The Impact of Electronic Infrastructure on Economic Growth and Productivity

A report for the Performance and Innovation Unit

by

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Table of Contents

1. Executive Summary 3

2. Introduction 9

3. Section A. A Review of the Literature 10

US studies 11
EU and OECD studies 13
UK studies 19
A different approach to measure the impact of ICT on economic growth in OECD countries 24

4. Section B. Industry Specific Evidence 24

Case study 1. The Manufacturing Industry 25
Case study 2. Retailing. The case of DELL 26
Case Study 3. Financial Services: Retail Brokerage 28
Case Study 4. Health Care 29
Case Study 5. Public Sector: e-Government 30

5. Section C. The Literature on Investment in Infrastructure and its Applicability to Infrastructure Characterised by Network Externalities 34

The demand for products characterised by network externalities 36
Empirical studies on network externalities 37

6. Section D The Impact of Broadband on the UK and the effects of Uncertainty on Investment 38

Uncertainty and Investment in Broadband 42

7. Section E Research Agenda 43

A Desirable Research Agenda for Stage Two 43
A Feasible Research Agenda for Stage Two 47

8. Conclusions 49

9. References 52

10. Acknowledgements 57

11. Appendix 1 58

12. Appendix 2 60

13. Appendix 3 61

1. Executive Summary

This report has been prepared by the London Business School (LBS) for the Performance and Innovation Unit (PIU). It reviews existing evidence on the impact of Information and Communication Technology (ICT) on labour productivity and economic growth, and examines the applicability of these results to electronic infrastructure and broadband in particular.

Section A begins with an explanation of how ICT can affect productivity and growth via different channels. It then continues with a discussion of a number of studies investigating the impact of ICT on productivity and growth in different countries. First, it reviews studies conducted on the US. Second, it reviews studies conducted on OECD countries. Finally, it examines in more detail recent investigations focusing on the UK.

Our review highlights the fact that the results of several studies differ because different definitions of ICT are adopted, and different measurement methodologies are employed. Nonetheless, some main findings are similar. US studies demonstrate that the impact of ICT on labour productivity and growth is positive, and its impact is especially felt in the second half of the 1990s. The magnitude of this impact, however, differs in different studies. Some tables are reproduced from previous studies that have conducted a review and comparison of these results.

Rather fewer studies have been conducted on OECD countries. We discuss the findings of four recent studies. The first two, produced in 2000, suggest that UK, Germany and France are lagging behind the US because of a slower growth of capital deepening due to a slower adoption of ICT in Europe with respect to the US. Unlike these two studies, the third study adopts official data and 'harmonised deflators' to control for data differences in different countries. This concludes that across the nine OECD countries examined, ICT has contributed to economic growth between 0.3% and 0.9% in the period 1995-2000. The US still sees the highest positive effect, with other countries following. The last study reviewed suggests that under-performance of the non-intensive ICT using sector explains the small improvements in labour productivity in European countries.

Finally, the UK studies are reviewed, and attention is focused on a recent study by Oulton (2001). Oulton looks at the period 1979-1998, and his findings confirm that although ICT provides a significant contribution to capital deepening in the UK, this is still lower than in the US. We discuss Oulton's findings and report some tables illustrating his results. Oulton suggests that by correcting TFP estimates to take into account a 'human capital' factor, TFP estimates are reduced. He explains that part of the productivity slowdown in the UK is due to slower productivity in the non-ICT sector, this might be an explanation for the negative growth of TFP in the 1994-1998 period in the UK.

Section A concludes with a discussion of a study by Röller and Waverman (2001). This study provides the first theoretical and empirical evidence that telecommunications infrastructure has strong external effects on economic growth, but only after a critical mass of near-universal service has been achieved. Thus providing evidence that there are important non-linear externalities in the growth effects of telecommunications infrastructure.

Section B reviews a number of case studies that try to illustrate the impact of the Internet and of ICT technology on different sectors-subsectors-companies. These studies mainly represent experience in the US, which is due to the fact that they are the only examples where an attempt has been made to estimate the *economic impact* of these technologies/Internet. Experience of broadband is too recent to provide any indication of its impact on a country economy, but sectoral-subsectoral experience can provide valuable indications of the gains that can be achieved both in terms of labour productivity gains and for its contribution to output growth.

Firstly, we discuss some examples in the manufacturing industry, and the impact of the Internet on different subsectors, and on a specific manufacturer, Cisco. Secondly, we look at the retailing industry, and illustrate in detail the success of DELL computer following their adoption of retailing via the Internet. Thirdly, we discuss some examples in the financial services industry, and we focus on retail brokerage where the gains estimated from the adoption of 'on-line trading' are estimated to account for a very large reduction in price (and cost) of these transactions. Other examples of banks and life insurance cases are mentioned. Fourthly, we describe the potential impact of the introduction of the Internet in the Health Care sector, and the magnitude of the savings that could be achieved in the US according to some studies looking both at public and private provision of health services. Fifthly, we illustrate the potential impact of the Internet on public services. The estimates of the savings to be derived from e-Government, both from its internal information administration, and from its external relations with citizens and businesses, are substantial.

Finally, we discuss other general examples, and the case of education in particular, where gains from the introduction of the Internet could be very large, but whose impact on economic growth would not be easily measurable. The general case for the positive impact of the Internet on productivity growth is illustrated as mainly deriving from its expected impact on: (a) significantly reducing the transaction costs for producing and distributing goods and services; (b) increasing management efficiency, both internal and external to the firm; (c) improving competition by allowing price comparisons; and (d) increasing consumes choice and convenience.

Section C then reviews some studies looking at the impact of investment in public infrastructure networks like gas, electricity, water, etc. on economic growth. It considers the case for extending the results obtained by those studies to the electronic infrastructure network. Some studies are discussed, whose results have been proven to be affected by mis-specification problems. The highly positive estimates of the impact of investment in infrastructure obtained by those early studies do not hold once these estimates are corrected by means of proper econometric methodologies. Nonetheless, positive effects are still found, even though their magnitude is much reduced. We consider the case for the applicability of these results to investments in telecommunications, and conclude that this would not be appropriate. Our conclusion is due to the fact that telecommunication infrastructure is characterised by the presence of network externalities. This implies the presence of non-linearities in the impact of such investments on the economy. The same is not true for other infrastructure. Roads, for examples, would be more realistically characterised by negative externalities, as the utility to consumers diminishes are more consumers adopt that network (congestion effects). We review the case of goods and services characterised by network externalities and illustrate some empirical results obtained by some recent studies.

In Section D we then describe broadband technology, and its adoption in the UK as compared to other OECD countries. We briefly mention some reasons to explain the fact that the UK was ranked 22nd for broadband penetration at the end of the year 2000. Following the OECD (2001) analysis, we suggest that, market structure as well as the regulatory structure are key variables to explain the delays in the UK, however, we suggest that the constraints on the capital markets following the recent slowdown could also contribute to explain these delays.

We then discuss the existence of any studies in the literature looking at broadband. Apart from the discussion on regulation of cable vs. telecom companies in the US, there are no studies that look at the economic impact of broadband. Only one study (Goolsbee, 2001) does discuss the value of broadband to consumers, and suggests that subsidising producers is a superior scheme than subsidising consumers in order to improve broadband penetration. However, this study has received strong criticisms.

We consider whether a tentative estimate of the impact of investment in broadband is feasible on the basis of the studies reviewed in the previous sections. We reach the conclusion that this is not the case for several reasons. Firstly, because most studies that have looked at the impact of ICT on labour productivity and growth have adopted a ‘growth accounting’ framework which does not include data on broadband. We suggest that, given the presence of externalities, this is not the ideal framework to estimate the impact of broadband. An ideal methodology would need to take into account the use of the technology as well as the investment in ICT. In other words, an endogenous growth model would be more appropriate to assess the impact of electronic infrastructure like broadband, on the economy. Secondly, the literature results do not apply to our case because of their definition of ICT. Most of them do not include telecommunications infrastructure, and the few that do include it, do not include essential elements to our question like the Internet, e-commerce, etc.

The lack of specific studies on broadband is given to its recent experience, and its low market penetration. Because of these reasons, data are not available to conduct a thorough investigation. However, we argue that adopting the results of existing literature on the impact of ICT on the economy and transferring these to estimate the impact of broadband is not a viable alternative.

Section E proposes a research agenda to tackle the question in a rigorous manner. We illustrate a desirable approach (medium to long term) and a feasible approach (short term) for Stage Two. In the description of the desirable study we discuss a very recent study by Quah (2002). He maintains that the link between technology inputs and labour productivity improvements is still not well understood, but more important than focusing the efforts onto trying to improve the estimations of the impact on the economy of the cost side, we should look at the consumers' side. The use of ICT rather than its production becomes the crucial variable to assess the importance of new ICT advances on the economy. This is consistent with Röller and Waverman (2001), and both studies point towards the adoption of an endogenous growth model for a proper investigation.

An ideal investigation would involve multiple stages. A first stage would look at demand, and the crucial variables that determine demand. It would look at the supply side, and would attempt the estimation of a micro-model of demand and supply for telecommunications. In order to account for broadband we would investigate data availability from different sources (ONS, OECD, ITU, OFTEL, Bank of England, Office of the E-Envoy). The micro-model would then be estimated jointly with a macro-equation, and non-linearities will be explored to assess the presence and scale of network externalities. We will consider data availability for a panel of regions (to investigate 'digital-divide' arguments), industries, and countries.

A feasible approach is then described, where we suggest some data manipulation that could be conducted on the basis of the data used by Oulton (2001) for his study of the UK. Such data would be deflated in order to estimate a 'growth accounting model' that would include corrected data for telecommunications equipment to generate some estimates of the impact to be expected from broadband investment on economic growth and productivity. We also illustrate some microeconomic analysis that could be conducted within the short-term project to investigate demand and supply side features of the market for broadband.

We conclude by summarising the literature's findings of the impact of ICT on different countries' economies and suggesting that following the discussion of this literature, these findings are not applicable to the question at hand, and some more analysis is called for.

2. Introduction

The London Business School (LBS) has been asked by the Performance and Innovation Unit (PIU) to produce a report discussing existing evidence on the economic impact of electronic infrastructure on labour productivity and economic growth.

The main question at the heart of this project is: what should the Government's strategy be regarding investment in electronic networks over the next five-ten years? In order to provide a reliable answer to this question it is important to have a clear understanding of the impact that such investments would have on the economy overall.

The approach that we follow in this study consists of a critical review of existing literature and assessment of available evidence. It concludes by advising on desirable future work and specifying the type of analysis needed.

The report is organised as follows. A review of the literature is presented in Section A, which focuses on the literature on the impact of ICT investment on labour productivity and economic growth. Section B reviews available evidence deriving from case studies. Section C discusses the impact on economic growth of investment in other infrastructure industries, and the transferability of those results to electronic infrastructure and broadband.

On the basis of the material investigated in the previous sections, Section D then discusses whether a reliable estimate can be produced of the likely impact of investment in electronic infrastructure on the UK economy over the next 5-10 years. This section highlights the strengths and weaknesses of available evidence.

Section E then provides an indication of feasible studies that could be conducted to help achieve a clearer understanding of the impact to be expected from electronic infrastructure and more specifically, broadband, on economic growth. Conclusions are drawn in the final section.

3. Section A. A Review of the Literature

Productivity and its determinants are at the heart of economic debate. Output per person or per capita is still the most influential measure of the prosperity of nations. Productivity depends on the quantity and quality of the factors of production available to a country and the social framework within which they operate.

There is little doubt that investment in public infrastructure has a positive impact on productivity and is a necessary condition for long-run economic growth, however, the exact magnitude of this effect varies in different contexts. This has been the subject of a large number of economic studies, which have tried to disentangle all different components of this process and identify the correct econometric specification to correctly estimate these components, as well as their magnitude.

This issue has been addressed in different contexts (US, OECD, EU) and different estimates have been provided of the impacts of Information and Communications Technology (ICT) in different areas. However, many questions still remain unanswered.

The conclusion reached by the extensive analysis conducted in the literature is that ICT does have a positive impact on labour productivity and on economic growth. This result is especially clear in the US where the second half of the 1990s was characterised by high levels of ICT driven innovation and growth. However, "*recent contributions to the debate urge caution. […] the recessionary tendencies since the second half of 2000 are a reminder that identification of the effects of ICT diffusion on growth need to be based on a much longer period of time than a five-year upswing of a business cycle,*" (Forth, Mason, and O'Mahony, henceforth, NIESR, 2001, p.21).

ICT affects growth and productivity in several ways. First the production of ICT goods which are purchased as part of final goods and services form part of GDP.[1] Hence if ICT production is growing faster than other segments of the economy, growth is attributed to GDP. This growth is an important contribution of the ICT sector but its true value requires remeasurement of ICT prices given the enormous quality change and price fall in ICT over the past two decades. Official statistics are quite good for computers but not for both software and telecom equipment and thus the contribution to growth from telecom is understated, (see Oulton 2001).

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[1] As does exports (minus imports).

The second major contribution of ICT is the ways in which it enables greater labour productivity growth. This is called capital deepening and involves the intermediate goods and services of ICT growing faster than labour hours. Indeed since 1994 in the UK, 90% of capital deepening has been ICT – a phenomenal statistic. However, the disaggregation of this capital deepening between computers, software and telecom is unclear.

A third major contributor to growth is technological progress which is not reflected in simple capital deepening – for telecom this would be better communications- lower transactions costs, the enabler of innovative practices such as just-in-time production. Measuring this contribution of telecom is particularly difficult.

Thus we here survey the literature to provide a reference point for an estimation of the contribution that future electronic infrastructure could make to growth and productivity. This literature however measures the contribution of ICT not telecom, and the contributions estimated are not without controversy as to their magnitude and long term significance.

The NIESR conducted a very thorough survey of the literature, which refers to all the results obtained by different investigations conducted in several countries (US, OECD, EU, and UK) by means of several different methodologies. Below we report some of their tables, which summarise the literature findings.

US studies

Table 1: Developments in the US economy, 1959-2000

(Average annual percentage rates of growth in the US private, non-farm business sector)

	1949-58	1959-73	1974-90	1991-95	1996-2000
Gross Domestic Product (constant prices)	3.37	4.41	2.94	2.38	4.1
Hours worked	n.a.	2.30*	1.68	1.68	2.58
Average labour productivity	2.74	2.97	1.30	1.52	2.48

* Data only available for the period 1964-73.

Sources:

Gross Domestic Product	US Bureau of Economic Analysis, Table S1
Hours worked	US Bureau of Labor Statistics, series EEU00500040
Average Labour Productivity	US Bureau of Labor Statistics, series PRS85006092

NIESR (2001, p.10)

Table 1 above illustrates the markedly high levels of GDP and labour productivity between 1996 and 2000 in the US. Different results are obtained when different definitions of ICT and measurements are adopted in estimating the impact of ICT on GDP and labour productivity growth. A comparison of the results obtained by various studies conducted in the US is reported in Table 2 produced by the NIESR and reproduced in this report in Appendix 1.

A study by Stiroh (2001) distinguishes the impact of 'intensive' and 'non intensive' ICT-using sectors on productivity growth in the US and compares average annual rates of labour productivity growth for the periods 1987-1995, and 1995-1999. He adopts data on investment in hardware, software and telecommunications equipment to differentiate these two categories. His findings suggest that both ICT producing and intensive ICT-using industries had registered a sharp increase in productivity growth, about 3.7% in the former and 2% in the latter. The corresponding statistic for non-intensive ICT-using industries was only 0.4%. Stiroh's conclusion is that ICT was crucial for the US productivity revival, quite apart from any cycle effects.

Gordon (2000, and 2001) maintains that the economic cycle is a strong component of the high growth rate of GDP in the US. Some studies (inter alia, Council of Economic Advisors, 2000) argue that this is not the case as the exceptional economic growth experienced in the US in the second half of the 1990s does not have a strong cyclical component. These studies suggest that ICT has contributed to the reduction of the Non Accelerating Inflation Rate of Unemployment (NAIRU) by means of the efficient labour market clearing provided by the Internet job market. Wadhwani (2001 a) suggests that although the rate of unemployment and inflation have been constantly over-predicted during the 1990s in the US, this does not imply that the business cycle is dead. A conclusive answer to the question of the contribution of the cycle to economic growth in the US has not yet been provided. This will only be clear in future, when longer data series are available.

Interestingly, a report by McKinsey (2001) investigating industry-level contributions to the post 1995 increase in productivity in the US finds that just six industries from a large number of industries were driving the productivity growth. They note that TFP growth in the US for the period 1995-1999 was negative (-0.3%) for the remaining industries, which accounted for the 70% of the economy. Their conclusion is that full benefits from ICT investments can be generated once complementary investments in workforce skills and organisation are in place.

EU and OECD studies

Although the number of studies conducted in the US is much larger than that for European or OECD countries, a number of investigations have recently been produced that examine the impact of ICT on these countries.

Schreyer (2000) constitutes one of the first investigations of similar issues on countries other than the US. Schreyer found that there was little evidence of a contribution of ICT to output growth in European countries. This result, however, is not very robust due to lack of proper data to investigate the question in depth.

Gust and Marquez (2000) look at some major European countries and compare their productivity growth with the US in the 1996-1999 period. **They find that labour productivity growth in France and the UK was lower than in Germany and well below the US. They argue this is due to the slower growth of capital-deepening rather than of TFP. Thy regard the slower adoption of ICT in Europe as the explanation for the slower productivity growth in Europe compared to the US.** Their estimates are reported in Table 3 below.

Table3

Average growth rates in output, inputs and labour productivity in the US, UK, France and Germany, 1996-99

	US	UK	Germany	France
1996-99 Average growth rates in:				
GDP	4.84	2.78	1.72	2.53
Labour hours	2.30	1.29	-0.41	0.91
Capital stock	5.59	3.10	2.33	2.17
Labour productivity	2.57	1.47	2.14	1.61
of which:				
Capital deepening	1.11	0.54	1.06	0.50
TFP	1.47	0.95	1.07	1.12

Source: Gust and Marquez, 2000

Colecchia and Schreyer (2001) improve on the analysis previously conducted on OECD countries (Schreyer, 2000) by including a larger number of countries in their study, for which they are able to use official data which were not available for previous investigations. They remark that price indeces are a key element in order to obtain correct measurements. "Accurate price indices should be constant quality deflators that reflect price changes for a given performance of ICT investment goods,. Thus, observed price changes of 'computer boxes' have to be 'quality adjusted for comparison of different vintages," (Colecchia and Schreyer, 2001, p.8). These authors remark that, as already pointed out by other economists, large differences in computer prices observed in OECD price indices could be due to differences in the statistical methodologies adopted rather than real differences. More specifically, they suggest that countries that adopt hedonic price methods to construct deflators for ICT tend to register larger drop in ICT prices than others. Colecchia and Schreyer (2001) adopt a set of ‘harmonised deflators’ to control for some of the differences in these methodologies. Their results are reproduced in Table 4 below.

Table 4 : Percentage point contribution of ICT to output growth

Business sector, national price index, 1980-2000 or latest available year

National price index

		Australia	Canada	Finland	France	Germany	Italy	Japan	United Kingdom	United States
growth of output	80-85	3.39	2.66	2.80	1.48	1.13	1.54	3.31	2.59	3.35
	85-90	3.79	2.90	3.42	3.46	3.59	3.04	5.14	3.90	3.31
	90-95	3.37	1.79	-0.70	0.97	2.22	1.44	1.33	2.12	2.64
	95-99	4.72	4.09	5.62	2.60	1.73	1.93	1.10	3.48	4.43
	95-2000	**4.62**	**4.20**		**2.81**	**2.06**			**3.55**	**4.40**
contribution (percentage points) from:										
IT and communications equipment	80-85	0.22	0.28	0.14	0.11	0.09	0.11	0.08	0.10	0.36
	85-90	0.35	0.27	0.18	0.15	0.13	0.13	0.16	0.20	0.32
	90-95	0.31	0.21	0.00	0.11	0.16	0.10	0.14	0.13	0.29
	95-99	0.57	0.36	0.11	0.19	0.14	0.12	0.29	0.25	0.61
	95-2000	**0.56**	**0.38**		**0.19**	**0.15**			**0.25**	**0.62**
software	80-85	0.05	0.04	0.04	0.03	0.01	0.02	0.00	0.01	0.07
	85-90	0.16	0.09	0.08	0.05	0.03	0.06	0.02	0.03	0.11
	90-95	0.16	0.08	0.01	0.02	0.06	0.01	0.00	0.02	0.14
	95-99	0.21	0.11	0.09	0.08	0.07	0.04	0.00	0.03	0.25
	95-2000	**0.23**	**0.12**		**0.08**	**0.07**			**0.02**	**0.25**
total ICT	80-85	0.27	0.32	0.18	0.14	0.10	0.13	0.09	0.12	0.44
	85-90	0.51	0.36	0.25	0.21	0.16	0.20	0.18	0.23	0.43
	90-95	0.47	0.28	0.01	0.13	0.22	0.10	0.14	0.15	0.43
	95-99	0.78	0.47	0.20	0.26	0.21	0.16	0.29	0.28	0.86
	95-2000	**0.79**	**0.51**		**0.27**	**0.22**			**0.27**	**0.87**
total capital services	80-85	1.63	1.14	0.68	0.69	0.58	0.72	1.01	0.70	1.25
	85-90	1.97	1.15	0.83	0.91	0.80	0.86	1.38	1.10	1.10
	90-95	1.35	0.63	0.03	0.73	0.99	0.62	1.33	0.74	0.97
	95-99	1.74	0.92	0.15	0.75	0.81	0.82	0.97	1.05	1.69
	95-2000		**0.97**		**0.78**	**0.83**			**1.04**	**1.71**

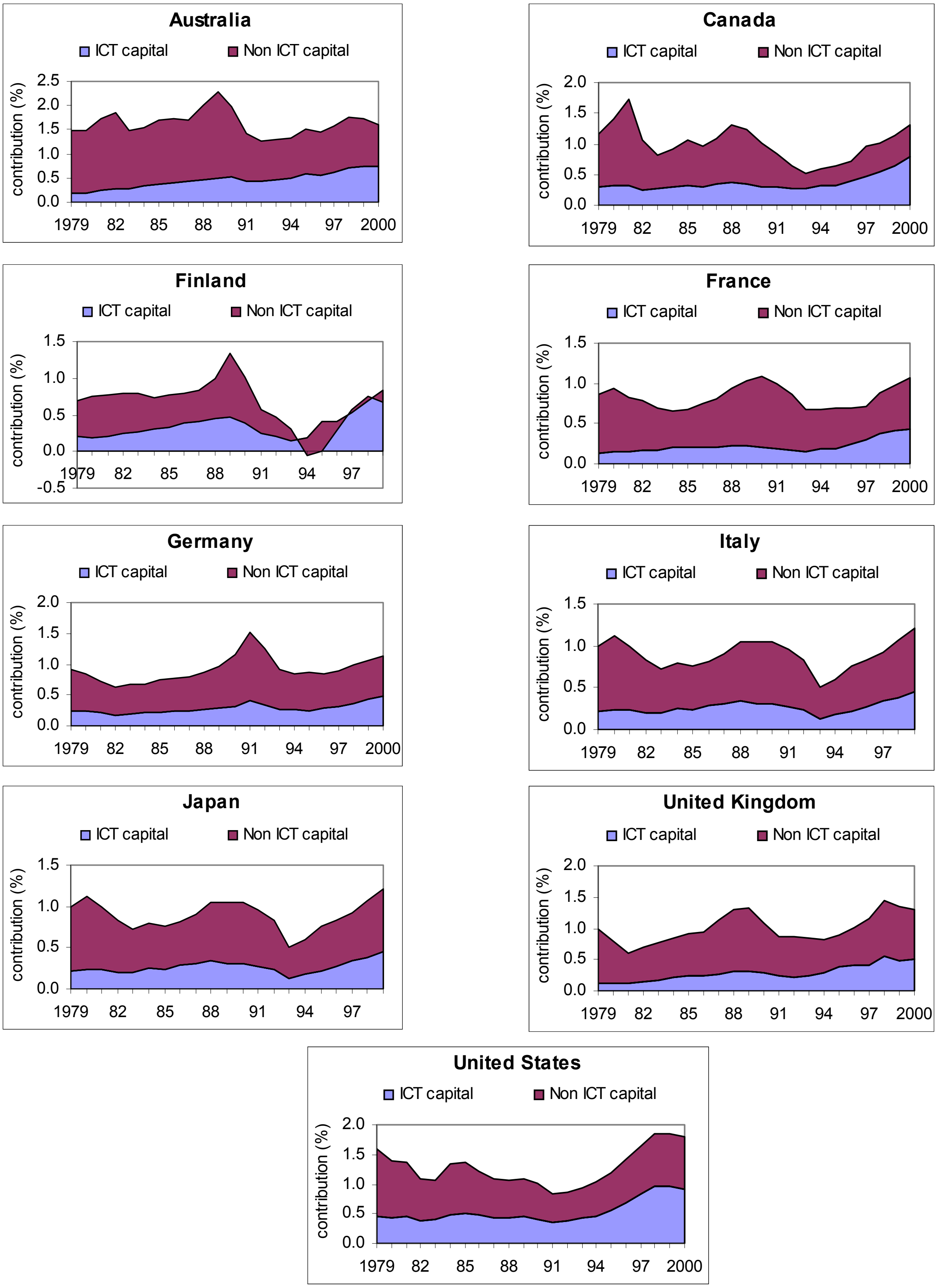
Harmonised price index

		Australia	Canada	Finland	France	Germany	Italy	Japan	United Kingdom	United States
growth of output	80-85	3.39	2.66	2.80	1.48	1.13	1.54	3.31	2.59	3.35
	85-90	3.79	2.90	3.42	3.46	3.59	3.04	5.14	3.90	3.31
	90-95	3.37	1.79	-0.70	0.97	2.22	1.44	1.33	2.12	2.64
	95-99	4.72	4.09	5.62	2.60	1.73	1.93	1.10	3.48	4.43
	95-2000	**4.62**	**4.20**		**2.81**	**2.06**			**3.55**	**4.40**
contribution (percentage points) from:										
IT and communications equipment	80-85	0.24	0.25	0.21	0.13	0.18	0.21	0.16	0.16	0.36
	85-90	0.34	0.24	0.30	0.17	0.23	0.23	0.23	0.25	0.32
	90-95	0.37	0.21	0.17	0.16	0.24	0.18	0.25	0.23	0.29
	95-99	0.53	0.39	0.46	0.23	0.28	0.29	0.36	0.42	0.61
	95-2000	**0.53**	**0.43**		**0.25**	**0.30**			**0.43**	**0.62**
		0.20	0.23	0.26	0.30	0.20	0.18	0.05	0.10	0.29
software	80-85	0.05	0.04	0.07	0.05	0.03	0.02	0.02	0.02	0.07
	85-90	0.12	0.09	0.12	0.05	0.04	0.08	0.07	0.04	0.11
	90-95	0.12	0.09	0.07	0.02	0.06	0.02	0.06	0.04	0.14
	95-99	0.13	0.12	0.16	0.10	0.07	0.07	0.02	0.05	0.25
	95-2000	**0.15**	**0.13**		**0.10**	**0.07**			**0.04**	**0.25**
total ICT	80-85	0.29	0.30	0.28	0.18	0.20	0.23	0.18	0.18	0.44
	85-90	0.46	0.33	0.42	0.22	0.27	0.31	0.30	0.29	0.43
	90-95	0.48	0.30	0.24	0.18	0.30	0.21	0.31	0.27	0.43
	95-99	0.66	0.51	0.62	0.33	0.35	0.36	0.38	0.47	0.86
	95-2000	**0.68**	**0.57**		**0.35**	**0.38**			**0.48**	**0.87**
total capital services	80-85	1.66	1.11	0.77	0.72	0.69	0.82	1.10	0.76	1.25
	85-90	1.93	1.13	1.00	0.92	0.91	0.97	1.50	1.15	1.10
	90-95	1.37	0.65	0.26	0.78	1.08	0.73	1.49	0.85	0.97
	95-99	1.63	0.96	0.57	0.82	0.95	1.01	1.07	1.23	1.69
	95-2000		**1.03**		**0.87**	**0.98**			**1.25**	**1.71**

Source: Colecchia and Schreyer (2001)

These results are illustrated in Figure 1

Figure 1: ICT contribution to output growth. Business sector, based on harmonised price index



The conclusion reached by Colecchia and Schreyer's study is that in the nine OECD countries they examined ICT contributed to economic growth between 0.2 and 0.5 percentage points per year over the last two decades, and this contribution rose to 0.3 to 0.9 in the second half of the 1990s. The highest positive effects have been experienced in the US, with Australia, Finland and Canada following. They found that a suitable framework is required for ICT use to have a high impact on growth. Interestingly, their results reveal that the presence of a large ICT producing industry is neither a necessary nor a sufficient condition to produce the positive effects of ICT on growth.

Finally, they report the main differences between their study and other country-specific studies, specifying the main differences in the data adopted, the results obtained and the methodologies adopted for the estimations. A comparison of their results with some US and UK studies is illustrated in Table 5.

Table 5 Comparison of Colecchia and Schreyer (2001) with other studies

	Periods	**ICT contribution to output growth (percentage points)**		
		Software	IT Equipment	Communications equipment
		United States		
Colecchia and Schreyer (2001)	1990-1995 1995-2000	0.14 0.25	0.20 0.47	0.08 0.15
Oliner and Sichel (2000)	1991-1995 1996-1999	0.25 0.32	0.25 0.63	0.07 0.15
Jorgenson and Stiroh (2000)	1990-1995 1995-1998	0.15 0.21	0.19 0.49	0.06 0.11
		United Kingdom		
Colecchia and Schreyer (2001)	1990-1995 1995-1999	0.31 (Total ICT equipment) 0.51(Total ICT equipment)		
Oulton (2001)	1990-1995 1995-1998	0.34 (Total ICT equipment) 0.41(Total ICT equipment)		
Source: Adapted from Colecchia and Schreyer (2001)				

Van Ark (2001) estimates the contribution of ICT producers versus users in ten major OECD countries. He finds that the US and the UK have similar shares of ICT-producing industries, about 7% of gross economic activity. Nonetheless, the US share of ICT producers, which contributes the most to labour productivity gains, is remarkably higher than in the UK in the period 1995-1999. Van Ark concludes that under-performance of the non-intensive ICT using sector explains the underperformance of Europe in increasing their labour productivity. In the case of the UK he attributes the negative growth of labour productivity in the second half of the 1990s as compared to the first half to the slower productivity growth in non ICT-producing manufacturing industries. These findings are summarised in Table 6 below.

Table 6: Labour productivity growth by sector 1990-95 and 1995-2000

	US	UK	Germany	France
		% rate of growth		
1990-95				
ICT-producing sectors	4.8	6.8	6.8	4.1
Intensive ICT-using sectors	1.6	1.3	2.2	0.9
Other sectors	0.8	2.0	1.7	0.6
Total economy	1.2	2.5	2.1	1.1
1995-99				
ICT-producing sectors	7.2	4.9	11.1	8.5
Intensive ICT-using sectors	3.5	1.3	1.5	0.7
Other sectors	1.6	0.9	0.8	0.8
Total economy	2.1	1.2	1.7	1.3
Acceleration (1995/99-1995/90)				
ICT-producing sectors	2.4	-1.9	4.3	4.4
Intensive ICT-using sectors	1.9	0.0	-0.7	-0.2
Other sectors	0.8	-1.1	-0.9	0.2
Total GDP growth (%)	**0.9**	**-1.3**	**-0.4**	**0.2**

Source: Van Ark (2001)

The NIESR (2001) reports the following table (Table 7) comparing TFP growth rates in four major countries in the last decade.

Table 7: TFP growth rates, 1989-1999, US, UK, Germany and France

	US	UK	Germany	France
Market Economy (a)				
1989-95	1.09	1.24	1.75	-0.08
1995-99	2.63	0.58	0.63	0.74
Manufacturing				
1989-95	2.20	2.47	2.68	1.31
1995-99	2.85	0.35	1.04	1.97
Distributive trades				
1989-95	1.06	-0.13	1.55	-0.59
1995-99	4.65	0.03	-1.45	0.81
Financial & business services				
1989-95	0.16	-0.13	-2.12	-3.12
1995-99	2.17	1.14	-1.12	-0.63

Source: NIESR (2001)
(a) Excluding health, education, public administration and residential buildings.

Finally, O'Mahony (2001) suggests a large acceleration in TFP growth in ICT-using sectors in the US, which is not matched by similar industries in European countries. According to her results the increase in TFP due to the ICT producing sector is not obvious. It appears that in Europe ICT producers match US levels of TFP growth, while the same is not true for ICT users.

UK studies

Kneller and Young (2001) look at the UK. They find that the growth in investment in computing equipment in the UK is similar to that in the US since 1974, even though this increases more rapidly in the US from 1995. However, they find that the income share of the computing equipment in the UK is currently less than half that in the US. Nonetheless, their estimate of its contribution to output growth in the UK improves from the 0.18% of 1974-1990 and the 0.13% of 1991-1995 to 0.27% in the second half of the 1990s. They attribute the labour productivity slowdown of the second half of the 1990s to the manufacturing sector. Kneller and Young suggest that manufacturing has suffered a loss in competitiveness due to the high value of the pound, and this has adversely affected its productivity performance. As a result, output per hour over this period was growing at 1.4% per year, instead of the 4.1% per year, experienced in the previous five years.

Oulton (2001) provides a thorough study of the UK. This contribution to the literature takes a wider view than previous studies examining the UK (e.g., Kneller and Young, 2001) as it includes software as well as hardware, telecommunications equipment and semiconductors (chips). However, it does not include the contribution of the Internet, e-commerce, and digital media. Oulton finds a significant and increasing contribution of ICT capital deepening to labour productivity growth in the UK, though, this is still considerably lower than the US in the same time period, as illustrated in the Tables below.

Oulton's estimates of the contribution of ICT refer to the 1979-1998 period, as investment series beyond 1998 are not available. He finds that the share of ICT output in GDP at current prices was 0.6% in 1979, but has risen steadily since then, reaching 3.1% in 1996. The computer share falls slightly from 1996, corresponding to a deterioration in the net trade position. Oulton adjusts some estimates of GDP growth by using different price indices to deflate software. The results of the estimations with and without the adjustment are reported in Table 8. This shows that the addition to the annual growth rate coming from the new estimates from 1994 to 1998 is between 0.25% and 0.33%. With an equal contribution from hardware and software, and a smaller contribution from telecommunications. He then asks the question, what is the contribution of ICT output to the growth of GDP (that is, the share of final output of ICT in GDP multiplied by the growth rate of ICT output)?

ICT contribution to output. **Oulton shows that despite the small share in GDP, ICT accounted for 13% of output growth in 1979-1989, and 21% in 1989-1999. On average, over 1994-1998 ICT contributed 0.57% a year to output growth.** This is illustrated in Table 8 below. The 1990s are characterised by a rising share of ICT in output. Exports of ICT also grew rapidly over the same period due to the fall in price of semiconductors. However imports were growing at a faster pace than exports, thus producing a negative net effect on GDP of 0.11% per year.

Table 8 Contribution of ICT output to GDP growth: annual average

	ICT (High software adjustment)		**Growth of GDP**
	Contribution	**Proportion of GDP growth**	
Period	(% p.a.)	**%**	(% p.a.)
1979-1989	0.33	13.3	2.52
1989-1998	0.46	20.7	2.21
1989-1994	0.36	25.2	1.44
1994-1998	0.57	18.2	3.16

Source: Adapted from Oulton (2001), p.31

ICT contribution to Input. This is the contribution of ICT capital to the growth rate of the aggregate capital stock per unit of labour. It is calculated as the share of aggregate profits attributable to ICT capital, multiplied by the growth rate of ICT capital. Oulton reports that the ICT profit share has tripled since 1979, and reached a level of 15% in 1998.

ICT and TFP growth. Following his adjustment to the data for the calculation of ICT impact, Oulton shows that the growth rates of output and capital are not very different to the unadjusted calculations. See Table 9.

Table 9 Growth of TFP: comparison of estimates

	Hours	
	Baseline	**High software**
Period	(% p.a.)	(% p.a.)
1979-1989	1.79	1.70
1989-1998	1.27	1.16
1989-1994	1.55	1.50
1994-1998	0.92	0.73

Source: Adapted from Oulton (2001), p.35

Labour productivity growth: the contribution of TFP, ICT and non-ICT capital. Oulton then estimates the contribution of ICT to capital deepening and assesses its impact on labour productivity growth. Since 1979 he finds that ICT contributed 45% to capital deepening in the period 1979-89; this contribution rises to 55% in 1989-98. Overall the contribution of capital deepening to labour productivity growth has been increasing. Within the overall capital deepening, ICT has contributed 25% to labour productivity between 1989-1998, reaching 48% between 1994 and 1998.

Current estimates do not account for improvements in the quality of labour. Given that Oulton (1997) estimated that human capital per worker was rising at a rate of 0.47% per year over the period 1965-90, he corrects his TFP estimate by allowing for human capital changes, and thus obtains a new, reduced estimate of the contribution of TFP growth to labour productivity of 0.34%.

Part of the productivity slowdown in the UK is due to the lower contribution of other forms of capital. Surprisingly, total factor productivity (TFP) growth in the UK fell by 0.76% a year while it was rising in the US. It is odd that the UK does not seem to have benefited post 1994 from a world-wide experience of TFP growth.

Oulton argues that this could be due to the fact that the realised rate of return on ICT investments has been lower than that on other assets. He might therefore have overestimated the contribution of ICT by giving too large a weight to the fastest-growing part of the capital stock. As a result TFP would have been underestimated.

However, for growth accounting methodologies generally the reverse seems to apply as network externalities are generally not included in the calculation of the contribution of ICT, thus inflating TFP. Oulton's results are reported in Tables 10 and 11.

Table 10 Productivity and the contribution of ICT a US-UK comparison

	US		**UK**	
	1990-95	**1995-99**	**1990-95**	**1995-99**
Growth of output per hour (% p.a.)	1.53	2.57	3.01	1.47
Growth of output (% p.a.)	2.75	4.82	1.35	3.09
Contributions from (p.p. p.a.):				
ICT capital	0.51	0.96	0.40	0.64
Other capital	0.11	0.14	1.10	0.08
TFP plus labour quality	0.92	1.47	1.51	0.75
Memorandum items%				
Income shares (% of GDP)				
ICT	5.3	6.3	2.2	3.7
Of which:				
Computers	1.4	1.8	1.0	1.5
Software	2.0	2.5	0.9	1.6
Telecommunications equipment	1.9	2.0	0.3	0.6
Growth rates of inputs (% p.a.)				
Computers	17.5	35.9	18.6	28.4
Software	13.1	13.0	17.8	12.6
Telecommunications equipment	3.6	7.2	8.7	13.5

Source: Adapted from Oulton (2001), p.40

Table 11 Productivity acceleration/deceleration in the second half of the 1990s: US and UK compared

	US	UK
	1995-99 over 1990-95	**1994-98 over 1989-94**
Growth of output per hour (% p.a.)	+1.04	-1.54
Growth of output (% p.a.)	+2.07	+1.73
Contributions from (p.p. p.a.):		
ICT capital	+0.45	+0.24
Other capital	+0.03	-1.02
TFP plus labour quality	+0.55	-0.76
Memorandum items%		
ICT income share (% of GDP)	+1.00	+1.48
Growth rates of inputs (% p.a.)		
Computers	+18.40	+9.78
Software	+0.30	-5.20
Telecommunications equipment	+3.60	+4.86

Source: Oulton (2001), p.41

To assess the future contribution of ICT, one needs to be able to forecast technical progress in this sector. An important question is whether the contribution of ICT to output growth will remain as high as in recent years.

If output share is 3% and the volume growth is 20 % a year, then the contribution to GDP growth is 0.6% a year, which is substantial. But if prices for ICT fall the contribution will steadily diminish and approach zero. This also applies to the input side. However rapidly ICT capital is growing if its profitability falls towards zero, the contribution of ICT capital to total input will also tend towards zero.

Therefore the sign will depend on whether the ICT prices fall faster than volume rises or not. In other words the sign of the net effect will depend on the elasticity of substitution, (this is generally constrained by the functional forms chosen for analysis.) Oulton concludes that the contribution of ICT capital to economic growth will continue to increase.

Finally, Crafts and O'Mahony (2001) study labour productivity in Britain and find that the 26% labour productivity lead of the US over the UK can be a result of the higher ICT capital to labour ratios in the US. These economists obtain a negative contribution when they compare the UK with France, and a zero impact when they compare the UK with Germany. So, they conclude, ICT capital is an important factor to consider when comparing differences in labour productivity levels among these countries.

A different approach to measure the impact of ICT on economic growth in OECD countries

In their study Röller and Waverman (2001) provide the first theoretical and empirical evidence that telecommunications infrastructure has strong external effects on economic growth, but only after a critical mass of near-universal service has been achieved. The data used for their study cover OECD over the period 1970 –1990. This important paper provides evidence that there are important non-linear externalities in the growth effects of network infrastructure.

Röller and Waverman's research calls into serious question the traditional growth accounting approach to measuring the impacts of ICT on growth and productivity. This work motivates fundamental new analysis of the impact of ICT. The ICT revolution is not just the spread of telecommunications infrastructure, but the spread of networked computer systems, the internet and the world-wide-web. In conjunction with the OECD and the EU, new data could be gathered which would allow the investigation of the crucial question of how the spread of computers, the internet, and broadband promotes productivity and economic growth.

Several recent studies attempt to investigate some of these questions, but all have the flaw of using a traditional growth accounting framework, measuring total productivity or TFP. TFP is the difference between total growth in GNP and the growth of all possible inputs. This 'residual' type analysis is a standard procedure, but the problem is, as Röller and Waverman demonstrate, ICT cannot be treated as simply another input like labour. Instead the crucial non-linearities of networks must be investigated.

4. Section B. Industry Specific Evidence

In this section we provide an overview of case studies where the Internet has been instrumental either to make success cases, or it is expected that it will have a large impact given the experience to date, (Litan and Rivlin, 2001). Experience of broadband is still too recent to provide wide-ranging evidence, but the impact of the Internet can be regarded as a good proxy to provide an indication of the potential impact of broadband. The impact of the Internet is not measured by normal statistics. This makes growth accounting techniques not appropriate to infer the impact of broadband on economic growth, unless special adjustments to the data are made. Industry specific evidence can be very informative to illustrate the potential impact of electronic networks.

The case studies discussed below describe quite distinct experiences. They are quite different from the aggregate growth accounting studies as they analyse **how** ICT provides productivity enhancement. Nonetheless, they can serve to illustrate some general principles. These cases show that a positive impact of the Internet on productivity growth is driven by:

- Significantly reducing the cost of transactions necessary to produce and distribute goods and services;
- Increasing the efficiency of management, especially by enabling more effective communications both internal to the firms, and external with partners, suppliers and customers;
- Making prices more transparent, and thereby improving competition, and broadening the market for buyers and sellers;
- By increasing consumer choice and convenience (via e-commerce) in a way which is not quantified by normal statistics.

Case study 1. The Manufacturing Industry

Brookes and Wahhaj (2000) have conducted a thorough analysis of the impact of the Internet on seventeen US manufacturing and extraction industries. They show that the impact of the Internet was strongly felt by the manufacturing industry, but in different ways in different sub-sectors. Brookes and Wahhaj found that the purchase cost of inputs could be reduced by as much as 40%, in the case of electronic components and as little as 2%, for coal. Overall the lower costs allow producers to increase output and, in many cases to shift demand outward. This study estimates that output in the US could increase by as much as 5% with the majority of this increased production being concentrated in the first ten years. This translates into an increase in GDP growth rate of at least 0.25% a year over this period.

McAfee (2001) provides an estimate of internal cost reduction brought to US manufacturing by the Internet. He discusses the example of Cisco, a manufacturer of routers and other Internet networking equipment. In 1994 Cisco started a series of Internet-based initiatives that transformed its internal and external practices, and substantially reduced their production costs. In late 1999 Cisco conducted an internal review to quantify the results in costs reduction terms of these initiatives, the results are illustrated in Table 12.

Table 12 Cisco Cost-Saving from Internet-Based Efforts, 1994-1999

Category	**Cumulative Savings** (million US dollars)
Customer care	269
Internet commerce	57
Supply chain management	269
Work force optimisation	55
Total cost savings	650
Cisco 1999 revenue	12,2000
Cost savings as a % of revenue	5.3

Source: McAfee (2001)

The data reported in Table 12 represent an upper bound. Other companies attempted to emulate Cisco but did not reach the same level of cost savings. Part of this success story is attributed to the fact that being the market leader, Cisco managed to move all its suppliers to join a digital community for exchanging information, this was the equivalent of an e-market place when e-commerce was not yet available.

(For further examples of the impact of the Internet on manufacturing see Rayport and Jaworski, 2001).

Case study 2. Retailing. The case of DELL

According to Bailey (2001) although the Internet has the potential for changing the future of retailing, so far it has accounted for less that 1 % of total retailing revenues. Bailey assumes that even if retailing via the Internet experiences a tremendous growth in the future, this may never exceed 10% of total retailing revenue.

Dell was one of the first companies to take advantage of the marketing potential of the

Internet. With the exception of its unsuccessful entry into the retail channel, Dell had relied on a 'build to order' sales/manufacturing/logistics system directly to and from consumers, thereby avoiding the use of traditional distribution systems. By selling directly to its final customers, Dell eliminated reseller mark-ups, and thus could offer better prices than its competitors, who still relied on retailers to distribute their products. Dell had a six days inventory process while its competitors had an average of 36 days. This gave Dell the ability to immediately reflect input cost reductions in the final prices to consumers, thanks to a component cost reduction of 8-12% per quarter. Moreover, Dell was able to get new technology to the market 30-90 days ahead of its competitors.

Dell refers to the model combining information and technology as 'Virtual Integration'. It was this virtual integration that constituted the element which differentiated Dell from its competitors. This combined aspects of the strong supply chain that are characteristic of vertical integration with the focus and speed of 'virtual' companies. Finally, it allowed collaboration across the company boundaries and generated much higher levels of productivity and efficiency. Figure 2 below illustrates the time frame of Dell's successful Internet operation.

Figure 2 Dell's Internet Operation

Late 1980's	**1994**	**1995**	**1996**		**1997**			**1998**	
Dell Launches an FTP site for customers to download files	www.dell.com launched with technical support content and e-mail gateway	Online quotes launched	February: Marketing content added to site	July: Dell starts selling systems online. 80,000 online user sessions per week	January: $1 mill. per day selling mostly Dimension line	March: Sites launched in Asia and Europe: 225,000 online user sessions per week	Novem: Over $3 million sales per day Sales in 36 countries	May: Focus on Corporate customers $ 4 mill. per day	Dec: $14 mill per day

Source: '*DELL Computer: Business to Business Over the Web',* Darden Graduate School of Business Administration, University of Virginia, US, mimeograph (1999).

Bailey (2001) discusses sources of efficiency gains for retailers to be derived from the Internet. He identifies:

- efficiency in transacting with consumers
- efficiency in transacting with suppliers (especially through automating ordering)
- efficiency in competition among retailers.

The Internet has become a business tool as important as the telephone. He argues that the differences among retailers arise not from whether they use the Internet, but how they use it. Bailey concludes that the Internet will successfully promote retail transactions and that a growing proportion of "traditional" retailers will develop their Internet presence in order to benefit from these efficiency gains.

Case Study 3. Financial Services: Retail Brokerage

The impact of the Internet on financial services has been remarkable. The World Wide Web has enabled the creation of new types of products developed and distributed at low cost of transactions. Retail brokerage is one of the sub-sectors that have experienced a very dramatic change.

The emergence of low-price on line securities trading and free financial information services has produced radical transformations to the retail brokerage market. A large number (over 200 in the US) of retailers now operate on line, providing low cost trading. Prices for an order to buy/sell securities at the market prevailing price have fallen from a range of $100 -$300 with traditional full service brokerage retailing, to a range of $5-$30 for a typical size order on line. Overall the industry has experienced dramatic growth.

Clemons and Hitt (2001) provide some estimates that try to assess the impact to be expected from the Internet over retail financial services. In the brokerage operation sub-sector they estimate that the savings to be expected are about $5.16 billion. They obtain this estimate by assuming that about 44 million brokerage accounts will be on line by 2005, these will trade about 25 times a year, and on the basis of an estimate of cost savings per operation of $6.25 per trade they obtain their final figure[2]. Using the

[2] The underlying assumption for this calculation is that the 44 million accounts will carry 75% of their operations online, thus generating a total number of 825 million online trades. Multiplying this number

same set of assumptions they adopted for estimating the impact of the Internet on retail banking, they expect that additional savings of $224 million will be generated due to statement generation and mailing savings.

Brown and Goolsbee (2000) find that the Internet has the potential to significantly reduce search costs by allowing consumers to engage in low-cost price comparisons online. This study provides empirical evidence on the impact that the rise of Internet comparison shopping sites has had for the prices of life insurance in the 1990s. Using micro data on individual life insurance policies, the results indicate that, controlling for individual and policy characteristics, a 10% increase in the share of individuals in a group using the Internet reduces average insurance prices for the group by as much as 5%. Further evidence indicates that prices did not fall in the period before the insurance sites came online. These results suggest that growth of the Internet has reduced term life prices by 8% to 15% and increased consumer surplus by $115-215 million per year and perhaps more.

Another interesting example of the positive impact of ICT on the financial sector is provided by Mason et al (2000). This study looks at banks in the UK, Germany and the US. They show that US banks benefited from the early adoption of computers, and new work organisation forms. This reduced the cost of small customers operations and made them much more efficient.

Case Study 4. Health Care

Danzon and Furukawa (2001) report that national expenditure on medical care in the US reached $1.2 trillion, or almost 14% of GDP in 1999, up from 8.9% of GDP in 1980 and estimates of future health care spending are extremely high[3]. Investment in medical technology accounts for a large share of this. Nonetheless IT equipment has been invested in, which has not yet been fully integrated in administration practice and business functions. As a result, Danzon and Furukawa maintain that the potential economic impact of improved productivity in health care is huge. The main areas for potential improvements they identify are: (1) administration; (2) reduction of 'medical errors' and deriving costs; (3) reduction in 'unnecessary care' (4) estimates of saving from purchasing supplies via e-commerce are about 1% of total health care spending. These figures seem to suggest that there is potential for very large savings. Moreover,

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by the expected saving of $ 6.25 per trade they obtain a total of $5.16 billion.

[3] HCFA Health Care Financing Administration, 2000. 'National Health Expenditure Projections'. www.hcfa.gov/stats

gains are to be expected for the wider economy deriving from productivity improvements in health care, and, by consequence better population health, lower time for patient care, and lower public expenditure. "*Health improvement is the ultimate output of the medical services sector, but that output is not captured by standard GDP measures. Nonetheless, better employee health could increase labour productivity throughout the economy by reducing work loss caused by disability and illness*," (Danzon and Furukawa, 2001, p.190).

Danzon and Furukawa (2001) suggest that a 'connectivity system' could provide access on line to patients and health care centres, which would have a large impact on efficiency improvements for the administration as well as saving time for patients. The elements that would be included in this online system would enable access to: electronic medical records, clinical decisions and guidelines for patients, prescriptions, test ordering and results reporting, real-time verification of reimbursement eligibility, claims processing, appointment scheduling and referrals, patient education and interaction, compliance monitoring. The gains to be expected from the implementation of such system are substantial. This is particularly germane to a study of the impacts of broadband.

The Bureau of Economic Analysis report data showing that the health service sector employs 6.9% of the labour force in the US. This labour force is characterised by a lower average productivity growth. This was negative (-2.2%) during 1987-1997, which, compared to the positive 0.6% of the 1960-1973 period implies a slowdown of –2.8% (Danzon and Furukawa, 2001).

Danzon and Furukawa (2001) conclude that, with all the caveats that apply to estimating the effects of the Internet in this sector, they expect that the potential savings in health care are equal to at least 1%-2% of the total health spending.

Case Study 5. Public Sector: e-Government

Fountain and Osorio-Urzua (2001) suggest that the US government is in the early stages of a deep transformation as a result of the Internet and related developments in ICT. They maintain that the rapid growth of web-based applications in the government sector promises substantial cost-savings through structural changes in the delivery of government services, and consequently, large efficiency gains. Some of these gains can be estimated in terms of cost-reductions, some others however, cannot possibly be quantified. The estimates provided by this study suggest that the US could experience annualised costs saving to the government sector of as much as $12 billion. Nonetheless, Fountain and Osorio-Urzua suggest that in order to realise these gains serious structural and political obstacles should be eliminated. Challenges to the government include development of information infrastructure, tackling privacy and security concerns, eliminating/transforming bureaucratic processes, promoting technical expertise in government, managing uncertainty.

Some illustrative innovative plans adopted in E-Government services in the US are reported in Appendix 2.

Government more than any other sector is characterised by operationally complex information processing. Therefore, large gains are to be expected from creating interfaces that enable efficient exchange between government and (1) citizens, (G2C) seen as consumers -e.g., tax processing, and other services; (2) business, (G2B) e.g., procurement; and (3) government, (G2G), i.e., internal management.

Fountain and Osorio-Urzua (2001), (see their study for details of assumptions and calculations) report some examples of the volume of savings to be expected in G2C and G2B areas. For G2C, they report that web-based tax processing alone could generate savings of $2.83 billion a year in the US for the period 2000-2006. These savings are equivalent to 0.031% of GDP –in 1999 US dollars-.

To calculate the savings from G2B, Fountain and Osorio-Urzua adopt some estimates produced by Goldman Sachs. These estimates of 'government spending to business' report a value of $1.65 trillion for the year 1998, with only 0.3% of these being carried over the Internet. Their projections estimate this spending to grow to $2.09 trillion, of which 4.5% will be online by 2001.

The economic impact of the Internet on Government-to-Government (G2G) is potentially enormous, yet poorly understood and estimated. Conservative predictions would lead us to expect that gains would accrue from at least three categories: lower transactions costs, efficiency gains as a result of network externalities, and new operational possibilities enabled by the Internet.

For example, the use of electronic mail alone is reported as having generated an annual average saving of $9,000 per office worker, or productivity gains of about 15% (Fountain and Osorio-Urzua, p 237). They quote estimates from a report by Ferris Research that found that an office worker saves, on average, 381 hours a year by using e-mail, while losing 115 hours, with a remarkable positive balance of working time saved.

Quite dramatic examples of transactions costs reductions come from cost differences between traditional paper operation and web-based operation. According to E2Gov.com, a provider of e-government software and services online, bill payment is between 67.2% and 95.6 % more efficient than paper-based operations (Fountain and Osorio-Urzua, p 238). The US Department of Commerce estimates that the cost to the Government of processing a payment would be reduced from $1.65-$2.70 to $0.60-$1.00 for web-based operations.

Positive network externalities might increase the value of the estimated savings. The larger the number of users of web services, the greater the benefits of using them – for example, for electronic mail the benefits to users increase with the number of other users they can reach.

Adding the cost savings estimates from the two sectors G2C and G2B, with the first only including tax processing savings, yields an estimate of $59.78 billion from 2000 to 2004, that is $11.96 billion per year. These 'highly conservative' estimates of cost savings represent the 0.13% of GDP. To these one should add the gains deriving from G2G discussed above, where, these authors expect, major results could be obtained in terms of cost savings and higher efficiency, but these will depend on internal organisational and structural change, and cannot really be estimated.

Infrastructure though is potentially a limiting factor for the development of e-Government. The speed and reliability at which transactions can be completed are of paramount importance. Hence, funding of electronic infrastructure that might enable the expected efficiency gains is perceived as a constraint towards the achievemt of the development of e-Government. Asymmetric funding in different federal states, the authors warn, might develop an asymmetric network, and therefore hinder the generation of network externalities, which are at the heart of the process generating the expected efficiency gains. This is especially so because the costs savings of e-government depend on penetration, or usage, growth of the Internet by businesses and the public as well as the government. The higher the degree of penetration, the higher the benefits to be expected.

The cases illustrated above are only a small number of many sectors and subsectors that might experience large gains from the development of electronic networks, and broadband. Many of these however do not directly contribute to GDP, and their impact on social welfare cannot be measured. One such case is the educational sector.

This is a sector where the wide introduction and penetration of broadband is probably going to produce a very large contribution, as most part of the material used for educational purposes cannot easily be provided on low bandwith.

A considerable impact is to be expected on the supply of education as well as on the demand side. The supply will see both state schools and private educational institutions (e.g. postsecondary education). Goolsbee (2001) predicts that over the next ten years the number of people seeking postsecondary education in the US is expected to rise by almost 2 million, many of whom will be looking for distance education. The clear advantage on the supply side is that the marginal cost of providing on-line education is extremely low. The demand side is also likely to be generated by very diverse sources. Internet use in schools and related on-line education is likely to grow. Large demand is expected for IT training, executive education, and distance learning. The value to be expected from on-line education however, varies a lot depending on the type of educational program. Interesting programmes of electronic education have been introduced in some Brazilian prisons to rehabilitate young offenders.

One last relevant case worth mentioning is reported by Abernathy et al (1999). This study provides evidence of far reaching results from the introduction of new technologies in a way that was not envisaged when the new technology was adopted. Abernathy et al (1999) report that in the 1970s supermarkets adopted bar codes as a system to improve workers' productivity at checkouts. These barcodes later proved to be indispensable tools for information management: order of new stock, deliveries, and inventory management.

Finally, Litan and Rivlin (2001) suggest that there is a real potential for the Internet to enhance productivity growth over the next few years. The major impact to date according to their review has been felt in the reduction of costs and improvement of information flows across traditional sectors. The Internet constitutes an important tool to enhance business performance by improving management efficiency in many diverse ways. It can improve consumers' welfare by improving their choice and convenience, and by reducing prices as a result of promoting a higher degree of transparency (see the life insurance example referred to above). However, the real question is can this impact be measured? How large is it going to be?

Litan and Rivlin (2001) produce a table with some estimates including different industries on the basis of some studies conducted in the US (some of which are illustrated in our case studies above). These estimates of potential Internet-related cost savings are reported in Table 13.

Table 13 Estimates of Potential Internet-related Cost Savings

Sector	Annual cost savings in five years (billion 2000 US dollars)
Education	Not clear
Financial Services	19
Government	At least 12
Health Care	41
Manufacturing	50-100
Retailing	Not clear
Trucking	3-79
Total	125-251

Source: Litan and Rivlin (2001)

Litan and Rivlin's calculations suggest that the total cost savings for sectors that collectively account for about 70% of GDP range roughly between $125 billion and $251 billion. In the US economy, whose annual output is approximately $10 trillion (in 2000 US dollars), these correspond to savings of about 1.2-2.5% of GDP. This, they suggest, would correspond to annual gains in productivity of 0.25-0.5%.

5. Section C. The Literature on Investment in Infrastructure and its Applicability to Infrastructure Characterised by Network Externalities

A wealth of economic studies demonstrates the tremendous impact of investment in public infrastructure (e.g., electricity and gas networks, water and sewerage systems), on the economy.

Several studies address the question of returns to public infrastructure investments. An influential study by Aschauer (1989), estimated a production function on time series data and found a very large contribution of infrastructure to output. Aschauer suggested that the stock of public infrastructure capital is indeed a significant determinant of total factor productivity growth. He also found a striking relationship between the US productivity growth slowdown and the decline in the rate of growth of the public capital stock. These early estimates did have a large impact on the public policy debate in the U.S., as infrastructure is often cited as an answer to the problem of maintaining high labour employment levels.

Unfortunately, these early empirical results appear to collapse once more sophisticated econometric procedures are used[4]. The Aschauer model constitutes a classical production function approach and can be criticised for its failure to account for the appropriate causalities and correlations. For example the work by Holtz-Eakin (1993, 1994) and Garcia-Mila and McGuire (1992) demonstrates that the introduction of state-level fixed effects reduces the returns dramatically.

Similar results are obtained by Kelejian and Robinson (1994) and Pereira and Frutos (1995) who use other econometric corrections. Using a cost function model, Nadiri and Mamuneas (1996) show that the returns to public infrastructure are comparable to those of private investments. Hulten and Schwab (1984), (see also their 1991 study) estimate a production function for the manufacturing sector on state-level data. They found that most of the cross-state variation in value-added growth was explained by variations in the rate of private and capital accumulation, leading them to suggest that public infrastructure capital was irrelevant in explaining differences in productivity growth.

Balmaseda (1996) argues that the results found by Aschauer can be explained by simultaneity and aggregation biases. He shows that the claimed large positive effects of public investment on growth can be reduced to zero, if causality and aggregation biases are accounted for. Hulten (1994) offers several explanations for this empirical finding of zero return on public infrastructure. More recently, Fernald (1999) investigates the relationship between infrastructure (as measured by roads) and productivity. He finds that road-building explains much of the productivity slowdown through a one-time unrepeatable productivity boost in the 1950's and 1960's.

Röller and Waverman (2001) conclude that the available evidence regarding the returns from public infrastructure appears to be that the original high returns do not hold up once a number of econometric measures are employed.

Telecommunication infrastructure is intrinsically different from other types of infrastructure: information highways are different from transportation highways. One seemingly important characteristic of telecommunication technologies, which is not

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[4] For a survey of the infrastructure literature see Munell (1992) and Grammlich (1994).

present in other types of infrastructure, is the presence of network externalities*:* the more users, the more value is derived by those users[5]. Given that these network externalities are not equally present in public infrastructure in general, one might expect that telecommunication infrastructure investments lead to larger growth effects than have been found for the other types of infrastructures[6].

Another implication of such network externalities is that the impact of telecommunication infrastructure on growth might not be linear, as the growth impact might be larger whenever a significant network size is achieved. This would imply that positive growth effects might be subject to having achieved a 'critical mass' in a given country communications infrastructure.

The demand for products characterised by network externalities

Demand for software, electronic and telecommunication services is characterised by network externalities. This means that the demand curve has some peculiar features that are not present in 'normal' demand curves. Consumers' utility depends on the size of the network, i.e., the number of adopters, therefore, demand will depend on consumers' expectations on the number of adopters. Technically speaking, this implies that for the same price there can be different levels of demand depending on expectations, in other words we have multiple (Nash) equilibria. More specifically, in our instance we have two Nash equilibria, one with almost no adoption (only early adopters will acquire the new technology while the majority will not); or mass adoption (a sufficiently large number adopts the new technology to make everybody follow suit). One of the key variables in solving this 'chicken and egg' problem is the price. The 'critical number' of consumers might have a willingness to pay below the supply price, that is, supply and demand do not meet at a price that would ensure mass adoption, and thus the market could be locked in the low-adoption equilibrium. Pushing the market towards the high-adoption equilibrium might require a lower price. However, new technologies generally entail high costs, which are reflected in initially high prices. As the technologies develop costs come down, and similarly prices. This explains why sometimes it takes time for new technologies to cross the critical threshold. In monopolistic or oligopolistic markets

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[5] For instance, in transportation infrastructures no such (positive) network externality exist. In fact, there might be significant *negative* network externalities present in transportation due to congestion.

[6] The NIESR (2001) study reports that Crafts (2000) has shown that the contribution of ICT to output growth in the second half of the 1990s was 50% higher than the contribution of electricity over a comparable period.

suppliers sometimes decide to subsidise initial products/services to ensure that their market will converge towards the high adoption equilibrium. This for example was the choice of mobile telephony operators who decided to subsidise the price of handsets to boost their market in the UK. This strategy was not adopted in other countries (e.g. Italy) where the willingness to pay of consumers was much higher and such subsidies were not needed to make the market tip over to the high adoption equilibrium. An interesting example is the development of the installed base for fax machines (see Cabral, 2000). Available to consumers from the 1960's, the fax market reached a critical mass only in 1986, when the market tipped and suddenly reverted to the high-adoption equilibrium. Predicting when the market for broadband will reach the critical threshold that will make it switch from the low to the high adoption equilibrium is not a straightforward task. Adoption does not depend only on the cost of the technology, and the price to the consumers, but also on the stochastic changes to the cost which derive from new technology advancement and are not at all predictable.

Empirical studies on network externalities

Some studies have been conducted recently to investigate the impact of network externalities in different sectors. Goolsbee and Klenow (2000) examine the importance of local spillovers such as network externalities, and learning from others in the diffusion of home computers. They use data on 110,000 U.S. households in 1997, and find that people are more likely to buy their first home computer in areas where a high fraction of households already own computers or when a large share of their friends and family own computers. They suggest that these patterns are unlikely to be explained by unobserved individual traits or by area features. When looked at in more detail, the spillovers appear to come from experienced and intensive computer users. They are not associated with the use of any particular type of software but do seem to be highly tied to the use of e-mail and the Internet, consistent with computers being part of an information or communication network.

A very recent study presented at a conference on 21 November 2001 by Atrostic and Nguyen of the Center for Economic Studies of the US Census Bureau provides some very preliminary evidence on the effects of computer networks on US manufacturing productivity. This study uses new plant-level data on computer networks to estimate their effect on labour productivity across the manufacturing sector. It presents two main findings. First, that average labour productivity is higher in manufacturing plants with networks than in plants without networks. Second, that computer networks have a positive effect on labour productivity after controlling for other characteristics. The paper concludes that, depending on the model, labour productivity increases by 10%-20% in manufacturing plants that use computer networks.

All the features described above are characteristic of telecommunications infrastructure but not of other infrastructure networks. Thus, the results obtained from the study of other infrastructure networks cannot be extended to the case of telecommunication networks.

6. Section D The Impact of Broadband on the UK and the effects of Uncertainty on Investment

On 13th February 2001 the Office of the e-Envoy published '*UK online: the broadband future*', an action plan to facilitate the roll out of broadband and higher bandwidth services across the UK. The strategy sets out a new goal: for the UK to have the most competitive and extensive broadband market in the G7 by 2005. Further discussion of this goal can be found in the Pre-budget report by HM Treasury, reported here in Appendix 3.

Broadband represents additional bandwidth over and above the 56kbps generally provided by a standard dial-up modem[7]. This higher level of capacity allows 'always on' and higher speed access to the Internet. By means of this larger capacity new value-added services can be delivered to businesses and consumers.

As the case studies reported in Section B above suggest, it is to be expected that the benefits to businesses would mainly derive from reduction of transaction costs and improvements of productivity, among other things, due to easier access to consumers and producers. For consumers, on the other hand, broadband will allow services like video-on-demand, multiplayer games, streaming of audio and video, software distribution to be offered over the Internet, and a number of public services (e.g., education).

Broadband penetration in the UK, however, is still quite limited. The UK was ranked by the OECD as 22nd for broadband penetration at the end of 2000, as illustrated in Figure 2. According to the OECD (2001) report this is surprising given the early establishment of network competition in telecoms in the UK.

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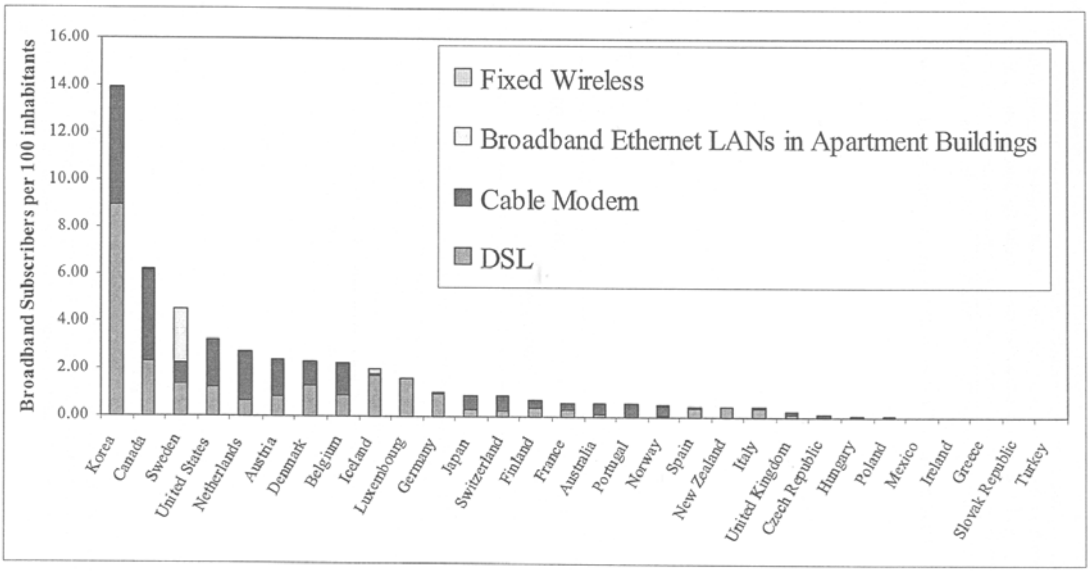
[7] For an accurate description of broadband see 'How broad is broadband' in OECD (2001).

Figure 2: Broadband penetration in OECD countries, June 2001



Source: OECD (2001)

There are two leading technologies used by subscribers to obtain broadband, cable modems and DSL (Digital Subscriber Line). Alternative technologies are available (for example in Sweden broadband is provided by Ethernet Local Area Networks, LANs, installed in apartment buildings). Satellite provision is an option, although it tends to involve higher prices and its first platforms were being installed in the US in 2001 to cover areas not serviced by terrestrial broadband networks. Fixed wireless broadband is also gaining market, though its adoption is still very low compared to cable and DSL. The high capital cost of wireless technologies could hinder the development of wireless broadband at present, given that capital markets are unlikely to finance any significant investments in new infrastructure following the financial collapse of this sector in 2001.

One of the key explanations for the fact that some countries are lagging behind in broadband adoption is the structure of the market. According to the OECD (2001) report, some countries have managed to achieve high levels of penetration because of the presence of competition between different networks with different technologies. This report suggests that competition is a necessary prerequisite for the development of broadband. In the UK, despite local loop unbundling (LLU), new entrants are lagging. This might be due to the current constrained capital market situation. On the other hand BT, the owner of the infrastructure, has been accused of 'dragging its feet' and delaying the introduction of DSL because this would have created a problem of cannibalisation of its ISDN revenues. As long as entry from competitors is not a threat, delays do not imply losing market share for BT. However, the UK is the only EU country to impose flat rate pricing for internet service. OFTEL suggests that UK consumers use less broadband but still have unmetred access which is unavailable in other countries.

Competition from cable has proven vital in other countries in order to overcome the delays induced by the late adoption of LLU and the lack of entry of new telecom operators providing broadband. Cable operators are present on the UK market, but, partly due to consolidation and partly to current financial constraints, these have not been very dynamic in promoting broadband. On the other hand, strict regulation of the incumbent could also constitute a crucial element in eliminating commercial incentives to commit large investments. The regulatory framework, as well as market structure, will have to be suitable in order to guarantee the growth of this market.

Industry structure has a crucial role to play in the development of the market for new technologies. The high degree of competition in the UK mobile telephony market, for example, is regarded as one of the most important factors that made possible large and fast diffusion.

Given the current low broadband penetration in the UK, the risk could be that further delays in investment will occur if the market follows existing incentives without government intervention. But is there a market failure that requires the government intervention? If the answer to this question is that there is no market failure to justify public investment, what would be the cost to the UK economy of missing out in the early development of broadband?

The answer to this last question is not clear. Despite the large amount of literature on the impact of ICT on the economy, no analysis has been conducted on the impact of broadband on labour productivity and growth. This is no doubt, simply because broadband is a very recent phenomenon, and reliable data are not yet available. However, given its current low degree of penetration of the market, growth accounting studies do not include in their estimates the impact of broadband. In the next section we suggest a way to obtain some estimates of the impact of broadband by means of a study aimed at correcting the data to include a quality deflator for telecommunication equipment in the UK.

Very few studies have been conducted on issues relating to broadband outside the literature discussing the asymmetric regulation of cable companies and telecom companies in the US for the provision of broadband.

In fact, estimating the value of broadband deployment, regulatory barriers, and subsidies to consumers and to the wider economy is rather arduous. One interesting study was conducted by Goolsbee (2000) at the University of Chicago. Goolsbee looks at various approaches to estimate the value of broadband to consumers. By extrapolating the results of a consumer survey conducted in 1999, he finds that the desirability of a subsidy programme for broadband depends on whether the subsidy simply incentivates consumers with low willingness to pay to subscribe or permits suppliers to overcome the high fixed –and sunk- cost of rolling out broadband to new areas. Goolsbee concludes that subsidising producers by means of a lump sum is superior to subsidising consumers.

This paper was criticised by Robert Crandall from the Brookings Institution, who remarked that, firstly, the study is based on old data from 1999, a year when broadband had a very low level of penetration; and secondly that Goolsbee's study does not attempt to assess the 'network effects' deriving from higher broadband penetration.

Based on the literature reviewed in Section A, and the discussion presented there, we suggested that investment in ICT infrastructure could lead to economic growth in several ways: (1) the investment itself can lead to growth because of the increase in the demand for goods necessary for the production of the infrastructure; (2) as infrastructure improves, the costs of doing business fall and output increases (see for example the impact of the telephone discussed by Hardy, 1980); (3) telecommunications infrastructure has important spillovers on other productive activities and thereby contributes to economic growth; nonetheless, the role of network externalities is the crucial element in this sector.

The importance of network effects for broadband is not yet clear. The evidence deriving from the cases illustrated in Section B does suggest that for the Internet to generate a success story it has to reach a critical mass. However, the marginal difference in generating network externalities between narrowband and broadband is not easy to calculate.

One could speculate that given the positive impact of the Internet in individual businesses and public services, the introduction of broadband will almost certainly have a net positive effect on the economy[8]. Microeconomic evidence from these

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[8] This magnitude will depend on demand and whether this will be large enough to generate network

sectoral cases can provide an indication of the impact to be expected at macroeconomic level. The magnitude of this effect, however, cannot be easily quantified, given the basis of the data and calculations available in the growth accounting literature.

Uncertainty and Investment in Broadband

Will broadband become an essential standard for the future of seamless telecommunications? It is extremely difficult to devise a long-term strategy when there are a large number of elements that are very hard to predict because of the high degree of uncertainty that characterizes them.

Uncertainty is a crucial element for new technologies. Will a new technology encounter high demand? What will be its rate of diffusion? Will it be a transient technology or a new pathbreaking one? Will it be profitable? And what will be its impact? Some of these questions can be investigated and some tentative answers in some cases can be provided. However, the crucial question for the telecommunications market is whether this new technology will become a universal standard. In other words, will it be adopted by a sufficiently large number of people that will induce the entire population to switch?

Demand for broadband is still subject to a very high degree of uncertainty. The consumers' willingness to pay has not yet met the supply price for a large majority. On the one hand, many consumers – particularly households – are not yet entirely clear about the value of the benefits that broadband offers to them as content has not yet fully developed, and available content is not actively marketed. On the other hand, consumers who stand to gain larger benefits might not yet have access to broadband, as is the case for small businesses in remote areas.

Uncertainty also holds for demand from Small and Medium-sized Enterprises (SMEs) despite the fact that the expected benefits are clearer than for households. SMEs could potentially experience large transactions costs savings and productivity improvements. Additionally, the price of broadband for SMEs should be less of a constraint to take-up than for households, as a result of specific government incentives that have been made available (see Appendix 3 in this report).

externalities, in a fashion that could be analogous to the text-messaging via mobile phones, which has produced a shift in demand beyond any predictions, resulting in almost complete market penetration. If this turned out to be the case, then there would be no need for public policy on broadband.

When there is uncertainty on demand in the market, as in our case, a private company (as well as a public institution) can maintain the option to invest in that market until some of the uncertainty is dispelled, thus an automatic incentive to wait is created. This option to wait has a positive value (see Dixit and Pindyck, 1994, for a thorough discussion of investment under uncertainty). Given current constraints on the capital markets, and uncertainty on demand, this "real option" theory of investment leads us to expect that commercial operators would delay their investment until their expected returns are less risky (real option theory looks at the variance as well as the mean of expected returns).

The cost of this delay to the UK economy is not clear. Some countries have decided to subsidise the provision of broadband and thus to spur adoption to speed up its penetration. The advantage of promoting the development of broadband could derive from network effects, but as mentioned above this cannot be estimated, as indeed it might turn out to be negligible with respect to narrowband. One reason to promote the development might be to avoid the potential "digital divide" between urban and rural areas. However, in this case too there would be an incentive to wait. Wireless technologies might develop and make access in rural areas feasible at lower costs than would be incurred by investing in fixed infrastructure. As long as there is a large number of sources of uncertainty, the market might be locked into a "low adoption" equilibrium.

An accurate study should be conducted in order to assess whether network externalities would be generated and their expected scale. We discuss this in Section E below.

7. Section E Research Agenda

A Desirable Research Agenda for Stage Two

Our review in Section A has highlighted the fact that analyses of the impact of ICT on productivity and growth have been conducted within traditional production theory. This methodology was originally derived from Solow in the 1950's, (for a discussion see the paper OECD, 2001, *Measuring Productivity- OECD Manual: Measurement of Aggregate and Industry-Level Productivity Growth*). The extent of ICT has been measured to date primarily by the spread of mainline telephones and the spread of computers and software. The measures of computer and telephone penetration differ across countries, and there is no systematic examination of how different measures of ICT account for differences in the impacts.

This constitutes part of the research agenda at the London Business School, where our plan is to compare different analyses and to account for measurement biases as well as to consider how the spread of ICT should be measured. Our research programme is to investigate the effects of ICT on the economy both at a macroeconomic and at a microeconomic level. Below we describe an ideal approach to investigating the questions discussed in this report. The timeframe for this ideal research programme would be 10-18 months.

Quah (2002) maintains that one of the problems with existing literature on ICT and the New Economy is the fact that it focuses on the supply side and on how it has changed (see Gordon, 2000). By contrast, Quah argues "*The New Economy is not only or even primarily a change in cost conditions on the supply side, then affecting the rest of the economy that uses that technology. Instead, it is the change in the nature of the goods and services to become increasingly like knowledge*," (Quah, 2002, p.16).

This paper shows that the link between technology and the consumer is a critical link for this industry. The demand side is more important than the poorly understood link between technology inputs and labour productivity improvements, which has given rise to a number of paradoxes (Quah, 2002). The importance of these goods (including, among others, the Internet, intellectual assets, electronic libraries and databases, biotechnology) is growing, both as a share of total consumption and in the number of consumers involved.

Furthermore, these 'intellectual assets' or 'knowledge products' are crucial to the understanding of the New Economy and command a shift of the attention on the demand side. In other words, the technology parameter, T, included in the production function:

$Y= F (K, L, T)$

-where: K= Capital, L=Labour-

has to be transferred into the agents' preferences. Thus, the utility function becomes :

$U = U(C, T)$

-where: C= Consumption-.

The understanding of consumers' behaviour is paramount for the understanding of the New Economy.

Jalava and Pohjola (2002) obtain statistical evidence consistent with Quah's demand side hypothesis, suggesting that (a) ICT **use** in the US during the 1990s provided benefits exceeding those of **production**; and that (b) in Finland the contribution of ICT **use** to output growth has more than doubled in the 1990s. These results are consistent with an endogenous growth from the interaction of demand and supply features, (Quah, 2002).

Following the indications of Röller and Waverman (2001), and Quah (2002), a desirable study should follow an endogenous growth approach. This approach would involve several stages. In a first stage the objective would be to specify both the demand and the supply side by means of a microeconomic formulation. This would be followed by a second stage wider macroeconomic analysis in an endogenous growth framework. Furthermore, the correct modelling framework applicable to the case at hand should take into consideration the fact that some variables might have to be endogenised by model estimations in order to account for simultaneous causation. Therefore in a third stage the precise nature of the relationship should be studied to correctly represent non linearities due to network externalities. This study would investigate the 'critical mass' level, and assess whether the evidence obtained would suggest the required size of the network to ensure that network externalities and ultimately, economic growth are achieved.

Regional/Sectoral/sub-sectoral specification

One of the risks for the economy is that the ICT revolution will create 'haves' and 'have nots', i.e., regions, industries, groups of individuals who do not have access to the new technologies, in other words, a digital divide. Furthermore, ICT is not just a productive input that affects all industries or all firms in the same way. It also changes the nature of industries' competitive dynamics, and re-defines the competitive drivers for corporate success. In order to gauge the impact of ICT, a fourth stage should examine the impact of ICT at regional/sectoral level, looking at the organisation of industries, the level of competition and regulation, and the organisation of firms as they are affected by the new technologies. Thus, the fourth stage would result in a multi-level investigation of how ICT is changing the division of profits at the industry, firm and economy wide levels. It is on these multiple-level impacts of ICT, on the real economic and business divide that ICT implementation creates that a proper analysis should focus on.

In a final stage, the objective of the investigation would be to quantify aggregate effects of ICT in a given economy over time in a panel of countries/regions, and/or in a panel of industries. This would identify how much of the variation in aggregate economic performance (not least GDP growth rates) can be explained by *both* cross-sectional and time series variance in the importance of ICT.

Data.

In recognition of the significance of e-commerce and its likely impact on the future performance of the economy, the UK Government set itself the target of becoming 'the best environment in the world to do e-commerce.' In response to this policy need, the Office for National Statistics (ONS) has developed a package of measures to help monitor the UK's progress towards this aim. In addition to the e-commerce inquiry, the ONS also carries out a monthly survey of Internet Service Providers to measure the change in levels of active subscribers to the Internet, and the type of connections used. A monthly index was published for the first time on 17 December 2001, showing the changes between January and October 2001 and this is updated on a monthly basis[9]. We would link with ONS and explore the data that has been compiled to date on ICT, in general and broadband in particular both at aggregate and firm level. Further data sources to be explored include: OECD, ITU (International Telecommunications Union), Office of the e-Envoy, the London School of Economics, and the Bank of England.

To sum up, an ideal project would be to adopt a novel approach integrating micro-economic considerations within a macro-economic model. Examining a panel of data on a number of countries/regions/industries will identify whether the impact of ICT on productivity and growth varies systematically, and whether its dimensions are global, local or sectoral.

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[9] http://www.statistics.gov.uk/themes/economy/articles/e_commerce.asp

A Feasible Research Agenda for Stage Two

The key problems for conducting reliable estimates in a short-term project on broadband investment are that this investment, is (1) very recent, and therefore does not provide long enough data series that could be used to conduct reliable econometric analysis, and (2) it is still too small a part of the total economy to produce a meaningful answer in aggregate terms.

In a short-term project we expect it would be feasible to conduct some analysis at both macro- and micro-level.

A) Macroeconomic study

It is objectively difficult to forecast the impact of ICT on economic growth because of the difficulties of forecasting the rate of growth of ICT expenditure and its volatility. This makes capital deepening resulting from ICT difficult to forecast, and the difficulty for broadband would be exacerbated by the fact that available data are not appropriate for such estimations. Below we describe a feasible approach to derive some estimates in a short-term project.

1 This project would consist of adopting a standard growth accounting approach. We would acquire the data adopted by Oulton (2001) and correct the telecommunications component of its ICT measure. This correction would be based on an adjustment of prices for 'quality' based on data for fiberoptics, which we would be able to acquire from fiberoptics providers Nortel, and JDS Uniphase. In this way we would obtain a form of hedonic prices for the quality of telecommunications equipment.

2 Having corrected the data with this quality adjustment we would estimate a growth accounting macroeconomic model and benchmark our results to Oulton's to derive the difference attributable to telecoms quality to be used as a proxy for the impact of broadband.

3 We would obtain data on future investment by talking to the industry and discussing the spending plans of the main industry players (the 3G licence holders and BT).

4 On the basis of the results from (2) and (3), we would estimate the impact to

be expected from broadband investment.

B) Microeconomic study

A short term microeconomic approach would complement the macroeconomic approach making it more robust and offering additional insights in to the sectoral behaviour and take-up. (Behavioural analysis by sector on Demand and Supply side would provide a basis from which to move to a later model to be developed for an endogenous growth analysis). It would consist of collecting evidence from different sources and deriving some tentative lessons on the demand and supply sides of the market for broadband. This would consist of three main steps:

1 Review all the studies conducted by the consulting firm "Analysis" for the Office of the E-Envoy, and derive:
   - (a) obtained evidence
   - (b) data (we have obtained the agreement of the Office of the E-Envoy to share their information and data with us)
   - (c) evidence on consumers' and producers' behaviour in the broadband market
   - (d) derive conclusions in view of estimates of the impact of broadband at the microeconomic level.

2 Review relevant studies concluded at LSE (Contact with Professor Robin Mansell has been established).

3 Collect data on levels of prices and adoption of broadband in different countries to investigate consumers' behaviour, i.e., the demand side of the equation and to understand whether the price variable would be the best instrument to achieve a "high adoption" equilibrium in the market for broadband. We would consider cases such as Korea, Switzerland and other countries where different pricing policies have been adopted.

8. Conclusions

Alan Greenspan, the Chairman of the US Federal Reserve Board suggested that Information and Communications Technology (ICT) had created the 'New Economy', an economy with high productivity gains, high economic growth and low inflation.[10] Even today, with recessionary tendencies globally, US productivity growth remains high. The same is not true for the UK.

The inquiry we propose is timely and important, as much of the evidence on the performance-enhancing effects of ICT is anecdotal, incomplete, or unreliable. Moreover, other than limited evidence for the UK, little of the positive effects of ICT experienced by the US appear in Europe. Why? Is it that the US is so much more ICT-intensive? Is it that the US already has an industrial structure that is compatible with the spread in ICT increasing productivity? Is it a measurement problem issue? Or, rather, is ICT affecting the US in a different way than it is affecting the rest-of-the-world, perhaps due to the management structures of US firms?

The answers to this multi-level question are most important because it may not be just connecting machines that aids productivity. Alternatively, are we now just beginning to see the effects of past ICT investment in Europe? Is there is a productivity boom about to occur in Europe generally and in the UK in particular? Or is the current slowdown on capital markets likely to affect the ability of the UK to experience future high levels of productivity and growth as experienced by the US in the second half of the 1990s?

In 1990, information technology industries (including hardware, software, and communications) accounted for 5.8% of U.S. gross domestic income. By 1999, those industries accounted for an estimated 8.2% of gross domestic income.[11] In contrast, in Europe, and the UK in particular, ICT industries were not nearly as important

[10] Alan Greenspan, "The revolution in information technology," speech delivered to the Boston College Conference on the New Economy, March 6, 2000; and Testimony before the Senate Banking Committee, as quoted in Richard Stevenson, "Pondering Greenspan's Next Move," *The New York Times*, Tuesday, March 21, 2000, page C1. In January 2001, Mr Greenspan testified to Congress that high productivity growth continues even though economic growth has slowed.

[11] See J. Stiglitz at al, The Role of Government in a Digital Age, Computer and Communications Industry Association, October 2000

producers of final goods.

More importantly, ICT seems to affect the performance of other sectors that make use of the newly found technological opportunities. Over the periods 1980 – 1990 and 1990 – 1995 real GDP grew at approximately the same rate in the UK as in the US (3.2% and 2.5% per year respectively in the 2 periods). However in the period 1995-1998, US economic growth accelerated to 4.5% per year but in the UK only to 3 % per year.

Oliner and Sichel (2000) concluded that investments in ICT and efficiency improvements in the production of computers explain more than two-thirds of the increase in productivity growth in the US between the early 1990s and the late 1990s. In that period, growth in computers per household and in Internet hosts accelerated in the US, widening the gap with other countries. As the OECD study *'A New Economy? The Changing Role Of Innovation And Information Technology In Growth'* states, this growth spurt in the US is not consistent with a catching-up story: the gap between the US and other countries such as the UK appears to be widening. The recent (February 2001) UK Government Report "UK Competitiveness Indicators", is consistent with the OECD analysis. It finds that 22% of all UK business trades online, ahead of all other benchmarked countries (section 3.11), "(t)here is evidence of a sharp pickup in ICT investment in the UK, but as yet little sign that this is boosting overall productivity performance in the same way that it appears to have done in the US" (section 5). UK GDP remains 21% below the G7 average and regional disparities are widening. "Between 1997 and 1999, the gap between the UK and the US (in terms of output per worker) widened" (section 5).

The use of the Internet within the UK shows wide disparities as well, with London based firms at 74%, strikingly above other regions such as Wales (48%) and Northern Ireland (44%)[12]. ICT's adoption by size of firm and industry also varies widely in the UK. Are these lags in the UK caused by a "digital divide" in the penetration of ICT in each region? Does ICT exhibit externalities of consumption? Or are the impacts of ICT really mediated from the industry structure and the ability of the value chain to be

[12] UK Competitive Indicators, February 2001 section 4.11

reconfigured? Or, finally, might it be that firm-level attributes explain these differences in productivity and profitability? What are the appropriate Government policies?

What are the implications of ICT for productivity and profitability? Many case studies report stories of industry transformation. And there is little doubt that the fortunes of industries and companies are significantly affected by these new technologies. To improve our understanding of these relationships and how they work, there is a clear need to focus not only on the aggregate-level impacts of ICT, but also on more micro-level data, on the industry and firm level of analysis.

As a potential Stage Two aimed at investigating the questions highlighted by this Stage One report, we specify a desirable study, of an approximate duration of 10-18 months, and a short-term feasible study, of an approximate duration of 6 months. These results derived from either approach to Stage Two should be of significant help in formulating solid economic policy.

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11. Appendix 1

Table 2a: Sources of labour productivity growth, 1973-95 and 1995-2000

Comparison of 1973-1995 with 1995-1999/2000

	CEA* (2000: Table 2.3)	CEA (2001: Table 1.1)	Gordon (2000: Table 2)	Gordon (2001: Table 2)	Jorgenson (2001, Table 8)	Oliner and Sichel (2000: Tables 2 and 4)	Whelan (2000: Table 4)
Period 1	1973 – 1995	1973 – 1995	1972 – 1995	1972 – 1995	1973 – 1995	1974 – 1995	1974-95
Growth rate	1.43	1.39	-	-	1.24	1.41	1.16
Period 2	1995 – 1999	1995 – 2000	1995 – 1999	1995 – 2000	1995 – 1999	1996 – 1999	1996-98
Growth rate	2.90	3.01	2.75	2.86	2.11	2.57	2.15
Acceleration in growth rate	1.47	1.62	1.33	1.44	0.86	1.16	0.99
Cyclical component (Period 2)	-	0.04	0.50	0.40	-	-	-
Acceleration in trend	-	1.58	0.83	1.04	-	-	-
Decomposition of	1.47 (Actual)	1.58 (Trend)	0.83 (Trend)	1.04 (Trend)	0.86 (Actual)	1.16 (Actual)	0.99 (Actual)
Contribution of:							
Price measurement	-	-	0.14	0.14	-	-	-
Capital deepening:	0.47	0.38	0.33	0.37	0.49	0.34	-
IT capital	-	0.62	-	0.60	0.52	0.50	0.46
Other capital	-	-0.23	-	-0.23	-0.02	-0.14	-
Labour quality	0.05	0	0.05	0.01	-0.12	0.05	-
Total-factor productivity:	0.93	1.19	0.31	0.30	0.5	0.80	-
IT-producing sectors	0.23	0.18	0.29	-	0.3	0.43	0.27
Other sectors	0.70	1.00	0.02	-	0.21	0.36	-
Per cent of acceleration in labour productivity growth attributed to ICT[a]	16-48	49	22-47	21-31	95	80	73

*= Council of Economic Advisors.

Source NIESR, 2001, Table2, Part A.

Table 2b: Sources of labour productivity growth, 1973-95 and 1995-2000

Comparison of 1990-95 with 1995-1999/2000

	Jorgenson and Stiroh (2000: Tables 3 and 5)		**Jorgenson (2001, Table 8)**		**Oliner and Sichel (2000: Tables 2 and 4)**	
Period 1	1990 – 1995		1990 – 1995		1991 – 1995	
Growth rate	1.37		1.19		1.53	
Period 2	1995 – 1998		1995 – 1999		1996 – 1999	
Growth rate	2.37		2.11		2.57	
Acceleration in growth rate	1.0		0.92		1.04	
Cyclical component (Period 2)	-		-		-	
Acceleration in trend	-		-		-	
Decomposition of	1.0 (Actual)		0.92 (Actual)		1.04 (Actual)	
Contribution of:						
Price measurement	-		-		-	
Capital deepening:	0.49		0.60		0.48	
IT capital		-		0.46		0.45
Other capital		-		0.14		0.03
Labour quality	-0.12		-0.20		-0.13	
Total-factor productivity:	0.63		0.51		0.68	
IT-producing sectors		0.19		0.25		0.37
Other sectors		0.44		0.26		0.30
Per cent of acceleration in labour productivity growth attributed to ICT[a]	19-68		77		79	

a = The denominator is taken as the actual increase in rate of productivity growth (not the trend rate, where estimated).

Source NIESR, 2001, Table2, Part B.

12. Appendix 2

Table 2c : Selected innovations in e-government services in the US

Access Washington (www.access.wa.gov)	State government web portal offering: technology procurement for state and local agencies; fraud reporting system; business and excise tax filing; criminal records search; unedited coverage of state government deliberations and events; vital records ordering; unemployment insurance benefits filing.
Washington State Enterprise	Internal agency budget development and monitoring Budget and Allotment tools. Reduces response time for budget proposals Support System (BASS) by 50 percent.
State of Georgia Georgia Net (www.ganet.org): TeachGeorgia.org	Renew professional licenses; www.permit.com: purchase hunting and fishing licenses and boat registrations Teacher recruitment site for Georgia public schools; students pay state university tuition online by credit card.
North Carolina (www.ncgov.com)	Three separate Yahoo-integrated state portals for citizens, business, and state government employees.
Virginia (www.state.va.us)	Allows users to create a customized "My Virginia" homepage linking to government services and features selected by the user.
New York State (www.state.ny.us)	Offers 1,108 permits online for 187 types of business.
Maryland State (www.state.md.us)	More than 40 types of professional licenses may be renewed online.
City of Indianapolis (www.indygov.org)	Integration across agencies at the website level, use of geographical information systems, wealth of information, ease of use, range of interactive features.
Contra Costa County, California (www.co.contra-costa.ca.us)	Use of geographic information systems for customized mapping using assessor's office property parcels and values; school, police, and fire station locations; risk of natural disaster; environmental hazards; and political districts. Use of visual information for identification and adoption of stray animals.

Source: Fountain and Osorio-Urzua (2001)

13. Appendix 3

Source: http://www.hm-treasury.gov.uk/Pre_Budget_Report

Broadband

The UK is one of the most connected economies in the world, with higher internet use than any other major European country. Broadband provides new opportunities and the Government's ambition is for consumers, firms and the public sector to take the fullest advantage of its potential benefits.

Take-up will undoubtedly rise as the benefits become available. The challenge is therefore primarily one for industry - to stimulate demand for innovative services, to be responsive in satisfying that demand and to offer choice. The market is the best mechanism for achieving this. The Government's broadband target is to have the most extensive and competitive broadband market in the G7 by 2005, with significantly increased connections to schools, libraries, further education colleges and universities.The Government's role is to set the right framework for that market, promoting competition where possible and regulating effectively where not. The Government also has important, but tightly defined, roles as a purchaser in its own right for public services and in helping firms and others make the most of new technology. The Government is already taking action in a range of areas:

- **teleworking**: personal benefits' taxation was relaxed in 2000 in relation to employees working at home, assisting in the provision of broadband connectivity to home teleworkers;
- **capital allowances for broadband**: small enterprises can now take advantage of 100 per cent first year capital allowances up to 2003, and SMEs permanent 40 per cent first year allowances, for capital costs of broadband connections. Firms can obtain tax relief on non-capital expenditure incurred in establishing and maintaining broadband connectivity. These rules also apply to employers paying for broadband connectivity at an employee's home;
- **regional schemes**: £30 million has been allocated to the RDAs and the devolved administrations to take forward innovative schemes to extend broadband networks and encourage the use of broadband by business and consumers; and
- **public purchasing:** the Office of Government Commerce has been asked to look at what more might be done to help government departments buy broadband more effectively.

In addition, the Government has been working with the Broadband Stakeholders Group to develop a long-term strategy based on this pro-competition, market-based approach.