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Economic Growth in the New Economy

Evidence from Advanced Economies

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Abstract

By definition, the 'New Economy' is an economy where business firms have learnt to take advantage of both the ICT revolution and the globalization of business activities in ways which improve productivity. First, by surveying recent research findings, this paper confirms that both the production and use of ICT have been the factors behind the improved economic performance of the United States in the 1990s. The benefits from ICT use are likely to have exceeded the benefits from ICT production. However, the evidence for the New Economy is much weaker outside the United States. In the other G7 countries, the contributions to output growth from the use of ICT have generally been less than half of the contributions estimated for the US.

Second, the paper estimates the contributions from the use and production of ICT to output growth in Finland which is one of the leading ICT producers in Europe. It is shown that the contribution from the use of ICT to output growth in the market sector has increased from 0.3 percentage points in the early 1990s to 0.7 points in the late 1990s. In addition, the fast growth of multi-factor productivity in the ICT producing industries has had a substantial growth contribution which has been at least as large as that from the use of ICT. However, unlike in the US, there has been no acceleration in the trend rate of labour productivity in Finland. Other factors, notably the decline in the use of non-ICT capital per worker, have offset the productivity-enhancing impact of ICT. In this sense, the New Economy is yet to demonstrate its strength.

Keywords: growth accounting, economic growth, ICT, information and communication technology, information technology, IT, new economy, productive capital stock, productivity

JEL classification: O3, O4, O5

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1 Introduction

The popular view is that information and communication technology (ICT) will change the world by boosting productivity and economic growth. But while ICT has many visible effects on the modern economy—the growth in electronic commerce and in Internet use for example—its impact on productivity and economic growth has been surprisingly difficult to detect. Although investment in ICT has exploded since the mid-1970s, aggregate productivity growth remained sluggish until the mid-1990s in the United States which is the world's leader in both the production and use of ICT. Therefore, many policy-makers and economists have taken the strong performance of the US economy in the late 1990s as most welcome evidence for the view that the large investments in ICT have finally started to pay off. It is generally believed that the United States has become a 'New Economy' in which business firms have learnt to take advantage of both the ICT revolution and the globalization of business activities in ways which improve productivity. Indeed, the growth rate of labour productivity has doubled in the late 1990s.

The defining characteristics of the ICT revolution are the fast improvement in the quality of ICT equipment and software, and the concomitant sharp decline in their quality adjusted prices. For example, in the United States the price of computer investment declined 18 per cent per year in 1960-95 and 28 per cent per year in 1995-98 (Jorgenson and Stiroh 2000). Profit maximizing firms respond to the change in relative prices by substituting ICT equipment and software for other capital equipment and structures. A larger portion of investment will be in assets with relatively high marginal products, and the aggregate capital service flow increases. This increase in capital intensity raises labour productivity in the ICT using industries. The standard argument for the fact that it has taken so long for the productivity impact to show up in the productivity statistics is that firms have not yet invested enough in ICT (see, e.g., Oliner and Sichel 2000). Even if information and communication technology investments earn hefty returns, the share of nominal income accruing to computers has been rather small until recently.

Besides improving productivity in the ICT using industries, the rapid technological advance should also raise productivity in the ICT producing industries and, consequently, should contribute to productivity at the aggregate level as well. Consequently, the mechanisms underlying the structural transformation of the industrial economy into a 'new', ICT-based economy are easy to understand by applying the basic principles of economic theory. The problems lie on the empirical side.

Growth accounting is the standard technique for assessing the impacts of both the use and production of different types of assets including ICT. The method is briefly reviewed in the next section. Sections 3 and 4 take stock of the productivity debate by reviewing recent research on the impacts of both the use and production of ICT in the United States and other advanced countries. Section 5 contains the findings of our own application to explaining economic growth in Finland. This country is of special interest because it is one of the leading producers of ICT in Europe and is sometimes regarded as a model country in ICT consumption as well. It is well known that Finland ranks among the top countries in the world in terms of the number of Internet hosts and mobile phones per capita.

2 Accounting for ICT's contribution to output and productivity growth

Information and communication technology is both an output from the ICT producing industries and an input into the ICT using industries. Therefore, to assess ICT's contribution to economic growth, it is helpful to express the aggregate production function in the form

$$(1) \qquad Y(Y_{ICT}(t), Y_O(t)) = A(t)F(K_{ICT}(t), K_O(t), L(t))$$

where, at any given time t, aggregate value added Y is assumed to consist of ICT goods and services Y_{ICT} as well as of other production Y_O. These outputs are produced from aggregate inputs consisting of ICT capital services K_{ICT}, other capital services K_O and labour services L. The level of technology or multi-factor productivity is here represented in the Hicks neutral or output augmenting form by parameter A. Assuming that constant returns to scale prevail in production and that product and factor markets are competitive, growth accounting gives the share weighted growth of outputs as the sum of share weighted inputs and growth in multi-factor productivity (see, e.g., Jorgenson and Stiroh 2000):

$$(2) \qquad \hat{Y} = w_{ICT}\hat{Y}_{ICT} + w_O\hat{Y}_O = v_{ICT}\hat{K}_{ICT} + v_O\hat{K}_O + v_L\hat{L} + \hat{A}$$

where the ^-symbol indicates the rate of change and where, for the economy of notation, the time index t has been suppressed. The weights w_{ICT} and w_O denote the nominal output shares of ICT and other production, respectively, and they sum to one. The weights v_{ICT}, v_O and v_L also sum to one and represent the nominal income shares of ICT capital, other capital and labour, respectively.

It can now be seen from equation (2) that information and communication technology can enhance economic growth in the following three basic ways. First, the *production of ICT* goods and services contributes directly to the total value added generated in an economy. This contribution—$w_{ICT}\hat{Y}_{ICT}$ in equation (2)—is calculated by multiplying ICT's nominal output share by the growth rate of the volume of ICT production. OECD (2000) estimates that ICT goods and services typically constitute between 3 and 5 per cent of total GDP at current prices. But their contribution to output growth can be larger than what these shares imply when ICT industries grow faster than the rest of the economy.

Second, the *use of ICT* capital as an input in the production of other goods and services can also make a significant contribution to economic growth. The benefits from ICT use are even likely to outweigh the benefits from ICT production, which are limited to just one sector of the economy. As is shown in the next section, Oliner and Sichel (2000) estimate that almost one-half of the recent labour productivity pick-up in the United States is due to the increased use of ICT capital in the production of output in the overall economy whereas close to 25 per cent of the labour productivity step-up is due to multi-factor productivity improvements in the ICT industry. The standard way of estimating the growth contribution of ICT use is to treat ICT as a specific type of capital good in which firms invest and which they combine with all other types of capital as well as with labour to produce output. As shown in equation (2), the growth contribution of each input is then obtained by weighting its rate of change with a coefficient that represents its share in nominal income. ICT's contribution is thus $v_{ICT}\hat{K}_{ICT}$.

The third way in which information and communication technology can enhance economic growth is via the *impact of ICT industries on multi-factor productivity*. If the rapid growth of ICT production is based on efficiency and productivity gains in these industries, this contributes to productivity growth at the macro level as well. For example, Gordon (2000) argues that improvements in the production of computer hardware account for the entire acceleration in labour productivity which has occurred in the United States since the mid-1990s. The productivity impact of ICT production cannot, however, be directly deduced from equation (2) but the analysis has to be accompanied by an evaluation of the part of $\hat{A}$ attributed to productivity growth in the ICT industry. The problem with interpreting an increase in multi-factor productivity as being caused by technological change is, however, that other non-technology factors will also be picked up by the residual. Such factors include changes in efficiency, scale and cyclical factors and measurement errors.

To assess the contribution from ICT use and from multi-factor productivity improvement to the growth of labour productivity, let us denote the number of hours worked by *H(t)* and labour productivity by *Y(t)/H(t)*. The basic growth accounting equation (2) can be rearranged to

$$(3) \qquad \hat{Y} - \hat{H} = v_{ICT}(\hat{K}_{ICT} - \hat{H}) + v_O(\hat{K}_O - \hat{H}) + v_L(\hat{L} - \hat{H}) + \hat{A}.$$

It shows that there are four sources of labour productivity growth. The first one is ICT capital deepening, i.e. an increase in ICT capital services per hour worked, and the second source is other capital deepening. The third component is the improvement in labour quality which is defined as the difference between the growth rates of labour services and hours worked. The fourth source is a general advance in multi-factor productivity.

Equations (2) and (3) are based on the assumption that the private and social rates of return from the use of ICT capital are equal to each other. But they can also be applied in the case where ICT generates positive externalities. The benefits above those reflected in the measured income share cannot, however, be directly observed but will be captured by the multi-factor productivity residual $\hat{A}$. Consequently, there is no reason to expect such externalities to exist if increases in multi-factor productivity cannot be observed. And even if they can, the problem is that they may have been caused by other factors than those associated with externalities emanating from the use of ICT.

The growth accounting technique described above can be applied to incorporate the fact that the capital input is not homogenous but consists of heterogeneous assets. A dollar spent on new ICT equipment can provide more productive services per period than, say, a dollar spent on a new building. For any given type of asset, there is a flow of productive services from the cumulative stock of past investments. These flows are not usually directly observable but have to be approximated. The standard assumption in growth accounting is that service flows are in proportion to the stock of assets after each vintage has been converted into standard 'efficiency' units. The so computed capital stock is called the productive stock of a given type of asset (see, e.g. OECD 2001a). It is the appropriate measure for growth accounting, as it measures the income-generating capacity of the existing stock over a given time period. This concept differs from the wealth stock which measures the current market value of the assets in use.

Aggregate capital service flows can be estimated by using asset-specific user costs or rental prices to weight each heterogeneous asset and to account for substitution between them. Under competitive markets and equilibrium conditions, user costs reflect the marginal productivity of the different assets. They thus provide a means to incorporate differences in the productive contribution of heterogeneous investments as the composition of investments and capital changes (OECD 2001a). For example, as firms respond to fast declining ICT prices by substituting away from other capital equipment or structures and toward ICT equipment, a larger portion of investment will be in assets with relatively high marginal products, and the aggregate capital service flow increases. This can also be interpreted as an increase in the quality of capital (Jorgenson and Stiroh 2000).

The user cost of ICT capital services will also be needed in estimating the share of nominal income accruing to ICT capital. Unlike the wage share, it is not directly observable in income statistics. The user cost is obtained as

$$r_{ICT} = p_{ICT}(i + d_{ICT} - \hat{p}_{ICT}) \quad (4)$$

where p_{ICT} is the acquisition price of new ICT capital goods and $\hat{p}_{ICT}$ its rate of change, i is the internal rate of return and d_{ICT} captures economic depreciation. ICT capital's income share is then obtained as $r_{ICT}S_{ICT} / p_Y Y$ where S_{ICT} is the real wealth stock of ICT capital and p_Y is the output price.

3 Lessons from the United States

The performance of the US economy was remarkable in the 1990s. The trend rate of GDP growth rose from 2.5 per cent at the start of the decade to 4.5 per cent at the end. This rapid advance was accompanied by a substantial increase in the growth of labour productivity. The growth of output per hour worked in the non-farm business sector accelerated from around 1.6 per cent per annum before 1995 to almost 2.7 in the period 1996-99. By applying the standard growth accounting framework (3), Oliner and Sichel (2000) estimate that the growing use of ICT equipment and the efficiency improvements in computer production account for about two-thirds of this one percentage point step-up in labour productivity growth.

Table 1 summarizes Oliner and Sichel's (2000) findings on the contributions of the input factors to real non-farm business output for three time periods. Output rose at an average pace of about 3 per cent in the first two periods covering 1974-90 and 1991-95, and all ICT capital services accounted for about 0.5 percentage points of this growth. The contribution from computer hardware was the highest of the ICT components: about 0.3 percentage points a year. The third period, 1996-99, displays a significant change in the growth process. Output grew at the average rate of 4.8 per cent and the

ICT contribution increased to 1.1 percentage points per year. Computer hardware contributed 0.6, software 0.3 and communications equipment 0.2 percentage points, respectively. It is also interesting to see that since the start of the 1990s, ICT contribution to output growth has exceeded the contribution from the rest of the capital stock.[1] An increasing share of growth can also be attributed to multi-factor productivity whose contribution seems to have more than doubled in the late 1990s.

Jorgenson and Stiroh (2000) come up with estimates which are quite similar to Oliner and Sichel's. They show that in the late 1990s the growth contribution of computer hardware was 0.5, software 0.2 and communications equipment 0.1 percentage points per year. The discrepancies in the findings primarily reflect the slight differences in the time periods and output concepts. Jorgenson and Stiroh's output concept is somewhat broader than the one used by Oliner and Sichel, making ICT output shares lower.

But what explains the observed increase in the growth contribution from information and communications technology? In their previous analysis, Oliner and Sichel (1994) concluded that this contribution had been relatively small through the early 1990s, especially if one focused on computer hardware alone. The reason was that, in spite of the large investments, computers were still only a small fraction (3-4 per cent) of the existing capital stock, and, consequently, the share of nominal gross income accruing to computers was rather small, about 1 per cent. Now they find that this share increased to 1.8 per cent in the late 1990s. Similar increases are also observed for software (from 0.9 to 2.4 per cent) and for communications equipment (from 1.6 to 2.1 per cent). In conclusion, 6.3 per cent of income accrues to ICT capital, making it an important component of the capital stock in the US. This technology has diffused sufficiently widely to have a visible impact on aggregate economic growth.

Table 1
Contributions to real non-farm business output in the US, 1974-99

		1974-90	1991-95	1996-99
Output growth[1]		3.1	2.8	4.8
Contributions[2] from:	ICT capital	0.5	0.6	1.1
	Hardware	0.3	0.3	0.6
	Software	0.1	0.3	0.3
	Communications eq.	0.1	0.1	0.2
	Other capital	0.9	0.4	0.8
	Labour hours	1.2	0.8	1.5
	Labour quality	0.2	0.4	0.3
	Multi-factor productivity	0.3	0.5	1.2

Notes: [1] Average annual log difference multiplied by 100.
[2] Percentage points per year.
Numbers may not add to totals due to rounding.
Source: Oliner and Sichel (2000).

[1] The measure of the rest of the capital stock encompasses producers' durable equipment, non-residential structures, residential rental structures, inventories, and land.

Table 2
Alternative estimates of the source of the acceleration in labour productivity in the US in the second half of the 1990s

	Oliner & Sichel (2000)	Jorgenson & Stiroh (2000)
Change in the average growth rate of labour productivity	1.0	1.0
Contributions from:		
Capital deepening	0.5	0.5
ICT	0.5	0.3
Other	0.0	0.2
Labour quality	-0.1	-0.1
Multi-factor productivity	0.7	0.6
Production of ICT	0.3	0.2
Other production	0.4	0.4

Note: Numbers may not add to totals due to rounding.
Source: Sichel (2000).

Both Oliner and Sichel (2000) and Jorgenson and Stiroh (2000) also apply growth accounting to break down the observed one percentage point step-up in the growth rate of labour productivity between the first and second halves of the decade. The results are displayed in Table 2 which shows that the growing use of ICT capital accounted for almost half a point of the rise in productivity.

In addition, Oliner and Sichel (2000) observe that the rapidly improving technology for producing computers and embedded semiconductors has contributed another 0.3 percentage points to the acceleration. This second channel works through the multi-factor (A) productivity residual in the standard growth accounting model (3), and Oliner and Sichel estimate the impact of the efficiency improvement of computer and semiconductor production in a three-sector model. Taken together, these two factors—the use and the production of ICT—account for about two-thirds to four-fifths of the pick-up in labour productivity growth since 1995. Multi-factor productivity in the rest of the economy provided the remainder, with labour quality actually falling somewhat which is consistent with the marked expansion in employment in this period. Jorgenson and Stiroh (2000) analyse a broader set of 37 industries, but their findings about the productivity impacts of the use and production of ICT are again quite similar to Oliner and Sichel's.

Regarding the acceleration of the multi-factor productivity from about 0.3-0.5 per cent per year in 1974-95 to over one per cent per year in the late 1990s, Jorgenson and Stiroh (2000) conclude that its source can be traced in large part, but not entirely, to the industries which produce computers, semi-conductors and other high-technology equipment. There is, however, little evidence of spillovers from production of ICT to the industries using this technology intensively such as finance, insurance and real estate and other services. The reasons for the sluggish productivity growth in services are not self-evident. Productivity is, of course, difficult to measure in many service activities, and ICT is still a rather new technology, but it may also be the case that computers and telecommunications equipment are not very productive in some industries.

Gordon's (2000) view about the impacts of ICT on labour productivity is somewhat more pessimistic than either Oliner and Sichel's or Jorgenson and Stiroh's. He first attributes a sizeable part of labour productivity growth in the late 1990s to cyclical factors. Labour, being a quasi-fixed production factor, tends to adjust only partially during cyclical swings of output. Consequently, if output is growing faster than trend, then labour productivity is also growing faster than trend. Secondly, after making adjustment for ICT capital deepening and other factors, Gordon finds that there has been virtually no change in the rate of productivity growth outside of the durable goods manufacturing sector which accounts for 12 per cent of the US GDP. He concludes that, in the remaining 88 per cent of the economy, the New Economy's impacts on productivity growth are surprisingly absent and that ICT capital deepening has been remarkably unproductive. Consequently, the productivity impacts of ICT investments have been limited to the computer and other durable goods manufacturing sector. However, a recent study by Nordhaus (2001), based on a new dataset and on new methods of measuring productivity growth, confirms that there indeed has been a rebound in labour productivity growth in the US but that it is not narrowly focused in the ICT sectors only. Baily and Lawrence (2001) arrive at similar conclusions.

But if information and communication technology has been the key factor of the improved productivity performance of the US economy in recent years, when can we expect the ICT revolution to occur in the rest of the advanced industrial countries?

4 Lessons from the G7 countries

The principal problem in analysing the impacts of ICT is that, except in the US, national income and product accounts do not provide detailed enough information about ICT investment, quality-adjusted price indices and measures of the ICT capital stocks. As described above, there now exists a view of the role that ICT plays in the US economy, while even most other OECD economies still leave ICT out of the picture. The lack of data on other countries makes it difficult to make international comparisons that have to rely on alternative sources and use simplifying assumptions for purposes of comparison between countries. It also explains the bias towards the United States which is reflected in many studies in this field.

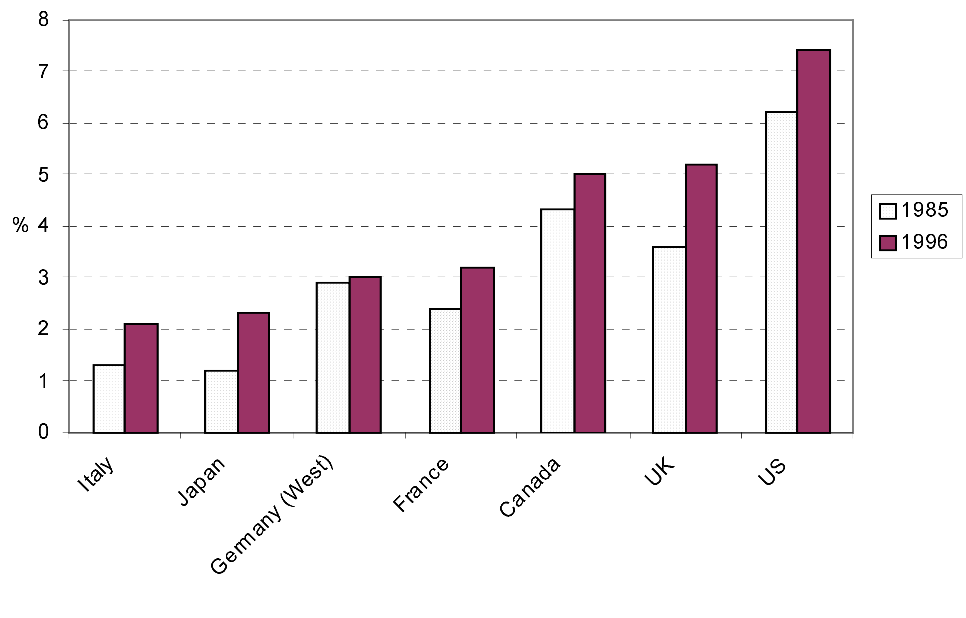
There are, however, some private providers of ICT data. For example, International Data Corporation (IDC) publishes an annual report on the status of the world-wide information technology market in about 50 countries. The report contains data, based on the revenues of primary vendors, on spending on computer hardware equipment, data communications equipment, computer software and computer services including both professional and support services. The data produced by private consulting and other agencies may not be as accurate and reliable as the national accounting data, but they have the advantage of a symmetric treatment of all countries.

Schreyer (2000) has tapped this data source for current price expenditure on ICT goods, software excluded, in the G7 countries. Indicators of ICT investment volumes can be obtained from such data by dividing current price expenditures with appropriate price indices, but the problem here is that methodologies to measure price change in ICT goods vary greatly across OECD countries. Schreyer has solved this problem by developing a common deflator for all the countries under investigation. It is based on the assumption that the differences between price changes for ICT capital goods and non-ICT capital goods are the same across countries. Under this assumption, information about the quality-adjusted ICT prices for the United States can be used in estimating similar prices for the other countries.

Given information about the age-efficiency patterns of ICT goods, the investment volume data can be used to estimate productive capital stocks for ICT goods. Schreyer (2000) applies an age-efficiency pattern that declines slowly in the early years of an ICT capital good's service life and rapidly at the end, similar to the ones used by the US Bureau of Labor Statistics and the Australian Bureau of Statistics.

Figure 1 displays Schreyer's estimates for the shares of ICT in the productive, non-residential capital stocks of the G7 countries.[2] In 1996, the share was the highest, 7.4 per cent, in the United Sates and the lowest, 2.1 per cent, in Italy. All the G7 countries have been adding to their IT capital stock at two-digit rates over the period 1979-96. However, only in the United States, Canada and the United Kingdom has this process of building up IT capital accelerated in the mid-1990s. With the exception of Japan, the G7 countries have accumulated communication technology capital at a much lower pace than IT capital, the average annual growth rate being 8 per cent in 1979-96.

Figure 1
ICT capital as a percentage of the productive capital stock



Source: Schreyer (2000).

2 Schreyer's measure of the capital stock encompasses non-residential structures, other non-residential construction, transport equipment, IT hardware, communications equipment, and other non-transport equipment. Software is not included.

Table 3 summarizes Schreyer's (2000) estimates of the contributions from ICT capital to output growth in the G7 countries in 1990-96. They are obtained by multiplying the annual growth rates of the IT and CT productive capital stocks by their respective income shares, by adding the IT and CT contributions together and by averaging over the period. In 1990-96, the ICT contribution to GDP growth was roughly 0.2 percentage points a year in France, Western Germany, Italy and Japan, 0.3 percentage points in Canada and the UK, and 0.4 percentage points in the US where it amounted to almost half of the contribution of the entire fixed capital stock. The growth contribution was larger in the US than elsewhere because both the ICT investment rate was higher and the ICT income share was larger there than in the rest of the G7 countries. The higher income share, in turn, reflects the larger share of ICT assets in the total capital stock, as shown in Figure 1.

Schreyer also shows that the ICT contribution has been relatively stable in all countries over the longer period 1980-96. But when considered in terms of a share in total output growth, its relative importance to economic growth has risen in all countries in the 1990s. Interestingly, however, as shown in the last row of Table 3, even the absolute contribution measured in terms of percentage points per year seems to have increased significantly in the US in the late 1990s, confirming Oliner and Sichel's (2000) findings.

Moreover, the new version of the System of National Accounts (SNA93) recommends treating computer software as gross fixed capital formation, and not as intermediate consumption as previously. Also the US has implemented this recommendation in its national accounts, making it possible to assess its contribution to output growth. Schreyer (2000) estimates that in 1996-98 software added 0.2 percentage points of growth to the 0.72 percentage points of ICT hardware displayed in the last row of Table 3. Consequently, ICT hardware and software accounted for a larger share of growth than the rest of the capital stock did.

Table 3
ICT contribution to output growth in the G7 countries, 1990-96

	Average annual growth rate of *			Income shares in 1996 **		Contributions to output growth from *	
	Total output	IT capital	CT capital	IT capital	CT capital	ICT capital	Total capital
Canada	1.7	17.6	4.3	1.5	1.3	0.28	0.7
France	0.9	11.0	2.1	0.9	0.9	0.17	1.0
West Germany	1.8	18.6	3.4	0.8	1.1	0.19	1.0
Italy	1.2	12.9	9.2	0.9	0.9	0.21	0.7
Japan	1.8	14.5	15.0	0.8	0.4	0.19	1.0
UK	2.1	17.6	2.2	1.5	1.6	0.28	0.8
US	2.7	23.8	5.1	1.7	1.9	0.42	0.9
US 1996-98	4.6	..	..	..	..	0.72	1.8

Notes: * = percentage points.
** = per cent.
.. = information not available.
Source: Schreyer (2000).

Schreyer's (2000) cross-country comparison raises at least two important questions. First, has the growth contribution of ICT been larger in those countries which are more advanced in the deployment of ICT than in the other G7 countries except the US? Second, has the growth contribution picked up in such countries in the late 1990s?

5 Evidence from Finland

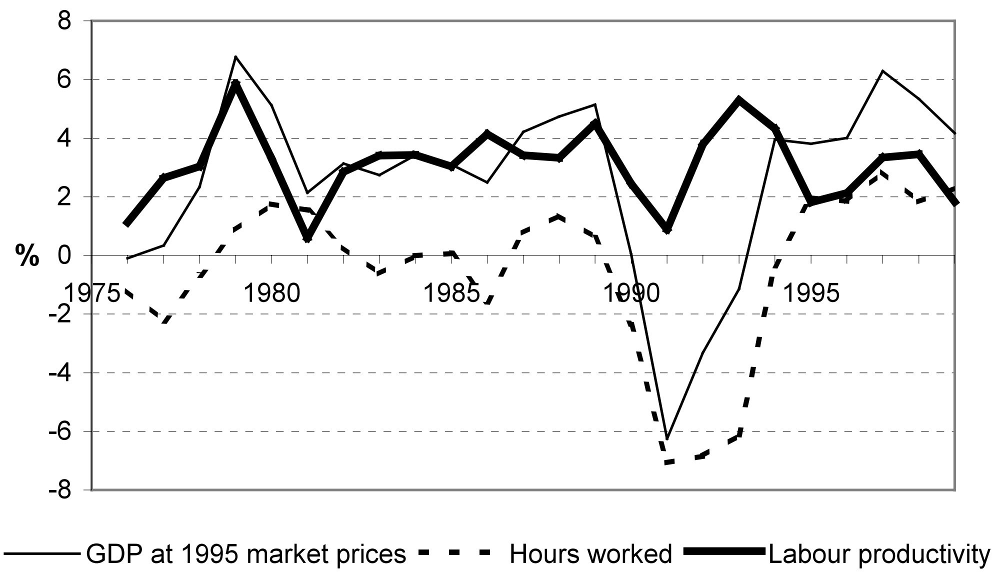
Finland is one of the leading ICT producers in Europe (see Koski, Rouvinen and Ylä-Anttila 2001), and it is sometimes regarded as a model for other countries in ICT consumption as well (Quah 2001). Indeed, it is well known that Finland ranks among the top countries in the world in terms of the number of Internet hosts and mobile phones per capita. However, not much systematic evidence is available about the impacts of the production and use of ICT in this country. The only macroeconomic analysis we are aware of is Niininen's (2001) growth accounting study in which he demonstrates, among other things, that IT hardware contributed 0.4 percentage points of GDP growth at the average annual rate of 2.4 in the period from 1983 to 1996.

Our aim here is to update and extend Niininen's (2001) findings in such a way that the results become comparable with the findings for the G7 countries reviewed above. Besides IT hardware, we also include software and communications equipment in our measure of the ICT capital stock. And, instead of using the net capital stock as the capital input measure like Niininen does, we estimate the productive capital stocks and apply them in the growth accounting analysis. In fact, this is the first time that productive capital stocks are estimated for Finland. As explained earlier, the productive capital stock is the appropriate measure for growth accounting as it measures the income-generating capacity of the existing stock over a given time period. This concept differs from the wealth stock which measures the current market value of the assets in use. The difference between these measures can be quite substantial for assets like computers which tend to lose their market value at a much faster rate than their income-generating capacity.

5.1 Growth contribution from the production of ICT

Figure 2 displays the annual changes of the volume of GDP, hours worked and labour productivity in Finland in 1976-99. The recession of the early 1990s was one of the most severe ever experienced in an industrial country in peacetime. The volume of GDP declined by 10.4 per cent between 1990 and 1993. Since 1994, GDP has grown at the average annual rate of 4.6 per cent which is substantially higher than the pre-recession rate of 3.0 per cent. However, similar acceleration cannot be observed in labour productivity which is here defined as real GDP divided by the number of hours worked. In fact, its annual growth rate has been smaller (2.5 per cent) after the recession than before it (3.1 per cent) although a substantial adjustment in the level of labour productivity took place during the recession years. At a first glance, it is difficult to detect any signs of the new economy in these time series, and it may be the case that the economy is returning to its trend growth path.

Figure 2
Annual growth rates of GDP volume, hours worked and labour productivity in Finland, 1976-99



Source: Statistics Finland's National Accounts Database.

It is well known that the production of ICT goods and services has played an important role in the recovery from the recession. As shown in equation (2), the direct growth contribution of the ICT industry can be calculated by multiplying the rate of change of its value added by its share in nominal income. To make the results comparable to those reviewed above, our analysis is confined to the market sector which encompasses non-financial corporations, financial and insurance corporations and unincorporated enterprises. Table 4 shows that the direct contribution to output growth from the production of ICT goods and services increased fourfold in the late 1990s amounting to two percentage points per year.

Table 4
Output contribution of ICT production in the market sector, 1975-99

	1975-90	1990-95	1995-99*
Output growth, %	3.2	-0.7	6.0
Contribution from ICT industries, percentage points	0.3	0.5	2.0

Note: * preliminary estimate.
Source: Statistics Finland's National Accounts Database.

Table 5 presents our definition of ICT industries and shows that their output share has increased steadily.[3] In 1999, the Finnish nominal GDP was 6.8 times as large as in 1975, but the nominal gross value added of ICT industries was 21 times as large as it was in 1975. Manufacture of radio, television and communications equipment and apparatus (i.e. ISIC industry 32) has been the real success story. Its nominal gross value added was more than 72 times as large in 1999 as it was back in 1975.

Table 5
Shares of ICT industries in the value added of the market sector, %

	1975	1980	1985	1990	1995	1999*
Manufacture of electrical and optical equipment:	2.1	2.0	2.6	2.9	4.8	7.9
Office machinery and computers (ISIC 30)	0.1	0.1	0.3	0.4	0.2	0.1
Electrical machinery (ISIC 31)	1.2	1.2	1.1	1.0	1.2	1.1
Radio, television and communication equipment (ISIC 32)	0.5	0.4	0.8	1.0	2.7	5.9
Medical and precision products (ISIC 33)	0.3	0.3	0.4	0.5	0.7	0.8
Telecommunications services (ISIC 642)	1.2	1.6	1.8	1.7	1.9	3.0
Computer software and services (ISIC 72)	0.4	0.6	0.9	1.2	1.3	2.1
Total ICT	3.7	4.2	5.3	5.8	8.0	13.0

Note: * preliminary estimate.

Source: Statistics Finland's National Accounts Database.

5.2 Growth contribution from the use of ICT

The growth accounting framework of equation (2) is applied next to assess the contribution to output growth from the use of ICT capital as an input in the production of other goods and services in the market sector. Our definition of ICT capital encompasses IT hardware, software and telecommunications equipment. Since Finnish national accounts data are not available on hardware and telecommunications gross fixed capital formation, the analysis is based on the ICT expenditure data published by the World Information Technology and Services Alliance (WITSA 2001) for the years 1992-99 and provided by International Data Corporation Finland for the period 1983-91. For the earlier years ITC expenditure was estimated using the ITC output shares for the first year for which data exist. As telecommunications expenditure in the WITSA dataset includes both investment and services, we follow Schreyer (2000) in assuming that a 30 per cent share constitutes a lower bound on the investment expenditure

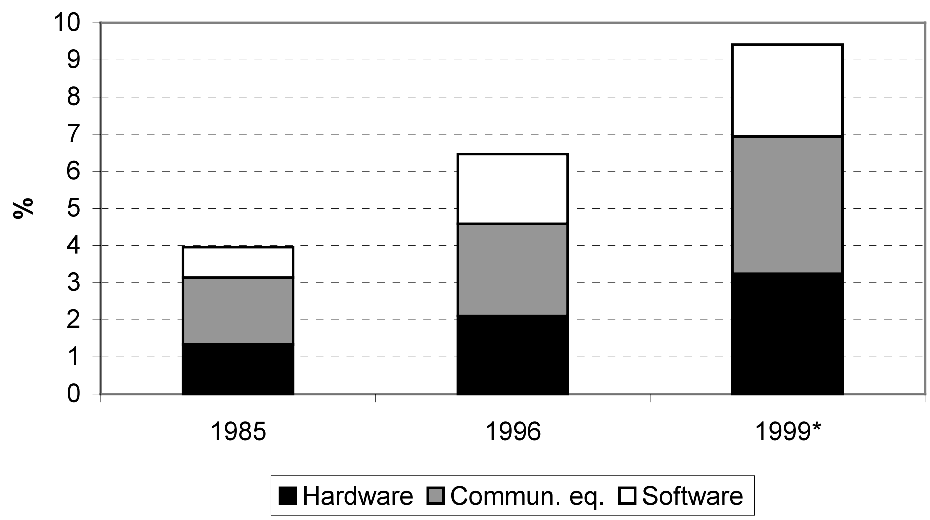
3 Because of problems with data availability, the ICT industries include neither wholesale trade in nor renting of office machinery and computers.

component in the total telecommunications spending. Information about software[4] investment was received from Statistics Finland.

To deflate the current price ICT investment series, we use the same US indexes as Schreyer (2000) for computer IT hardware and telecommunication equipment and correct them for the exchange rate changes.[5] The deflator for software investment is a weighted (50/50) average earnings index for industry computer and related activities and the pre-packaged software producer price index, corrected for the exchange rate, provided by the US Bureau of Labor Statistics.

Productive capital stocks are calculated by industry and asset type, and they are aggregated using their user costs—the rate of return *plus* depreciation *minus* holding gain—to get the appropriate measure of capital services (see Appendix for a more detailed explanation). Ten types of assets are distinguished, including the three ICT assets, transport equipment, other machinery and equipment, non-residential buildings and other structures. Residential buildings, consumer durables, inventories and land are not included. Hyperbolic age-efficiency profiles are applied to account for the loss in efficiency of the assets as they age. The rate of return needed for the evaluation of the user costs (see equation (4)) is estimated with the help of the accounting identity by which capital income equals the difference between value added and labour compensation. Given this estimate for the value of capital services, and given a measure of the capital stock, of depreciation and of capital gains, the rate of return is obtained as a residual.

Figure 3
ICT capital as a percentage of the nominal productive non-residential capital stock in Finland



Note: * preliminary estimate.
Sources: Statistics Finland's National Accounts Database and WITSA (2001).

4 Purchased and own-account software compiled using the commodity-flow method.

5 As the last year in Schreyer's analysis is 1996, we extrapolated the deflator series until 1999 by using the relative changes of the appropriate indexes obtained from the US Bureau of Labor Statistics.

Figure 3 displays our estimate of the shares of the ICT assets in the total productive capital stock. In 1999, about 9 per cent of this stock was in the form of ICT assets. Comparing Finland with the G7 countries shown in Figure 1, we have to exclude software and consider the latest year for which comparable data exist. In 1996, IT hardware and telecommunications equipment accounted for about 4.5 per cent of the Finnish productive non-residential capital stock. This share is close to the ones displayed in Figure 1 for Canada (5.0 per cent) and the United Kingdom (5.2 per cent) but well below the one for the United States (7.4 per cent).

As a measure of labour input we use hours worked adjusted for labour quality measured by the level of education. The hours worked are cross-classified by educational level, and the marginal product of each educational group is measured by the average salary of the group. Increases in labour quality reflect the substitution of workers with high marginal products for workers with low marginal products.

Table 6 presents the results of the growth accounting analysis. The entire period is divided into three subperiods. In the first phase, covering the years 1975-90, the value added of the market sector grew at the average annual rate of 3.2 per cent. ICT capital accounted for 0.2 percentage points of this growth. The second phase covers the first half of the 1990s and includes the deep recession in the Finnish economy. Market output declined, but the growth contribution of ICT capital remained positive averaging 0.3 percentage points per year. The third phase, consisting of the years 1995-99, depicts the rapid recovery from the recession. Output increased at the average annual pace of 6.0 per cent, and ICT capital's contribution doubled to 0.7 percentage points per year. Interestingly, however, the growth contribution from the rest of the capital services was still negative. This reflects the fact that capital was used rather inefficiently in the Finnish business sector in the past decades (Pohjola 1996) and that considerable improvement in its productivity has occurred after the recession.

A recent study by OECD (2001c) finds as well that the growth contribution from the use of ICT capital has doubled in Finland in the late 1990s. The output contribution was 0.58 percentage points in 1995-99. This is quite similar to our estimate of 0.7 percentage points. A closer comparison of these findings is, however, difficult because the OECD study does not describe the source of the ICT investment data.

When Finland is compared with the other countries analysed above, the following observations are immediate. First, in the period up to the mid-1990s, the contribution to output growth from ICT hardware was in Finland in the same range—from 0.2 to 0.3 percentage points per year—as in Canada and the United Kingdom. This contribution was, however, only about half of the level achieved in the United States. Second, just like in the US, the output growth attributed to the use of ICT, including software, doubled to 0.7 percentage points in the second half of the 1990s, but still remained at a level well below the US record of 1.1 percentage points per year. The panel in the middle of Table 6 shows the increasing importance of the ICT capital which is reflected in the rising income share attributed to this factor of production.

Table 6
Contributions to real output growth in the market sector, 1975-99

		1975-90	1990-95	1995-99*
Output growth[1]		3.2	-0.7	6.0
Contributions[2] from	ICT capital	0.2	0.3	0.7
	Hardware	0.1	0.2	0.4
	Software	0.1	0.1	0.1
	Communications eq.	0.0	0.1	0.1
	Other capital	0.8	-0.7	-0.4
	Labour hours	-0.4	-2.9	1.3
	Labour quality	0.2	0.2	0.3
	Multi-factor productivity	2.2	2.3	4.2
Income shares[1]	ICT capital	1.7	5.0	5.6
	Hardware	0.5	1.5	1.7
	Software	0.6	2.4	2.4
	Communications eq.	0.5	1.1	1.5
	Other capital	33.9	33.8	38.8
	Labour	64.4	61.3	55.6
Growth rates[1]	ICT capital	16.5	7.2	12.4
	Hardware	29.7	15.1	28.1
	Software	12.9	2.7	5.6
	Communications eq.	9.9	9.1	10.2
	Other capital	2.8	-2.1	-1.1
	Labour hours	-0.7	-4.5	2.3

Notes: * preliminary estimate.
1 per cent.
2 percentage points
Numbers may not add to totals due to rounding.

The third observation is rather surprising. In spite of the rapid accumulation of ICT capital, the growth rate of labour productivity declined in the Finnish market sector in the second half of the 1990s. This is seen from Table 7 which, by applying equation (3), displays the contributions of the production factors to the growth in labour productivity. It can be argued that its growth rate was unusually high in the early 1990s because of the structural adjustments which took place during the recession. But in the late 1990s labour productivity grew also at a lower rate than it did in 1975-90.

Table 8 looks for an explanation for the deceleration in labour productivity growth by contrasting the labour productivity trends in Finland and the United States. As noted above, the contribution from ICT capital deepening has been lower in Finland than in the US, but this cannot explain the observed fall in the growth rate of labour productivity. Also, the contributions from multi-factor productivity have had similar impacts in both countries, increasing rather than decreasing the pace of improvement in labour productivity. Consequently, the explanation lies in the decline of the amount of non-ICT capital per worker. As mentioned above, this reflects the fact that capital was used rather inefficiently in the pre-recession era. It is worth pointing out, however, that even in the late 1990s the growth rate of labour productivity was higher in Finland than in the US. It is not the level of this growth which is the problem but its declining trend.

Table 7
Contributions to labour productivity in the market sector, 1975-99

	1975-90	1990-95	1995-99*
Growth rate of labour productivity[1]	3.7	3.9	3.5
Contributions from[2]			
ICT capital	0.3	0.6	0.5
Hardware	0.1	0.3	0.4
Software	0.1	0.2	0.1
Communications eq.	0.0	0.1	0.1
Other capital	1.0	0.7	-1.3
Labour quality	0.2	0.2	0.3
Multi-factor productivity	2.2	2.3	4.2

Notes: * preliminary estimate.
[1] per cent.
[2] percentage points.
Numbers may not sum to totals due to rounding.

Table 8
Sources of the changes in labour productivity growth rates in the second half of the 1990s

	Finland	United States
Change in the average growth rate of labour productivity in 1995-99 over 1990-95	-0.4	1.0
Contributions from:		
Capital deepening	-2.1	0.5
ICT capital	0.0	0.5
Other capital	-2.1	0.0
Labour quality	0.0	-0.1
Multi-factor productivity	1.8	0.7

Notes: Percentage points. Numbers may not sum to totals due to rounding.
Source: Oliner and Sichel (2000) for the United States.

5.3 Growth contribution from productivity improvement in ICT industries

Regarding the comparison between Finland and the other countries, the final observation concerns the contribution to output growth from multi-factor productivity. As shown in Table 6, this has been quite large in Finland. Moreover, it has increased over time from 2.2 percentage points in 1975-90 to 4.2 percentage points in 1995-99. Although rising over time as well, the growth rates have been more modest in the United States: 0.3 and 1.2 percentage points, respectively (see Table 1). Schreyer (2000) finds growth contributions of equal size for the rest of the G7 countries in the first half of the 1990s, ranging from 0.4 percentage points in France to 1.3 in Germany.

International comparisons of multi-factor productivity should, however, be interpreted with caution. For one, the quality of the growth accounting data differs between countries and these differences will be picked up by the residual term $\hat{A}$ which is used as an estimate of multi-factor productivity growth. If, for example, the quality of capital and labour cannot be measured accurately, the measurement errors will be reflected in the residual. For another, this residual also picks up the impacts of other non-technology factors such as business cycles and changes in the scale and efficiency of economic activity. As already noted above, efficiency improvement may be one of the explanations for the fast productivity growth in Finland after the recession.

Leaving these problems aside, we could still try to trace aggregate multi-factor productivity growth to its sources in the productivity growth of individual industries following Oliner and Sichel (2000) and Jorgenson and Stiroh (2000). To do this properly, however, would require the estimation of the productive capital stock for each industry. Also, because industries differ from each other with respect to their use of intermediate inputs, the application of the so-called *KLEMS* growth accounting framework would be preferable instead of the one applied here which is based on measuring output in terms of value added. In the *KLEMS* approach, industry output is measured using a gross output concept and the inputs include capital services (*K*), labour services (*L*) as well as intermediate inputs, energy (*E*), materials (*M*) and services (*S*) (see, e.g., Jorgenson and Stiroh 2000). Unfortunately, adequate data are not available in Finland for measuring either the industry-level productive capital stocks or the intermediate inputs, and we have to be content with less satisfactory methods.

A recent OECD (2001b) study evaluates the contributions of ICT using and ICT producing industries to labour and multi-factor productivity growth in 11 member countries using OECD's STAN database and measuring output in value-added terms. For Finland, the study finds that about 20 per cent of the multi-factor productivity growth in the total economy can be attributed to the ICT industries in the 1990s. Using our estimate of productivity growth, this means that the contribution from ICT industries was 0.8 percentage points on average in the late 1990s. Adding this up with our estimate of the contribution from the use of ICT implies that the overall ICT contribution to output growth was 1.5 percentage points in 1995-99.

6 Conclusions

The research findings surveyed in the first part of this paper confirm that both the production and the use of ICT have been the factors behind the improved economic performance of the United States in the 1990s. The acceleration in the growth rates of labour and multi-factor productivity has not only been limited to the computer and semi-conductor producing industries but much—if not even most—of it has taken place outside this sector, i.e., in the industries using ICT.

The evidence for the New Economy is much weaker outside the United States. In the other G7 countries, the contributions to output growth from the use of ICT were less than half of the contributions estimated for the US in the early 1990s. Moreover, a recent update of these calculations (OECD 2001c) finds that the output contributions have increased only in the US, Australia and Finland in the late 1990s, being 0.9, 0.6 and 0.6 percentage points, respectively. The fact that Australia is not a significant producer of ICT can be taken as evidence that ICT production is not a necessary condition to experience the growth effects of ICT.

Our analysis of the Finnish growth experience confirms that indeed the contribution from the use of ICT to output growth in the market sector has increased from 0.3 percentage points in the early 1990s to 0.7 points in the late 1990s. In addition, the fast growth of multi-factor productivity in the ICT producing industries has had a substantial growth contribution which has been at least as large as that from the use of ICT.

However, in spite of the significant role played by ICT in the recovery from the deep recession, there has been no acceleration in the trend rate of labour productivity. Other factors, notably the decline in the use of non-ICT capital per worker, have offset the growth-enhancing impact of ICT. In fact, the growth performance of the Finnish economy has not been very outstanding when considered over the whole decade of the 1990s. The unemployment rate is now around 8 per cent, and the economy is still returning to its trend growth path. The New Economy is yet to demonstrate its strength.

What is it then that the US economy has and the others do not have to enable it to benefit so much better from the diffusion of ICT? Baily and Lawrence (2001) suggest that the answer lies in the fact that the US has globally competitive service industries seeking out new technologies to improve their productivity. ICT innovations have been driven by the demand for improved technologies in the using industries. But the productivity gains not only reflect increased investment in ICT, but also complementary innovations in business organization and strategy. This is what the New Economy is all about.

Appendix

This appendix explains how capital and labour inputs are defined and measured in the analysis carried out in the paper. For a more comprehensive coverage of the various concepts, see for example OECD (2001a).

Gross capital stock

Gross capital stock (*GS*) is the value of the capital used in production, valued at 'as new' prices, i.e. regardless of age or condition. Thus, the decline in the efficiency of fixed assets is not taken into account when calculating gross capital stocks. *GS* consists of the accumulated value of past investment less accumulated retirements of fixed assets. In Finland,[6] retirements are assumed to follow a skewed Weibull distribution. Thus, the survival function of the share of year *T*'s investments still in use at the end of year *t*, is assumed to be:

$$w_{t-T} = \exp\left\{-\left[\frac{\Gamma\left(1+(1/\alpha)\right)}{E}\tau\right]^{\alpha}\right\},$$

where $\tau=t-T+0.5$, E is average service life and α is a shape parameter. The subscripts for industry (i) and asset type (j) have been suppressed for notational simplicity.

The real gross capital stock at the end of year t is:

$$GS_t = \sum_{T\geq t-J_t+1} w_{t-T} I_T \ ,$$

where $T\geq t-J_t+1$, and I_T is the real gross fixed capital formation of year T. $J_t = max\{1.5\theta_t,100\}$, meaning that the maximum service life of a capital asset is assumed to be 1.5 times the average service life θ, but not more than 100 years.

Productive capital stock

Estimates of productive capital stocks have not yet been officially published by Statistics Finland, but they are still being developed. Following the US Bureau of Labor Statistics (1997) and the Australian Bureau of Statistics (2000), we use a hyperbolic age-efficiency pattern to construct productive capital stocks. The productive capital stock is defined as

$$K_t = \sum_{T\geq t-J_t+1} h_t w_{t-T} I_T \ ,$$

where $h_t = (E-A)/(E-(B)A)$ is the relative efficiency of a t-year-old asset, E is the average service life, A is the age of the asset and B is a parameter that defines the

6 See Statistics Finland (2000).

specific shape of the efficiency decline. This parameter is assumed to be 0.5 for equipment and intangible capital, and 0.75 for structures.

User cost

The user cost or rental price of capital is defined as the rate of return plus depreciation minus capital gain/-loss:

$$r_{ijt} = p_{ij(t-1)} i_{it} + p_{ijt} d_{ijt} - (p_{ijt} - p_{ij(t-1)}),$$

Here, for industry i and asset type j, r is the rental price, p designates the price index for new capital goods, i is the rate of return and d the rate of depreciation (i.e., real consumption of fixed capital divided by real wealth capital stock), and t denotes time.

There are two principal ways of estimating user costs. The opportunity or ex-ante approach uses some exogenous value of the rate of return i, for example the base rate of the central bank. The residual or ex-post approach estimates the internal rate of return i with the help of an accounting identity. Defining capital income to equal nominal value added less labour compensation,[7] and given information about depreciation, holding gains and capital stock, the rate of return can be estimated residually as

$$i_t = \frac{capital\_income - \{p_t d_t - (p_t - p_{t-1})\} S_{t-1}}{p_{t-1} S_{t-1}},$$

where S is real wealth capital stock and pS the nominal wealth capital stock, i.e., the market value of the capital stock. The wealth (or net) capital stock is the market value of the productive capital. It is calculated by subtracting the accumulated depreciation from the accumulated value of past investment. To estimate the rate of return, we use the ex-post approach. Ideally, individual rates of return should be calculated for different industries, but since we do not have a breakdown of hardware and communication equipment by industry, a single internal rate of return is calculated for the whole market sector.

Capital services

The user costs are used to aggregate the productive capital stocks by asset type (and/or by industry). We assume that aggregate capital services are a translog function of the services of individual assets (see Jorgenson, Gollop, Fraumeni 1987). Thus the aggregate volume index of capital services is:

7 This is the national accounts compensation of employees to which we added the labour income of the self-employed. This income component is estimated by using the hours worked by the self-employed multiplied by the average salary of employees.

$$c_{jt} = \frac{K_{jt}}{K_{j(t-1)}} = \prod_i \left(\frac{K_{ijt}}{K_{ij(t-1)}} \right)^{v_{ijt}},$$

where the weights ν are defined as

$$v_{ijt} = \left(\frac{r_{ijt} S_{ijt}}{\sum_i r_{ijt} S_{ijt}} + \frac{r_{ij(t-1)} S_{ij(t-1)}}{\sum_i r_{ij(t-1)} S_{ij(t-1)}} \right) / 2 .$$

Here c is the volume index of capital services and K and S denote the productive and real wealth capital stocks, respectively.

Asset types and service lives

The asset types and average service lives that we use for capital goods are shown in Table A1. With the exception of hardware and communications equipment, they are identical to the ones used by Statistics Finland. Capital goods (except hardware and communications equipment) are also classified by industry which explains the variations in service lives shown in Table 1. Household consumption goods, inventories and land are not included in our definition of capital goods.

Table A1
Capital goods' asset types and average service lives

Asset	Average service life in years
Non-residential buildings	20-50
Civil engineering and other structures	20-70
Transport equipment	7-25
Hardware	7
Communications equipment	15
Other machinery and equipment	5-32
Mineral exploration	10
Computer software	5
Entertainment, literary or artistic originals	10
Improvement of land	30-50

Labour input

As a measure of labour input we used hours worked adjusted for labour quality. The hours worked are cross-classified by educational level and by the average salary of each educational group. In aggregating the volume index of labour input it is assumed that the aggregate input is a translog function of the quantities of individual labour types:

$$\ln L_t - \ln L_{t-1} = \sum_l \overline{v_l}\left[\ln L_{lt} - \ln L_{l(t-1)}\right],$$

where the weights are given by the average shares of each labour type in the total value of labour compensation:

$$\overline{v_l} = \frac{1}{2}\left[v_{lt} + v_{l(t-1)}\right]$$

and

$$v_{lt} = \frac{p_{lt} L_{lt}}{\sum_l p_{lt} L_{lt}},$$

with p_l being denoting the wage rate of labour type l.

A six-category classification of labour by the level of education is applied. To obtain data on hourly wages by educational groups, we use the longitudinal census file for the years 1975, 1980, 1985, 1990 and 1995 (the intermediate years were interpolated). It contains information on 6.4 million people and their economic activities. For the years 1996-99, we use the labour force survey and the wage structure statistics. All data are adjusted to national accounts levels.

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