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Assessing the economic impacts of ICT

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Summary

This paper is a wide-ranging overview of issues related to the economic impacts of ICT. It discusses the broad issues of theory and method involved in thinking about a new radical technology, such as ICT, in economic change. However this discussion is extended in several directions – into a discussion of statistical and measurement issues, into an overview of the empirical dimensions of ICT in economic growth both at OECD and European levels, and into a discussion of the nature of ICT as a technology. Part of the empirical discussion also relates to the indirect use of ICT competence, and here we use Norwegian data to make a more general point about the impact of ICT. The basic argument here is that many of the analytical claims for regarding ICT as a key driver of economic growth are overstated, and that this has important policy implications.

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Chapter 1. The analytical and policy significance of ICT

How important are information and communications (ICT) technologies in economic growth, and how important are ICT policies in wider policies for innovation and economic growth? There are many in economics, business and government who argue that economic growth has been and is being driven by the growth and inter-industry impacts of ICT. This idea is of obvious analytical and policy significance. From the analytical point of view, if ICT is a core driver of growth, then we have a direct route to understanding differences in the growth rates of firms, regions and countries. It simply means that performance differences can be explained either by differences in rates of investment in ICT, or by differences in diffusion paths, or differences in returns to ICT investment. From the policy perspective, if it is the case that ICT is a primary driver of growth and employment creation, then it deserves to be at the centre of innovation and industrial policies. The policy conclusion seems straightforward – governments should invest in the creation of ICT industries, and in the diffusion of ICT products and services.

There are many who argue for such perspectives on growth and policy. For example, Fagerberg et al, in a recent study of European growth, argue that:

> … the problems that Europe faces in key areas such as growth, equality and employment are all related to its failure to take sufficient advantage of technological advances, particularly the ICT revolution…science-based industries, particularly those drawing heavily on ICT, have become the main driver of technological change and economic growth since the 1980s. (Fagerberg et al, 1999, 235)

The policy conclusion from this seems very clear:

> …what Europe has to do is to is to take steps to embed new technologies, especially ICTs, in society. This should bring together regulation, science and technology policy, and employment initiatives. (Fagerberg et al, 1999, 235)

These arguments and conclusions are rather common. Those cited here are unusual only in that they are drawn from a serious work of economic analysis, which seeks to identify, analyse and understand Europe's growth path, on the basis of well-formulated hypotheses that are tested against good-quality data. There are many far less serious expressions of the same views, particularly in policy arguments. In policy arenas it is common for politicians, policy-makers (and the lobbyists who seek to influence them and to profit thereby) to promote ICT as a technology which stands alone in its impact and implications.

But how justifiable is the idea that ICT is a key driver of growth, and how valid is the claim that it should be at the centre of innovation policy? The objective of this paper is to evaluate concept, methods and empirical evidence in assessing the economic impacts of innovation in information and communication technologies. The basic issue is this: *How can we conceptualise the actual and potential impacts of ICT, and how adequate are the economic and statistical methodologies that seek to measure those impacts?* Part of what follows is a critique of positions that dominate both innovation analysis and policy discussion at the present time. But the intention is to move beyond this, towards an analysis of how ICT relates to growth and change. The argument here is that ICT is part of a wide process of economic change. But it is only a part: it fits into a very wide set of more or less independent technological changes and framework changes. It is by no means a 'core' driving force of recent economic history, and it is unlikely to be so in the future. Both its economic importance and its policy role therefore require careful qualification.

These issues remain both under-researched and of considerable public importance. In terms of public research policy, ICT remains the largest single field of technological and R&D investment in virtually all OECD economies. This will almost certainly continue, and so it is extremely important both for public debate and for policy design to clarify the economic role of ICT. But understanding the role and impact of new sectors and new technologies involves subtle conceptual problems. In the field of ICT, too many conclusions have been drawn too soon. It is time to reflect in more detail on the conceptual and methodological background: let us turn to this.

1.1 Analytical questions

Understanding the economics of ICT involves exploring at least five related analytical questions, all of which are more or less unresolved at the present time. They are:

- How adequate are the existing approaches to the links between ICT and economic growth? How good are they conceptually, and how to they stand up in relation to relevant empirical evidence on growth? What are the theoretical and empirical issues involved in assessing the economic significance of the ICT industry, the inter-industry impacts of ICT, rates of return to ICT investment, and the growth and productivity impacts of ICT?

- What is 'ICT'? What does it mean to speak of ICT as a technology? In what ways can we define ICT as an industry? What is the relationship between the growth of ICT as an industry, and the impact of ICT as a generic technology?

- How adequate are existing economic statistical frameworks (such as the NACE and ISIC classifications) for understanding the dimensions of ICT? How good are recent attempts by OECD, and by national agencies such as Statistics Norway, to revise or re-order industrial statistics to take account of ICT?

- What are the issues in understanding problems of causality with respect to ICT? Under what circumstances can we speak of ICT 'driving' or 'explaining' economic change? Alternatively, what are the issues in understanding the shaping of ICT itself?

The following pages will address these issues in turn.

Chapter 2. ICT and economic growth

Understanding the economics of ICT requires an understanding of how it is that a new technology generates economic impacts. In terms of ICT we have had two basic types of argument; these will be overviewed and discussed critically in later sections of this paper.

Firstly, there is what we shall call the 'structural change' argument. This position argues that economic growth is driven by the emergence of new sectors embodying new technologies. These affect growth in two ways. On the one hand the new sectors exhibit higher growth rates of output, employment and productivity, so that they in some sense 'drive' overall growth in the economy. On the other hand, new sectors change the conditions of other sectors in the economy, either by providing a new range of inputs that raise productivity, or by generating new production methods that can be imitated, or both. There are those who argue that ICT is exactly a sector and technology of this type, that its quantitative effects are large, and that its qualitative effects are creating a totally new type of economy.[1] The OECD, in its discussion of the 'new economy', suggests that "The term 'new economy' has been used extensively in recent years to describe the workings of the US economy and in particular the part of its economy that is linked to ICT", linking ICT to its inter-industry effects: "Due to more efficient business practices linked to ICT use, the new economy may experience a pick-up in trend growth, due to higher multifactor productivity growth".[2]

Second, there what we shall call the 'productivity growth argument'. Here the view is that ICT is a new type of capital good, and that increasing investment in ICT by businesses ought to raise labour productivity and also – if ICT incorporates real technical change – total factor productivity as well. But for most of the past thirty years this has not happened, leading to a large and long-standing literature on the so-

1 See for example, C. Freeman and C. Perez, 'Structural crisis of adjustment: business cycles and investment behaviour' in G. Dosi et al, Technical Change and Economic Theory (London: Pinter 1988). They argued that ICT was driving a 'techno-economic paradigm shift' and leading to a completely new growth trajectory and organizational structure for the advanced economies.

2 OECD: A New Economy? The Changing Role of Innovation and information Technology in Growth (OECD, Paris) 2000, p.17

called 'productivity paradox'. The acceleration of ICT investment which began in the 1970s has been associated with falling or stagnant productivity indicators.[3] In the past two years, the approaches used to explore the productivity paradox have in many cases been used to argue that, far from having no effect on growth, ICT has in fact been driving US growth over the past five years. This literature is almost entirely econometric in character, based on only one form of assessment, namely the computation of total factor productivity indicators, accompanied by an attempt to explain why the ICT inputs are associated with falling or rising growth rates of total factor productivity.

2.1 ICT and Economic Growth (I): the structural change argument

Most economic analyses of growth assume that growth is in some sense related to qualitative change – that is, it involves doing new things with new processes, so that growth is not just an extension of existing activity, but involves change in the character of economic activity. But there are a number of ways in which this insight can be interpreted. For example, in *The Wealth of Nations*, Adam Smith that growth was associated with a more complex division of labour, so that components of existing activities would 'spin-off' as separate activities, and would then be subject to productivity growth as people specialized in these activities and became more skilful at carrying them out. Smith also foresaw that knowledge creation would become a separate activity, and that this would impel further productivity growth. In this framework, growth would follow from widespread productivity change across almost the whole spectrum of activities, with specialization driving the growth outcomes.

A different interpretation of the relation between growth and change is to see it in terms of the growth of completely new activities. To some extent, this is the perspective of Marx in *Capital*, where a great deal of attention is paid to the emergence of mechanical technologies and the mechanical engineering industry. However this perspective only fully emerged early in the twentieth century, in the work of the historian Arnold Toynbee. In writing about the Industrial Revolution, Toynbee argued that growth sprang from the development of four key industries –

3 Solow's famous remark about computers being everywhere except in the productivity statistics was made in the mid-1980s. The productivity paradox as a research area was well-established by 1990. See, for example, the extensive literature published by OECD: Technology and Productivity. The challenge for economic policy (OECD: Paris) 1991.

textiles, engineering, coal and shipbuilding. This put the focus on specific new industries, an approach that became very influential during the twentieth century. A well-known summary of this argument can be found in Kuznets, one of the most influential of modern growth theorists:

> '(A) sustained high rate of growth depends upon a continuous emergence of new inventions ands innovations, providing the basis for new industries whose high rates of growth compensate for the inevitable slowing down in the rate of invention and innovation, and upon the economic effects of both, which retard the rates of growth of older industries. A high rate of overall growth in an economy is thus necessarily accompanied by considerable shifting in relative importance among industries, as the old decline and the new increase in realtive weight in the nation's output'[4]

This kind of approach was originally systematised by Joseph Schumpeter, particularly in his *Business Cycles. A theoretical, historical and statistical analysis of the capitalist process*.[5] However the explanations that he offers are not clear-cut. On the one hand, Schumpeter assigns innovation a central role in shaping economic dynamics, and argues the hypothesis that innovation drives wave phenomena; there is a rather brief discussion of the character of such innovation.[6] On the other hand, there is much discussion of entrepreneurship, investment expenditure, money and banking and so on - the point about innovation here is that it provides the motive for a growth process which is investment-led. But the real problems are entrepreneurship, finance, demand and so on. From one perspective, Schumpeter sees the growth impacts of innovation/investment not in terms of productivity enhancement but in terms of aggregate demand:

> 'If innovations are embodied in new plant and equipment, additional consumers' spending will result as quickly as additional producers' spending. Both together will spread from the points in the system on which they first impinge, and create that complexion of business situations which we call prosperity.'[7]

This is not dissimilar from a straightforward Keynesian account of the business cycle. What is genuinely different is the account of the nature of relevant innovation, and its effects on historical development. Schumpeter in fact offers no theory of the generation of innovation, but he makes three important points which he seems to treat as empirically founded: 'stylised facts' as it were. They are:

- *Innovations are clustered together and 'are not evenly distributed in time'.*

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4 Kuznets 1959, p.33

5 J. Schumpeter, Business Cycles. A theoretical, historical and statistical analysis of the capitalist process (Philadelphia: Porcupine Press, 1989).

6 Schumpeter, op.cit, pp.75-6.

7 Schumpeter, op.cit, p.121.

- *Innovations 'concentrate on certain sectors and their surroundings'.*
- *There are discrepancies between the growth of sectors: 'some industries move on, others stay behind'.*[8]

Innovations disrupt equilibria and cannot be smoothly absorbed into the system. However, 'those disturbances must be "big" in the sense that they will disrupt the existing system and enforce a distinct process of adaptation'.[9] What 'big' means in this context emerges gradually:

> 'Historically, the first Kondratieff covered by our material means the industrial revolution, including the protracted process of its absorption. We date it from the eighties of the eighteenth century to 1842. The second stretches over what has been called the age of steam and steel. It runs its course between 1842 and 1897. And the third, the Kondratieff of electricity, chemistry, and motors, we date from 1898 on.'[10]

The historical analysis consists of three long chapters covering the period 1786 to 1929. The first of these chapters begins with serious hesitations about whether the term 'industrial revolution' is appropriate at all. The discussion is entirely focussed on the US, and offers no account at all of innovation as a driving force of the wave; rather, there is extensive discussion of agricultural developments and political conditions, with technologies being mentioned in an entirely *ad hoc* way. Although Schumpeter remarks that 'The main feature of industry, in the strict sense, was the introduction of power machinery which began to turn the workshop of the craft type into the factory', no evidence or systematic discussion is offered, and he seems sharply aware of the limitations of this. In fact he goes so far as to remark that 'Technological innovation, let alone "invention" was not in prominence'.[11]

In turning to the second Kondratiev wave, Schumpeter is on more confident ground, stressing railroads: 'railroadization was obviously the "big thing" or "backbone" of the bourgeois Kondratieff'.[12] This theme is heavily stressed, but there is an accompanying discussion, which concentrates largely on extractive technologies (coal, iron ore, petroleum etc.), but also mentions a wide range of techniques

8 Schumpeter, op.cit, pp.75-76.

9 Schumpeter, op.cit, pp.75.

10 Schumpeter, op.cit, p.145. It should be noted that Schumpeter is rather vague about the periodization: 'These datings do not lack historical justification. Yet they are not only tentative, but also by nature merely approximate. A considerable zone of doubt surrounds most of them…'.

11 Schumpeter, op.cit, p.192.

12 Schumpeter, op.cit, p.215; he remarks elsewhere that 'For the United States, a history of the cyclical process could, in the period of the second Kondratieff, be written almost exclusively in terms of railroad development' (p.231.).

developed during the period. In other words, despite the argument that there is a 'carrier' technology which drives growth in each period, Schumpeter in fact undercuts the argument by focusing on the pervasiveness of technological change. The third Kondratiev wave is also ostensibly oriented to one technology: 'In the same sense in which it is possible to associate the second Kondratiev with railroads, and with the same qualifications, the third can be associated with electricity'. However, once again, a wide range of technologies is discussed. Moreover in both of these chapters there is also extensive discussion of social conditions, war, finance and banking, political conditions and so on. Schumpeter's approach is always qualified and eclectic, and it is far from clear how the key technologies actually relate to the growth process. In other words, the core claims advanced by the book are simply not developed or sustained in the text. In fact, although Schumpeter remarks that 'innovation is the outstanding fact in the economic history of capitalist society', he is cautious about the historical explanatory power of the approach, remarking rightly that 'the fact that innovation would suffice to produce alternating prosperities and depression does not establish, of course, that these cycles are actually the ones which we historically designate as business cycles'.[13] He goes on to say that

> 'Our proposition that innovation … is actually the dominant element which accounts for those historical and statistical phenomena, is so far only a working hypothesis, which will be on trial through this book. Moreover our hypothesis is not yet in a shape to serve at all and it remains to be seen how much matter unconnected with its present content will have to be added to it.'[14]

There is scope for disagreement about the extent to which Schumpeter succeeds in confirming this hypothesis. Given that his argument explicitly requires growth to be driven by large-scale discontinuities, we can question the extent to which he demonstrates that these discontinuities actually exist, and the largely descriptive approach he adopts to innovation seems to prevent - despite the title of the book - any statistical link to the growth process which would support his hypothesis.

Schumpeter's careful qualifications to this argument are not maintained by his more recent followers. Here the approach tends to be far more assertive, assuming both that Kondratiev waves exist and that they are technology driven. The most

13 Schumpeter, op.cit., pp.61,115.

14 Schumpeter, op.cit., p.115.

systematic work is by Christopher Freeman, one of the most influential modern writers on innovation and technological change, in collaboration with Carlotta Perez and Luc Soete. It is in the very influential paper by Freeman and Perez, Schumpeter's approach is systematised, and then developed into an argument that the key driving force of growth at this time is ICT.[15] The explanatory framework on offer is explicitly that of Schumpeter, summed up by the type of schema shown in Figure 1.

Figure 1: Clusters of pervasive technologies: systems and organization

Period:	1750-1820	1800-1870	1850-1940	1920-2000	1980 -
Dominant technology system	Water power, sail shipping, turnpikes, textiles	Coal, sail shipping, canals, iron,steam power, mechanical equipment	Railways, steam ships, heavy industry, steel, chemicals, telegraph	Electric power, oil, nuclear, cars, radio and TV, consumer durables, petro-chemicals	Gas, aircraft, space-based tele-communications, information technology, opto-electronics
Emerging system	Mechanical techniques, coal, stationary steam, canals	Steel, distributed energy supply, telegraph, railways	Electricity, cars, trucks, radio, telephone, roads, chemicals	Nuclear, computers and IT systems, tele-communications , air transport	Biotechnology, AI, IT-telecom integration,
Dominant methods and/or organization	Manufacture, localised enterprise	Centrally managed enterprises, joint stock companies	Standardised parts, M-form corporation	Fordism/ Taylorism, mass production, TNCs.	Quality control, globalised enterprises, de-centralised management

In this framework, growth is driven by very radical technological changes that shift the entire 'techno-economic paradigm': this involves new forms of best-practice organization, new skill profiles in the labour force, new location patterns, new infrastructures, new consumption patterns, new types of dominant firms etc.[16] A standard schema for this kind of account is shown in Figure 1 on the following page. The key point to note is that central to this kind of account is the larqe Schumpeterian technology change, which in the modern era is seen as ICT.

In this work, and the substantial body of work influenced by it during the past 15 years, it is very unclear how these very dramatic changes in the social and economic

15 C. Freeman and C. Perez, "Structural crises of adjustment: business cycles and investment behaviour" in G. Dosi et al eds, Technical Change and Economic Theory, (London: Pinter) 1988

16 ibid., p.59

framework are actually related to ICT and new technologies generally. Nevertheless, this type of approach is frequently turned into an argument concerning the growth role of ICT at the present time. For example, Fagerberg et al suggest that

> It is often argued that if the prospects for technological change and productivity growth differ across industries, countries that happen to be specialized in the technologically most progressive industries are likely to get a growth bonus. Conversely, the argument goes, countries that are specialized in the technologically lagging or 'wrong' industries tend to do rather badly.[17]

The authors conclude that Europe has indeed failed to keep pace with its competitors, and has failed more generally in employment creation and growth. The conclusion is that what matters is

> …the ability to exploit areas of high technological opportunity, which in recent years have been dominated by ICT. However the analysis shows that Europe has lost ground in a number of strategically important sectors, particularly those related to ICT.[18]

This type of neo-Schumpeterian argument has been dominant in policy circles for many years, and constitutes – as suggested above – one of the two core arguments for the claim that ICT is important in the shaping of growth.

However there are many problems associated with these ideas, and there can be no doubt that the Kondratiev/Schumpeter approaches are open to a number of quite basic objections. Firstly, these approaches tend to conflate innovation and diffusion - they tend to assume that radical innovations generate rapid impacts. But this assumption is simply not supported in the various historical studies which have been made of some of the allegedly breakthrough technologies. These technologies, when examined closely, take a long time to diffuse and even longer to have an economic impact. (The same point can be argued of ICT at the present time – as we shall see below, there are serious empirical problems in claims that IT is driving growth at present). Secondly, these new sectors - even when fully diffused and established - do not necessarily

17 Fagerberg et al, op. cit., p.15. This passage cites papers by Lucas and Reinert, the latter of which explicitly follows the Schumpeter-Freeman-Perez approach sketched above. It is important to note that neither Lucas nor Reinert offer any account of how or to what extent technological opportunity differs across sectors, of how this affects actual patterns of growth; each paper cited consists of bald assertions backed by neither argument nor evidence. Although Fagerberg et al ask the question 'can Europe's performance be explained in this way', they do not critically examine the idea – rather they and their contributors simply follow it by arguing that Europe's 'failure' lies in ICT – see Chapters 3, 4, 5 and 10 in particular.

18 Ibid.p.230

contribute to output in a significant way. Obviously the automobile complex of industries grew to be a large element in output, but something like the hardware IT sector (ISIC 3825) does not make up more than about four percent of manufacturing output in any OECD economy. So although new technologies and new industries may exhibit rapid growth rates, they are invariably growing from very low levels, and the overall impact may be small. Thirdly, such theories obviously cannot account for growth in countries which do not possess the industries in question. This applies in particular to small economies. Referring back to Figure One, it is clear that these epochal shifts cannot account for growth in the Nordic area, in Switzerland, in Australia and New Zealand, in the Benelux countries, since on the whole these countries are not active in the allegedly core technologies of the various waves. A real problem here is that these are not only among the richest economies in the world, but several of them have been rapidly growing in the late 1990s. So these economies are characterised by high growth and high incomes, and yet are not significantly involved in these allegedly central technologies or industries.

2.2 The 'Productivity Growth' argument.

During the past twenty or so years a substantial econometric literature has developed that seeks to place ICT in the context of an analysis of growth. For most of the past 20 years, the results of this literature have been somewhat disappointing for proponents of the ICT revolution: ICT investments have been associated with falling productivity growth and appear to have made little impact on the growth process or on employment. The past two years, however have seen a dramatic change of position: a number of analysts have claimed that finally, at long last, ICT has made an impact. However this impact is largely confined to one economy: the claim is that US growth in the late 1990s (that is from around 1995) has been driven by ICT investment. We should note, however, that this claim is by no means generally accepted.

Both the conceptual and technical background to this work is the Solow growth model, developed in the 1950s. In the late 1950s a number of economists, the most important being Robert Solow, attempted to isolate the relative contributions of capital investment and technical change to the growth of productivity (output per worker) in the United States. In an important paper, Solow showed that the long-run growth of the US economy could not be ascribed to growth in labour or capital inputs, but was primarily influenced by a "residual factor", which Solow labelled "technical change".[19] This startling result led to a wide debate on the measurement of factors contributing to economic growth, as well as to attempts to explore the impacts of unmeasured quality changes in inputs, such as skills in the labour force. This led in turn to a transnational research programme "growth accounting", that attempted to quantify such factors as increasing labour skills, better capital goods, the role of technical change in shaping long-term growth patterns. One of the basic outcomes of this long programme of research has been that although technical change is no longer seen in quite the same dramatic terms as in Solow's original paper, it is now consistently recognised as one of the basic forces underpinning economic growth.

The basic neo-classical approach consists of a growth equation that relates output to the level of technology (a technology shift parameter) and inputs of capital and labour. These make it possible to look at the extent to which output grows independently of factor inputs – this is the residual, often labelled 'technical change'. Much of the econometric work consists of attempts to quantify the impact of specific investments or inputs, such as educational qualifications or ICT investments, on either productivity (output per worker) or total or multifactor productivity (that is, the impact on the residual).

ICT has played a large part in this research effort in recent years. In a sense, many economists within the 'productivity growth' framework have taken up the notion that ICT is the core technological change of our period, and have attempted to quantify its impacts. This research tends to distinguish between *direct* impacts (the growth of ICT sectors, both in terms of output and employment), and *indirect* impacts - the effects on other industries of the use of capital and intermediate goods from the ICT sector. How is ICT contributing to growth in user sectors? If there is an indirect impact then we should see (a) higher productivity growth in firms that invest intensively in ICT, (b) higher productivity growth in sectors which are big ICT users, (c) higher than

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19 Robert Solow, "Technical change and the aggregate production function", Review of Economics and Statistics, Vol 39 No 3, 1957, pp.312-320. See also Moses Abramowitz, "Resource and output trends in the United States since 1870", in N. Rosenberg The Economics of Technological Change (London 1971), pp.320-343.

average rates of return to investment in ICT than investment in the economy generally. There has been a major effort in applied economics to look at some these issues. The project will make a detailed critical overview of these efforts, seeking to assess their strengths and weaknesses.

There are two significant bodies of work. The first is the substantial programme of work conducted through the Brookings Institute in Washington, primarily by Daniel Sichel, and published in a range of articles and one major book. This work attempts to quantify the size and productivity impacts of the ICT capital stock, both hardware and software; the validity of the analysis depends partly on the strength of these estimates, and partly on the ways in which impacts are quantitified.[20] The second body of literature is unified by a method: the analysis of residual growth within a production function approach. That is, the method seeks to measure quality-adjusted labour and capital inputs, then to weigh these inputs according to their contributions to output, and finally to estimate output growth not accounted for by input growth. The latter is 'total factor productivity' growth, and the questions concern its correlations with the use of ICT.[21] However there are serious measurement issues and questions of econometric technique embodied in this literature.

This overall effort to identify the benefits of ICT has had to face a major problem. This is that the ICT revolution has been underway for a very long period – at least since the 1960s. In a sense, this is not a new technology at all, it is a rather old one, and moreover a technology in which there has been significant amounts of investment over long periods. As Griliches pointed out

> … average TFP [total factor productivity] dropped from about 1.7% per year in 1947-73 to less than 0.5% for the 1973-89 period. At the same time, Office Computing and Accounting Machinery (OCAM) as percent of all Producers' Durable Equipment (PDE) investment rose from about ½% in the 1960s to 12% in 1992, while investment in "information" equipment rose from about 2% to close to 35% of the

20 S. Oliner and D. Sichel, 'Computers and output growth revisited: how big is the puzzle?', Brookings Papers on Economic Activity, 2, 1994, pp.273-317; and Daniel Sichel, The Computer Revolution. An Economic Perspective (Washington: Brookings Institution), 1997

21 This literature begins in the late 1980s, and is continuing. For an early example, see Martin Neil Bailey and Robert Gordon, 'The productivity slowdown, measurement issues and the explosion of computer power', Brookings Papers on Economic Activity, 2, 1988, pp. 347 - 423; recent important contributions are D. Jorgensen and K.Stiroh, 'Information technology and growth', American Economic Review, May 1999, pp. 109-116. Other results are surveyed below.

> total. If the promise was that there would be an excess return to this investment, it was not delivered. Or else it was too small a fraction of the total to be noticed. [22]

Figure 2 sums up some of the research efforts to understand these problems.[23] It can be noted that they tend to share both a methodology and a focus on the USA (the implications of which will be discussed further below).

Figure 2: Economic impacts of ICT: background research results

Authors	*Unit of analysis and country*	*Performance concepts and measures*	*Input measure*	*Type of analysis*	*Key findings*
Roach 1991	Service sector - USA	Labour productivity	Total IT capital stock	Trend comparisons	Large-scale increases in IT capital stock relative to other capital inputs, coupled with stagnant productivity, suggest no payoff from IT
Franke 1987	Insurance and banking - USA	Labour productivity	Total IT capital stock	Econometric time series 1958-1983	Declines in capital productivity associated with specific IT innovations
Morrison and Berndt 1990 and 1992	20 Manufacturing industries -USA	Labour and multifactor productivity, and profitability	Total IT capital stock	Econometric – pooled cross section and time series, 1968-86	IT capital has no impact on productivity compared to non-IT capital
Siegel and Griliches 1991	Manufacturing - USA	Multifactor productivity	IT capital stock	Econometric – pooled cross section and time series	Found significant impact of IT on productivity but serious doubts over data reliability
Brynjolfsson and Hitt 1993	Firm level in US manufacturing	Labour productivity (general and in information services, plus profitability	Market value of computing stock and information services labour expenditures	Econometric – pooled cross section and time series, 1987-91	Large return on IT capital investment (54.2% annual ROI); productivity paradox disappeared by 1991

22 Z. Griliches, "Comments on measurement issues in relating IT expenditures to productivity growth", Economics of Innovation and New Technology, Vol 3, 1995, p.317

23 Drawn from Wilson 1995, p.237-238

It is only very recently that a literature has emerged claiming unambiguously that ICT investment has driven the growth of the US economy since 1995. Over the period 1995-2000, US productivity growth was at record levels, and this was accompanied by significant increases in ICT investment. Oliner and Sichel (2000) and Jorgenson and Stiroh (2000) have each claimed that this is the long-awaited pay-off to ICT investment.

We can suggest, however, a number of problems with this literature. The most important issues to note are:

1. *The methodology of econometric modelling based on some form of production function involves the underlying assumption that the economy is in some form of competitive equilibrium. In effect, the models operate by assuming that investment in computing is rational, and that ICT investments earn a competitive rate of return – in some cases it might be argued that this is to assume what needs to be proved.*
2. *In understanding the growth process, the assumption is that growth can only follow from new inputs and the technological advances embodied in them. In other words, macroeconomic possibilities (such as exogenous shocks to demand) are not considered. In the US this is particularly important, since the period in which ICT is said to have paid off was one in which a major macroeconomic shift appeared – the US savings rate fell to zero. The implications of such developments for output growth and the measurement of ICT impacts are not explored.*
3. *These models are invariably only for the USA, and this should be borne in mind when 'global' conclusions about ICT are drawn. It is particularly important to note that the US is not the only rapidly growing economy in 1995-2000 (and in fact is not the world's fastest growing economy during this period). Within the OECD and the transitional economies, productivity in the late 1990s grew at 2.1% p.a. in the USA, but it grew faster in Australia, Austria, Belgium, Finland, Hungary, Greece, Ireland, Iceland, Poland, Portugal, Sweden and Turkey.*[24] *Presumably ICT was part of the growth story in Ireland and Finland, but it is very hard to believe that it underpinned this very widespread story of economic growth. If we really want to understand the impacts of ICT we need more than partial studies of the USA.*

2.3 Empirical aspects of long-run growth in Europe and OECD

On of the curious features of the claims concerning ICT is that they are rarely tested against empirical evidence in the broad sense. For example, when it is claimed that ICT is central to growth, this is rarely checked against the growth of other industries, or against the growth of countries other than the USA. In this section we look at the role of ICT in two ways. First, we look at its *direct* contribution to output and growth.

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24 OECD 2000 Table 1, p.21

That is, we look at how much it contributes to value-added, employment, R&D and so on in the OECD countries. This contribution is surprisingly small. Then we look at the contribution of ICT to growth, introducing a simple formal framework for identifying this contribution, and showing the broad dimensions of ICT and non-ICT sectors. The argument here is that the on-ICT sectors are far more important. The question then arises, what about the *indirect* contribution of ICT? Here we look at Norwegian data on the use of highly-qualified ICT personnel in user industries; we show that the indirect contribution is large.

High-tech and science-based industries.

Before moving to a specific analysis of ICT in in industry, it is necessary to make a diversion via the concept of ‘high-technology’. In much policy analysis it is common to use the terms 'high-technology' or 'knowledge intensive industries' in a somewhat loose way, as though in fact they are both meaningful and interchangeable terms. But we ought to remember that the term ‘high technology’ is a rather recent invention, and that its meaning is far from clear. For the most part, it actually means ‘ICT’.

The standard approach in this area rests on a classification developed by the OECD in the mid-1980s.[25] The OECD distinguished between industries in terms of R&D intensities, with those (such as ICT or pharmaceuticals) spending more than 4% of turnover being classified as high-technology, those spending between 1% and 4% of turnover (such as vehicles or chemicals) being classified as medium-tech, and those spending less than 1% (such as textiles or food) as 'low tech'. In fact the OECD discussion of this classification was rather careful, and offered many qualifications. Chief among these is the point that direct R&D is but one indicator of knowledge content, and that technology intensity is not mapped solely by R&D. Unfortunately the qualifications were forgotten in practice, and this classification has taken on a life of its own; it is widely used, both in policy circles and in the press, as a basis for talking about knowledge-intensive as opposed to traditional or non-knowledge-intensive industries. This is a serious problem, since the OECD classification as it is used rests on only one indicator, namely intramural R&D. This is open to two important objections. First, it is by no means the only measure of knowledge-

25 See OECD, OECD Science and Technology Indicators, No 2: R&D, Innovation and Competitiveness, (OECD:Paris), pp. 58-61.

creating activities. Second, it ignores the fact that the knowledge that is relevant to an industry may be distributed across many sectors or agents: thus a low-R&D industry may well be a major user of knowledge generated elsewhere. This issue will be discussed in a more empirical manner below.

Even so it is not clear that this classification helps us, even in a limited analysis of trends. One great problem is that in fact the high-tech sector thus defined is small, and there are therefore some difficulties in arguing that it is driving the growth process. In the OECD, for example, the USA has the largest share of high-tech in manufacturing, but this is only 15.8% of manufacturing output, which in turn is only 18.5% of GDP. So the high-tech sector is less than 3% of GDP. It is hard to see how either the direct or indirect impacts of such a small component of output could have a significant effect on overall economic growth. Most discussions of the role of high-tech are conducted in terms of share analyses, or even – in effect - share-of-share analyses. This can easily confuse matters. In virtually all of the OECD economies the share of high-tech in total manufacturing has risen in the longer term, and this is widely used as an argument for the claim that such industries are central to growth. However this is complicated by the fact that that the share of manufacturing in total output has been in long-term decline. So between 1980 and 1995, the high-tech share of US manufacturing increased from 10.5% to 15.8%, while the share of manufacturing in GNP decreased from 21.6% to 18.5%. What this actually implies is that the share of high-tech manufacturing in total GNP rose over fifteen years by well under one percentage point.[26] It is not uncommon to see quite sweeping claims made for the high-tech sector which are not supported by readily available evidence. For example, OECD's *Knowledge Based Economy* claims that 'Output and employment are expanding fastest in high-technology industries, such as computers, electronics and aerospace'.[27] But the OECD's own 'Scoreboard of Indicators' actually shows long-term *negative* growth rates of employment in high-tech manufacturing in eleven of fifteen OECD countries for which data are presented (including the USA, where high-tech employment declined at a faster rate than manufacturing employment generally).

26 All of the data here is drawn from OECD, Science, Technology and Industry, Scoreboard of Indicators, 1997.

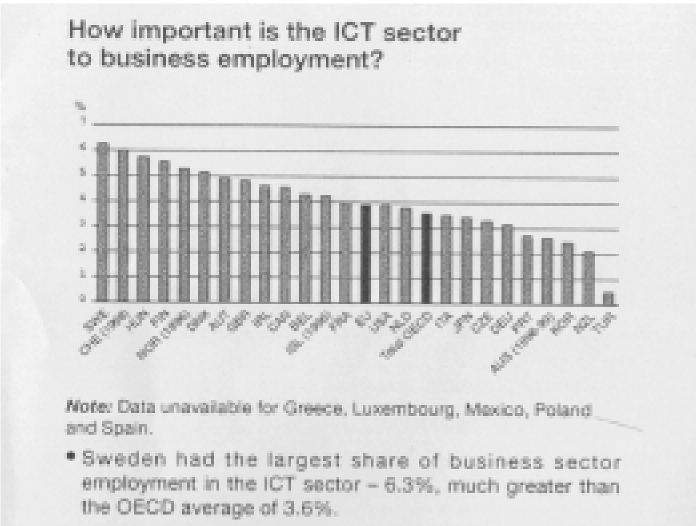
27 Op. Cit., p.9

Such problems have not led to any questioning of the high-tech/low-tech distinction. On the contrary, the high-medium-low-tech approach has recently been extended, to divide the medium-tech category into medium-high and medium-low technology industries. Such classificatory manoeuvres cannot, however, alter the fundamental limitations of the category, and ought to cause us to question the identification of knowledge intensive and high-tech industries.

ICT in the economic structure: the direct role of ICT

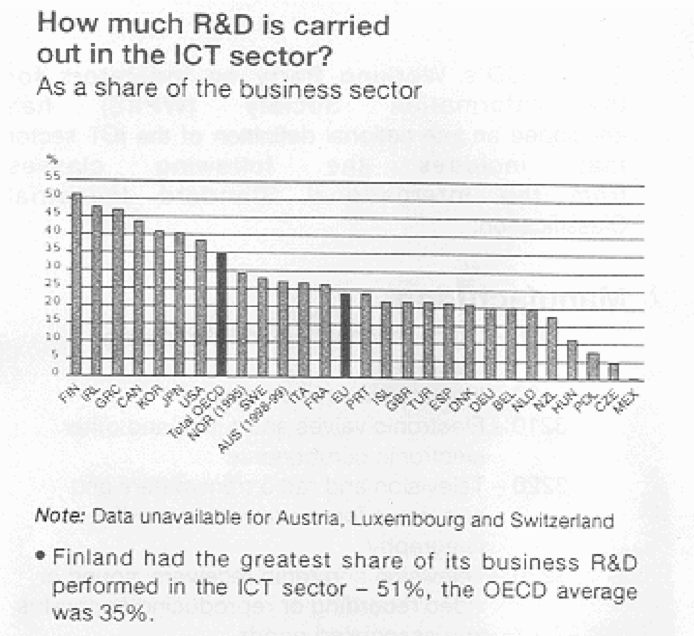
Most definitions of the ICT sector relate to office equipment and computing, scientific and technical instruments, and telecommunications. In this section e look briefly at ICT as a share of business employment, business R&D, business trade, and business value added in OECD countries. In general these contributions are low. Within the OECD as a whole, ICT makes up less than 4% of business employment. The countries of the Nordic area (Sweden, Norway, Finland and Denmark) are all above the OECD average. But in general the direct employment contribution is small, even in above-average countries.

Figure 3: ICT employment as share of total business employment in OECD countries 1997



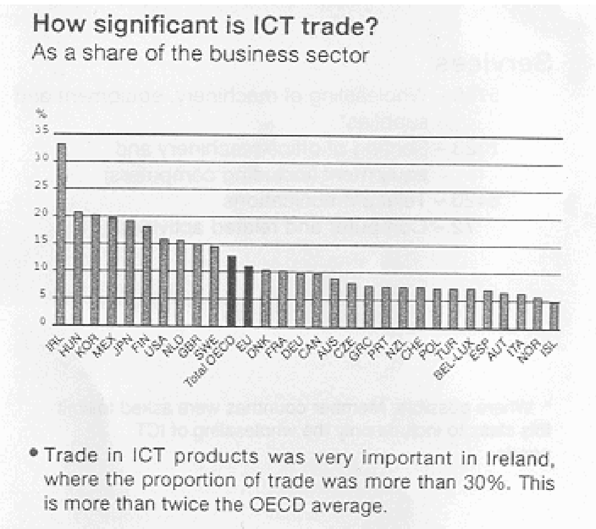
In terms of R&D, the picture is different. ICT is in general terms the largest single sector of R&D performance – on average, the ICT sector account for around 35% of business R&D.

Figure 4: R&D expenditures as share of total business R&D in OECD countries, 1997



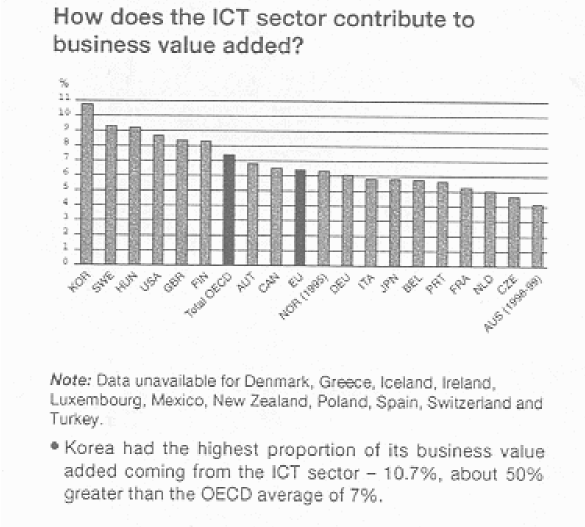
For most of the OECD ICT is only a small component of business trade – roughly 12 percent. However there are a number of outlier countries, particularly Ireland which has become established as a major production site for ICT-related Foreign Direct Investment.

Figure 5: ICT trade as share of total business trade in OECD countries, 1997



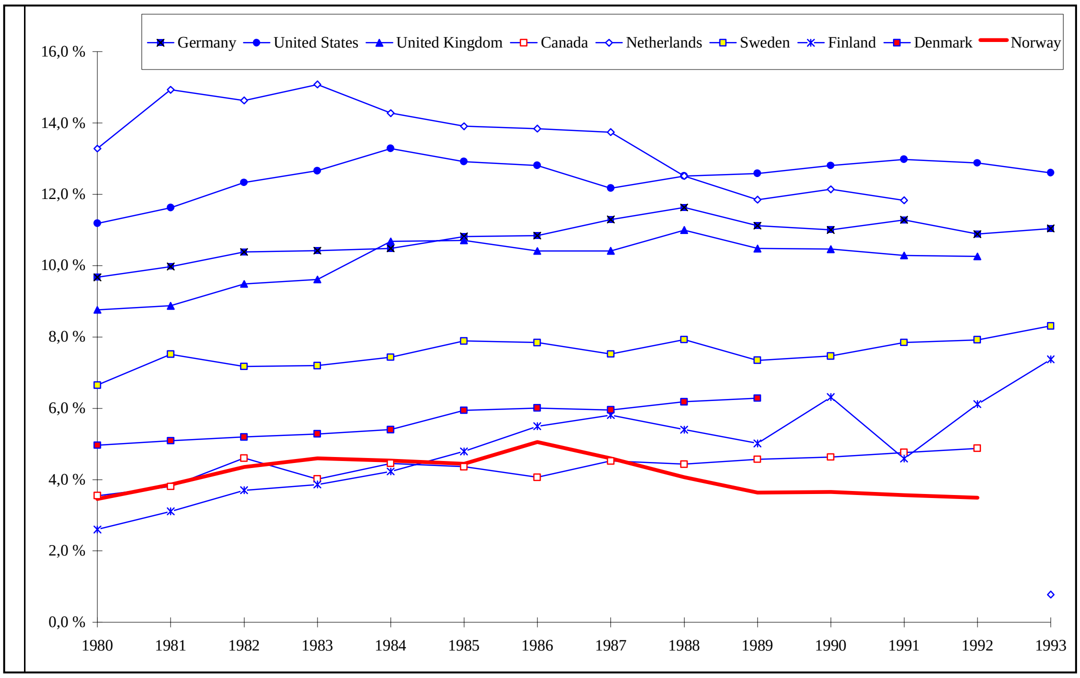
As with employment, ICT is a relatively small part of business value added in the OECD, so the direct output contribution tends to be small.

Figure 6: ICT share of business value added in various OECD countries, 1997



It can be noted that these features of the direct contribution of ICT have not altered very much over the long run. Figure 5 shows the trends for ICT as a share of manufacturing in a number of OECD countries during the 14 years from 1980 to 1993. The point to note is that the shares are both stable and low:

Figure 7: Value added in ICT manufacturing industries 1980-1993, various OECD countries (ISIC 3825, 3832 and 385), Source: OECD, STAN.



***Measuring ICT user competencies: indirect roles of ICT*[28]**

Information and communication technologies are generic technologies. This means they can be implemented and used in many industries and sectors – the graphics industry, the energy sector, clinical medicine, food processing, and the public sector are among user areas that have significantly invested in and implemented ICT tools the last decade. Car manufacturing is increasingly robotised, there exist digitalised, automated milking machines for cows, taxis use both digital pay systems, global positioning systems and advanced telecommunications, kitchen ovens are programmed to sense when food is ready, etc. A huge amount of activities around us is therefore based in some way on use of ICT.

At the same time, ICT-based systems become increasingly user-friendly, and so use is to a decreasing extent preconditioned on direct technological knowledge for operation operate: taxi drivers use digital pay systems without knowing what is going on inside the pay card reader, etc. It is increasingly simple to exploit the possibilities of ICT without knowing the technological details of the technology. However this does not mean that ICT has become a standardised commodity. People with higher education in, and technological knowledge about, IC graduate in increasing numbers from universities and colleges. When they go into employment, people in information services continue to receive above-average wages, indicating that ICT competencies are still in excess demand.

We can therefore assume that companies hiring persons with ICT competencies would do so because they have some kind of active relation to ICT – beyond ordinary consumption of standardised technology. Hiring ICT skilled persons would indicate that the given company is actively developing, adapting or adopting IC-technology. Persons with formal skills in ICT start to work in companies that specifically need these kinds of competencies. What we seek to do in this section is overview the extent to which this occurs outside the ICT sector itself. We therfore seek to map the use of ICT competences outside the ICT sector itself.

Norway has exceptionally detailed data on the qualifications and mobility patterns of all persons employed in the economy, and this data is available via the ‘labour force

28 This section was written in collaboration with Thor Egil Braadland.

register'. The mapping carried out here uses person-level register data to idetnify the location of persons with formal ICT competencies. Looking at employees' highest education, we identify persons with ICT-related formal skills. Using ICT education as a proxy to ICT competencies, it is possible to identify companies, industries and regions with high shares of employees with formal ICT skills?.[29]

First we should acknolwedge a number of drawbacks with this way of mapping ICT competencies. First, register data is a combination of data from many public datasets gathering a wide range of employee and company information. This means that there of course are, as in all large datasets, mistakes, missing values, wrong codes for companies, industry, location, employees etc. The set is, however, as good as it can be. The aggregate data is collected and joined by Statistics Norway. Second, we only have access to the *highest* exam results per individual. This means that a person with an ICT exam as a part of a higher degree in social science will not be covered by our statistics. A person with the same ICT exam *without* the social science degree will be covered. This is regrettable, but is the only way to identify ICT personnel as long as every person in the register is denoted with only one (the highest) passed exam. Third, we equate ICT skills with formal education in ICT. There exist of course many persons that have no qualifications in ICT, but with operational skills in the topic. We have reason to believe that this group of people is not insignificant, given the fact that ICT skills have been in demand for quite some years now. We have no possibility to map real competencies, but we fully accept its existence. Fourth, persons are counted as one with no regards to how high a degree or exam they have in ICT related topics. A person with only one year from college and a full PhD from a university are both counted as one. Fifth, persons are accounted for with no regards to what their actual activities in the job are. An ICT student working part-time as postman will turn up in the statistics as one person with ICT competencies working

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29 We use the Statistics Norway dataset for employees, 1989-1999. The register data contains data on person-level, with every employees' highest education (six digit standard UNESCO ISCED codes). In addition, every employee is tagged with company size the person is working in, company's industry (NACE 5 digit), company's location (municipality), among others. By manually deciding what educational directions and or levels we regarded as being ICT-related, we were able to pick those employees in Norway with formal ICT competence, and decide their location with respect to industries, regions and company sizes. There are about 6.000 education codes, but most of them are on levels below higher education. We decided to go for higher educated personnel. We sorted manually out those educations that seemed ICT-related; i.e. containing 'computing', 'electronics', 'programming', 'cybernetics', 'DAK/DAP', 'informatics', 'programming', 'telecommunication' etc.

in Transport and Communications. There is unfortunately no way to separate employees by function in the dataset.

Including all ICT related higher education, we find a total of 26651 employees with ICT competencies in Norway in 1999. This represents about 1.4 percent of total employment in Norway this year. Using an aggregated NACE categorisation on industrial activities (see Appendix for list), we find that about 57 percent of employees with ICT competencies worked in ICT user industries – defining user-industries as all industries except Electronic and optical industry and Business services and computing[30]. The most intensive ICT user industries (measured as ICT competencies as share of total industrial employment) are: Power and water supply, Oil extraction, Manufacturing of machinery and equipment, Chemicals, Transport and communication and Manufacturing of transportation equipment. All these user industries had more than 15 ICT-skilled persons per 1.000 employees in 1999. However, the most ICT-intensive industries were: Electronic and optical industry and Business services/computing, with respectively 113 and 48 ICT-skilled persons per 1.000 employees (Table 2).

Table 1: Industries with high shares of ICT-skilled employees

Industry	**ICT-skilled employees**	**ICT-skilled employees per 1000 employees**
Electronic and optical industry	2537	113
Business services, computing	8655	48
Power and water supply	744	42
Oil extraction	726	28
Machinery and equipment	651	28
Chemicals	284	17
Transport and communication	2556	17
Man. of transportation equipment	617	16
Financial services	636	14
Other services	779	12
Pulp and paper	103	11
Public adm., defence	1548	10

We ended up wit a list of 129 education levels (see Appendix for list [in Norwegian]). This is the canonical list we use from now on.

30 One may critise us for using a traditional two-split between ICT producer and ICT user, and thereby ignoring the transmitting, ‘in-between’ role of the ICT consulting services. Such services are of huge importance in terms of national ICT capabilities, and could well have formed a third category. For simplicity, however, we have categorised this industry as ‘producer industry’, because ’computing’ is a part of the Business service, computing industry group used here.

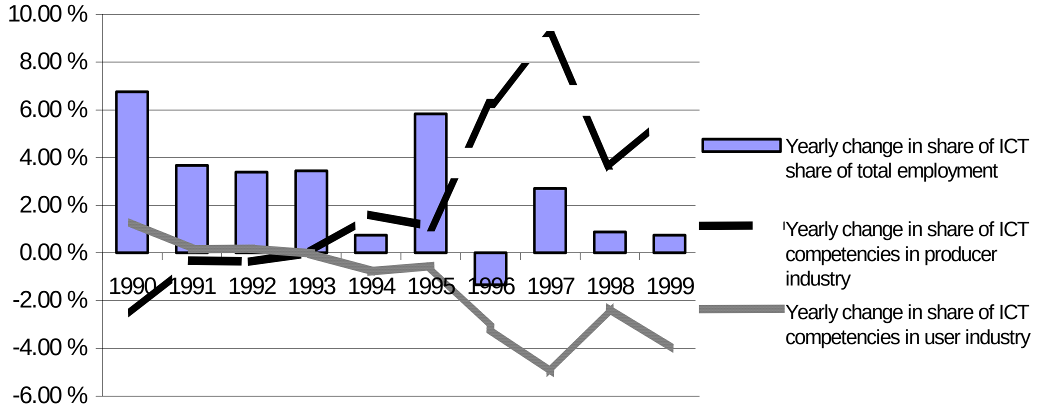
However, looking at mere numbers of employees with formal ICT competencies, large activities like Retail and Public administration and Defence come quite high on the list. For example, about 11 percent of all ICT-skilled persons are working in Retail, which is actually higher than the number of ICT-skilled persons working in Electronic and optical industry.

Table 2: Industries with most ICT-skilled persons in Norway, 1999

Industry	Number of ICT-skilled persons	Share of all ICT-skilled persons
Business services, computing	8655	33,0 %
Retail	2873	11,0 %
Transport and communication	2556	9,8 %
Electronic and optical industry	2537	9,7 %
Public adm., defence	1548	5,9 %
Teaching, education	1470	5,6 %
Other services	779	3,0 %
Building and construction	775	3,0 %
Power and water supply	744	2,8 %
Oil extraction	726	2,8 %
Machinery and equipment	651	2,5 %
Financial services	636	2,4 %
Man. of transportation equipment	617	2,4 %

How has the amount and distribution of ICT skills changed over the years? The number of employees with formal ICT-competencies has of course increased. The increase from 1989 to 1999 was about 50 percent, from 17.673 persons to 26.281. The increase has been fairly stable from year to year, measured in number of new entrants. However, beyond the surface there are interesting patterns. This is shown in Figure 8, showing yearly change in (i) ICT employment as share of total employment, (ii) share of ICT-skilled persons working in producer industry and (iii) share of ICT-skilled persons working in user industries.

Figure 8: Yearly change in (i) ICT employment as share of total employment, (ii) share of ICT-skilled persons working in producer industry and (iii) share of ICT-skilled persons working in user industries, 1989 to 1999.



The figure shows two interesting findings. First, the growth of ICT-skilled employees as share of the economy was largest in the first half of the 90s, with yearly increases in shares on four to six percent. From 1996 and on, the yearly increase in share has been much lower, on average about 1 percent. Second, there is a marked shift from ICT user industries towards ICT producer industries. We see in the figure that change in share of ICT-skilled persons working in the user industry has been negative throughout the 90s, to the advantage of producer industries. In 1989, two out of three persons with formal ICT skills worked in user industries. 10 years later, the share is reduced to about 57 percent.

The producer industry that has increased most is Business services and computing, with almost 5.000 new ICT-skilled persons in the ten-year period. This represents more than half of all new ICT-skilled persons entering working life in this period. Other industries with substantial increases in ICT capabilities are Transport and communication, Public administration, Defence, Retail and Health Services.

Table 3: Top industries with highest increase in ICT capabilities 1989-1999, measured in new employees with ICT capabilities.

Industry	Increase 1989-1999 (pst)	Increase 1989-1999 (empl.)	Share of total number of new ICT employees
Business services, computing	134,5 %	4964	57,7 %
Transport and communication	34,4 %	654	7,6 %
Public adm., defence	44,1 %	474	5,5 %
Retail	17,4 %	425	4,9 %
Health services	138,6 %	287	3,3 %
Electronic and optical industry	12,6 %	284	3,3 %
Man. of transportation equipment	79,9 %	274	3,2 %
Machinery and equipment	63,6 %	253	2,9 %
Other services	40,1 %	223	2,6 %
Financial services	53,6 %	222	2,6 %
Chemicals	127,2 %	159	1,8 %

There are also some interesting findings regarding distribution of ICT competencies across different company size classes. Table 4 provides an overview of how employees with ICT competencies are distributed by company size class, compared to distribution of employees with any higher education in the same classes. The table shows that large companies have a much higher share of ICT competent people than small companies have, compared with the distribution of higher educated employees in general. Large companies (100+ employees) employ about 40 percent of all employees with higher education, but more than 52 percent of all employees with

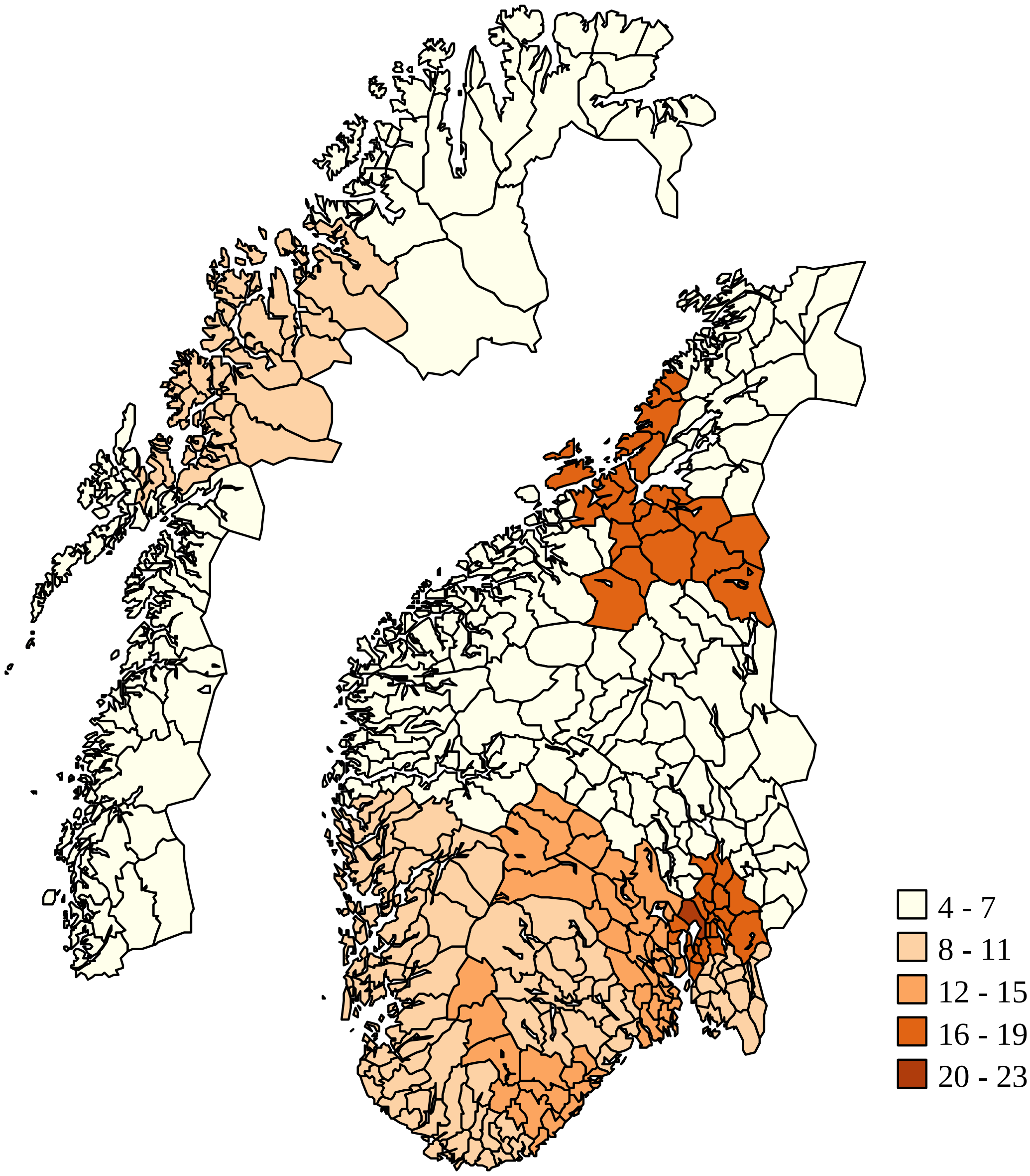
ICT competencies. For companies with 1-49 employees, the share is about 45 percent of those with higher education and only 34 percent of the employees with ICT competencies.

Table 4: Distribution of employees with ICT competencies by company size class, compared to distribution of employees with any higher education, Norway, 1999

Company size class	Distribution of employees with higher education	Distribution of employees with formal ICT competencies
1-9	14,5 %	10,5 %
10-49	30,8 %	23,0 %
50-99	15,4 %	14,5 %
100+	39,3 %	52,1 %
All companies	100,0 %	100,1 %

We also find an uneven regional distribution of employees with ICT competencies.

Figure 9: Number of ICT-skilled employees per 1.000 employees, by county, Norway, 1999



The map in Figure 9 shows number of ICT-skilled employees per 1.000 employees, by county. There are two main areas for ICT competence. This is (i) the Oslo and Akershus counties (south east, the capital area), and the Trondheim region (mid Norway). Both areas are shaded darker than the other regions. The capital region is characterised by a large share of ICT companies (both manufacturing and consulting), many R&D departments, University of Oslo and the Kjeller research park[31]. The Trondheim region is recognised by NTNU (a major technological university), SINTEF (Norway's largest research institute group) and a range of ICT companies. In addition, the map shows two more regions with more than 12 ICT-competent employees per 1.000 employees. These are (i) the two counties of Buskerud and Vestfold (west of the capital area) and (ii) the Aust-Agder region (southern Norway). Both Buskerud, Vestfold and Aust-Agder have important technical colleges and large ICT companies (see Braadland 1998 for details).

The most important outcome of this mapping has been to demonstrate empirically how ICT activities are more than what is commonly measured by using traditional industry statistics. Using ICT competencies as a gateway to ICT activities, we can see that about 50 percent of ICT activity is taking place in user industries.

The results from this mapping are interesting in three ways. First, The mapping provides a quantitative measurement of the extent of ICT activities in user industries, which has not been done in a broad way before. Second, insofar as ICT technologies are important aspects of innovation activities, the distribution of ICT competencies are of crucial importance to understand actual and future innovative capability. Finally, these results are important in signalling the need further work on creating comparable statistics for other European countries on use and diffusion of information and communication technologies. Hitherto, only the Nordic countries have gathered such detailed information.

It is probably going too far to draw strong conclusions from this data. However on the one hand it does seem to suggest that the economics of ICT are going to be very strongly shaped by the distribution of ICT skills across industries. On the other, it suggests that ICT as a technology is not necessarily being shaped by the ICT indus-

31 Braadland et al (1998)

tries themselves. That is to say, user industries are very likely playing a key role in the evolution and shaping of ICT itself. This of coruse depends a great deal on something we know little about, namely the links between users and producers of ICT products and services. There are more questions than answers here, but the implications are important. Given (as we have shown above) the small size of the ICT sector, it may well be that policy ought to focus on the sectors that really generate employment and output, namely the user sectors.

Chapter 3. What is 'ICT'?

One very basic analytical problem is the assumption that we have good concepts and definitions of ICT, both as a technology and as an economic activity. This is not necessarily the case, however, and it is important to give some consideration to the notion of ICT itself. The question here is not simply whether we can think of ICT as an industrial sector, or even a more or less unified industrial activity. It is also whether it makes sense to speak of ICT as a unified technology, or whether it is in fact many technologies, perhaps only loosely related to each other. As we shall see, this process of differentiation within the technology is very important in understanding differences on productivity, skill levels, work organisation and quality, the income generating effects of ICT, and so on. At the most basic level, within both manufacturing and services, we can distinguish between

- *Consumer electronics (TV, video and audio, PCs, telephony, radio etc)*
- *Electronic components (that is, electronic devices incorporated in final products of other sectors)*
- *Professional electronics (meaning the extremely broad array of products within industrial electronics - such as robots, machine tools, process and control equipment, instruments, medical technologies, and defence electronics)*
- *Telematics (meaning all equipment and services involved in diffusing information, images and sound)*
- *Service provision (including voice networks, cable, mobile and satellite communications, data transmission, networks etc)*

Within software development and delivery we should make similar distinctions - ranging from activities related to architectures and languages, to very wide arrays of professional and personal software, to different types of content providers, where quite different types of organization and skills are required. This kind of approach can be extended almost without limit. As Houghton et al remark:

Seen either in broader or narrow terms the information industries are highly complex and diffuse. There are few traditional industrial classifications that escape inclusion in whole or part in the broader conceptualisations of the information sector or information economy. Even in narrower conceptualisations focusing on the IT-producing industries, almost anything from pulp and paper to multimedia content, from components (electronic and otherwise) to supercomputers and from cables to consulting services are elements of the IT industries. Faced with such a situation, developing a simple yet functional model of the IT industries is a major challenge.[32]

What is needed here is classificatory and taxonomic work, to untangle the content of 'ICT' with a view to understanding the different skills levels, entry conditions, pricing behaviour, and growth characteristics of the activity concerned. These are important issues in understanding the growth effects of ICT - it is not obvious, for example, that all aspects of ICT are new, or that high value-added activities, or that they create knowledge externalities, or other desirable economic effects.

In seeking to define the technology, we can distinguish between four major dimensions of information gathering, processing and dissemination. Houghton et al make a four-way distinction. In the area of products, we can distinguish between information and communications equipment, on the one hand, and information products (such as software and contents) on the other. In the area of services we can distinguish communications services (meaning broadly the services need to make communications hardware work), and information services (meaning the services need to make information products accessible). A cross-cutting categorization distinguishes between transmission channels (what Houghton et al call 'Form/Conduit') and content. This leads to a broad classification as follows:

32 J.W. Houghton, M. Pucar, and C. Know, 'Mapping Information Technology', Futures, Vol. 28 No.10, pp.903-917, 1996.

Figure 10: ICT products, services, technologies

Services	BASIC TELEPHONY SERVICES Voice, local, STD, ISO Mobile Voice, Paging Data Equip rental & repairs Etc		CALL/TELEPHONY SERVICES Resale/Aggregation Callback Account mgmt Call Centres	HIGHER LEVEL & NETWORK SERVICES EFT & Transactions EDI, Voice/E-mail Video conference Video & Broadcast News & Directory svcs etc		PROFESSIONAL SERVICES Consulting Systems Integration EDP Accountancy Engineering services Education & Training Etc
	COMMUNICATION	-	SERVICES	INFORMATION	-	SERVICES
	BCS/TRANSMISSION Interconnection Transmission services		LEASED LINE & PSON SERVICES Leased lines Data network svcs VANs, VPNs, IVANs etc	NETWORKS & SERVICES ASP MSN, Compuserve, etc Pay-TV Broadcast nets etc		COMPUTER, COMMS & SOFTWARE SVCS Bureau/Data Proc FM Outsourcing Maintenance
	LINE, TRANSMISSION & B'CASTING EQUIP Cable and Wire Line, Cellular, Radio Microwave & Satellite Transmission equip etc		SWITCH, LAN/WAN & DATA EQUIP COS Bridges, Routers Hubs, Multiplexes Data etc	NETWORK SOFTWARE Net Operating Systems Net mgmt/Diagnostics Navigation index OSS Etc		PACKAGED SOFTWARE Applications Tools etc
	INFORMATION	&	COMMS EQUIP	INFORMATION	-	PRODUCTS
Products	TERMINAL & PERIPHERAL EQIUP CPE Mobile & Paging I/O Devices Components Office equipment Etc		COMPUTER EQUIPMENT PCs Workstations Small-scale Mid-range Large-scale etc	SYSTEMS SOFTWARE Systems Utilities etc		NETWORKED CONTENT Online publications News services content Database content Programming Multimedia etc
	Channels					Content

What emerges here is a pattern of considerable complexity, in which ICT can be seen as a very wide array of technologies and activities. In this kind of approach, it is important to note that some sections of the activity are likely to be highly innovative and knowledge intensive (such as work on semiconducting materials or architectures) while others are likely to take the form of low value-added commodity production. The relevant conclusion is that it, in talking about ICT, it is extremely important to distinguish among its components – only a few are likely to play important roles in innovation and growth.

Other approaches to ICT have focussed not on the technology, but on the category of ‘information’, and the employment patterns associated with it, The first significant attempt to overcome the statistical problems was the work of the economist Fritz Machlup.[33] Machlup reorganised the industrial classification of the US into five major groups of information activities: education, research, communications, information equipment and information services. Studying output and employment trends in these activity groups, he showed through an analysis of the US national accounts that such activities accounted for 29% of US BNP and 31% of employment in 1958. Moreover during the previous ten years the information sector had been growing at twice the rate of the economy as a whole, indicating a substantial structural shift in the US economy.

Machlup's work was significantly extended in the mid-1970s in a very detailed nine-volume study for the US Department of Commerce by Marc Uri Porat.[34] Porat distinguished between a "primary information sector" consisting of firms which supplied information goods and services of all kinds, and a "secondary information sector" consisting of "all the information services produced for internal consumption by government and noninformation firms." He showed that the two sectors taken together accounted for 46% of US BNP, 40% of the workforce, and 53% of labour income. More recent estimates for the mid-1980s suggest that over 50% of the

33 F. Machlup, The Production and Distribution of Knowledge in the United States (Princeton, NJ, 1962), and Knowledge: Its Creation, Distribution and Economic Significance (Princeton, NJ, 1980).

34 The main body of Porat’s research is reported in The Information Economy: Definition and Measurement, 256pp, and The Information Economy: Sources and Methods for Measuring the Primary Information Sector, 188pp., US Dept of Commerce Office of Telecommunications, (OT Spec.Pub 77-12-1), 1977.

American workforce were then in the information sector, and that nearly 70% of labour costs and 70% of working hours relate to information (since information workers receive higher wages and work longer hours).[35] These information industries have much higher investment rates than other sectors of the economy: in the 1980s the capital stock of US "information producing" industries grew at 5% p.a., while the manufacturing capital stock grew at less than 2% p.a. It should be noted in this context that IT investment is concentrated such service industries, which by the late 1980s owned 84% of the US stock of IT equipment.[36] These trends in the US economy are probably consistent with trends in other advanced economies. They have in various places been used to argue that since the ‘information sector’ is so large, then the ICT sector must be of major economic importance. In Norway, for example, Porat’s approach to information has been followed by Egil Wulff, who then identifies information with knowledge, and concludes that the ‘kunnskapssektor’ is the largest economic activity in Norway. [37] This of course makes the same mistake as those who identify all pieces of IT hardware as equally knowledge intensive.

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35 E.M. Rogers, Communication Technology. The New Media in Society (New York, 1986), pp.10-13.

36 S. Roach, "Technology and the services sector: America’s hidden competitive challenge", in B. Guile and J. Quinn, Technology in Services (Washington, 1988), ss.118-137

37 Egil Wulff, Kunnskaps- og IT Sektor I Norge Investorforum Rapport 2/96

Chapter 4. How adequate are existing statistical frameworks?

Many of the problems in analysing ICT stem from the fact that ICT does not correspond to any straightforward category within the major sets of industrial statistics. At the present time we have two such classifications: NACE (the standard used by the European Union), and ISIC (the standard used more generally in the OECD). These classifications have important differences, particularly in the treatment of the relation between manufacturing and services. However they also have important features in common. In each of the classifications there are serious difficulties in arguing that ICT is an important sector of the economy. Within the ISIC classification, for example, hardware ICT is not a particularly large sector - if we take together the three broad industries 'office equipment and computers' , 'technical and scientific instruments', and 'telecommunications equipment', then there is no OECD economy in which these sectors combined make up more than about 15% of manufacturing output. In most OECD economies the manufacturing sector makes up about 25% or less of GNP (in Norway, manufacturing is 17% of GNP). So hardware ICT is in all cases only a very small component of GNP. Software, however it is measured, is also a relatively small sector. Within these definitions, ICT as a proportion of overall economic activity has not changed very signficantly over time, either. These considerations alone make it difficult to claim that ICT has any very noticeable measured contribution to growth.

These problems have led to considerable debate and work on ICT-related statistics, and any assessment of the economics of ICT must evaluate this statistical effort. In particular, the OECD has had a working group on these issues which seeks to redefine ICT in terms of company's 'main line of business'.38 The issues are complex, but essentially the ICT sector is redefined through this work as all electronics-using hardware, all software production and distribution, all telecommunications, all IT-related consultancy, and all wholesale and retail trade which distributes ICT products. (It can be noted that in Norway, this redefinition has the effect of including the entire activities of Elkjøp in the ICT sector).

38 OECD, Measuring the ICT Sector (OECD: Paris) 2000

On the basis of this redefinition, it has been claimed that ICT is in fact much larger than previously believed. These statistical issues are clearly very important. On the one hand, ICT in a primary activity across a number of sectors. On the other hand, this is also true of many other industries (such as oil), and we need to consider why it is that only ICT should be redefined: what are the arguments and rationales for classifying ICT in a completely different way from all other activities? We need only consider the impacts of treating the broad food-related set of activities as a connected whole. This would presumably include all agricultural input activities (machinery, fertilisers etc); all agriculture; all food marketing, distribution and trade; all food processing; all retail distribution of food products; and all of the food related service sector (including all hotels, restaurants, cafes etc). seeing that food processing alone is the biggest manufacturing sector in most OECD economies, and that hotels and restaurants is among the biggest activities in the service sector, it is certainly rue that food would end up many orders of magnitude larger than ICT. So we cannot conlude from recent statistical efforts that ICT is a substantial and growing sector.

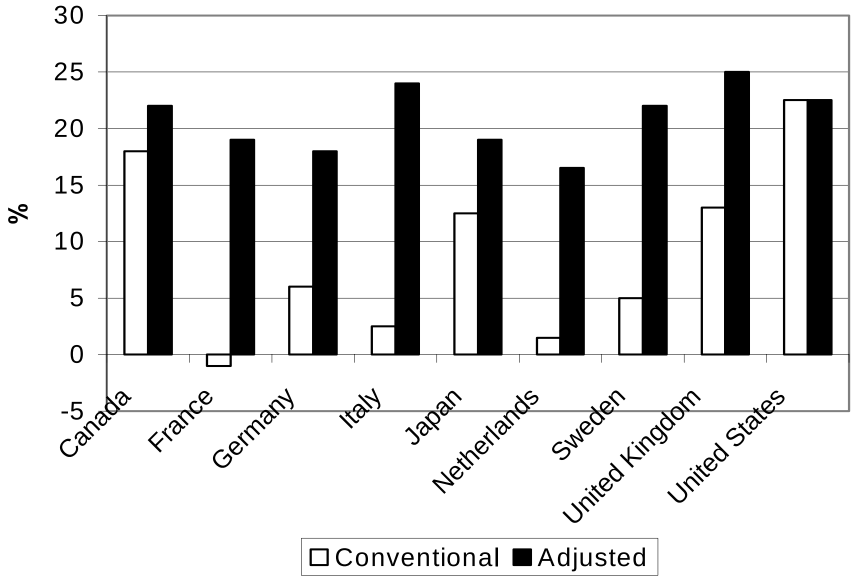
These statistical issues are complex in other ways, that severely inhibit our ability to make inter-country comparisons and thereby to assess growth impacts. Let us consider one such problem, namely the difficulties involved in compiling and comparing constant price output and productivity data. The basic raw material for international benchmarking is usually the statistical series produced by such organizations as OECD, Eurostat and UNESCO. These are often used in an uncritical way, as if the data itself is unproblematic. However this is not normally the case – there can be big variations in the quality and usability of data series across countries, and it is often necessary to be sensitive to this in benchmarking exercises. Three problems in particular can be mentioned. The first is coverage – data series often have gaps, errors, missing values and so on. Widely used datasets such as the OECDs STAN and ANBERD databases are explicitly attempts to overcome these problems for industrial and R&D data. The second problem is collection methodologies – statistical offices across countries often vary in how they view the relevant population, and in the sampling methodologies they undertake. For many series, especially rather new 'blue sky' exercises such as innovation surveys, the sampling frames and response rates vary so greatly as to make inter-country comparisons (though not intra-country analyses) very difficult. This also applies to the *Community*

Innovation Survey at the present time. Finally, there are differences in methods for converting current prices series onto constant price series.

This last issues – converting current to constant prices – may seem somewhat arcane, but it can be of major significance for benchmarking exercises. In the ICT sector, for example, the USA and Europe use quite different methods for computing the constant price values of computing equipment. The USA uses the so-called Hedonic price index method, which takes full account of quality improvements as well as price falls. European statistical agencies tend to use the so-called Matched-Model method, which gives an accurate account of price changes, but neglects the impact of quality improvements.

Andrew Wyckoff of the OECD looked at the implications of this, and explored what happened if the US methods were applied to European data, and vice versa.[39] The results were startling - it turned out that the much-analysed productivity growth differences between the USA and Europe in computing equipment were largely due to the price indexes used, and did not appear to reflect real productivity or growth differences.

Figure 11. Average annual labour productivity growth rates of office and computer machinery, 1980–1990



***Source*: Wyckoff (1995, page 285)**

39 A. Wyckoff, “The impact of computer prices on international comparisons of labour productivity”, Economics of Innovation and New Technology, 1995, Vol 3, pp.277-293

Figure 11 shows these results of this. It simply rebases the ICT productivity growth data for a number of countries, using the methodology of the US price index. The results are that the productivity growth differences largely disappear:

Wyckoff concluded that European productivity in the computer sector has been underestimated relative to US and Japan because of statistical differences in price deflators. This implies that the precision of international productivity comparisons is “severely limited” and that “Researchers should be aware that these [statistical] differences … can be a distorting factor in their modes of trade performance, investment behaviour and productivity”.

Chapter 5. Questions of causality

It is very common to hear, both in professional and popular discussion, such claims as ’ICT is driving economic growth’. These claims in effect assign a primary causal role to ICT - it is seen as something that initiates change, and causes society and economy to adapt. Here we examine two basic problems associated with such approaches. The first concerns the determinants of ICT development itself: the factors which shape the dynamics of ICT evolution. The second concerns the complexity of ICT - the fact that it is not one technology but many, and therefore the problems involved in assigning causality in the presence of complex inputs.

Many of the claims about ICT ’driving’ growth involve technological determinist approaches to society - the idea that technology develops autonomously and shapes social change. Although this kind of idea is widespread, it is questionable. Technologies come into existence mainly for social reasons - because people make decisions to search for new technical solutions, and to develop them. It is society that shapes technology, not the other way around. This has major implications for the understanding of ICT: the questions concern what it is that shapes technological search over time, and why it is that such intensive research and investment efforts are made in the area of information processing. In part, this obviously follows from the existence of technological opportunity – we happen to have discovered a way of storing information, and it is not strange that the implications and possibilities of this should be actively explored. But this does not tell us much about why the ICT effort has been so extensive. One reason, advanced by James Beniger, is that the increasing complexity of the social and technical divisions of labour places extreme demands on coordination, both technical and social, and that this is primarily a problem of information gathering and analysis:

> ... national economies constitute open processing systems engaged in the continuous extraction, reorganisation and distribution of environmental inputs to final consumption. Until the last century these functions, even in the largest and most developed national economies, still were carried on at a human pace ... so long as the energy used to process and move material throughputs did not much exceed that of human labour, individual workers in the system could provide the information processing required for its control.
>
> Once energy consumption, processing and transportation speeds, and the information requirements for control are seen to be inter-related, the Industrial Revolution takes

> on new meaning. By far its greatest impact from this perspective was to speed up society's entire material processing system, thereby precipitating a crisis of control, a period in which innovations in information processing and communications technologies lagged behind those of energy and its application to manufacturing and transportation.[40]

Exploring the development of ICT from this angle involves exploring the broad trends in economic evolution - such as globalization and general economic interdependence - which create incentives and opportunities for ICT developments and applications. Rather than seeing ICT, therefore, as an autonomous driver of change, we will seek to outline those economic trends which impel the evolution of ICT.

A related methodological issue concerns the link between technological complexity and interdependence, on the one hand, and economic effects on the other. We have noted several times that ICT is not one technology but many. At the same time, ICT is put to work in the context of major organizational changes, and often in the context of the application of other (unrelated) technologies. These facts are often neglected, with the effect that claims are made for the economic impacts of ICT which are not justified: the problem is to establish and use a framework which will allow interaction and multiple causality between technologies, organizational forms, and economic processes.

40 J. Beniger, The Control Revolution. Technological and Economic Origins of the Information Society (Cambridge, Mass., 1986), p.427.

REFERENCES

J. Beniger, **The Control Revolution. Technological and Economic Origins of the Information Society** (Cambridge, Mass., 1986), p.427.

Moses Abramowitz, "Resource and output trends in the United States since 1870", in N. Rosenberg **The Economics of Technological Change** (London 1971), pp.320-343.

Martin Neil Bailey and Robert Gordon, 'The productivity slowdown, measurement issues and the explosion of computer power', **Brookings Papers on Economic Activity**, 2, 1988, pp. 347 - 423;

E. Brynnjolfsson and L. Hitt, "Paradox Lost? Firm-level evidence of the returns to information systems spending", **Management Science**, 1995

E. Brynnjolfsson and L. Hitt, 1995, 'Information technology as a factor of prodcution: the role of differences among firms" **Economics of Innovation and New Technology**, Vol 3, pp.183-200

E. Brynnjolfsson and L. Hitt, 2000 "Beyond Computation: Information Technology, Oerganization Transformation and Business performance" **Journal of Economic Perspectives**, Vol 14 No 4, pp. 23-48.

C. Freeman and C. Perez, 'Structural crisis of adjustment: business cycles and investment behaviour' in G. Dosi et al, **Technical Change and Economic Theory** (London: Pinter 1988.

Fagerberg, J. et al 2000 (eds) **The Economic Challenge for Europe** (Cheltenham: Elgar)

R.Gordon 2000 "Does the 'New Economy' Measure Up to the Great Inventions of the Past", **Journal of Economic Perspectives**, Vol 14 No 4, pp. 49-74.

Z. Griliches, "Comments on measurement issues in relating IT expenditures to productivity growth", **Economics of Innovation and New Technology**, Vol 3, 1995, p.317

J.W. Houghton, M. Pucar, and C. Know, 'Mapping Information Technology', **Futures**, Vol. 28 No.10, pp.903-917, 1996.

D. Jorgensen and K.Stiroh, 'Information technology and growth', **American Economic Review**, May 1999, pp. 109-116.

S. Kuznets 1959, **Six Lecture on Economic Growth (**New York: Free Press)

F. Machlup, **The Production and Distribution of Knowledge in the United States** (Princeton, NJ, 1962), and **Knowledge: Its Creation, Distribution and Economic Significance** (Princeton, NJ, 1980).

D. Mowery and N.Rosenberg, **Paths of Innovation. Technological Change in 20th Century America** (Cambridge: CUP, 2000)

OECD: **A New Economy? The Changing Role of Innovation and information Technology in Growth** (OECD, Paris) 2000, p.17

OECD: **Technology and Productivity. The challenge for economic policy** (OECD: Paris) 1991.

See OECD, **OECD Science and Technology Indicators, No 2: R&D, Innovation and Competitiveness**, (OECD:Paris), pp. 58-61.

OECD, **Science, Technology and Industry, Scoreboard of Indicators**, 1997.

OECD, **Measuring the ICT Sector** (OECD: Paris) 2000

S. Oliner and D. Sichel, 'Computers and output growth revisited: how big is the puzzle?', **Brookings Papers on Economic Activity**, 2, 1994, pp.273-317;

S. Oliner and D. Sichel, "The resurgence of growth in the late 1990s: is Information technology the story?" **Journal of Economic Perspectives**, Vol 14 No 4, pp. 49-74, 2000

Marc Uri Porat, **The Information Economy: Definition and Measurement**, 256pp, and **The Information Economy: Sources and Methods for Measuring the Primary Information Sector**, 188pp., US Dept of Commerce Office of Telecommunications, (OT Spec.Pub 77-12-1), 1977.

E.M. Rogers, **Communication Technology. The New Media in Society** (New York, 1986), pp.10-13.

S. Roach, "Technology and the services sector: America's hidden competitive challenge", in B. Guile and J. Quinn, **Technology in Services** (Washington, 1988), ss.118-137

J. Schumpeter, **Business Cycles. A theoretical, historical and statistical analysis of the capitalist process** (Philadelphia: Porcupine Press, 1989).

Daniel Sichel, **The Computer Revolution. An Economic Perspective** (Washington: Brookings Institution), 1997

Robert Solow, "Technical change and the aggregate production function", **Review of Economics and Statistics**, Vol 39 No 3, 1957, pp.312-320.

D. Wilson 1995, " IT Investment and its Productivity Effects. An Organizational Sociologist's Perspective on directions for Future Research, **Economics of Innovation and New Technology**, Vol 3, 1995, p.235-251

Egil Wulff, **Kunnskaps- og IT Sektor I Norge** Investorforum Rapport 2/96

A. Wyckoff, 1995, "The impact of computer prices on international comparisons of labour productivity", **Economics of Innovation and New Technology**, Vol 3, pp.277-293

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STEP-gruppen ble etablert i 1991 for å forsyne beslutningstakere med forskning knyttet til alle sider ved innovasjon og teknologisk endring, med særlig vekt på forholdet mellom innovasjon, økonomisk vekst og de samfunnsmessige omgivelser. Basis for gruppens arbeid er erkjennelsen av at utviklingen innen vitenskap og teknologi er fundamental for økonomisk vekst. Det gjenstår likevel mange uløste problemer omkring hvordan prosessen med vitenskapelig og teknologisk endring forløper, og hvordan denne prosessen får samfunnsmessige og økonomiske konsekvenser. Forståelse av denne prosessen er av stor betydning for utformingen og iverksettelsen av forsknings-, teknologi- og innovasjonspolitikken. Forskningen i STEP-gruppen er derfor sentrert omkring historiske, økonomiske, sosiologiske og organisatoriske spørsmål som er relevante for de brede feltene innovasjonspolitikk og økonomisk vekst.

The STEP-group was established in 1991 to support policy-makers with research on all aspects of innovation and technological change, with particular emphasis on the relationships between innovation, economic growth and the social context. The basis of the group's work is the recognition that science, technology and innovation are fundamental to economic growth; yet there remain many unresolved problems about how the processes of scientific and technological change actually occur, and about how they have social and economic impacts. Resolving such problems is central to the formation and implementation of science, technology and innovation policy. The research of the STEP group centres on historical, economic, social and organisational issues relevant for broad fields of innovation policy and economic growth.