this process occurred against the backdrop of a national urban system oriented to exports-led growth. This means that all major cities were industrial nodes, and that manufacture –oriented toward processed goods and advanced equipment in rich countries, and toward extractive industries in developing countries- was considered to have "strong multiplier effects" on urban and national development (Sassen 1991).

Certain patterns underlying this configuration deserve mention. Since industry was the economic base of all cities, the input and output flows of goods around these cities were comparable, both satisfying the general trend of industrialism toward unchecked physical growth. These material flows of commodities added to the increases in human transport to create deep congestion and contamination problems in big cities.

[40]This apparent paradox is further examined in 4.3.3.

Another relevant aspect of this order is that the geographical and organizational concentration of vertically integrated corporations was supplemented by an overarching hierarchical role of the state, in regulation as well as in infrastructure development and control. In this regard, a key contribution is Polanyi's (2001). This author hypothesized a cyclic movement in capitalism whereby two contrary tendencies seamlessly succeed one another: (i) a free-market dynamics, characterized by radical pro-market policies whose implementation carried huge social suffering, followed by (ii) semi-cycles of political response from states, featuring new social contracts aimed at counteracting the effects of the first semi-cycle. The period 1920-70 was of the latter sort, especially after the war. In assessing the Great Depression of the 1920s –an overproduction crisis resulting from a period of financial deregulation-, the economist John M. Keynes took a macroeconomic stance to advocate economic policies of fiscal expansion through deficit spending, seeking to raise employment levels in order to secure levels of aggregate demand and allow capital to continue accumulation, though at the expense of risking inflationary bursts. This view underpinned the US New Deal and the Bretton Woods agreements and led to the creation of Welfare States in Europe, which allowed European middle classes to thrive in a period of economic expansion that lasted 30 years (the *Trente Glorieuses*).

Alternatively, Keynesianism is also read as a strategy of the U.S. and its area of influence (Europe, Japan) against the U.S.S.R-led Eastern Bloc, all throughout the Cold War. Key factors in this strategy were the influence of large U.S. corporations and banks; the absolute hegemony of the dollar as a single world currency, in substitution of the pattern gold; and the huge foreign investments from U.S. to Japan, Europe and Latin America –paralleled by the U.S.S.R.'s conditioned support to developing countries, mainly African and Asian, through the COMECON. All these factors converged to yield an integrated and recognizable multi-level hierarchy of powers and spaces: local, regional, national and international. Except for the alluded conflicts, this scheme is claimed to have secured national cohesion and general prosperity while reinforcing the dependency of citizens and companies to states; peripheries to capitals; and developing countries to the major power of either of the two blocs (Sassen 1991; Milanovic 2003).

Finally, Fordism was the system of industrial mass-production that prevailed in most Western countries during these decades. Fordism involved an interpretation and application of the economic principles devised by Marx and other classic economists of the 19th and early 20th centuries (see 3.1). Its philosophy was inspired by *productivism*, i.e. an economic view focused around production, seen as synonym to value creation; and was embodied on concrete technologies and rationalization techniques. Specifically, steam-powered engines, transmission belts and continuous-processing technology enabled the sequencing and continuity of operations within factories, while the Taylor system underpinned the organization of work in shop floors. Taylor had empirically analyzed production tasks in simpler movements, each of which could be carried out by independent workers in a repetitive fashion, all working together and synchronically within the rigid and highly structured schemes of assembly lines. In this way, assembly lines were thought to extract the maximum value of both machines and hired labor. Further, as most production segments were specialized in the production of single parts, the role of inventories was crucial: every segment had to store massive amounts of components, in order to avoid bottlenecks that could bring production to a halt. This is why Fordism also came to be known as a *just-in-case* system (van Dijk 2006).

Therefore, Fordist companies aimed at ever-higher production intensities, within an increasingly automatic, continuous functioning of both the parts and the whole process. The long term business plan was clear: to scale-up, in order to broaden markets as much as possible, so that a virtuous cycle of productivity rises, scaled-up production and competitive prices could be established. If a company produced bigger volumes than its competitors, and more efficiently and quickly, then it would simply absorb the latter in its vertically integrated organization. As Graham and Marvin remark (1996, 56 ss.), this model of economic activity also entailed decisive rationalistic assumptions about the circulation process and, more generally, urban development, to which industrialists, geographers and economists tended to abide. While the physical growth of cities was admittedly explosive and, in the long run, deemed unsustainable, agents were “seen to behave and locate in economically rational ways ”in that the frictional effects of distance were thought to determine economic choices. Factories would locate “where they could best access markets as well as raw materials”, and human interaction decreased directly with distance. Related, the effects of telecommunications on space were completely disregarded, and transaction costs, i.e. those involved in forming markets or integrating economic spheres, assumed to be negligible. Further, as socioeconomic patterns were seen to be evenly distributed across territories–exception taken for the urban division of labor within the national system and the related demographic variances, they were deemed largely predictable, and thus amenable to long term policy-making.

4. The Information Society as a socioeconomic restructuring of capitalism

Here I discuss the interplay between ICTs and the emerging social order of the 70s and 80s. More specifically, I shall complement the "technological determinist" approach to ICTs, offered in the two first chapters, with the analysis of industrial capitalism provided in chapter three. The aim will be to understand the crises of the 70s, as well as the responses that were given to them, under the premise that these responses have shaped ICTs, while being supported and accelerated by their development and use.

Following Castells and others, I have provisionally labeled these processes as a socioeconomic restructuring of capitalism taking place in response to a period of crisis in the 70s, especially in the years 73-75. However, this label is not without problems. On the one hand, it is both too abstract and incomplete. It is too abstract because this restructuring can be further analyzed in a bundle of processes; and incomplete, because certain crucial social changes cannot be straightforwardly imputed to capitalism without further qualification[41]. On the other hand, some readings of the crisis stress a specific response to it, while, conversely, an interest on particular transformations has often led authors to emphasize one aspect of the crisis above the rest. Since my aim is to integrate views on the issue, I shall discuss four convergent transformations, all of which were decisively supported by ICTs, while also being fundamental in their shaping:

- From Keynesian economic and regulatory regimes, to neoliberalism (4.1).
- From Fordism to a new corporate philosophy, Toyotism, and a new mode of production, the*just-in-time* system (4.2).
- From industry-based national urban systems, to a global urban system where certain information-intensive sectors appear as the new leading sectors (4.3).
- A new social contract and a "new anthropology" (4.4).

4.1. The turn to neoliberalism

One widespread reading of the 73-75 crises focuses on the oil prices shock and draws immediate attention to subsequent geopolitical realignments such as changes in the U.S. policy toward the OPEC, or the emergence of new strategies of development and management of infrastructures. In explicit argument against this view, Castells affirms:

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[41]Otherwise, we would be replacing the technological determinism of chapters 1-2 for a politico-economic determinism where the inner dynamics of capitalism suffice to explain all processes and events. Instead, it is prudent to assume that social and historical contingencies, such as the Cold War, have also influenced both the development of ICTs and the restructuring of capitalism –see, for example, pp.39-40. Likewise, there is abundant evidence of the power of autonomous social forces in shaping ICTs (Feenberg 1998).

> "[t]he real crisis of the 1970s was not the oil prices shock but the inability of the public sector to keep expanding its markets, and thus income-generating employment, without either increasing taxes on capital or fueling inflation through additional money supply and public indebtedness." (Castells 1996, 86)[42]

Ever since Keynesian policies were first applied, thinkers like Hayek criticized the interventionist role that the state took on them. For Hayek, interventionist states were an affront to the liberty of individual entrepreneurs and even all citizens; further, rather than unclogging the economy, they in fact adulterate it, thus preventing progress. These views were unpopular on the heyday of Keynesianism, until a series of events got them back in fashion through the work of economists such as Milton Friedman. To mention some of these events, "severe fiscal crises" in New York, Tokyo and especially London forced governments to cut public jobs and services by the mid-1970s, leading to an unemployment crisis (Sassen 1991, 191; Streeck 2013). At the same time, while many infrastructures of industrial cities, developed during the preceding 50 years, "were reaching the end of their useful lives" (Graham & Marvin, 65, 285ss), new demands were placed on them as a result of control crises, mainly related to traffic congestion and pollution (van Dijk 2006, 65). The difficulties to finance the necessary renewal of those old networks, including public deficits, coincided with the development of ICTs, an emergent group of technologies that could be plausibly used in infrastructure reform. Further, business-led movements were long demanding a shift away from Fordism toward a new mode of production(see 4.2), as well as the retreat of Keynesianism in favor of another free-market semi-cycle, and ICTs were perceived as helpful in both regards. The oil shock converged with all these factors to accelerate the events. Institutions such as the International Monetary Fund (IMF) and the World Bank (WB), created as part of the Bretton Woods agreements, now begun to promote policies of economic *neoliberalism*, which conditioned financial support to governments on their compliance with two basic precepts. On the one hand, states ought to control inflation via fiscal consolidation[43], i.e. rationalization measures such as the contraction of public employment or the privatization of entire economic functions. On the other, they should

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[42]Of course, there is no such thing as the public sector, but only public sectors of different states. Likewise, Keynesianism received different interpretations and realizations. A complete analysis should specify which countries depended more strongly on production or exports, and the role that their states held as a demand or contractor, as well as a generator of employment. In other words: although the limits of this work do not allow it, this and similar analyses would benefit from a finer degree of geopolitical detail.

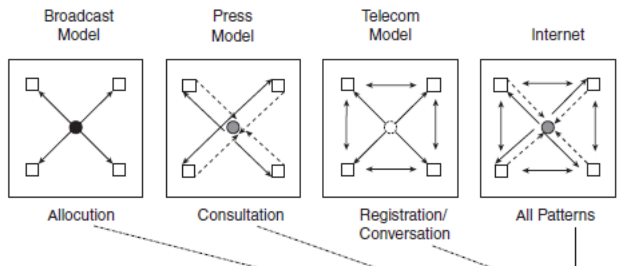
[43] This included an active dismissal of fiscal policy in favor of monetary policy managed by central banks, whose goal is generally to ensure price stability and to reduce risk by providing financial liquidity during downturns, while containing inflationary pressures during upturns (Solow & Clement 2002).

lift out restrictions on job markets, world trade, foreign direct investments and other markets, i.e. they should deregulate them. These institutions would gain special prominence during the Third World debt crisis of the 80s and in the face of decreasing opposition from the Eastern Bloc (Sassen 1991; Milanovic 2003; Streeck 2013).[44]

These processes are largely interlinked, so that their separate analysis is not easy. Still, here I focus on the general trends of deregulation and privatization, leaving for the next two sections analyses about, respectively, rationalization (4.2) and the deregulation of job markets and finance specifically, the latter including its globalization (4.3).

ICTs have enabled or facilitated deregulation and privatization in a variety of ways.

First, digitization over broadband cable networks has favored the deregulation and liberalization of ICTs. For some, this is partly a consequence of the intangibility of ICT services and the invisibility of ICT infrastructures, which prevents both "empirical work and policy-making on telecommunications and cities" (Graham & Marvin 1996, 52). Van Dijk (2006) offers a more nuanced interpretation of the process by comparing the features of Internet with those of electric media. In particular, mass media used electromagnetic infrastructure, where the scarcity of frequencies made public regulation desirable. In contrast, Internet usually operates over broadband networks, which are normally run by cable due to the superior bandwidth capacities of cable over wireless. This removes the factor scarcity, thus favoring deregulation and private exploitation. Further, mass media offered real-time transmissions with universal service and access. This raised cultural and public security concerns both with regards to the contents issued and the sender's intentions, which often led states to restrict broadcast licenses. In this connection, the digitization of infrastructures afforded bidirectional exchange and huge increases in transmission bandwidths (see 2.7). At once, this made possible a higher number of channels offering simultaneous transmission, and the creation of segmented audiences whose access to broadcasts could be restricted through pay-per formulae. These factors coalesced to promote the



Infrastructure Regulation	High	None	High	High
Content Regulation	High	Low	None	Low
Central Control	High ●	Low ●	None ○	Low ●
Sender Access	Closed	Open	Open	Open
Receiver Access	Open	Open	Closed	Limited

Fig. 4.1. Van Dijk's models of media regulation

[44]The U.S.S.R would disintegrate shortly afterwards, in the early 90s.

deregulation of mass media (1980s) and telecommunications (1990s). According to van Dijk, telephony and the press were always less regulated than mass media, and the regulatory model of the Internet currently stands in the middle (Fig. 4.1). However, the integration and convergence of ICTs has also been a force behind the regulation of older media toward the more flexible Internet model, based on limited access, strong infrastructure regulation and low content regulation. One reason for this shift seems to be that the capabilities of ICTs enable companies to easily invade each other's markets, which, in mainstream economics, advises against regulation (Graham & Marvin 1996).

Second, the computational capabilities and the selectivity of ICTs have been used to erode all other natural monopolies in infrastructure operation and management:

> What used to be public goods—because it was difficult to monitor and measure the exact consumption of specialized services, can now be privatized." (ibid, 303 ss.)

In other words, these tools make the idea of universal service irrational by affording precise information about the cost-efficiency of servicing various locations, or even different proximate households or customers (ibid, 32). A company that can fully specify its target niche is now able, for example, to develop tailored products and focus all its production and marketing strategy in well-defined and customized tasks. It can also reorganize its whole corporate structure by using GIS and similar tools to estimate how profitable it is to hold a branch office in a particular city or neighborhood. As a result, companies can focus on the places where value is concentrated: while there is an intense competition to serve profitable demand segments, even if they involve high investment costs; there are also incentives to dump expensive, marginal and poor customers in suburban or rural areas (Graham & Marvin, 40 and 151). Since these processes entangle the self-reinforcing dynamics of network polarization with geographical and other associated social patterns within the context of pay-per schemes, they provide support to the claim that computer networks have favored an expansion of market relations (see 2.6). Moreover, telematic tools have made the time- and space- control of infrastructure capacity use more flexible to transport operators and utilities, since they allow a fine-tuned and real-time balancing of demand and supply, like in smart grids (EOP 2013; Mazza 2013). In short, ICTs enable a completely new logic of service provision and management that has affected not only ICT infrastructure and services themselves, but also utilities and transportation. In fact, given that the U.S. transportation sector was probably among the first to undergo deregulation in the 70s, and that telematic tools were essential for undertaking the transformation of the transport sector[45], it is no surprise that the very meaning of telematics has come to be strongly associated with IT solutions used specifically in transportation management.

Third, the development and growth of ICTs since the 50s, and the restructuring of the sector since the 80s, has become a model of development, growth and restructuring for other technology-based sectors, and even for innovation in general. Castells provides a structured timeline of these events. Although the World War II is usually mentioned as the origin of ICTs, its advances often remained confined to university departments. ICTs received the definitive impulse when groups of researchers from Stanford University left the university to establish the commercially oriented innovation milieu of Silicon Valley. However, these entrepreneurs kept close contact both with their university departments and their military contractors. This was decisive, for, while academic contact ensured the electronics industry a constant stream of new knowledge, military markets afforded it protected niches to consolidate and experiment with new products. Ever since then, similar strategies were followed by Japanese or Korean firms, which relied on national protection to consolidate before expanding to cleverly targeted global markets. In short, this enabled them to "build up economies of scale in order to reach economies of scope" (Castells 1996, 86; see p. 37). Over time, then, these carefully delimited public-private joint ventures became a model for organizing neoliberal innovation systems. In this model, there is a strong public impulse to basic research and to new innovation milieus, coupled with a strict protection of new market niches (Schot & Geels 2008). Once the knowledge diffuses and companies consolidate, the sector is opened to exploitation with soft regulations (Collingridge 1980). In the ICT sector, one the key events in this trend of deregulation was the divestiture of ATT in 1984 (Castells, ibid). However, several other laws were passed that prepared the strong but short period of growth of 1996-2004 (Gordon 2012; 2014), which concluded with the well-known bubble of the dot.com.

These events have had seemingly paradoxical effects on ICTs. First, the progressive liberalization of telecommunications has had to grapple with the ongoing tendencies of the sector toward concentration (see 2.5), as exemplified nowadays by the persistent lobby exercised by powerful consortia of ICT giants in initiatives such as smart cities. In sum: oligopolies if not quasi-monopolies are proliferating, which, according to some, should be reason to subject these companies to anti-trust laws (Taplin 2017).

[45] More on this below, in section 4.2.3

Another paradox is that, while old infrastructures served as an enduring and stable developmental force in the 1920-70s, during neoliberalism they became "restraints on the freedom with which economic forces or public policy can reshape the city" (Graham & Marvin 1996, 329). As a result, opportunism in urban development is now the rule: international providers or governments alternatively take on the central role depending on the existing infrastructure or in the entry costs and interests a given project arouses.

Lastly, deregulation and liberalization have both promoted an effective explosion of redundant infrastructure. Before the breakup of ATT, for example, some competition was allowed in U.S. telecommunications during the 60s and 70. As a result, microwave systems[46] or miniature satellite receptors (vSAT)[47]were commercialized and indeed diffused quickly. But the information explosion and the rapid innovation trends in microelectronics rendered these technologies somewhat obsolete in the 80s, where fiber optics took over large infrastructure projects. As a result, while some old infrastructures still co-exist with the new ones in a sort of patchwork, many of them have been largely abandoned. According to van Dijk (2006), this is a social and a natural waste that continues today with the ongoing competition between cable and wireless operators.

4.2. A restructuring of forms of production and organizations.

The socioeconomic restructuring of the 70s and 80s is also characterized by an ICT-enabled integral transformation of corporations in the material economy and a change in mode of production: from Fordism to Toyotism. Here I address this change in four steps. I begin by explaining the shortcomings of Fordism (4.2.1). Then I explain three ways in which ICTs supported the overcoming of Fordism. First, ICTs helped to develop a new corporate philosophy, Toyotism, by empirically supporting an improved scientific view of the economy (4.2.2). Then, they enabled the application of the *just-in-time system* of production and supplies, which advanced Toyotism by reengineering production and supply chains (4.2.3), and by a reengineering of business organization (4.2.4).

4.2.1. The crisis of Fordism

The 70s saw the demise of the Fordist mode of production. Fordism aimed at optimizing all the parts of the production process, with special attention to building economies of scale by increasing speed and productivity (pp. 40-41). However, this philosophy had

[46]They are widely used as backups in short-distance, line-of-sight transmission in congested cities.

[47]Mainly in narrowband, on-the-move communications (Graham & Marvin 2009)

problems. First, evidence shows that, by the 60s, the complexity of consumer goods had grown, both due to intrinsic product features –in the emerging consumer electronics market- and to a trend of customization or segmentation of the demand[48]. This raised a problem for Fordist companies, which used to produce standardized goods, and where the linearity of production chains, mirrored by the vertical integration of management, made difficult to increase the complexity or customization details of their products. To some extent, such demands could be tackled, but at the expense of adding still further links to the production chain and more bureaucratic layers in management. This made the whole chain more prone to suffer bottlenecks in every link. As van Dijk reports,

> [since this] linear structure had too many phases and links working at different speeds… [it] was vulnerable to the smallest malfunction. An extensive hierarchical line structure was needed to coordinate all processes and divisions. The more complicated the end product, the longer and more complex the route between all the divisions. The results were long and unreliable delivery times. Only two decades ago a (part of a) product was processed only 5 percent of the time it spent in the factory; 30 percent of production costs were used for storage, coordination and transportation inside the factory. (2006, 67)

A related problem lied in the neglect of circulation assumed by this just-in-case system, which typically exposed Fordist companies to overproduction. The rationalistic assumptions about the irrelevance of transaction and coordination costs had been fairly accurate for decades, but, in facing raised global competition and the aforementioned customization trends of the late 60s, these companies ended up producing huge volumes of goods that could not be sold. This depreciated stocks and brands, reduced profits and slowed down returns on investment. The speed of capital turnover was not only low, but also increasingly unpredictable: the issue was not merely liquidity, but heightened risk.

Finally, these problems were aggravated by the fact that Fordist companies pursued productivity boosts as a matter of course, whereas increasing "productivity without a prior expansion of demand, or the potential for it, is too risky from the investor's point of view" (Castells 1996, 86). Therefore, this kind of company was rather unable to tackle the new demands of the consumer goods market while also increasing productivity and controlling the bottlenecks that such boosts typically created. As a result, by the late 60s the productivity growth rates were even declining (van Dijk 2006, ibid).

[48]Van Dijk suggests that more or less autonomous forces arising from civil societies were responsible of this supply-to-demand shift (ibid). Yet, by his own admission (see pp.24-25), ICTs decisively enabled the trend, as well as the new marketing techniques that afforded a controlled segmentation of the demand.

4.2.2. Toyotism as a new corporate philosophy

These factors, together with the crisis of the 70s and the opportunities opened up by ICTs, eventually led to the gradual substitution of the Fordist mode of production by an alternative that had been developing in Japan since the late 60s. This was the *just-in-time system*, often called *Toyotism* since Toyota pioneered its implementation.

As Castells (1996, 75) recalls, there are four ways to increase profits when prices are set by competitive markets: to reduce production costs, to increase productivity, to broaden the market (geographically or formally) and to accelerate capital turnover; all of which have been used both since the 70s and before then (see 3.1). Toyotism does by no means break with these methods, but it interprets and juggles them differently than Fordism to yield a corporate philosophy that involves new views about organization, production or corporate-customer relations.

Toyotism builds on the shortcomings of Fordism, and, in at least three senses, it advances a more integrated and scientifically sound economic view[49]: first, it grants circulation the same relevance as production; second, it acknowledges the key role of communication and transaction costs; and, third, it accords with the fact that, in seeking competitiveness, diversifying markets or reducing production costs are strategies just as valid as scaling-up production. But the crucial difference with Fordist companies is that, although these focused in production, they were often unable to avoid overproduction; while, in contrast, Toyotism seeks to avoid overproduction by all means.

Therefore, two motives seem dominant in this new corporate philosophy: on the one hand, rationalization and saving costs; and on the other, an ongoing "redistribution of added value towards where all the money is concentrated" (van Dijk 2006, 65), taking place in two related ways: a *customization* trend partly driven by the demand side[50] (Sassen 1991) and a *dematerialization of the value chain* in the supply side[51]. The fact that these two motives are typically urgent during economic recessions (ibid; Mandel 1995; see 3.2) makes them reasonable responses to the crisis of the 70s.

ICTs have provided 'intelligence' or empirical backing to this new philosophy in a number of ways. As shown above (2.6; 2.7), advanced software can monitor and analyze consumer trends; more generally, it can simulate the dynamics of any economic sphere,

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[49] See p.38, on the role on crisis as stimulants for the development and application of new business models and new scientific views on the economy.

[50] This will be addressed in 4.2.3.

[51] This trend already appeared in 2.6, but is further elaborated on 4.3.

and even entire economies (2.6). In finance or innovation, similar tools also expand investment opportunities while reducing epistemic uncertainties. Those equipped with advanced telematic tools can detect new markets, target the most profitable ones and reap them up in a pay-per basis -if they arrive first than their rivals. Further, companies can avoid risky investments and save costs, which makes business plans more flexible and reliable *a priori*[52]. Consider, as a case example, the avoidance of overproduction: to achieve this, corporations had to have, first and foremost, precise data and accurate scientific assessments about the bottlenecks and delays caused by Fordist production chains, such as those included in the above quote by van Dijk. These data can be better captured by telemetric means, and have to be processed by computers.

4.2.3. The just-in-time system: a reengineering of production and supply chains.

The just-in-time system reengineers production in three significant ways. First, it avoids overproduction by reducing or eliminating inventories. Then, production is made more easily adjustable to a changing demand; this counters overproduction too, but embeds this cost-saving strategy in the more comprehensive aim of concentrating production in added-value goods -by segmenting markets and providing customized service to the most profitable ones. Typical of the just-in-time system is also an ongoing, cost-saving drive to minimize the transit time of goods, that is, the lag between order and delivery.

To these effects, a key strategy has consisted in bringing about a timely adjustment of production to fast-changing and increasingly complex customer requirements; in other words, to match supply and demand more efficiently. Again, ICTs are extremely important in this regard. A first step is modeling the demand. Here, telematic systems allow companies to capture the real-time flows of goods, while data analytics software helps building more accurate customer profiles –today enhanced with data mining, i.e. tracking user online activity and processing it with advanced DMS and AI (2.5). Castells (1996, 157) also reports how Japanese engineers studied the control strategies used by American supermarkets to assess stock on their shelves, in order to extend them to programming tasks in the whole factory system. All this information has to be fed back to the production line in order to make it highly adaptive to orders with changing volumes and increasingly customized features.

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[52]Only *a priori*, for, as technology diffuses, competition escalates. Marketing strategies, for example, get increasingly invasive, and the spread of advanced software poses incentives for developing improved software at ever higher costs. This verifies the trends anticipated in 2.3, and casts them in a new light.

Then, Toyotist production is usually dispersed in networks of well-trained suppliers tightly connected to a major customer or a parenting company[53]. As Sassen documents, this dispersal is often truly global, for example,

> “when Japanese auto makers put twin plants in northern Mexico to make cheap auto parts for their plants in the US, where those exported to Europe are also produced." (1991, 190)

This physical dispersal of production, coupled with the requirements of feedback from the demand to production, entails the need for many other advanced ICTs. First, corporate broadband LANs must connect suppliers with branch offices and customer interfaces. Then, there is a need for advanced software to support the work of suppliers in making this ongoing, online adjustment of demand and supply (Castells 1996, 155).

More importantly still, high quality and reliable global transportation networks have to be in place in order to minimize inventories while also reducing the transit time of parts and goods. In turn, this introduces pressures to increase the flexibility of supply chain management. These pressures can be tackled by means of software, usually shared by partners, and whereby orders and deliveries are flagged with reference codes; stored, processed, and shipped together with other cargo; and followed door-to-door thanks to their reference codes. Such systems typically involve decentralized management, as is enabled by trends towards ubiquitous computing. Recently, blockchain technology operating in the IoT has appeared as an opportunity to take this trend one step further. In this way, too, *intermodal transport* solutions for goods and people become common. Intermodal solutions use infrastructure and operators from different transport modes (road, rail, sea, air…). They build on the smart use of infrastructure through real-time redistribution of infrastructure capacity, which, as noted above, is enabled by telematic systems (see 4.1; Graham & Marvin 1996, 281). In freights, these solutions have favored an overall shift toward road and air transport (Curtis 2009), the reason of which seems to be that, while the former is more flexible, the latter minimizes the circulation time in long distances, and these are both properties actively sought in the just-in-time system. A problem, however, is that road and air are comparatively less environmentally sustainable than other transport modes (ibid), especially in long distance[54].

[53] More on this below, in 4.2.4.

[54] The EU has tried to minimize freight transport by road at least since the Marco Polo program (born in 2003, ongoing), which justifies this recommendation by reference to environmental criteria. However, the initiative has had a limited success to the date. (https://ec.europa.eu/transport/marcopolo/)

Then, as was advanced, customization is only made possible by the use of interactive simulation tools in design (2.7). Now it is clear that, together with the dispersal of productive activity across distant plants, customized production originates still more needs for advanced ICTs. In particular, it requires microelectronics-based precision and advanced quality control all throughout the chain. On the one hand, all the parts of a product have to be "compatible to the smallest detail of specification" (Castells 1996, 96 ss.), so that mutually distant suppliers can build the parts and these are later assembled, while minimizing costs relative to material waste in all these processes. On the other, computerizing tasks is a precondition to create specific adaptations at low costs (Sassen 1991, 106). In this regard, planning and control tools like CIM (2.1) are particularly important. Supported by broadband LANs forming VPNs (Virtual Private Networks), they afford the flexibility and computational capabilities that factory plants require to cope with the huge control demands that the fully transformed supply and production chains of the just-in-system impose on manufacturing processes and cycles.

I conclude by discussing some trends in consumer electronics. This discussion is convenient because the just-in-time system finds a peculiar and seemingly contradictory expression in this field, which forces us to delimitate the scope and extent of the above explained changes. In particular, although the trends toward product customization and smaller production runs generally prevail, this dominance still depends on the product and the degree of competition in the relevant market. It cannot be overstated, for instance, that *avoiding overproduction does not mean to renounce mass production or mass markets, and much less disregarding productivity as a goal or as a performance criterion*. In fact, the buoyancy of the consumer electronics market shows that, while large companies cannot afford to serve only the richest segments of the demand, the need to expand sales volumes still provides ongoing incentives to increase productivity.

A curious tension thus arises from the need to reconcile productivity growth and economies of scale, on the one hand, with the need to avoid overproduction in the face of a fierce competition, on the other. In consumer electronics, a common solution to these *prima facie* opposing needs has been to force quicker capital turnovers, and one of the frequent means to achieve it has been to force increases in rates of product reposition.

This rapid rate of product reposition is perhaps best understood by reference to *planned obsolescence*, an old corporate strategy for achieving quick capital turnovers. Planned obsolescence is the deliberate reduction of a product lifecycle by design. Many techniques serve to effectuate planned obsolescence, such as manufacturing a product with cheap plastic parts or worse metal than usual, so that the product will age or break more easily; in this way, not only quicker capital returns are possible, but production costs may be dumped too. A less well-known method arises from the peculiar relation that exists between hardware and software, by which the computational, usability or graphic demands of some software may make it compatible with a specific hardware but incompatible with others (1.5). Companies like Apple or Microsoft can, for example, deliberately induce rapids rate of software innovation, thereby raising a software-led incompatibility with older hardware, and thus the obsolescence of this hardware with respect to new applications. In turn, this accelerates rates of hardware reposition, from which these companies benefit as manufacturers. In fact, these companies -especially Apple- are well known for engaging this strategy as a matter of course. As a result, a self-reinforcing cycle of endogenous innovation and ever-faster rates of product reposition has arisen in consumer electronics[55]. The fact that both cultural and technical planned obsolescence are prominent in this market is a crucial factor in explaining why some ICT giants can continue to seek expansion and productivity growth, while also managing to avoid overproduction.

4.2.4. Business reengineering: digitalization and outsourcing.

Here I discuss the dispersal of production and the subsequent restructuring of supply chains as trends embedded in a more general *business reengineering*, featuring two key elements: the general *digitalization* of corporate structure and the vertical disintegration of large corporations. Typical patterns emerging from business reengineering are, too, an ongoing *outsourcing* of services or parts of production from large firms with strong market positions to -often smaller-firms that depend on them; and a generalization of *networking* as a mode of flexible interaction between these two kinds of firms.

Digitalization

Digitalization has a broader meaning than its cousin *digitization*[56]. While the latter may refer to the simple adoption of technologies for digital signal processing, i.e. computers; the former has increasingly come to mean a broader restructuring of organization and work (Moore 2015). *Prima facie*, digitalization is simply another automation process. As

[55]The trends studied in 2.3 now gain a new dimension in light of software-driven obsolescence.

[56]See note 8.

explained in 3.1, industrial machines acted as technological delegates of the upper layers of corporate management, making obsolete both animal and human energy (steam engine, transmission belts) and human dexterity (machine tools). Industrial automation is generally associated with three sorts of effects (3.1). From the standpoint of companies and consumers, automation may boost productivity, dump production costs and, therefore, prices. On the side of work, it reduces the total number of working hours, i.e. the socially necessary work, thus raising chronic unemployment; and it deskills workers, now bound to perform more mechanized tasks. Finally, automation transforms capital-labor relations by allowing the former to accumulate fixed capital –the machines introduced- with which to increase the rate of relative surplus value extraction; in this manner, corporate profits can rise by employing a depreciated and shrunk workforce.

Digitalization certainly resembles prior automation processes. However, it also departs from them in important ways. An obvious difference lies in the technology used, together with the object of automation. Among the technology used we find advanced telecommunications equipment and software such as expert systems, DMS, CIM or ERP (Enterprise Resource Planning). In this regard, a basic definition of digitalization would be the process of application of these ICT technologies in automating routine corporate procedures. More specifically, these ICTs have swept many tasks of *explicit* information-processing, such as the routine processes of supervision and control of production on distant sites, which used to be embedded in the command-line, bureaucratic structure of Fordist companies. Since these activities were traditionally carried out by middle management levels reporting from plants to headquarters, or acting as intermediaries between the geographically distant divisions of these companies, digitalization has made obsolete and altogether replaced these middle management levels (Castells 1996, 169).

As a result, the application of ICTs in digitalization has improved the performance of companies in coordination functions, while also streamlining bureaucracies both in volume and in complexity. Although, according to van Dijk (2006), this belies Weber's claim that rationalization processes necessarily make bureaucracies grow, he also notes that bureaucratic procedures do not disappear; instead, they are only computerized, i.e. delegated to computers. At first glance, this might be thought to counter van Dijk's claim, since we do not say that industrial production disappears when factories get automated. Yet, crucial differences exist between computerized control and bureaucracy.

A first one lies in the superior flexibility and expediency of computerized systems, whose downside is an increased volatility, especially when these grow in autonomy. A second is that computerized bureaucracy breaks the link between the exercise of power in remote sites and the control of humans by other humans, which arguably raises the possibility of broader and deeper transformations in human relations (see pp. 32-33).

Other aspects exemplify the divergence between digitalization and the automation waves carried out within Taylorism-Fordism. On the one hand, digital jobs are said to be less dehumanizing than jobs in the semi-automated assembly lines of Fordism (Moore 2015), an issue that I elaborate in 4.4. On the other hand, ubiquitous computational capacities have not merely allowed human work to be replaced by capital; as suggested above, it has afforded large corporations the means to carry out a geographical and organizational dispersal of production and supply chains, resulting in the disintegration of these large firms in networks of producers, suppliers and service providers that are now formally independent, while at the same time remaining under the control of major firms or states (Castells 1996; see pp. 46-47). Now I turn to this transformation.

Outsourcing and networking

The large and vertically integrated structures of Fordist corporations have tended to disappear, while, in Toyotism, outsourcing practices are now dominant. Outsourcing, or externalization, is the process by which companies subcontract labor and/or services from independent organizations that are offering this service in the market. Its opposite process is in-sourcing, by which certain services previously acquired in the market begin to be developed in-house; a company now produces them for its internal consumption. In-sourcing relates to the absorption of the company developing the relevant service. Conversely, outsourcing often involves the partial disintegration of large companies.

Companies providing outsourcing services seek to establish a close liaison to a large company, where the latter acts as a parent company, and the former as subsidiaries; or these may become part of the network of suppliers of the larger company. These networks are flexible, but otherwise scale-free with regards both to the number of interconnected agents and the size of its markets served. Following the remarks made in2.4, the largest company in a network can also be seen as a highly visible, well-connected hub that raises a competition between various outsourcing services aiming to cluster around it; this phenomenon did not happen in Fordism, since Fordist companies did not outsource services frequently, but rather tended to in-source them, thus scaling-up organization as they scaled-up production. Toyotism, instead, promotes outsourcing and organization downscaling even though the scale of the markets served by a company –and more and more frequently a network of companies- has continued to grow.

A company does not outsource its functions randomly: rather, it keeps those that are deemed essential to the brand, either because they are more profitable or because they are indispensable management functions; and it dismisses the rest, not just because they are inherently costly, but also because they induce further coordination costs, which in turn diminishes both profit margins and operational flexibility. More specifically, van Dijk (2006) holds that the core functions to maintain in-house are management and other strategic tasks typically carried out by added-value divisions, such as product design or product marketing. To these services produced for internal consumption, however, one must add a wide spectrum of heterogeneous services that are outsourced or bought in the market, either because companies externalized them or because they began to be developed only recently, together with further innovations in software or ICTs. These include added-value information services like consulting or advertising, but also services like catering, back office, cleaning and maintenance, which belong to the low-end of the value chain. Often, outsourcing has also affected industrial segments of production, in which case it is commonly labeled as an *offshoring* process. Recall that Marx predicted a progressive displacement of skilled labor, due to economic pressures for the automation of manufacturing. Though this remains a permanent incentive to companies, industrial offshoring has slowed down its effects since the 80s. The reason is the relative cost-efficiency of cheap foreign labor, as compared with the unpredictable cost-profit relations that industrial automation could provide during this period.

With digitalization and outsourcing, a large company reduces its size, simplifies its structure and consequently dumps costs. But, being a rationalization process, business restructuring does not merely save costs. Marx already suggested that rationalization may increase productivity (3.1). In fact, restructuring has afforded individual companies an opportunity to concentrate their activity in the profitable segments of production (van Dijk 2006). Further, outsourcing companies do not just act as suppliers, but also as "captive markets" or local customer interfaces for the large company in a network (Castells 1996). As a result, large companies can now focus in the operations of a much reduced organization disseminated across a few central places and even clustered in a single headquarter, while keeping their global markets and other global interests under control, and even enhancing their global position.

Finally, note that outsourcing is not a mere corporate trend. As a rationalization technique, it may be generalized to any organization, and in fact it soon merged with neoliberalism to penetrate public administrations, being frequently used in planning and executing the partial or total privatization of public services (van Dijk 2006, 65).

For digitalization and outsourcing to be successful, however, companies must place huge investments in the hardware, software and advanced information services with which to coordinate the activity of all other companies in their networks. Some of these ICT-enabled capabilities were already surveyed: if broadband networks are important to provide the quick intra-corporate information flows required by geographic expansion, they are indispensable when it comes to affording efficient coordination between distant partners with independent organizations. Often, these networks are used as VPNs to implement corporate intranets that afford services of information transfer, but also resource-sharing platforms and, more generally, decentralized control capabilities. This, in turn, grants more autonomy to distant offices, which entails the option to decentralize responsibilities while automating many of the pre-existing bureaucratic routines. It is in this capacity that ICT were decisive to favor, in a single stroke, the elimination of middle management layers and the outsourcing of entire corporate functions and divisions – and, in parallel, to the neoliberal privatization of government functions and agencies.

4.3. Globalization and the service economies.

This section details the picture of the Information Society by placing a special emphasis on clarifying the differences and similarities with the Industrial order. In particular, I discuss two differences and one similarity between informationalism and industrialism. First, informationalism involves a higher degree of global economic integration than industrialism; which has occurred at the expense of a lesser integration of national systems (4.3.1). Second, a trend of dematerialization of the value chain in the supply side (van Dijk 2006, 65) has displaced industry as the leading sector, a role that now belongs to information-intensive sectors that include finance, innovation and producer services. This supplements the trend toward product customization to promote a self-reinforcing process of concentration of wealth and economic activity in added-value parts of the economy –whose correlate is an increased socio-economic polarization (4.3.2). A common note of these two trends is that the simplification of individual organizations has raised new needs in the interfaces between corporations and between corporations and governments, which has resulted in more complex economies and societies. On the other hand, informationalism resembles industrialism in that both share certain self-reinforcing patterns: a growth in the volume of goods and information mobilized; increasingly polarized land use patterns (extreme agglomeration and extreme dispersal); and synergies between urban agglomeration and the growth of transport and communications infrastructure. These patterns supplement the socio-economic polarization above described with distinctly geographical determinations (4.3.3).

4.3.1. Globalization and finance

A clear measure of the complexity gain above referred is the globalization of corporate activity, which is closely linked to the processes entailed in business restructuring. Business restructuring was itself possible due to neoliberal deregulation in matters such as finance, transnational ownership or supply chains; once widely applied, however, it massively increased the amount of transnational corporations (TNCs) and their total capitalization, thus providing global substance to a new regime (Sassen 1991).

Another major drive of globalization has been the deregulation and globalization of financial markets. This can be traced at least to the 60s, where the diffusion of telex, together with relevant institutional changes, helped to reduce communication costs, transaction costs, and thus the costs of raising capital (Battilosi 2009)[57]. This made possible the formation of the Eurodollar market by U.S. banks, which, in the 60s and 70s, was a key niche for innovation in financial tools such as liability management, security trade and other information services in bank portfolio transformation –for smoothing and distributing liquidity, for more efficiently managing financial risk-sharing…- or in brokerage –for reducing information asymmetries in transactions. These tools have a somewhat ambivalent status: *a priori* they are services but, due to financial deregulation, they could be traded as commodities since the mid-70s and especially the 80s (Sassen 1991). Another example of these new tools is the phenomenon of "emissions trade", by which firms subject to cap-and-trade schemes come to speculate on, or exchange, the liabilities they have regarding their performance in ecologically sensitive indicators.

In spite of the earlier origins of this financial restructuring, the growth of finance in 1970-90 represents a true discontinuity with respect to earlier periods (ibid, 189 ss.).

[57] This explosion of telex-enabled financial tools links financial growth with the trends examined in 2.3.

Some differences are quantitative: for instance, the magnitude of acquisitions and the number of financial transactions have skyrocketed at a global level. But qualitatively new phenomena have also emerged. Certain cities have become "transnational centers" with a global orientation, which contrasts with the strong ties that industrial cities held to national markets. Cities like New York, London and Tokyo accumulate the production, trade and consumption of financial and other information-intensive services; and they attract management functions of both individual corporations (headquarters) and of the whole economy (banking and the FIRE sector, comprising Finance, Insurance and Real Estate).For this reason, these cities have been labeled "global command centres" (ibid).

These cities now concentrate foreign transnational corporations (TNCs) that handle business "on behalf of both host country firms and co-national firms operating in the host country". Indeed, the terms "foreign" or "domestic" are now almost meaningless with regards to TNCs, since the creation of international property markets has involved the "transnationalization of corporate ownership and control" (ibid). Even more to the point is the fact that, although governments still have to legitimate the arrangements for developing functional financial arenas, they rarely participate in finance *per se*. This contrasts with the key role of the U.S. government in the "investments and acquisitions in Latin America during the 50s and 60s", which often reinforced the political inequality between the intervening countries. A new landscape has emerged with this shift away from state-controlled finance, where the major command centers specialize in different roles and come to control a large part of the capital flows within the global networks of financial operation. Thus, in the 80s Tokyo became the major exporter of capital, London the main processor and New York the major recipient and site for decision-making as regards to investments; while, in Europe, cities such as Paris or Frankfurt also centralize key financial functions of the continent. Also importantly, this tendency to the retreat of states has favored new forms of public governance at the municipal and intermunicipal levels –a development which is not unrelated to the increasingly central role of "highly innovative cities" in the global economy (Graham & Marvin 1996, 329-355).

ICTs afforded the global connections, data integration and advanced software that enabled the globalization and growth of financial and property markets. Recently, this software has come to include bots that autonomously carry out financial transactions. This raises prospects for the ongoing automation of added-value services, as follows from pressures towards higher rates of relative surplus value extraction and relative rather than absolute exploitation. On the other hand, the use of advanced AI will surely increase unpredictability and volatility in the already quite volatile financial sector –and therefore, in a global economy where finance has become more central than ever.

4.3.2. Innovation and producer services

Many corporate activities are now about producing informational inputs, or otherwise based on an intensive use of ICTs. This has generated an increasing variety of specialized services and a huge growth of information production and exchange. As information-intensive activities and ICTs gain weight in the economy, all economic agents, including entire countries, increase their dependency on information and software.

Post-industrial theory addressed these facts long ago. Bell argued (1973) that, in the 70s, a transition begun from industrial economies to knowledge economies. This change was characterized by three shifts. First, a shift away from the production of goods to service delivery, building in the product-to-service transition (see 2.6); second, a shift from industry to information-based sectors as the leading sectors –the main source of productivity growth and, generally, economic growth; finally, the workforce becomes predominantly "informational", i.e. formed by experts in knowledge-based activities.

However, these claims received substantial criticism. Economists find, for example, that productivity growth rates and other growth indicators have in fact declined since the 70s, except for a short-lived growth period in 1996-2004 (Solow 2002; Gordon 2012, 2014). Then, Castells argues that the link of information-based sectors with the industry is still essential for growth, as shown by the fact that, since the 70s, Japan and later the Asian Tigers –which retained or formed strong industrial sectors- grew more rapidly than U.S. or U.K –where both offshoring and the dependency on service sectors were more intense (1996, 200 ss.). Further, Castells (ibid) and Sassen (1991) stress that the shift to services has also generated a rapid growth in low-paying and low-end informal jobs, and even in criminal activity -especially in large cities.

Perhaps the insights of both post-industrial theory and its critics can be integrated by tracing the source of these changes in four processes: neoliberal deregulations (4.1), the explosion of innovation activities (2.3), business restructuring (4.2), and innovation, globalization and growth in finance (4.3.1). Since most of these trends were already analyzed, I now address innovation, and specifically the growth of producer services.

In 2.3 we saw that the historian Godin sees, in the 50s and 60s, a deliberate political impulse of innovation activities in the OECD countries, coupled with a parallel concern about the best way to manage the massive informational outputs that such activities were generating. As Castells explains, many of these innovations were technological and retained a link to industry -we examined this kind of activity with the example of Silicon Valley. However, a new kind of innovation emerges in the 60s and 70s, whose link to the industry is much more remote. As explained, the 50s-60s period is also described by Godin as one in which information came to be overwhelmingly perceived and treated as a commodity –for instance, with the commercialization of new financial instruments or software tools for business restructuring. In fact, this process seems to have induced new needs in the economy, of two main sorts: services to carry out the restructuring itself, and services in the interface between different organizations and economic agents that have already restructured or simply born in the new context. This is a new type of service, whose explosion needs separate clarification.

Many authors (Sassen 1991; Graham & Marvin 1996; Castells 1996; van Dijk 2006) report "a fierce competition" between the operators of all telecommunication platforms in the production of value-added network services (VANs) that combine information and communication services. These firms are, mostly, transnational oligopolies that offer ICT facilities and connectivity for a growing number of often smaller service companies. These, in turn, specialize in the R&D of highly customized telematic services that allow for the ongoing "division and dematerialization of the value chain" (van Dijk 2006, 79). Sassen (1991) offers an elaborate account of these new, small and specialized firms. Since they service other companies rather than particulars, they produce intermediate economic inputs, intermediary services of production, or *producer services.* Producer services have raised another important "virtuous cycle" in the information economy. They are often required to carry out the processes involved in business restructuring and, since they are virtual, they have low reproduction costs. This favored the quick generalization of business restructuring. But this, in turn, intensified competition among producer service firms, which proliferated and diversified. As Sassen explains:

> "Diversification of product lines, mergers, and transnationalization of economic activities all require highly specialized skills in top-level management. These… increased the dependence of the corporation on producer services, [promoting the] growth and development of higher levels of expertise among producer service firms" (1991, 10)[58]

[58]The self-reinforcing dynamics of growth, diversification and increased complexity of these information services is evidence for the existence of the trend postulated in 2.3, and the same time specifies the nature of this trend and the processes that are involved in its reproduction. See also note 57.

These companies offer solutions in domains like consultancy or business analytics, which are highly demanded by all companies seeking to operate globally. *Pace* Castells, who stresses their link to the industry, Sassen holds that many of the major clients of these firms rather belong to the immaterial economy, especially to banking and the FIRE sectors (Sassen 1991), which have increasingly concentrated money and assets since the 70s.Trends toward centralization and global operation are also frequent among these firms. In consultancy, TNCs such as Deloitte or Price Waterhouse Cooper are abundant. A paradigm is SAP (standing for “Systems, Applications & Products in Data Processing”), a spin-off from IBM that has engaged in dozens of mergers and acquisitions. This company specializes in tailored software services that provide its clients with precise and updated information with which scientific assessments of any economic issue can be elaborated, incorporated in business plans and used to direct operations. Decisively, many of the core processes involved in business restructuring are incorporated in SAP’s portfolio[59].

Above we had portrayed economic dematerialization as involving the virtualization of pre-existing commodities and the creation of natively digital, new commodities (2.6). A closer look on producer services now shows that this is a more complex process, linked with many techniques of business restructuring. Van Dijk describes quite precisely how economic dematerialization and business restructuring are rooted in the scientific capabilities of ICTs, applied to the study and control of the economy:

> “[i]ncreasingly, all available information about the production, distribution and consumption process is detached from the process itself… This information is processed electronically and sold separately.” (2006, 79)

We studied these processes as rationalization techniques used for (i) saving costs and (ii) concentrating value in certain segments of production by creating customized products serving a segmented demand. Now, this segmentation entails a polarization: while value concentrates in some economic activities, it flows away from others. The benefits of this concentration of value may accrue not just to the outsourcing company but also to others that belong to its network and offer added-value information services –firms like SAP. However, many outsourced tasks, spanning from industrial activities to low-order information and maintenance services, now concentrate less value and have,

[59]Consider products such as Enterprise Resource Planning (ERP), Product Lifecycle Management (PLM), Supply Chain Management (SCM), Customer Relationship Management (CRM) or Supplier Relationship Management (SRM).

to a greater or lesser extent, degraded. As a result, digitalization, coupled with employment deregulation, has become a powerful force of socio-economic polarization.

First, outsourced services enter into a direct dependency from parent companies; yet, since they no longer belong to large companies, they must fight for a market share in precisely the economic segments where profit margins are lower due to the correlative concentration of wealth in other, added-value segments. Then, Sassen documents the growth of informal jobs and sweatshops in large cities, a backward phenomenon that she deems intrinsic of the new economy, and that belies Marx' hypothesis regarding a shift toward relative surplus value extraction[60]. Third, the dispersal of economic activity and its reorganization in flexible networks that can be quickly controlled or remodeled by online information flows, mainly finances, undermines workers' solidarity and their organizational capacity. In fact, industrial relocations have become more frequent, and usually towards places were labor costs are lower, workers are not unionized, and work regulations are scarcer and abusive. Finally, although offshoring processes create jobs in other countries, the fact that this employment is worse paid itself means that value has flown away from that segment of production. From Marx' labor theory, this is entailed by the fact that the costs of reproducing labor in the country of offshoring are less than they used to be before; otherwise, offshoring would not have occurred in the first place.

It is tempting to see this process of polarization via economic dematerialization as one entailed by the socialization of network relations (2.6) in a way that the typical self-reinforcing dynamics of networks (2.4) conjoin with pre-existing conditions of social polarization to accentuate these conditions (Sassen 1991). Frequently, companies have had to choose between redefining their business models in order to better suit the network logic; or sitting down and waiting for a native digital company like Amazon to take them over by making a scientific assessment of the economy and then efficiently exploiting the opportunities that e-commerce gives for quick and massive returns on low entry investments (van Dijk 2006, 79). In truth, Amazon is nothing but an internet platform listing goods and services: its role in the broader economy being nothing else than that of a mediator that communicates libraries or stores with customers. However,

[60]However, recall that a shift toward relative rather than absolute exploitation is taking place through the introduction of bots in finance and other added-value segments of the value chain, thus yielding opposing tendencies in this regard. Perhaps the trend toward increased absolute exploitation seen in industry and low-end services can be explained by historical-political contingencies like the political culture of a nation or the current state of class struggle in a given society. Class struggle would thus be a semi-independent variable with respect to changes in the composition of capital (Marx 1959; Mandel 1995).

its software capabilities help it to pick up the added-value segments of these sectors. Further, since most of its operations are computerized, its labor costs are negligible and its profit margins higher than competitors, even at low prices. This is a business model that other paradigmatic companies of the informational economy, such as AirBnB or Uber, exploit fruitfully too. In a context of few or no governmental regulations, this has meant that thousands of workers and businesses got quickly displaced by these mediating Internet companies, or otherwise absorbed by them. This has resulted in new, ICT-enabled, global monopolies providing all sorts of services at low costs[61], but also creating very few jobs and therefore taking the concentration of wealth one step further.

4.3.3. Self-reinforcing growth and concentration of fixed and mobile capital

As seen in 3.3, the industrial order raises a tetradic relation between media; transport and other infrastructures; organization and work; and land use patterns. This relation involved a geographical and organizational polarization: while basic telephony allowed control and coordination functions to concentrate in CBDs, workers' residences and factories dispersed across suburbs in order to save costs in real estate. But these costs shifted to transportation, which now had to support daily commutes. This promoted the joint growth of industrial cities and transport networks. Here I analyze how ICTs have helped to pronounce this pattern, despite their apparent capabilities for promoting alternative ones. Further, this geographic concentration-dispersal can be shown to converge with other socio-economic polarities to yield mutually reinforcing effects.

First, recall that the aforementioned tetradic relation was critical in pre-Modern and early modern times, where communication was mainly through face-to-face contact and artificial memories. This generated pressures for urban agglomeration and for building efficient transport networks, thus justifying the claim that cities and transport networks can also be understood as media (1.1). In contrast, the deployment of electric media of the late 19th century afforded societies a form of quasi-instantaneous transmission of signals where codes, substrate and carrier merge upon the same route, link or channel.

[61]This is favorable evidence for Rifkin's idea that ICTs are driving us to a zero marginal cost society (note 27). The growth in barters, consumer groups and support communities in the Internet confirms it too, but in a more contradictory way. The reason is that these trends boost the informal economy, especially its second-hand segments, by affording citizens new chances to enjoy access to the social wealth even when their income is stagnant if not radically reduced (Milanovic 2015). Further, this may be beneficial for sustainability, since many formerly non-marketable goods are now rehabilitated for use. As a result, the inability of citizens to afford new and expensive goods, coupled with an increased preference for the informal economy, would pose both direct and indirect pressures toward a zero marginal cost society. Yet, one may rightfully wonder about the viability of a capitalist economy with a constantly shrinking demand.

This meant that some tasks of information exchange and processing were theoretically decoupled from the needs to agglomerate in cities or to intensify transport use; likewise, organizations could decentralize to some extent. Yet this potential remained unrealized: organizations grew in size, agglomerations and transport use intensified, and all this posed widespread concerns about authoritarianism, pollution or congestion.

Sharing these concerns, authors like Toffler (1981) believed that the root of those problems were the industrial drives to scale-up, concentrate or standardize production and organization –all present in capitalist and socialist countries alike. Toffler, however, was optimistic about the prospects ICTs raised for bringing about a new age that looked past Industrialism. In succeeding Industrialism, Informationalism would resemble the first wave of civilization (Agriculturalism), in that it would promote the decentralization of communities and power. But unlike small ancient communities, the new civilization would draw support from advanced science and technology. Online purchases would substitute for shopping trips, workers would "telecommute", and "electronic cottages" would allow the long distance coordination of social activities through videoconference and the like –thus realizing economic dematerialization in the sense described in 2.6.

However, Toffler's expectations have not been fulfilled so far. Instead, the evidence shows that transport and urban agglomeration have continued to grow together with telecommunications use, and even while organizations downscaled (Fig. 4.2).

There are many possible explanations of this fact. A plausible one might build on Castells' remark that informationalism follows the dynamics of capitalism (1996), to suggest, with Marx, that this informational capitalism inherently promotes a convergent trend of self-reinforcing concentration and growth of fixed and mobile capital (3.1).In other words: the compound accumulation of advanced technological infrastructure, especially in transport and communications, and of mobile capital (money and humans), places strong pressures for further accumulation and agglomeration.

This explanation has its advantages. It captures the fact that the wealthiest global cities (New York, Tokyo, London…) are financial and service centers in a context where these are the leading sectors; being also the hubs for the most advanced transport and telecommunication infrastructure worldwide (Sassen 1991, 108-9). Then, the same evidence that shows the terms of the tetradic relation unfold in mutually reinforcing loops, also correlates increased telecommunications use, GDP and population growth and increased resource and energy use (Fig. 4.2), thus implying that our tetradic relation may be embedded in more complex system dynamics, such as those addressed by Marx.

A problem of this explanation is that, at face value, it is too abstract and vague. True, it can be detailed in more elaborated models of the interaction between socio-economic and environmental dynamics (Meadows et al. 1972; Motesharrei et al. 2014; Steffen 2015). Still, however, such analyses exceed the scope of this article and, related, they do not specify the roles that ICTs have in promoting urban agglomeration, transport growth, and changes in organization or working habits. On the other hand, previous sections have made apparent some ways in which ICTs have been partly responsible for the ongoing growth of energy use and transport of persons since the 70s. So I will pull this thread.

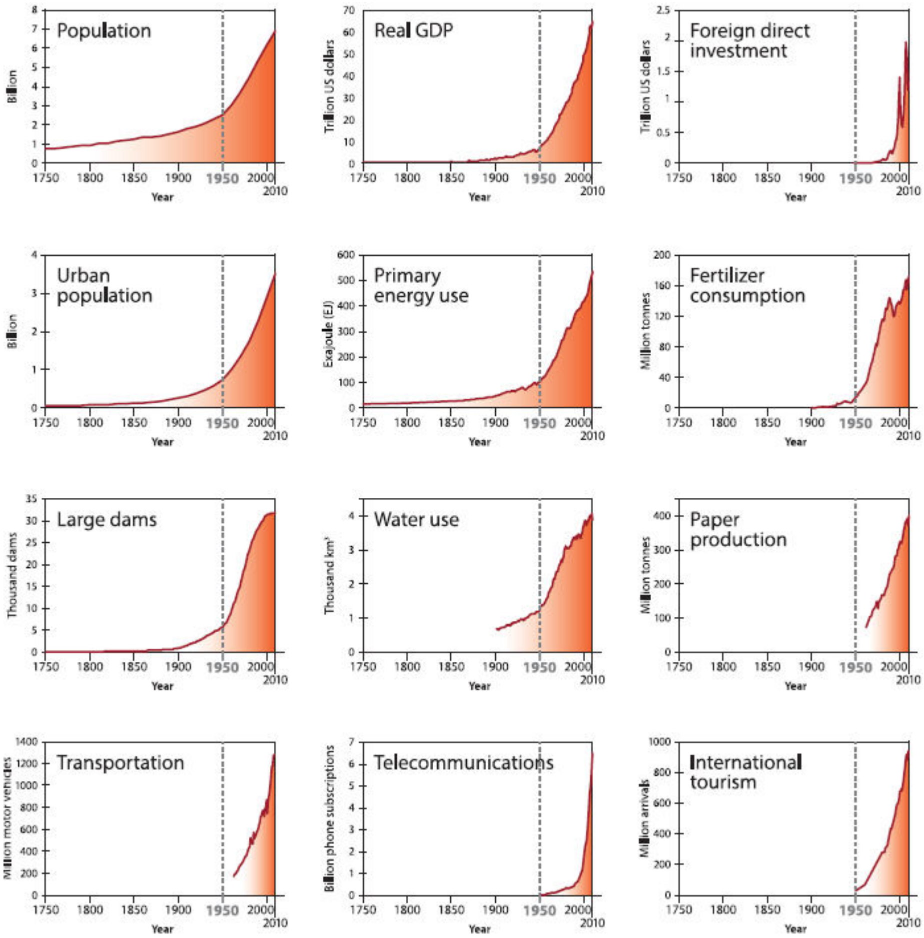

Fig. 4.2. Trends (1750-2010) in globally aggregated indicators for socio-economic development (Steffen 2015). See the original article for an elaborate explanation of the graphics and their original sources.

First, ICTs made possible the dispersal of production and a highly integrated global division of labor, based on the flexible and cost-efficient use of global transport infrastructures (4.2.3). This expansion of urban hinterlands triggered a huge increase in the number of vehicles (Fig 4.2; Steffen 2015), in the distance covered by products throughout the production chain, and in the ratio of road and air over other transport modes (Curtis 2009). This is a typical case of rebound effect (3.2), where telematic solutions in freight transport and logistics have made long-distance transport more cost-effective, thus expanding the demand and boosting competition on innovation oriented to further efficiency improvements.

Another key phenomenon is the explosion of the tourism industry since the 50s, driven by the expansion of Western and Japanese middle classes (Fig. 4.2). Although this dynamics fits a widely predicted shift toward consumption of intangible commodities – in this case, experiences- it also entails a huge boost to the transport of persons, and *a fortiori* to energy and resource use. Modern media fostered this explosion in making exotic goods and experiences perceptually available (Brey 1998a), thus inciting a desire to travel (Graham & Marvin 1996). The Internet supports this trend by increasing both the informational availability of new offers to potential customers, and the competition between touristic operators.

Then, Toffler's forecasts about the replacement of commutes or meetings by their virtual counterparts never came to realize. Instead, the incidence of telecommuting, virtual meetings and the like remained limited to the diffusion of new and more flexible working schemes where workers occasionally telecommute, but physical presence is still required some days a week in offices or business arrangements (ibid). However, a clear difference emerges between the working habits enabled by telephony and modern ICTs. While telephony helped synchronizing lifestyles with the routines of the industrial city and its hinterlands (3.3), ICTs have allowed the de-synchronization of individual and social schedules to yield more flexible lifestyles (ibid). Yet this flexibility may lead to more intensive patterns of transport and land use:

> If employees become telecommuters and only have to travel to work two days a week, they may move to more affordable or desirable housing many miles from work. This may effectively increase the distance of their total weekly commute. [Furthermore,] Newman (1991; 342) found an 'exponential increase in gasoline use as density falls' (ibid, 264)

Note, however, that this is just a statement of fact: it does not explain why, although teleworking facilitates the dispersal of residential areas, these areas themselves come to cluster around large cities. In other words: given the possibilities for decentralization that ICTs open up, agglomeration itself should be explained by other factors.

At this point, some precisions are convenient. Authors who analyze recent trends of urban agglomeration coincide in their acute unevenness (Sassen 1991; Castells 1996; van Dijk 2006). While industrial areas have undergone offshoring processes, leading to an irreversible loss of employment, wealth and population, agglomerations are observed mainly in -and around- "global command centers". Further, these cities feature a highly polarized occupational structure where industrial and middle management jobs recede, while added-value informational jobs, and especially low-end service jobs, grow rapidly.

The agglomeration of low-end service jobs in global cities is partly explained by the joint action of industrial offshoring and the concentration of added-value service jobs in global cities. Absent other opportunities, nationals would join international migrants to seek service jobs in these cities. Yet this merely explains the background of employees in these sectors, not why low-order services have grown. More convincingly, Sassen (1991) points that high-income workers in the added-value sectors demand amenities and personal services. This adds up to corporate demands for maintenance and other lower order services. The question about the explosion of low-end services then leads us to ask about the reasons for the explosion and agglomeration of added-value service jobs.

The causes of the latter phenomenon are complex and entangled. Sassen (1991, 161 ss.) cites a survey conducted among Japanese managers, where four factors emerge as the main reasons for TNCs to establish their headquarters in a global command center, in this case Tokyo. One was "the need of central locations to oversee branch offices and factories over a wide geographic area". This trend already arose in the industrial city, and seems to require no further explanation if one considers the huge growth of TNCs. However, Sassen supplements her view with the intriguing observation that the trend of product customization -arising from new social demands and the newly available technology, constituted a major independent pressure for companies to operate globally. This elicited the simultaneous need to disperse production and to carry out a business restructuring which involved the concentration of management functions:

> "Customization… contributes to the weight of headquarter functions but in a way that differs from the tendency toward the centralization of location. The ability to serve clients in the home country is more and more frequently associated with the ability to serve the firm in foreign locations as well. Given customization and specialized markets, profitability is increasingly linked to [global operation]." (ibid, 106)

But the most frequent answer in that survey highlights the needs that firms have for "raising investment capital and financial investments". As Graham and Marvin suggest, globalization has made competition more intense, and the economy "more complex and volatile" (1996, 140). In this context, the concentration of TNCs in financial centers would not be merely a strategic choice of individual companies, but rather a collective attempt of business communities to reduce risks and uncertainties by strengthening their networks. This is consistent with the results of this research (2.4) and other views on the issue (Castells 1996; van Dijk 2006). Similarly, a common view states that the dispersal of production and the globalization of finance were both key factors in the concentration and centralization of control functions (Sassen 1991, 22) and that "coordination and control [costs] tend to rise faster than the material capacities of the economy". These remarks match well with Beniger's suggestion that the resolution of material bottlenecks speeds up the emergence of information bottlenecks (3.2), as well as with our own observations (2.3).

The other two prominent answers in the study stressed the needs to gain "access to goods and marketing" and to "information from business organizations…and administrative agencies" as reasons for TNCs to place their headquarters in global financial centers. These answers can be linked with the other two if one recalls Sassen's observation that TNCs require increasingly complex, diverse and advanced producer services in order to carry out the business restructuring necessary to sustain global operation (p. 67). In turn, the corporate transactions that these processes involve need a "simultaneous participation of several specialized firms providing legal,

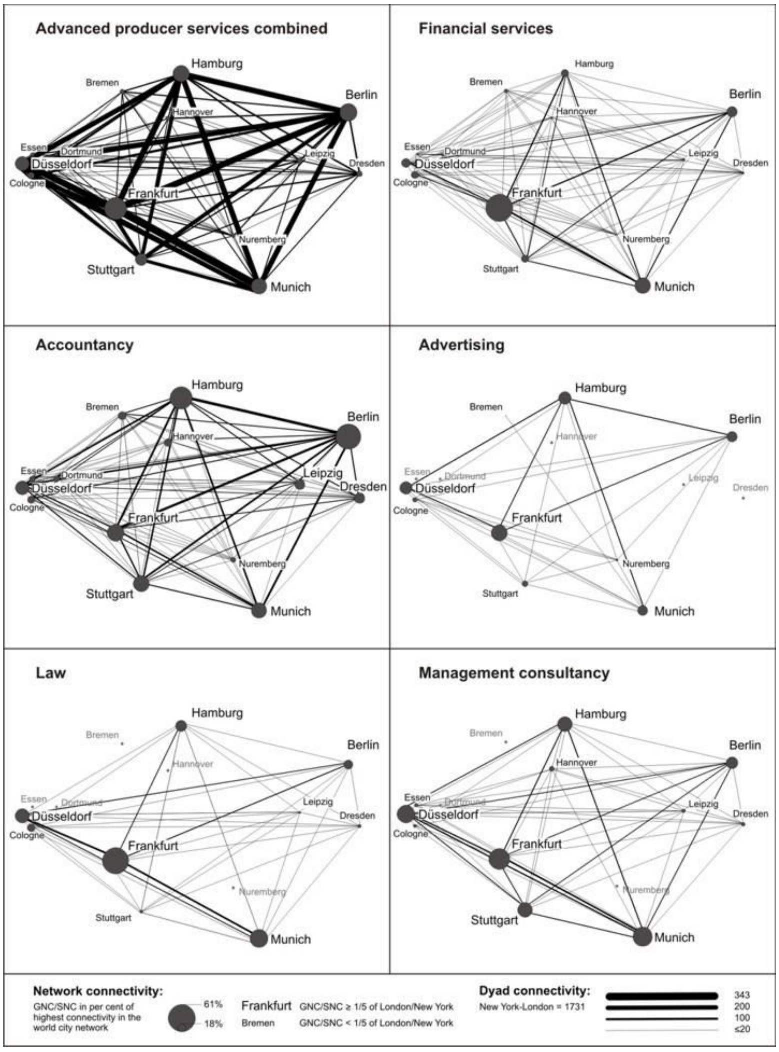

Fig. 4.3. "The German space economy as practiced by advanced producer service firms" (from Hoyler 2011)

accounting, financial, public relations [or] management consulting services" (Sassen 1991, 11-13), which demands the physical proximity of many such services. In this connection, the strongest coupling observed is between financial, marketing, legal and management services (Sassen 1991; Fig. 4.3).

These arguments can be supplemented at least by three other, more or less related, agglomeration factors.

One widespread account of urban agglomerations highlights the ongoing need for face-to-face contact in business contexts (Giddens 1990). This cognitive and situated aspect of human relations has received considerable attention from economists (Polanyi 1967; Nonaka & Takeuchi 1995) since the philosopher Ryle (2002) argued for the huge relevance of tacit knowledge for human intelligence. For Ryle, tacit knowledge was distinct from, and complementary to, explicit knowledge; further, tacit skills, whose exercise requires the physical co-presence of performers and observers, would enhance the interpretation and production of explicit knowledge. This argument led philosophers like Dreyfus to deny that the total automation of cognitive work by advanced AI can ever be possible (1.5). On the other hand, another way to look at this issue is to highlight the close link between tacit and non-routine information exchange, and the sheer exercise of power. Business would prime agglomeration in order to build the material conditions for secrecy, thus allowing the powerful to make use of their influence by easing the exchange of "informal and clandestine information based on social networks and trust" (Graham & Marvin, 1996, 142). Locational asymmetries can thus be seen to reinforce informational asymmetries and other power asymmetries.

Castells, who focuses on the conditions required to develop and maintain innovation milieus, also stresses the importance of physical contact for exchanging tacit knowledge in order to build and consolidate networks of various kinds: of users and producers, of researchers and entrepreneurs, of business and government. The ongoing and stable social conditions required to this effect are hard to build and often require the careful construction of environments where joint experiments and other intellectual exchanges can take place. In other words: closeness is a pre-requisite of such milieus. But once a genuine innovation is produced, it comes to reinforce the social conditions that promote further innovation, thus accelerating the process (1996, 36-7). As a result, innovation milieus enter in "virtuous cycles of innovation" (Graham & Marvin 1996) where network dynamics such as the Matthew Effect happen as a matter of course (2.4).

Finally, another factor in promoting agglomeration is the pre-existence of advanced telecommunications and transport infrastructure in a location. Unlike industrial cities, large service centers do not produce and ship away goods in amounts comparable with their incoming goods. Still, ever higher demands are placed on transport networks in order to allow the distribution of incoming freights and an efficient control of the traffic of persons. Then, financial industries and producer service companies depend on their access to advanced telecommunication facilities in order to sustain and enhance their position in global networks. This places high demands as regards to pre-existing infrastructure, or otherwise high demands of capital investment, on any city that is willing to attract such firms. This argument can be conjoined with Castells' remarks about the requirements of strong innovation milieus, which feature technical aspects in addition to social ones. Innovative areas oriented to global operation have an ongoing need to reassert themselves as centers of techno-economic innovation, and this forces them to incorporate material innovations in order to keep up with software innovations and other demands posed by increased global competition[62]. In this way, highly uneven geographies of power appear (Graham & Marvin 1996), where an element of differential physical wealth entangles with informational and politic-economic asymmetries to yield scenarios of self-reinforcing polarization (Milanovic 2003). This also explains why some cities have become global communication hubs increasingly linked to one another and less and less connected with their "natural hinterlands", especially with the rural areas.

As can be seen, the above discussion takes us to back to the first hypothesis advanced: agglomerations of professionals working in the leading economic sectors, together with accumulations of wealth and advanced infrastructure, are both necessary conditions and strong drives for further accumulation and agglomeration. However, these pages have also provided a more detailed content to this hypothesis, and one that highlights some of the important roles of ICTs in these and related dynamics.

4.4. A new anthropology and a new social contract

Throughout the text, many insights have surfaced describing key transformations that the Information Society is claimed to have induced in cultures through the massive diffusion of ICTs in workplaces, homes and the broader society. Here I discuss the socio-

[62]This is a second way in which software innovation promotes cycles of mutual boost with material innovations. Although this process is related to software-led planned obsolescence (4.2.3), it also involves other factors and for this reason is a more complex and intricate process.

cultural implications of two of these transformations. First I address how digitalization has redefined work while also eliciting social tensions and prospects of even more radical transformations for the immediate future. A related issue is the tensions that emerge from the effects of ICTs in transforming both individual human life and socially established habits of communication. These two phenomena are strongly conditioned by the polarizing socio-economic trends discussed in previous sections, and they interact to yield a highly dynamic but also uncertain social landscape.

A frequent remark about digitalization, reflected in section 4.2.4, is that it is less dehumanizing than other waves of automation. Taylor's system transformed factories into large chains of separate routine procedures to be mechanically repeated by workers. The dehumanizing character of this automation wave seems to lie in the very rationalization of work, that is, in the standardization and formalization of human action. Workers received instruction in sets of physical and mental disciplines that deeply affected their body and character, and machines became an oppressive power or alienating force through which owners exercised their power over employees. Instead, digitalization has replaced human work in both factories and offices; and yet, although there have been initiatives to "taylorize" office work, the changes in this regard have been rather basic (van Dijk 2006, 65 ss.); so that, rather than entailing a rigid form of behavioral engineering, ICTs seem to have simply removed uninteresting work. In fact, an article recently published by a renowned IT consultancy company states that digitalization has *rehumanized* work:

> But what if we redesigned work [in hospitals] using smart machines and the Internet of Things? Machines can do most of the monitoring, data collection and incident reporting, leaving nurses to do things only humans do well, like touch, talk, observe and empathize. (Moore 2015)

These claims, however, must be detailed and criticized in order to account for a series of tensions that underlie processes of digitalization.

First, *the behavioral engineering of the workforce and the citizenship does not disappear*, even if it is now of a more pleasurable kind than that required by industrial taylorism. More specifically, formal and informal educational activities are constantly deployed across society in order to secure specialized labor supplies that are required to fulfill certain socio-economic or institutional goals. VanDijk distinguishes three types of the so-called "digital skills": operational, information and strategic skills. *Operational skills* involve a large degree of routine tasks, such as routine checks in hardware or software maintenance (van Dijk 2006) –a profile that, although highly demanded in the job market, commonly belongs to the low-end spectrum of information jobs. As was explained, however (4.3.2), post-industrial theory claims that the Information Society is rather characterized by the expansion and increased relevance of jobs concerned with the search and production of useful information –enabled by van Dijk's *information skills* (2006, 183 ss.), or with the application of information in creating value for oneself and others –or *strategic skills* (ibid; Simon 1973; see 2.3). A "creative class" thus arises, formed by highly educated professionals and technicians concerned with knowledge-intensive and self-fulfilling tasks such as research, innovation or programming.

But second, and *contrary to van Dijk's classification and Simon's forecasts*, the above quote shows that *the highly demanded professional profiles now involve much more than the efficient management of explicit knowledge*. In fact, many tasks involving the control and production of explicit knowledge are now largely delegated to computers, and new demands appear in the interface between humans and, especially, between humans and ICTs. Highly demanded, for example, are skills in creative industries such as advertising or entertainment; or those where face-to-face contact is deemed essential in building trust in partnerships or business, such as commercial agents, representatives or other intermediaries (Giddens 1990). In other words: it is true that digitalization has meant the rise of a creative class dedicated to "postmodern jobs", that is, self-fulfilling, meaningful jobs where workers have the opportunity to exercise their creativity or to express themselves as they really are. But not all the postmodern jobs are mainly "digital", or about handling explicit information for the purposes of innovation.

Third, recall that *"service jobs" encompasses a highly heterogeneous and polarized occupational spectrum* that ranges from the "cognitive" and highly paid jobs of scientists, programmers or marketing advisors, to teaching or health care, and to low-end service professions like catering or maintenance (Sassen 1991). As has been pointed repeatedly, there is a growing polarization between the high- and the low-ends of this spectrum, the latter of which is increasingly casualized and usually affected by racial or gender typing (ibid). Sassen stresses that this polarization is indeed most prominent in the leading sectors, and that it reveals the tacit enforcement, since the 70s, of a new social contract whose main features are (i) flexibility and casualization of work schemes, and (ii) a severe shrinkage of the middle class.

Finally, digitalization has eliminated a large volume of jobs and is still expected to eliminate many more. Of course, as noted, many philosophers –and also economists- deny that the jobs above mentioned can ever be fully automated with software or AI. However, according to a recent study (Frey & Osborne 2013), the capabilities of existing AI already allow for the automation of still more routine tasks, as well as of an important range of intelligent processes of translation, communication, simulation or knowledge production. In fact, most marketing strategies are now based on Big Data, that is, automatic data gathering powered with machine-learning algorithms. Further, robots and bots are increasingly able to detect and exploit human vulnerabilities (Turkle 2011), and evidence suggests that AIs, especially those with advanced emotional features, may soon become more efficient than humans at this (Youyoua et al. 2015). These remarks announce, therefore, that still more consequential changes lie on the immediate future.

One possibility is that further waves of AI-led automation might lead to the slow but steady shrinkage of the just-emerged creative class. The plausibility of this scenario lies in the pressures toward increased rates of relative surplus value extraction, whose impact was illustrated with examples throughout the text. However, an important counter-tendency is the fact that the creative class seems to be a strategic ally of the major proprietors within the new "social contract" mentioned above.

Another possibility is that the informal economy continues to grow[63]while the polarizing tendencies of the Information Society aggravate. This might lead to socio-economic tensions and political uprisings, in parallel to an expansion of microeconomies and cultures based on stronger care networks, as advanced and celebrated by the leftist thinker André Gorz (1982). The flourishing of such cultures might be aided by virtual networks, which, as stressed in various passages of this work, could provide both an environment and a range of useful tools to this effect.

The socio-economic tensions induced by digitalization overlap in important ways with a process of cultural polarization arising from the tension between traditional cultures and the increasingly important role of ICTs in mediating and transforming lifestyles and human communication. Broadcasting, with its scalable and replicable point-multipoint configuration, had been the paradigm form of mass communication since the 30s. The spread of national radio and TV facilitated national integration, but was often closely coupled with propaganda and authoritarianism. Mass culture,

[63] See notes 26, 61.

decisively enabled by these nation-wide media, received widespread critique from thinkers that also repudiated its coalescence with the centralizing and homogenizing tendencies of planned economies and Western democracies alike (Horkheimer & Adorno 1947; Ellul 1967; Marcuse 1991). Since the 70s, however, the mass diffusion of computing devices and networks has somewhat changed this trend by dispersing communication and control capacities, and extending them globally. ICTs are consequently seen to promote critical and reflective practices (Giddens 1990) that can be appropriated by citizens for various purposes (van Dijk 2006; 2.7).

For instance, ubiquitous connectivity (2.2) and the supply-to-demand shift (2.7) have favored the development of new global communities that contribute to raising public awareness about problems that equally affect communities of all countries, such as warmongering or ecological crises. Many postmodern and post-human theorists have also noted the potentiality of globalization and modern technology for experimenting with one's own identity, thus overcoming old and deep-seated patriarchal or modern prejudices that are often linked to economic, racial or gender oppressions (Haraway 1991). Transhumanists take this logic one step further by reflecting on the technological possibilities to rationalize our bodies or minds by reprogramming or updating them with synthetic parts (Bostrom 2005). This raises perspectives for empowerment and for the flourishing of more diverse societies, a tendency in which the diffusion of computers has been instrumental. Consider only the fact that users can configure the memory of their computers, but also download, personalize or even create their own programs (1.5) –thus realizing, at least in virtual contexts, the postmodern dream of designing one's own "ontology" from scratch, and then freely share it or exchange it with others.

On the other hand, this growing diversity is not innocuous or uncontested. First, it is crucially grounded in the socio-economic trends toward product customization and an increased segmentation of the demand, which are actively sought by various monopolies and oligopolies. In 4.3.3 we saw how this process interacts with various forms of geographic and economic polarization induced by the drives of innovation and global competition, to yield undesirable effects from a social as well as from an environmental perspective. Here I would like to point that these dynamics also seem to exacerbate cultural divides. Pressures toward accelerating novelty generate unease and unpredictability, and society grows more difficult to read and to adapt to; which adds up to the growing volatility of finance and, generally, the global economy. In this context, the advocates of traditional institutions and community values seek for a social refuge in slums or rural areas, where economic regression –often resulting from de-industrialization- provides an ideal background for the diffusion of radical ideas and the subsequent emergence of religious sects and violent groups. As a consequence, identities, traditions and nationalist sentiments have first secluded in abandoned social landscapes, then radicalized and grown, and finally spread throughout society, often with the aid of virtual networks. A direct cultural antagonism thus arises between rural and urban life, the latter being increasingly perceived as promoting artificial, foreign, bombastic or grinding lifestyles–especially in the more global cities (Castells 1997). This unequivocally romantic spirit may lurk behind recent protests against globalization and its modernization processes.

5. Conclusion. Ideas and challenges for an ethics of information and ICTs

One of the most relevant authors in the field of Information Ethics, Luciano Floridi, contends that the Information Society is changing human nature slowly but steadily. Almost paraphrasing Aristotle's famous statement that all human beings by nature desire to know, he contends that we have become *inforgs,* or entities who strive for information and who can only thrive when provided with connectivity, that is, with ICT devices connected to global networks (Floridi 2010). Perhaps our generation might still, if necessary, stand a life without real-time and ubiquitous connectivity, since that is the way it grew. However, the latest generations are already children of the Internet, and could no longer do without it; so that, over time, the dependency of future generations on global information systems will only grow (ibid, 12). In this connection, some have argued that access to information, and perhaps instant connectivity, should be considered a primary good to which anyone has a right (Brey 1998b, Hoven & Rooksby 2008). Floridi seems to agree on this idea and, moreover, as we saw in 2.6, he thinks that the intrinsic properties of information as a commodity (zero marginal cost, non-rivalrous and non-excludable) provide a plausible justification to this ethical demand.

Yet, this thesis has advanced powerful reasons to reject that the three properties mentioned by Floridi are indeed inherent to information. Already in section 2.6 we noted that, although digital information can be copied and transferred very cheaply, thus dumping reproduction costs, the development costs of at least some kinds of new information remain high –a statement that only becomes more obvious if we recall the demanding social and technological pre-conditions of strong innovation milieus (4.3.3). Nor can information be non-excludable, since, as 4.1 shows, the very same capabilities that enable ICTs to reproduce information cheaply, also constitute opportunities, and indeed pressures, for generating exclusionary regimes of access to ICT infrastructure and other infrastructure, thus making information -and other goods- excludable through the use of information itself. Finally, information is perhaps the opposite of a non-rivalrous good, as demonstrated by my analyses about informational capitalism (4). These prove that *useful information* must not only be accurate, but also come from the right source to the right target, in the right format and at the right time. Indeed, many of the struggles for information are decisively shaped by the need to receive it faster than anyone else and, importantly, this need translates into struggles for face-to-face contact and proximity, which lead to physical agglomerations in financial or innovation centers.

For all these reasons, information cannot qualify as a public good, at least not in the terms advanced by Floridi. But why is Floridi's argument unsound?

I suggest that the main problem with this account is that it considers information in abstraction of characteristics as crucial as: (i) its source, target and timing and (ii) its infrastructure or substrate. As a consequence, it also abstracts from (iii) the impact that different forms of information production (i.e. different infrastructures and substrates, operating in concrete socio-economic contexts) have upon the regimes of infrastructure exploitation and management, including the infrastructures for information production and transmission. In other words: because Floridi engages in a form of neo-Platonism where information is a mere content whose essence is separate from its material embedding, he cannot explain why telephonic and telegraphic information do not elicit their excludability, while computers enable a fine-grained excludability of many aspects of infrastructure use, including the access to, and use of, information. Likewise, he cannot see how the most varied asymmetries reinforce one another to yield increasingly polarizing effects in modern societies.

But why would Floridi even distinguish information from its material embedding, when, in the last instance, all that exists comes down to information?

> In many respects, we are not standalone entities, but rather interconnected informational organisms or inforgs, sharing with biological agents and engineered artefacts a *global environment ultimately made of information*, the infosphere. (Floridi 2010, 9) [the italics are mine]

This metaphysical idea that all that exists is "ultimately made of information" is indeed a suggestive metaphor that can even prove fertile in the long term, for instance, in guiding scientific projects of theoretical unification. However, it begs the principle that fundamental categories of social analysis, such as "space", "power", "capital", "trust" or "institutions" are *a priori* reducible to information, which is a highly contentious move. Certainly, maps and representations of the space can be fabricated and digitized; and useful descriptions or tales about conformations of capital and power can be made and digitized too. Yet, we have all the reasons to believe that, as analysts, we lose more than we gain by conceptualizing, say, telecommunications infrastructure as simple clusters or packages of information. In fact, as has been argued, this move leads Floridi to misunderstand the important differences and complex interactions that exist between the accumulation of advanced telecommunications infrastructure, and phenomena such as information asymmetries, power asymmetries and geographic asymmetries. His "information ethics" is also consequently burdened by this deficiency.

By now it should be apparent to the reader that this thesis has followed a very different approach to the analysis of ICTs, information and the Information Society. Rather than assuming, beforehand, a total primacy of information, hardware, networks, capital or any other single kind of reality, this research has been conducted under the premise of a mutual irreducibility of these categories. In each case, I turned to the relevant philosophical or scientific accounts in search for the evidence and analytical tools that could help me to better specify and precise the similarities, differences and relations between the realities referenced by each of those terms. As shown above with our criticism of Floridi's views on information, the major findings of this thesis precisely emerge from the –often intricate- boundaries and relationships between hardware and software; capital and information; infrastructure and culture; technology and values.

Consider, as a second example, the trends and value conflicts that surfaced in our analysis of the consumer electronics market. We showed how the persistence of a trend toward the computerization of equipment (1.5), fueled by the huge advances in microelectronics, helped the diffusion of intrinsically multi-functional devices (2.1) that could replace many other physical goods or services with virtual counterparts (2.6), thus advancing environmental sustainability through a dematerialization of these goods and services.

Yet we also saw how other trends interact with these to yield contradictory results. For instance, ICTs have enabled the emergence of a more segmented and interactive demand and, *a fortiori*, a more diverse and participatory citizenship (2.7; 4.4). In turn, this favored an economic shift towards product customization (4.2.3) which has placed pressures for the globalization of corporate activity (4.3.1; 4.3.3) and consequently for a more complex form of economic dematerialization (4.2; 4.3) that involves many tensions and conflicts, including ecological risks (4.3).

On the other hand, this ICT-driven segmentation of society is intimately linked with the emergence of the postmodern values of flexibility, mobility and personalization, and these new demands converged with advances in the direction of ubiquitous computing and connectivity to yield technical trends toward increasingly personalized and portable devices (2.2). This drive partly explains why, despite their growing multifunctionality, electronic devices have been accumulating in households over the last 20 years, yielding domestic functional profiles that, at first glance, seem to be highly redundant (Ryen et al. 2014; 2015; 2.1, especially Fig 2.2). Yet, practices of software-led planned obsolescence, responding to a very different origin and cause, have ultimately been the decisive factor in the reproduction of this contradictory trend (4.2.3). This thesis has shown that any criticism of the ecological soundness of these practices, or the subsequent proposal of remedying policies, might gain in depth and accuracy if the intricate dynamics between innovation in software and hardware, as well as between technology and values, were better assessed.

In the introduction I mentioned two senses in which this thesis would follow a materialist method. I also hypothesized that studying technological and social forces separately, but also in their interactions, would allow us to get a finer grasp into the origin and implications of many ethically controversial issues regarding ICTs. I believe these expectations are now more than fulfilled, and that a materialist method of analysis offers boundless prospects for grounding our ethical and political reflections on ICTs in a rigorous scientific assessment of the trends and tensions that emerge in the interface between ICTs, the economy and the broader society.

Glossary of terms

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Annex I. PhD thesis proposal

The Information Society and the Ecological Challenges: Toward a sustainability-oriented ethics of ICTs

PhD Thesis Proposal

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Introduction

Capitalist globalization is a process that stretches back to early Modernity (Marx 1959, 1976). Its effects, however, have accelerated since the Industrial Revolution and, remarkably, after the 2nd World War (Steffen et al. 2015). A key phenomenon in this regard has been the worldwide deployment of Information and Communications Technology (ICT), which has sustained a trend toward increasingly global and instant connectivity, thus rising and distributing the patterns of information exchange (ibid; Castells 1996; van Dijk 2006). The deployment of this new technological system has aroused other profound socio-economic, political and cultural transformations which include –among other trends- a hugely increased material productivity and population, enlarged and complicated networks of trade, transport and management, the emergence of an array of transnational processes and institutions, and even of a Global Justice Movement (Nagel 2005).

In turn, the process has also elicited a huge variety of scholarly insights on the relations between ICTs, our present and our future. To name but a few, affluent societies are said to have transited to a Knowledge (or Information) Economy or to a Network Society (Beniger 1986; Castells 1996). As for humans, it has been argued we have become *inforgs* or entities who strive for information and who can only thrive when provided with connectivity, that is, with ICT devices connected to global networks (Floridi 2010). In this vein, access to information –and perhaps instant connectivity too- has come to be regarded as a primary good to which anyone has a right (Brey 1998, Hoven & Rooksby 2008).

Some accounts of the Information Society are strongly normative. ICTs have directly or indirectly opened opportunities for many and, as such, they are widely celebrated by users and public figures alike, as well as by academic authors coming from very different traditions of thought. In contrast, other consequences of these changes have raised new ethical concerns, which often called for subsequent changes in legal frameworks and even developing of new ones; and many of these issues are still controversial if not disturbing for other stakeholders. However, the application of ICTs in all spheres of society continues to grow, and so do the possibilities of convergence with other technologies to yield new discoveries and potentially radical applications.

In this connection, a widespread concern about ICTs has been that, despite their actual benefits and enormous potential, these technologies have not managed to make our societies more sustainable. Although ICTs have helped to fix or palliate some of the environmental excesses of industrialism, their widespread application and use has also occasioned numerous and irreversible ecological damages, raising the disturbing possibility that globalization is not sustainable, at least not in its current shape (Curtis 2009). Actually, not a few arguments have been advanced in support of the thesis that ICTs have made the Information Society even more unsustainable than the Industrial Society.

Yet, ICTs have also been claimed to make possible the decoupling of economic growth and environmental impacts, thus creating the conditions for overcoming, in the long term, what Marx (1976) once called a fundamental limit of capitalism –the contradiction between the needs for an ever-expanding production in order to sustain the growth in profits, and the external limits imposed by fixed amounts of natural resources or natural cycles of resource regeneration. In other words, many scholars and public institutions hold on to the view that economic growth in the Information Society will at last be unhampered by material limits. As production processes grow more efficient and an increasing number of services become virtual, information would act as the true fuel if not the basis of the economy, which could thus be de-materialized to all practical effects. As a result, ICTs help us to count on economic growth to effectively tackle global challenges such as poverty, while also bypassing the ecological collapse that might happen if material consumption continues to increase (Asafu-Adjaye et al. 2015).

This idea of a fully decoupled informational economy has received criticism from ecological economics, environmental ethics and other fields. One criticism has pointed that information could never be the basis of an economy whose very continuity depends on many resources with no sustainable synthetic substitutes available (Caradonna et al. 2015). Others contend that information industries are overvalued, that informational interpretations of the economy are misguided (Gordon 2012, 2014), or that the standards currently employed in measuring value are too unilateral (Brey 2016). In this way, discussions about the sustainability of the Information Society may come to revive old scholarly debates about the nature of value in different economies or models of growth (Jorland 1999). These questions and discussions are sometimes raised with a strong sense of urgency, for instance, in accounts that highlight how the present context of raging ecological catastrophes can only get worse due to climate change, peak oil, pollution, industrial miscarriages and other typical effects of the present model of growth. All combined, these factors have been claimed to endanger globalization as we know it, either by exposing us to an environmentally-driven collapse or by forcing a long period of economic degrowth (Meadows et al. 1972; Curtis 2009). Finally, many authors argue for degrowth with similar urgency, but also contend that the process of downscaling our economies could be both organized and beneficial (Illich 1973, 1974; Caradonna et al. 2015; Brey 2016).

The above review of perspectives exemplifies a debate where two main views about the Information Society and its environmental impacts are engaged. The debate is not primarily about whether the Information Society is sustainable at present –for all assume it is not. Rather, the question is *whether the Information Society bears a potential for building sustainable societies, while avoiding structural or dramatic social and institutional changes*. Different appraisals of this empirical question determine different normative approaches to ICTs, to the economy and to the political regulations that are required to promote sustainability. Conversely, too, opposed normative views about the challenges posed by environmental crises can be seen to favor different analytical approaches to the question (Glotzbach & Baumgartner 2012; Hector et al. 2014). This double disagreement poses extra difficulties for any initiative of ethical assessment of ICTs that aims to be especially sensitive with the value of sustainability.

A possible reason for the disagreement may be that practical commitments cannot be removed from this assessment. Conflicting interests or value tradeoffs may prevent the collective agreement of humans even in the most basic terms of discussion, and the features of existing or foreseeable strategies for a sustainable society can be shown to bring about plenty of such value tradeoffs.

In fact, a negative response to the above question already entails that the continuity of both globalization and the Information Society will yield unsolvable conflicts. These might be abrupt and broad in scope, coming to disrupt existing institutional frameworks or the global economy. Or they could be gradual and subtle, and yet equally shocking, such as the regional, national and international conflicts that might arise in processes of projection, determination or implementation of structural reforms in production and consumption. Some strategies or ideals advocated by authors who are critical with capitalism or globalization may, for instance, threaten deep-seated habits and values of affluent societies. Consider the claim that a less consumerist life, both in material and informational goods, could soothe people and induce healthy habits (Caradonna et al. 2015; Brey 2016), which is potentially contradictory with ethical demands that have been advanced in the name of *inforgs*. Then, proponents of degrowth have contended that a de-intensification of agriculture and a return to more agrarian values is necessary, and that such a transformation could re-localize and regenerate culture (Thompson 2008); but this seems to entail a demand for de-urbanization at the global scale, which may be rightfully rejected on different moral grounds. In short, one can legitimately ask whether such strategies could ever gain a broad social support, or whether the present socio-economic or institutional conditions give any room for their realization.

On the other hand, the possibility that radical value conflicts emerge in the near future is not conditioned upon a negative appraisal of the aforementioned empirical question. Other conflicts might arise in deploying technologies that can arguably help us to circumvent environmental constraints. A recent suggestion predicates the imminence of a Fourth Industrial Revolution fueled by a NBIC –or **N**ano-**B**io-**I**nfo-**C**ognitive-convergence, arguing that this revolution would be required to fight environmental challenges (Schwab 2016). In this context, ICT-enabled systems are said to offer prospects for integrating the flows of matter, energy and information; in so doing, they might be cornerstones of a future "circular economy" supplied by renewable energy sources and managed through a computerized control of material flows, leading to near-zero wastes. As a result of this info-economic integration, however, many entities and systems might have to converge and become interoperable in order to allow their effective coordination –in platforms such as cyber-physical systems and the Internet of Things (IoT). In turn, the processes or consequences that result from undertaking such projects might create conflicts with privacy[64], freedoms or other fundamental rights, in addition to economic-political conflicts. In sum: given the potentially disruptive character of existing or foreseeable ICT-enabled strategies for sustainability, value conflicts are likely to emerge in the implementation of any such strategy.

[64] Zoltan Istvan, one of the first self-declared "transhumanist" politicians and a libertarian candidate for California Governor, holds that platforms such as the IoT should be publicly embraced and supported, because, even though they will do away with privacy, they will also enhance our liberties and even yield "more liberal" societies. https://motherboard.vice.com/en_us/article/bjx5y5/liberty-might-be-better-served-by-doing-away-with-privacy

Besides these practical conflicts, there are also theoretical factors that explain the disagreement between the two main perspectives involved in these debates. One reason is that the effects of ICTs on the sustainability of our societies are manifold, complex and structural, not to mention that they are often difficult if not impossible to measure[65]. Then, although certain definitions of sustainability almost enjoy the status of common currency, the full import and significance of this value proves hard to capture in a definition, and much less in one that is operational for the purposes of technology assessment[66]. For all these reasons, there is not a widely accepted framework that enables us to detect how different values might interact in ICT-enabled strategies for sustainability, yielding situations of tradeoff or mutual support. As a consequence, authors may be led to overview one or other dimension of the problem and to produce simplified accounts of the issue, where convenience or ideology fill the gaps left by inaccurate or incomplete analysis.

A provisional conclusion is that ICTs might be truly essential to build more sustainable societies. An ethical assessment of ICTs should assume, however, that strategies in this regard will be more complex than just deploying new technology. They are likely to involve social costs and conflicts –and these should be anticipated whenever possible, with the help of the best science available. Given the paramount importance of sustainability as a value, as well as the urgency raised by many views on the issue, there is, therefore, an objective need to devise an analytical framework with which to anticipate the potential impacts of ICTs on sustainability and other values. Only in this way we can assess and, if possible, prevent the deleterious effects of ICTs, while also advancing the positive ones.

[65] Although there are, indeed, interesting attempts in this regard, efforts are clearly insufficient to the date. See (Berkhout & Hertin 2004; Plepys 2002) for an exhaustive review of the different kinds of impacts of ICTs on *environmental sustainability*; and (Erdmann et al. 2004; Hilty et al. 2006; Hilty & Hercheui 2010) for a scientific modeling of these same effects and their simulation against operational, widely accepted sustainability criteria. Then, analyses that address the economic or *socio-economic sustainability* of the Information Society are rather abundant: for example (Sassen 1991; Castells 1996; van Dijk 2006; Korowicz 2012; Gordon 2012; Gordon 2014; Streeck 2016). There are much fewer models that consider the interaction between these two broad dimensions of sustainability, the socio-economic and the environmental. An interesting attempt is (Motesharrei et al. 2014) that, however, does not disaggregate the role of ICTs and for this reason is too abstract and general for the purposes at hand.

[66] All the references cited in the previous note contain more or less elaborate scientific evaluations of sustainability. However, none of them is explicitly concerned with developing normative assessments of technology. In turn, few if any philosophers have built directly on the insights provided by these scientific accounts in order to develop normative frameworks that are able to capture the material constraints of any strategy for sustainability, and the way these constraints map into value tradeoffs or other practical conflicts that may render the relevant strategies ineffective.

Problem Statement and Research Questions

The above introduction raises the urgency of examining the following question:

> *Assuming that the present Information Society is unsustainable, to which extent might existing or foreseeable ICTs promote sustainability, and how might such initiatives advance or hinder other values or societal challenges?*

In turn, this question can be specified into a few others that, if correctly addressed, could help us provide a detailed response to the fuller problem. These might be:

- *In what ways have ICTs and the Information Society co-shaped one another, and how can we characterize the socio-political landscapes and challenges that have emerged in the process?*
- *How do different approaches in ecological debates conceptualize sustainability and its relations with other values or global challenges, and what are the essential elements in a comprehensive definition of sustainability that makes justice to those perspectives?*
- *What sorts of impacts may existing or foreseeable ICTs have on the environment, and which are the potential problems and value conflicts involved in the most relevant ICT-enabled strategies for sustainability?*
- *Considering the evidence and perspectives discussed thus far, can we devise ethical and political guidelines for the design and implementation of ICTs, and how could this initiative of technology assessment be enhanced by relevant institutional arrangements or collaborations with other social agents?*

Thesis structure

Each of the successive parts in the thesis structure, starting with part one, constitutes a separate attempt at assessing each sub-question; together, they aim to respond to the main research question. This results in a structure where the first, second and third part stand as bricks of a constructive process aspiring to synthesis in the fourth, which recapitulates the evidence, theories and arguments presented in previous parts of the study, and reflects upon them in order to propound a set of guidelines for the ethico-political assessment of ICTs[67].

Next I offer a provisional table of contents for the PhD thesis, followed by an explanation of the line of argument and methodology I intend to carry out in each part:

[67] See summary in pages 111-12.

Introduction: Problem, aim and structure of the thesis.

1. **The Information Society: Technological, socio-economic and cultural aspects**
   1.1. ICTs as the technical basis of the Information Society
   1.2. The intrinsic implications of ICTs
   1.3. ICTs and the industrial order
   1.4. The Information Society as a socioeconomic restructuring of capitalism
   1.5. Conclusion. Ideas and challenges for an ethics of information and ICTs
2. **Understanding sustainability**
   2.1. The idea of sustainability
      2.1.1. Environmental sustainability: key concepts
      2.1.2. Social sustainability: theories and concepts
      2.1.3. A philosophical definition of sustainability
   2.2. The sustainability of the Information Society
      2.2.1. Critical tendencies
      2.2.2. The status of environmental sustainability in current institutional settings
      2.2.3. Achievements and defeats of these initiatives
      2.2.4. The Anthropocene: reflections about the scope of the ecological crisis.
   2.3. Environmental sustainability and other global challenges
      2.3.1. The *Grand Societal Challenges*
      2.3.2. Intra-generational ethics and sustainability
      2.3.3. Intergenerational ethics and sustainability
      2.3.4. Environmental sustainability: a conflict between two dimensions of justice?
   2.4. Alternative strategic approaches to the ecological crises
      2.4.1. Ecological Modernization and sustainable development. Theoretical and practical commitments
      2.4.2. Sustainability as resilience. Theoretical and practical commitments
   2.5. Lessons about sustainability
      2.5.1. The relevance of theoretical problems and practical conflicts
      2.5.2. Sustainability and rival philosophies of technology and the good life
      2.5.3. A revised definition of sustainability
3. **ICTs and the environment: a critical review of actual and potential impacts**
   3.1. Views and expectations on ICTs for sustainability
      3.1.1. ICTs and the idea of "decoupling"
      3.1.2. Origin and centrality of this idea
      3.1.3. Standard criticisms
   3.2. Phenomena of interest. Analytical concepts, methods and taxonomies
   3.3. ICT-enabled strategies for sustainability. Main initiatives and potential problems
      3.3.1. Supply-side management
      3.3.2. Demand-side management
         - Persuasive eco-technology
         - Industrial ecology and other initiatives in changing household consumption
      3.3.3. Structural changes (supply and demand)
         - Cyber-physical systems

- Smart systems
- Transformation in energy systems, supply chains and land use patterns

3.3.4. Systemic change
- The circular economy
- A smart citizenship: Towards the Sharing Economy
- Initiatives for cybernetic eco-socialism
- The via of simplicity

3.4. The prospects for decoupling and the possibility of alternative paths
3.4.1. ICTs for sustainability and beyond: the Fourth Industrial Revolution
3.4.2. Emerging socio-political landscapes and their value conflicts: a synthesis

4. Toward a sustainability-sensitive ethics of ICTs

4.1. Sustainability in the fields of Information Ethics and Computer Ethics
4.2. Information and ICTs in Environmental Ethics
4.3. Anticipating value conflicts in sustainability-oriented initiatives of technology assessment
4.4. Ethical and political guidelines for sustainable ICTs
4.5. Technology assessment and beyond: alignments and coordination schemes of TA with other policy-making practices and governance institutions

The thesis will begin with a brief introduction in which I present the topic, main research question and aim of the thesis; discuss the methods used to answer it; and sketch the overall structure of the piece.

The first part discusses the key technical and social trends that have emerged from the global deployment of ICTs, which include a global transformation of technological systems, institutions, the economy, and human culture. The MSc thesis contained in this document has been aimed as a draft, as rigorous and complete as possible, of this first part of the PhD. Therefore, notwithstanding the possibility of making future corrections to details of this work, my aim is to use it as a scientific analysis of the Information Society, and a point of departure for other, more philosophical, parts of the PhD thesis.

Then, the second part retains the notion that globalization has produced a global culture which is partly embodied in a host of institutions promoting certain typical concerns and associated challenges, one of which is its own *sustainability*. Although this part will also draw evidence and conceptual resources from a variety of scientific disciplines, both its method and aim are more philosophically oriented.

The main goal of this part will be to produce a definition of sustainability that is operational for the purposes of technology assessment but also able to satisfy a series of additional requirements. In particular, I will seek to advance a definition that can (i) capture the manifold dimensions of this value; (ii) respond to the nature and scope of the factual challenges the Information Society faces in the context of the Anthropocene; (iii) be sensitive to the constraints imposed by the existing or potential institutional frameworks from which initiatives toward securing sustainability can be devised and implemented; (iv) disclose and specify the relations of mutual support and conflict that typically emerge between sustainability and other important ethical values.

To this effect, I intend to build on, and expand, a piece of research I have previously conducted on this topic (Cañizares 2016) in order to accomplish these goals in five steps.

First I will engage in a philosophical discussion about the meaning of sustainability (2.1) by performing a careful review of its most relevant scientific conceptualizations (Brey 1999; 2016; Marx 1959, 1976; Meadows et al. 1972; Sassen 1991; UN-GA 2015; WCED 1987), explaining what each of them entails (Daly & Farley 2004; Foster 1999; van Dijk 2006), indicating their potential shortcomings, and coming up with an original definition that integrates the essential aspects of them all. This discussion will allow us to disclose two interrelated but analytically distinct dimensions of sustainability: *social* and *environmental* sustainability (Motesharrei et al. 2014), each of which can be illustrated with the aid of concepts from economics, the environmental sciences and related fields. Our definition should be able to account for the nature of the challenges entailed by these two dimensions of sustainability; and provide grounds for recognizing both the differences and the relations between them.

Then I will conduct a preliminary evaluation of the sustainability of the Information Society with the aim to shed light on the *scope* rather than the nature of this challenge (2.2). This evaluation will build on the critical tendencies of the Information Society found in part 1, which shall be contrasted -and if necessary corrected- with claims that environmental scientists have advanced about the main causes of ecological crises and hazards (Meadows et al. 1972; Ehrlich 1971, 2014; Steffen et al. 2015). Then, after surveying the most important politico-economic institutional arrangements that have been created with the specific aim of tackling this challenge (Caradonna et al. 2015; UN-MDG 2015), the achievements and failures of these institutions shall be examined, and the resulting evaluations used to briefly reflect on the scope and urgency of the challenges posed by the Anthropocene (Crutzen & Stoermer 2000; Hall 2009).

The past sections already suggest that the critical problems aroused by the environmental challenges may partly stem from important difficulties in addressing the two broad dimensions of sustainability at once. The aim in 2.3 is, then, to zoom in the relations between sustainability and other key challenges of our age by investigating the relations of tradeoff or mutual support that typically emerge from their interplay. I will begin this enquiry by briefly reviewing formulations of the so-called *Grand Societal Challenges* (McGrath et al. 2014), and exploring the relations between sustainability and other challenges in light of the above findings. Then I will engage with a line of literature that approaches ethical issues by dividing them in two groups: *intra-generational* and *intergenerational* demands and obligations, each of which will be exemplified with arguments that allow us to grasp the place that sustainability holds among other demands along this axis (Nagel 2005; Rooksby & Weckert 2007; Hoven & Rooksby 2008; Glotzbach & Baumgartner 2012). Finally, a SWOT-like analysis will be conducted with the aim to conceptualize sustainability as a value whose advancement involves a conflict between different dimensions of justice, but also opportunities to overcome present institutional constraints (Drezner 2001; Selchow & Moore 2012; Mackenzie 2014).

This part concludes by critically assessing the main positions in debates about sustainability, global justice and other challenges (2.4), and using this assessment to improve our definition and understanding of sustainability (2.5). In 2.4 I address the key concepts and arguments used by the proponents of rival views about the environmental challenges, the assumptions they typically make, and the foresights and strategies each of them draws for the future of globalization and the Information Society. These rival views can be basically classified in two groups: advocates of ecological modernization and a rather heterogenous group of critics (Illich 1973, 1974; Shaw & Newholm 2002; Bookchin 2007; Curtis 2009; Spence 2009; Cato 2011; Park 2012; Hector et al. 2014; Asafu-Adjaye et al. 2015; Caradonna et al. 2015; Cahen-Fourot & Lavoie 2016). This discussion will enable us to determine and discern more clearly the theoretical and practical disagreements implied in different approaches to the problem. Together with the rest of findings of the chapter, these conflicts give us additional material to reflect about our first definition of sustainability, and to improve it by clarifying the role that technology, rival economic-political views, or differing views about the good life have to play in any serious initiative to advance this value.

The second part has already explored in what sense, and to what extent, different approaches to the environmental crises and challenges tend to view technology in a very different light. The third part then asks about the prospects that existing and foreseeable ICTs hold within the main strategies that have been advanced with the explicit aim of helping to build a more sustainable society. To address this question, I will build on the results reached on the two prior parts of the thesis in order to gain clarity and depth about (i) the specific capabilities of ICTs that each strategy for sustainability deploys or refers to, (ii) the way in which these strategies may interact with socio-economic, cultural and institutional contexts, (iii) their expected or foreseeable outcomes with regards to sustainability and other values. Since most of these strategies are consistent with the doctrine of ecological modernization, this part of the PhD thesis should provide abundant insights and arguments that will illustrate or, on the contrary, cast doubt upon, the credibility of the expectations raised by the advocates of this movement.

I have sought to pursue this enquiry in four sections.

In a first section I will extend the critical review about the doctrine of ecological modernization by advancing a precise variant of this doctrine which holds that existing or foreseeable ICTs are fundamentally capable to decouple economic growth from material constraints or, at least, from undesirable environmental impacts (3.1). I will collect arguments that exemplify this doctrine or make it more precise. Then, relying on prior analyses, I will ask what this idea entails and analyze the reasons for its prominent place in public discourse. After this preliminary contact with the idea, I will briefly review and classify some of the theoretical or normative criticisms it has received.

These criticisms can be found in articles from ecological economics (Plepys 2002; Houghton 2010; Horner et al. 2016) and even reports made for public institutions such as the EU (Erdmann et al. 2004; Hilty et al. 2006), and they show the existence of a long tradition of cumulative scientific effort in the analysis of the effects of ICTs in the environment. Some of them involve taxonomies of the environmental impacts of ICTs, which are hierarchically organized to account for varied impacts, spanning from the most direct ones to indirect and even structural effects induced by more radical socio-technical transformations. Others –especially the reports cited- even include simulations that account for the changes that different socio-political scenarios can induce in key sustainability indicators as a result of the application of these ICT-enabled strategies. This work is therefore very much in line with the goal of this thesis and, for this reason, I will build upon it. Consequently, the goal of the second section in part 3 (3.2) will consist, first, in explaining the methods, terms and taxonomies used in this line of work. However, although these studies normally take into account how socio-political contexts may affect sustainability, the reverse relation is usually left unaccounted for; in other words, these works disregard, to a large extent, the socio-economic or political effects that strategies for sustainability may have. Now, since we have seen that advances in sustainability may hinder or support other values, this forces us to improve these taxonomies in order to make them able to qualitatively assess[68] the complex interplay between the environmental and other global challenges. The result will be an analytical scheme that should reflect the lessons learned throughout the prior sections and that gives us conceptual and empirical tools that can be readily applied to the assessment of different types of ICT-based initiatives aimed at promoting sustainability.

In section 3.3 I will carry out such an exercise of assessment. This will not be a pure exercise of technology assessment (TA). The reason is that, although it will start from simple technological improvements in production processes, it will run through the different levels of the hierarchy of our scheme to study how increasingly complex and more structural transformations can even lead to new economic paradigms or social orders. In other words: this section will try to develop a critical and step-wise study of endogenous futures of our social systems, where the goal is to study how the interaction between specific ICT-based technology and other socioeconomic dynamics can advance or hinder sustainability and, at the same time, other values[69].

In principle, I have followed Hilty et al.'s hierarchy (2006) to divide this section in three types of ICT-enabled strategies: *supply-side* and *demand-side management*, and *structural changes* affecting both the supply and the demand, all of which will be exemplified and discussed with the aid of literature I have provisionally compiled in the bibliography of this proposal, and some more. Since structural changes already bring complex social and institutional aspects into the picture (see table of contents), their analysis will have to rely on the experience and theory provided by scholars that pay special attention to the difficulties involved in *technological regime shifts*, and

[68] I must stress that this analysis will be qualitative and directly aimed at preparing the more philosophical and normative part of the PhD, viz. part 4. In other words, I will not conduct any simulation, even though our criticism could highlight venues for further research to these and other researchers in the area.

[69] Another way to put it is that my objections to concrete initiatives may highlight the unlikelihood that sustainability is actually being promoted through that initiative; or, otherwise, they may point at other promising or disturbing effects that advancing sustainability in that way may have upon other values.

specifically shifts towards sustainable systems (Kemp et al. 1998; Schot & Geels 2008); likewise, I will also build upon the findings of existing studies of this sort that have been made for technologies such as cyberphysical systems (Technopolis 2016).

On the other hand, this literature is mainly concerned with technological regimes and does not seem to account for broader technical and socio-economic transformations such as the capitalist restructuring studied in the first part of this thesis. However, as we have seen, the possibility of such changes in the immediate future is something that should not be overseen, much less in a context of accelerated technological change like ours. For this reason, I have added a fourth subsection to reflect about potential, and more radical, changes or our social order (see table of contents). The interest of these transformations for our research topic can be justified with two reasons. First, ICTs also bear a decisive role in these strategies. And second: even though not all these strategies are aligned with the idea of decoupling economic growth from environmental impacts; and may even be radically opposed to it; they are still understood by its advocates as immanent possibilities of the present order, and for that matter, beneficial ones.

I conclude this part of the thesis by recapitulating the findings of the section and discussing the plausibility of the different initiatives and pathways presented, as well as the lessons they allow us to draw for devising our own original framework of ethico-political assessment of ICTs.

The previous three parts of the thesis have provided me with an analytically inclusive insight to the relations between the Information Society and the environmental challenges, thus informing the prospects for their joint evolution. In this fourth part, I build on the lessons learned throughout the thesis to engage in the creative task of devising ethical and political guidelines for the development and assessment of ICTs.

Precisely because this part of the work depends strongly on the results arrived at in the rest of the research, at this point it is hard if not impossible to anticipate what the outcomes of this creative process will be. However, I have provisionally sought to carry out the stated task in five steps.

In the first two sections (4.1 and 4.2) I will make a critical review of dominant ethico-political normative appraisals and frameworks about the desirable design and implementation features of ICTs, and the desirable use and management of information, from the standpoint of sustainability. Although this discussion may occasionally build on claims previously disclosed in parts 2 and 3, here the focus will be slightly different.

On the one hand, I will follow the materialist orientation of the whole piece to examine the soundness and the credibility of specific ethical or legal recommendations. This I will do by relying on the empirical evidence surveyed, and the feasibility claims made, all throughout the text. One example of the work I aim to produce in these two sections are the critical appraisals of Floridi's ethics of information, as contained in the pages 84-86 of the Conclusion in my Master thesis.

On the other hand, sections 4.1 and 4.2 will further the interdisciplinary approach followed through the thesis, and prove its potential benefits, by preparing the ground for integrating the perspectives present in different ethico-political fields and orientations. The key to achieve this will lie in (i) making a cross-evaluation of the accuracy with which information and computer ethics, as well as environmental ethics, respectively account for the potential roles of ICTs in any coherent and promising strategy for sustainability; (ii) assessing the resilience of dominant frameworks in these fields with regards to successful performance in handling potential value tradeoffs, as disclosed in parts 2 and 3. In this way, while section 4.1 considers and submits to criticism the way in which the main approaches to information and computer ethics handle the value of sustainability, section 4.2 asks whether environmental ethics takes seriously the crucial ethical issues that may emerge in information- and ICT-intensive promising strategies for sustainability.

In addition, this critical work may have to enter in a polemic with other traditional ethical frameworks, most of which are largely "humanist" in that they can not foresee, or in any case they openly reject, that contemporary technologies or rapid socio-economic and political changes are likely to converge to radically disrupt our identities, codes, values and legal frameworks. Moreover, it will also be informed by recent ethical or legal assessments of radical ICT technology, e.g. the recent publications ordered by the European Parliament on topics such as advanced robotics or AI with learning capabilities (Delvaux 2015; Nevejans 2015), which are more receptive to the disruptive effects of technology than some classical ethicists or ethical theories.

These analytical remarks open the way for the more creative sections of this part. In 4.3, I have thought it necessary to engage in a methodological discussion whose aim is to suggest strategies for anticipating and handling value tradeoffs and other conflicts within the very structure of an ethico-political framework. This discussion will draw on relevant literature and be particularly attentive to anticipating and, if possible, tackling the conflicts that emerge between sustainability and other values, as they have surfaced throughout the text. A secondary function of the section is, further, that it should round up one the main contributions of this work, which is its commitment to ethico-political realism, as clearly conveyed by its continuous, multi-layered and methodical appraisal of conflict. After that, I will set to advance an ethico-political framework for the design and implementation of ICTs for sustainable futures (4.4). This framework should satisfy a series of demanding requirements I have repeatedly insisted upon: it should build on the above analysis of the "endogenous" and scientifically informed futures of our social order; it should be especially sensitive to sustainability and its interplay with other values; and it should place particular attention on the conflicts that those scenarios may arouse, and the way in which these conflicts should be dealt. In other words: it should be highly realistic, interdisciplinary, and sustainability-sensitive.

The fourth part and the thesis concludes with a reflection (4.5) whose aim is to evaluate the recent history of technology assessment, and then suggest venues for improvement of the practice –especially in the interface with other social agents and institutions involved in the support and construction of sustainable futures as well as the promotion, design and policy-making of ethical ICTs. These suggestions should be vindicated by the findings of the thesis, and also implied in the demands introduced by the ethico-political framework hereby produced.

Philosophical justification.

My approach to this PhD thesis is grounded on the philosophical insight that a fairly accurate ethical and political assessment of ICTs (or any other group of technologies) needs to address all the concerns disclosed everywhere else in this proposal –and perhaps some more. This entails that any such assessment should be empirically well-seated, imaginative, rigorous and highly interdisciplinary. I believe that my MSc Thesis, which stands for the first part of the PhD, constitutes an example of this attitude and orientation, and also an illustration of the potential benefits that it may bring for the fields of philosophy of technology and technology assessment. This statement does not, by any means, imply that the author believes himself capable of simply bypassing the current scientific division of labor in the field. It does mean that, in order for the ethico-political assessment of technology to be effective, it needs to be strongly grounded in a knowledge of the current trends, limitations and opportunities of our social context: rather than being merely multi-disciplinary, it must become truly *interdisciplinary*. Throughout the PhD thesis I will try to remain faithful to this spirit: for in technology assessment, like in any other philosophically inspired enterprise, the goal cannot be just to know how the world is, or to make claims about how it should be. Instead, it should be to make visible how the world can be effectively changed, and what steps could be taken for this change to be desirable.

Technological Justification

The Fourth Industrial Revolution is set to build upon a global scale, capital-intensive deployment of ICT technologies, and thus it deepens tendencies already found in the Information Society. As it happens, it is also being promoted as an opportunity to foster economic growth while making societies more capable of complying with international agreements regarding sustainability. Yet, aside from concerns about its potential to further and accelerate an effective decoupling of growth and environmental impacts, this Revolution will bring conflicts of its own, many of which might hint at the very foundations of our societies. This becomes evident when one only considers the huge impact of already existing ICTs in the world, and then thinks about the prospects that such radical technologies as Cyber-Physical systems (Technopolis 2016) or the Internet of Things might bring about.

Timeline (provisional)

Phase	To be done and submitted	Deadline
1st: Ch. 1 and MSc Graduation	Final Draft of Thesis Proposal	25-Jan-17
	Final Draft of MSc Thesis	02-jun-17
	Presentation and Graduation	03-Aug-17
2nd: Ch. 2	Final Draft Ch. 2	01-jul-18
3th: Ch. 3	Final Draft Ch. 3	01-jul-19
4th: Ch. 4 and Intro	Final Draft Ch. 4	01-jun-20

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