1. Introduction and summary

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1.1 MOTIVATION

How important are information and communication technologies (ICT) in explaining fundamental changes in economic outcomes? How should we think about the digital society and what parts of society have changed over the past decades? How have modern economies changed as a result of digital goods and markets, and what are the policy implications and challenges of these changes?

The impact of ICT on economic outcomes and on society in general is founded on a number of technological breakthroughs that seem to be historically unique.[1] The recent consensus is that ICT has affected the design, management and control of production and service systems throughout the economy, based on an interconnected set of radical innovations in computers, software engineering, control systems, integrated circuits and telecommunications, which have drastically reduced the cost of storing, processing, communicating and disseminating information as well as drastically changing the modes of production and the supply of a range of new products and services. The pervasiveness of ICT is not just a matter of new products or industries, but of a radical new technology, which affects every industry and every service, their interrelationships, and indeed the whole way of life of modern societies. In terms of the concept of general-purpose technologies (GPTs) developed by Bresnahan and Trajtenberg (1995):[2]

> Most GPTs play the role of 'enabling technologies', opening up new opportunities rather than offering complete final solutions. For example, the productivity gains associated with the introduction of electric motors in manufacturing were not limited to a reduction in energy costs. The new energy sources fostered the more efficient design of factories, taking advantage of the newfound flexibility of electric power. Similarly, the users of microelectronics benefit from the surging power of silicon by wrapping around the integrated circuits their own technical advances. This phenomenon involves what we call 'innovational complementarities', that is, the productivity of R&D in a downstream sector increases as a consequence of innovation in the GPT technology. These complementarities magnify the effects of innovation in the GPT, and help propagate them throughout the economy.

These observations make clear two crucial ingredients of the ICT revolution: its generality and innovational complementarities. The strong effects of both have led to dramatic changes in our economies. To develop these arguments systematically and to answer the questions raised in a comprehensive way, the present volume offers an insight and overview of the changes ICT has brought about in our analysis and understanding of society.

1.2 SUMMARY AND MAIN ARGUMENT

In a certain sense, it is the task of economists to confront technologists with numerous social, economic and societal factors that are related to the diffusion of new technologies, no matter how radical the technology may be perceived to be by the business community and policy makers, scientists and technologists. From the perspective of its social and economic implications and broader societal embedding, the current cluster of ICT represents a potentially radical technological and organisational transformation. The cluster of what is currently described as ICT is based on a broad range of continuous, sometimes radical, converging technological breakthroughs that, when viewed as a group, appear to be historically unique in terms of speed and world-wide impact. Here we briefly review the most important applications and developments.

The first major change ICT brought about was a dramatic technological improvement in the capacity of semiconductors, which led to a giant increase in the capacities and speed of computers to store and process data. Using what is called Moore's Law, these improvements were described in 1965 as a logarithmic increase in the processing capacity of computer chips (e.g. Moore, 1965). This law still seems to apply 40 years after its formulation as clearly indicated on the Intel Website.[3] This trajectory of continuous technological improvement has been described in depth and analysed by a great many economists since the 1980s, so in fact there is not much new to it.[4] The process of technological improvement in semiconductors in particular gained momentum with Intel's invention of the microprocessor in 1971. In other words, the continuous technological improvements over the past 35 years combined with the individualisation of computer use thanks to personal computers has led to the ever-increasing diffusion of ICT applications throughout the various sectors of the economy. Thus ICT – and the increasing power of the (personal) computer in particular – has made its entry in the numerous economic analyses as a general-purpose technology, the diffusion of which is accompanied by a great many organisational changes and tensions leading to different organisational design, productivity changes, and division of labour.[5]

Second, there is the tendency to miniaturise ICT. The impact of ICT miniaturisation has been essential to the physical integration of electronic functions in existing (and new) equipment and has made this equipment itself more handy and efficient in use. Previously it was impossible to apply a lot of the old ICT equipment in both electromechanical capital and consumption goods, simply because it would have taken up too much space. Apart from the development of the miniaturisation of ICT equipment new, user-friendly products as illustrated in the case of the computer by the development of mainframe to mini-computer, PCs, laptops and palms, offer the possibility to include electronic intelligence in practically any existing mechanical apparatus. Thus ICT equipment seems to further increase the efficiency of existing products, whether they are instruments, machines, or household appliances. Miniaturisation also leads to a lower use of energy.[6] Ultimately, the possibilities for ever-increasing miniaturisation open the avenue to nanotechnology, that is, the production of electronic material at sub-micron level that can interact with tiny matter and cells, including live cells. As yet, the latter developments are clearly in their early stages and subject to research in a lot of countries. Nevertheless, these mainly technologically driven developments towards further miniaturisation are important, because they show that the technological trajectory within the ICT sector is far from completed and that the application areas of the technology extend further to other areas and sectors. In other words, ICT is not just limited to the Internet and the computers on our desks.

Third, there are the almost equally radical technological improvements in the area of telecommunication. The developments in the field of optical fibres allow for the transmission of digital signals without noticeable loss of energy. Combined with the trend towards miniaturising IT equipment described above – the routers and networks stations – and the strong expansion of the bandwidth of communication channels, this allows for the development of a communication network infrastructure in which information and communication goods can be supplied at minimal variable cost. Communicating with someone nearby or with someone on the far side of the globe will be virtually the same and the concept of the 'death of distance' is not as farfetched as it may seem, however, keeping in mind that when virtual and face-to-face interactions are complements the demand for real interactions is increasing as well.[7] It is mainly from this perspective that the technological developments in the area of communication technology differ from other, previous breakthroughs in the area of network technology, such as electricity (e.g. David, 1985). Apart from being dependent on the much higher capital costs of the various network stations, an electricity network is also dependent on energy loss over its own network. In other

words, in the case of electricity, contrary to ICT, distance continues to be an important cost factor.

Fourth, there are the specific developments in the area of mobile communication. In a certain sense, mobile communication represents the ultimate form of 'reachability'. Physical access to the infrastructure of the network is no longer necessary, but communication can occur from any place. Naturally, the antenna infrastructure continues to be a major cost factor (and the auctions of the UMTS frequencies have proven to be very expensive, e.g., van Damme, 2002), but this is not in proportion to the physical network costs of, for example, the distribution of electricity. As to the rest, the fixed network cost is formed by the property of a piece of space. Hence, mobile communication adds more than just the end of physical distance; it might be described in Marshallian terms as 'any place, any time, anywhere; information and communication is in the air'. It goes without saying that this additional 'reachability' dimension of communication explains the originally unexpected boom in mobile telephone communication in the 1990s. This area, too, is still in its initial stages of further technological development with the third generation telecommunication systems coming on stream only today (e.g. Gruber, 2004).

Fifth, there are the developments in the field of supporting technologies, such as software and other communication standards, in particular the Internet protocols (for example WWW), and mobile communication standards (such as GSM, WAP and UMTS). Software developments have appeared to be essential not only in the development of new information goods such as content, they have also shown to be particularly important in the improvement of the use of the physical communication infrastructure. ASDL, for example, allowed for the better and more efficient use of the old copper telephone lines. On the other hand, the different layers of open Internet protocols are crucial to the development of new information goods and Internet trade in general. Thus the possibilities of communication expand and the tradability of services increases due to new software developments and internationally accepted information and communication standards. Many of these developments face difficulties in terms of the adoption and harmonisation of consistent systems across countries (e.g. Leibbrandt, 2004 for payment systems).

Finally, the digital economy has been struggling with intellectual property rights (IPR) for a while now and the Open Source Movement has been an attempt to make software freely available. Many of the products available in a digital format share the properties of public goods in the sense that these commodities are non-rivalrous. A non-rival good is a commodity for which use of a unit of the good by one agent does not preclude its use by other agents, whereas a rival good is a commodity for which consumption

or use is restricted to the buyer of the commodity. In other words, the consumption of a non-rival (or public) good by one individual does not affect or restrain the supply available for other individuals. The recent discussion of copyright protection for recorded music provides a good illustration. The fundamental good produced by the record industry is a long string of sequences of 0s and 1s, which can be reused at no additional cost; so clearly a non-rival good once put on a CD. Napster provided an Internet site that made it possible to freely exchange this string (music) between consumers around the globe. In court Napster attempted to demonstrate that its activities did not reduce the value of the intellectual property protected by the record companies' copyrights by stating that (1) it involved mainly sampling of individual songs (no downloading of full albums) and (2) it engaged primarily in space shifting, using Napster to play a CD already owned. The first argument was used to show that sampling would increase the demand for the artist's CD because it would give the consumer a nice preview of the total album. The second argument was used to make a case analogous to time shifting (e.g., like recording a soccer match to view it later). Both arguments were dismissed in court because Napster substitutes for buying CDs and does not involve 'fair use' of intellectual property rights.[8]

In brief, what is historically unique in terms of technological developments in the area of ICT, is, in a certain sense, the historically long, unremitting technological improvement in various sub-areas, and on the other hand, the exceptional technological spillovers and convergence between the various ICT areas. Central to this issue, however, is the question of to what extent technologically driven developments lead to the emergence of a truly digital society.

1.3 RESEARCH OUTLINE

This book is in 14 chapters. In Chapter 2, Jean-Jacques Herings and Maarten Pieter Schinkel get to the microeconomic core of the digital economy. They introduce the distinction between goods information and information goods. Goods information in particular – the information about goods and services – is readily available in the new economy at lower cost. Information goods, defined as all goods that are also available in digital form, can be used both in production processes and in consumption. Both require an extensive information structure. Herings and Schinkel seem to be moderately optimistic as to the welfare-increasing impact of goods information, because markets become more transparent and transaction costs can be reduced. On the other hand, they fear that dominant

suppliers might affect information goods, because the consumer surplus could be skimmed off by consumer lock-in, the build-up of intellectual property rights and further product differentiation. Finally, the information infrastructure leads almost automatically to monopolistic market structures in view of the importance of network effects, both at the individual and the collective levels. Hence there is a need for a diversified public policy that takes account of these various developments, and Herings and Schinkel point to the role of the government in particular as the gatekeeper of the openness of the competition process, if the potential 'world-wide-welfare' gain of Internet is to be realised.

The next three chapters are more concrete applications of some of the microeconomic issues of the digital society sketched by Herings and Schinkel. These chapters deal with innovation in networks, the development of e-businesses and new market structures, respectively. Chapter 3, by Robin Cowan and Nicolas Jonard, presents a microeconomic model for the formation of strategic alliances in a digital world. In the model, innovation results from the recombination of knowledge held by the partners to the collaboration, and public knowledge. As a result of growing IT use, the fund of public knowledge is bigger, and more easily accessible. Hence a positive externality exists, firms drawing from the pool of available knowledge while at the same time contributing to it through the outcome of the R&D alliances they form over time. A tension exists between contributing to and benefiting from the public knowledge, and Cowan and Jonard study this tension as it changes with the relative ease 'cost' of resorting to bilateral agreements versus drawing from publicly available information.

In Chapter 4, Huub Meijers develops a model that uses indivisibilities and adjustment costs to explain the slow diffusion and adoption of e-business practices by firms. Using a model of monopolistic competition, e-business practices are introduced and typically network effects explain the diffusion pattern of this new practice. Since model simulations provide a better understanding of the relation between market structures and the diffusion of new technologies, and of the relation between firm size and the incentive to adopt new technologies, the second part of the chapter shows the diffusion patterns under a number of sets of model parameters. The results show that typically medium-sized firms adopt e-business practices first and that smaller and less productive firms are driven out of the market. On the other hand, some large firms may even rationally decide not to adopt the new practice but are still competitive enough to survive. Increased price competition shows that at first the diffusion process is faster, but that the ultimate diffusion level decreases. From a policy point of view, Meijers' approach shows the need for open standards to foster compatible technologies, thereby increasing the benefits from network

externalities. He also suggests that the further diffusion of e-business technologies can be promoted by the introduction of special programmes based on training and the diffusion of knowledge to help smaller firms to overcome problems related to indivisibilities, and by promoting labour market flexibility that reduces adjustment costs which are hampering diffusion among larger firms.

Harald Gruber, in Chapter 5, analyses the European auctions of radio spectrum for the provision of third generation (3G) mobile telecommunications services as a function of the (local) market structure. Unexpectedly high licence fees were observed in some countries, whereas in other countries they were far below expectations. Gruber's aim is to explain the large differences in government revenues between countries using an oligopoly model. The main question is whether market structure is consistent with the licence fee raised, and this question is analysed in terms of overbidding. Overbidding occurs when a firm engages to pay a higher licence fee than the expected oligopoly profit, which encourages a more concentrated industry or collusive behaviour that could lead to a slowdown in the diffusion of new services, with adverse welfare effects. Gruber's line of reasoning is contrary to the traditional argument that licence fees are sunk costs and thus should not affect post-entry behaviour, but it follows recent experimental research on the sunk-cost fallacy. To illustrate his arguments, he presents a theoretical framework focusing on the interplay between market structure and fixed costs. The features of the model are then contrasted with the empirical evidence from the European mobile telecommunications industry. On the empirical side, this study provides a structured interpretation of the aftermath of 3G licences and an explanation of the newly emerging market structure in the industry.

The contribution of Paul David in Chapter 6 is concerned with the question of whether the digital society needs the 'old' intellectual property rights institutions. Radical legal innovations in intellectual property protection have been introduced by the little-noticed European Database Directive of March 1996. This initiative poses numerous contentious issues in law and economics. These are likely to create ambiguities for business and non-profit activities in this area for years to come, and the terms on which those issues are resolved will materially affect the costs and organisational feasibility of scientific projects that are of global reach and significance. In general, the conduct of open, collaborative science may be seriously jeopardised by the consequences of the new IPR protections. David's analysis sets out the economic case for the effectiveness of open, collaborative research, and the forces behind the recent, countervailing rush to strengthen and expand the scope of IPR protection. Focusing on innovations in copyright law and the *sui generis* protection of hitherto

unprotected content, it documents the genesis and analyses the economic implications of the EC's Database Directive. David concludes his chapter by advancing a number of remedial proposals that are intended to promote greater efforts to arrive at satisfactory policy solutions for this aspect of 'the digital dilemma'.

In Chapter 7, Rishab Ghosh, Rüdiger Glott, Bernhard Krieger and Gregorio Robles give insight into the demographics of the open source movement. Although open source and free software are no new phenomena, they have shown a considerable increase in importance just in recent years. However, many aspects of this domain still appear unknown or even strange. Economic exchange relations, as they occur within the community of FLOSS developers as well as in the traditional parts of capitalist economies, are usually based on the fundamental principles of private property and monetary payments. However, these principles seem not to be applicable to FLOSS, and still this domain functions very well and gains more and more importance in the leading software markets. Based on an online survey of 2,784 open source/free software developers, this chapter provides insights into fundamental features of the FLOSS community and its economic principles. It sheds light on personal features of FLOSS developers, of their work and project organisation, their motivations, expectations, and orientations. Finally, it illustrates the fundamental dividing lines that characterise mainly the FLOSS community and cause its outstanding position, including the distinction between monetary and non-monetary rewards and the distinction between FLOSS and proprietary software.

Bas Straathof and Rifka Weehuizen, in Chapter 8, argue that there is a relationship between new technologies, most notably ICT, and the intensity of work, and between the intensity of work and mental health. They provide a theoretical framework linking technological change to mental health via its effect on the intensity of work, and demonstrate how more rapid technological change can lead to a deterioration of mental health and a greater incidence of burnout. Straathof and Weehuizen start with the observation that technological advances reduce the price of ICT relative to that of human labour, which causes entrepreneurs to automate a larger proportion of routine tasks. As a consequence, workers will carry out fewer routine tasks and spend more time on non-routine activities. It is shown, by means of two different models, that the shift from routine to non-routine tasks affects work intensity such that work pressure goes up. Workers are therefore more vulnerable to developing symptoms of burnout.

In Chapter 9, Wilfred Dolfsma goes into detail about the developments in an outstanding new-economy sector: the content industry, referred to previously as 'the cultural industries'. Dolfsma analyses in sharp detail the

big changes that these content or media industries are facing as typical information goods. They are, in Dolfsma's view, representative of what is in store for other sectors. Content goods represent the most important Internet trade, which is illustrated by, among other things, the top three on the list of the most searched for terms on the Internet: games, music and sex. About three million pieces of music are downloaded from the Internet daily. The content industry is thus characterised by continuous and rapid product innovations as a result of digitalisation, special problems related to the preservation of and compliance with existing intellectual property rights such as copyrights, bundled sales via platforms, rapidly changing team working environments with complex non-routine tasks, and so on. This detailed analysis of the media sector leads Dolfsma to argue in favour of more sectoral analyses and studies. Changes in the types of competition can be studied only at a disaggregated level before specific policy can be formulated. The balance between tendencies of monopoly formation and that of market fragmentation can be determined, according to Dolfsma, only at this level. The media sector is also particularly important and instructive from the perspective of the organisation of product innovations. In a certain sense, every new product is an innovation. For decades, media industries have been organised in such a way that they generate an optimal flow of product innovations. Although only a small percentage of the new products become a success, the sector in itself is successful. Teamwork is highly relevant in this process: in the end, truly innovative ideas are created only by the combination of different backgrounds. It looks, so it seems, suspiciously like the academic research community, when the latter is really creative.

In Chapter 10, Lex Borghans and Bas ter Weel discuss the impact of ICT, and of computers in particular, on the labour market. The growing importance of computers has led to a great deal of attention by policy makers on computer skills, which are viewed nowadays as essential qualifications. In the absence of both empirical and theoretical underpinning, however, the real importance of computer skills continues to be unclear. Borghans and Ter Weel use several data sources in their attempt to measure computer skills, the various levels at which computers are used, and the importance of computer use for one's job. They conclude that, in general, the lack of computer skills does not play a limiting role in the workplace. Thus, according to Borghans and Ter Weel, just like the fear back in the 1970s and 1980s concerning large-scale technological unemployment, the fear that without investment in computer skills part of the population will miss the boat, is unjustified. Nevertheless, they believe that, in a lot of professions, labour productivity will increase as a result of the use of computers and more ICT in general. They emphasise, however, the importance of infrastructure and availability of services, not only physical network structure, but also

software and information services. In other words, the impact of ICT on the labour market goes beyond the old vision of skill-biased technical change, and brings to the fore a full range of new skills. Rather than with computer skills, this development is concerned with a broader shift from the importance of a variety of skills in today's society.

In Chapter 11, Thomas Ziesemer develops a theoretical model to find the impact of ICT, bargaining power and monopoly power on x-best optimal unemployment benefits and on three market imperfections: search externalities, monopoly prices and variety externalities. The main contribution of Ziesemer's chapter is to consider not only labour-market imperfections (search externalities) but also goods-market imperfections (monopolistic firms and goods-variety externalities). His main result is that ICT and a reduction in a firm's monopoly power increase the optimal level of unemployment benefits, whereas a reduction in a worker's bargaining power reduces the optimal level of unemployment benefits.

Eric Bartelsman and Jeroen Hinloopen, in Chapter 12, also focus mainly on the economic underpinning of cashing in the digital growth promise, by looking at the increase in efficiency in information processing and communication as a result of the use of ICT. This increase in efficiency is translated into a decrease in transaction costs and an increase in the productivity of knowledge workers. According to Bartelsman and Hinloopen, this is translated into a possibly higher growth path of GDP at the macroeconomic level. After all, the lower transaction costs lead to a better match between supply and demand and higher added value per unit of production means. As more firms use ICT in their production process, and as the market share of the ICT-using firms increases and entrants are more productive than firms withdrawing from the market, productivity at the macroeconomic level will therefore also rise. The question is why this process seems to have been set in motion in the United States, but not in Europe. Bartelsman and Hinloopen argue that particularly the investments in ICT capital in Europe lag behind those of the United States. To find an explanation for this, they look at the higher costs of ICT capital in Europe, for example as a result of higher personnel and financing costs and less market pressure. Policy makers should therefore focus on these aspects, if they want to cash in the growth promise of ICT in Europe.

In Chapter 13 Adriaan van Zon and Joan Muysken build a model to analyse the impact of investment in ICT on subsequent knowledge accumulation and eventually economic performance. They formulate an endogenous growth model that incorporates a positive link between the production and the use of ICT on the one hand, and productivity growth at the aggregate level on the other. Van Zon and Muysken do this by introducing ICT capital as a separate factor in the production of final output

and in the accumulation of knowledge. This enables them to identify explicitly several transmission mechanisms for the growth effects emanating from the ICT sector, among which is its impact on the process of human capital accumulation that may become much more productive through ICT capital deepening. Thus ICT investment may influence growth performance directly and endogenously. Using the model, they study the structural features (as opposed to the transitional dynamics) underlying the steady-state growth performance of the economy, in which growth is not so much caused by ICT investment, but certainly strengthened by it. They conclude from their analysis that for reasonable parameterisations of the model, a positive link between ICT investment and economic growth does indeed exist. A study of this positive link under three different spillover regimes yields that welfare is positively affected the stronger these spillovers are, but also the more these spillovers are internalised. In addition to this, they find that under a system of decentralised decision-making, the economy will consistently tend to over-accumulate in comparison to the social planner solution. This suggests that there is room for policy intervention aiming to increase the impact on growth of these spillover effects, for instance through education policies that improve computer literacy.

Finally, Christopher Freeman and Luc Soete provide in their chapter, 'A digital society for us all: "old" and "new" policy reflections', a very intriguing view on the policy changes and aspects of the digital society by examining the policy implications made in 1995 in a 2005 context. Their main conclusion is that many of the policy issues debated and discussed ten years ago within the framework of an influential EU advisory expert group in which both Freeman and Soete participated, are today still as valid as ever. As they put it: 'To paraphrase Keynes: policy makers new to the job, who believe themselves to be quite exempt from earlier policy advice, are usually the slaves of some defunct EU policy report'. In short, even when looking at a set of radical general-purpose technologies such as ICT, expert policy conclusions seem to have a stickiness associated with them that makes them relevant for far longer periods than policy makers are likely to be in office and have attempted to implement them.

NOTES

1. See e.g. Freeman and Soete (1990, Chapter 3) for an overview of the development of information and communication technologies into modern ICT.
2. Quoted by Helpman (1998, p. 3).
3. See for example http://www.intel.com/research/silicon/mooreslaw.htm
4. See for example Katz and Phillips (1982), Dosi (1984) and Jorgenson (2001).

5. See for example Freeman and Perez (1988), David (1991), Bresnahan, Brynjolfsson and Hitt (2002), Bertschek and Kaiser (2004) and Borghans and ter Weel (2004).
6. The intensive use and large-scale diffusion of their widespread presence, for example computers, can of course, undo this energy benefit per appliance. According to calculations in the United States, the production and use of computers is responsible for 295 billion kilowatt hours of electricity demand, which equals about 8 per cent of the total American demand for electricity.
7. Cairncross (1997) argues that the revolution we are seeing is the third in a succession of great changes in the technology and cost of transportation over the past three centuries. The nineteenth century was shaped by the falling cost of transporting goods; the twentieth by the falling cost of transporting people; and the twenty-first century will be dominated by the falling cost of transporting ideas and information.
8. The *American Economic Review*, May 2002, published a discussion on the economic perspective of the Napster case. See also David (2001), Borghans (2003) and Soete and ter Weel (2004) for an analysis of access to research data in relation to the developments in the area of ICT.

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