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Understanding Productivity and Income Gaps in the OECD Area: Are ICT and Intangibles the Missing Links?

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1. Introduction

The past six years of growth experience in the OECD area have shown a major break compared to the slow growth performance of the two decades or so before. Firstly, since the mid 1990s economic growth in most OECD countries, notably in the United States, has strongly accelerated. Secondly, across the OECD the differential in output growth and, more specifically, in productivity performance increased substantially. And, thirdly, the slowdown in growth during the years 2000 and 2001 affected countries' growth performance in quite different ways.

An analysis of these trends and the explanation for differences over time and across countries is important for several reasons. Productivity measures the effectiveness by which inputs (materials, capital, and labor) are transformed into output. This transformation process is accommodated for by continuous improvements in the quality of inputs through, such as a rise in education, the creation of knowledge, organizational changes within firms and the setup of societal networks. All these factors, which I refer to as intangible investments in the economy, facilitate allocation of inputs to its most productivity uses.

Productivity – in this paper, more specifically, labor productivity – is important for social progress in two different ways. The first and most obvious way is that, together with a greater use of labor, productivity positively contributes to per capita income, which is a reasonable proxy of living standards in a country.[2] A second and less obvious reason is that the accumulation of intangible capital itself may contribute to social progress, as workers get equipped with more

[1] This paper was written while residing as a Visiting Fellow at the Economic Growth Center at Yale University, and presented at a workshop on "Productivity and Social Progress in Canada: Perspectives and Prospective", Center for the Study of Living Standards, 25-25 January, Ottawa. Parts of this paper are based on earlier work, including Van Ark (2001a, 2001b), van Ark and McGuckin (1999) and McGuckin and Van Ark (2001, 2002). I am grateful to Thomas Rymes, Andrew Sharpe and other participants at the workshop for their helpful comments.
[2] See, for example, the various issues of the United Nations' reports on the Human Development Index. See also Banting, Sharpe and St–Hilaire (2001).

human capital, greater knowledge and access to networks which – ultimately – may even lead to the creation of more social capital.[3]

The present paper aims to contribute to developing a link between economic performance and social progress by reviewing some of the reasons for differences in growth and relative levels of productivity and per capita income between OECD countries. Figure 1 presents the conceptual framework to study sources of growth and productivity differentials. This framework is rooted in a traditional growth accounting framework but with several crucial extensions. Firstly, it shows the importance of both productivity and increased labor participation driving per capita income growth. Section 2 documents the most recent evidence on this with preliminary estimates up to 2001. It is shown that much of the recent growth in per capita income in Europe (and Canada) is driven by a rise in employment/population ratios although but partly offset by a decline in working hours per person. The strong rebound in employment growth in Europe since the mid 1990s has been quite welcome after many years of relatively low labor force participation rates. But the expansion takes place along a track of slow productivity growth. In contrast, the United States seems to have embarked on an expansion along a high productivity path in combination with greater labor utilization.

<Figure 1 about here>

To investigate the driving forces behind productivity growth, one can basically adopt two approaches or – ideally – combine both. The first is to look at the sources of growth from the perspective of factor inputs, in particular capital, and their contribution to productivity at the aggregate level. The second approach is to investigate the contribution of industries to productivity growth, which may be the result of either productivity advances within industries or shifts of resources from low-productivity to high-productivity industries.

In recent years various studies have argued that the recent American productivity advances are due to large investments in Information and Communication Technology (ICT) goods and services and large productivity advances in the ICT-producing sector of the economy (Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000; Jorgenson, 2001). Section 3 discusses the scarce results available so far on the contribution of ICT capital vis-à-vis other physical capital to

[3] See Van Ark (2001a) for a more extensive discussion.

productivity growth across countries. The evidence suggests a significant acceleration of ICT investment in most OECD countries, but the contributions of ICT capital to output and productivity growth are mostly lower in Europe (and Canada) than in the United States. Unfortunately for most countries we still lack data on ICT capital at the industry level to investigate whether the differences in ICT capital contributions are not at least partly due to a different industry composition, such as the United States having a larger ICT-production sector.

In Section 4 of the paper we therefore look at the contributions to aggregate labor productivity growth from the perspective of three subgroups of industries. These subgroups of industries are classified as producers of ICT goods and services, those that typically are intensive users of ICT, and those that are less intensive users of ICT. The results suggest substantial differences in the productive use of ICT. It also appears that the strong employment growth in Europe's economies, observed in Section 2, is mainly concentrated in those industries that are typically not regarded as big users of ICT. Productivity in this group of less-intensive ICT users grows more slowly than elsewhere in the economy, but more so in Europe than in the United States. Differences in ICT investment and intensity are therefore unlikely to account for the whole story of cross-country productivity differentials we are trying to unravel.

Figure 1 shows that within-industry productivity growth is driven by a second type of investment apart from physical capital, namely investment in intangible capital. Section 5 focuses on differences in the creation of intangible capital that may account for part of the cross-country differentials in productivity growth and levels. Although other classifications are possible, I distinguish between human capital, knowledge capital and organizational capital as components of intangible capital. Making use of recent numbers from OECD, which includes those components of intangible capital which are easiest to quantify (software, formal higher education and R&D) I only find a weak relation between intangible expenditures and either productivity growth or productivity levels. However, I also argue that it is more likely that a larger effect from intangibles is to be found in the organizational component of intangible capital. In the concluding part of the paper, I summarize the implications for the link between productivity and social progress and I outline the agenda for further research.

2. Labor Productivity and Income Performance in the OECD

Labor productivity and per capita income are two key measures of economic performance. Per capita income is a reasonable (but incomplete) proxy of living standards. The attractive feature of the per capita income measure is that it can be easily linked to labor productivity, thereby opening up the comprehensive framework of investigating the sources of growth by way of growth accounting. Differences between countries in terms of growth or relative levels of per capita income and labor productivity are determined by differences in the number of annual working hours per person employed and the share of the population at work. For example, even when two countries have the same productivity levels, the less intensive use of labor—fewer hours of work, more unemployment, and lower labor participation rates—can cause one country to have lower per capita income than the other.

This relationship can be conveniently expressed with the following decompositions that link differences in per capita income and productivity. First, the relative difference in per capita income, O/P, between two countries (X and US), is expressed as the relative difference in labor productivity times the relative difference in labor input per person, H/P:

$$O/P^{\,x\text{-}us} = (O/H)^{x\text{-}us} * (H/P)^{x\text{-}us} \qquad (1)$$

Second, the differences in working hours per person are decomposed into differences in hours worked per person employed (H/E), the number of persons employed relative to the total labor force, i.e. employed persons plus registered unemployed persons (E/L), the ratio of the labor force to all persons aged 15 to 64, i.e. the working age population ($L/P1564$), and the share of the active population in the total population ($P1564/P$) and the share of employment in the total labor force (E/P) (see van Ark and McGuckin, 1999):

$$(H/P)^{x\text{-}us} = (H/E)^{x\text{-}us} * (E/L)^{x\text{-}us} * (L/P1564)^{x\text{-}us} * (P1564/P)^{x\text{-}us} \qquad (2)$$

Table 1 shows the relative levels of GDP per capita and labor productivity in 2001. The countries are ranked according to their relative level of per capita income. These estimates are based on most recent but still preliminary estimates for GDP, employment and hours derived from OECD national accounts and labor force statistics. GDP is converted from national currency to US dollars at 1996 purchasing power parities.[4]

<Table 1 about here>

The estimates show that the United States has by far the highest per capita income level across the OECD. Norway comes next with as much as 17 percentage points (or 5,500 US$) behind the US level. The European Union as a whole is 33 percentage points (or 11,000 US$) behind the US income level. Canada's per capita income is 23 percentage points (or 7,500 US$) behind the U.S. per capita income.

Productivity differences between the United States and most follower countries are considerably smaller than per capita income differences. In fact as many as four countries have a higher level of GDP per hour than the United States, namely Belgium (4.5 US$ per hour higher), Norway (3.5 US$ higher), and the Netherlands and France (about 0.5 US$) higher. Indeed the productivity level of the European Union as a whole falls only 13 percentage points (4.5 US$) behind the US level, which is 20 percentage points less than the distance relative to the United States in terms of per capita income. About 12 out of the 20 percentage points difference between the EU/US productivity gap and EU/US income gap is explained by lower working hours per person employed in the European Union (1,609 hours) than in the U.S. (1,808 hours). Another 9 percentage points is due to a lower ratio of employed persons vis-à-vis total population, namely 0.43 percent in the European Union versus 0.49 percent in the United States. By far most of the difference in the employment-population ratio is due to the lower share of the labor force in the working age population ($L/P1564$).

In the case of Canada, the smaller productivity gap (18 percentage points) compared to the per capita income gap (23 percentage points) is for 3 percentage points due to Canada's lower

[4] For all underlying data and a complete source description, see the GGDC Total Economy Database (http://www.eco.rug.nl/ggdc/ index-dseries.html). All dollar-based estimates are expressed at 1996 price levels. This price measure is preferred because all national currency estimates are converted to US dollars on the basis of purchasing power parities (PPP) for 1996 (OECD, 1999). It should be emphasized that exact rankings are hazardous given the margin of error of the estimates. Countries within a range 1-2 per cent in terms of productivity and per capita income cannot really be distinguished. See also Section 5. There can be slight differences between the data used here and the data from national statistical offices. Our measures are largely derived from OECD sources (national accounts and labour force statistics) that are most comparable internationally but may differ from national sources, because the OECD numbers are less up to date or somewhat differently defined. For example, in the case of Canada, mainly because of a lower estimate for 2001, the productivity rates from the GGDC database are somewhat lower than those from Statistics Canada for the period 1995-2001, and therefore show a somewhat larger deceleration compared to the early 1990s.

working hours per person (1,789 hours) and for the remaining 2 percentage points due to its lower employment population ratio (0.47 per cent), with some offsetting effects between higher unemployment and lower labor force participation on the one hand, and a somewhat larger working age population share in total population on the other.

The lower levels of working hours and labor force participation rates in both the European Union and Canada relative to the United States in 2001 are characteristic of the 1990s (and indeed of the two decades before). Until 1997 labor force participation and working hours increased at a much slower rate than in the United States (Table 2). In contrast, until about the same time productivity in the follower countries increased faster than in the United States, reflecting their long run process of catching up since World War II.

<Table 2 about here>

Since 1997, however, labor force participation in Europe and Canada has increased more rapidly than in the United States but still it did not lead to a further narrowing of the income gap for at least two reasons. Firstly, in particular in Europe working hours per person continued to decline, because of labor time shortening schemes (such as in France and Germany) and the creation of many part-time jobs (such as in the Netherlands). Secondly, productivity growth in the United States zoomed ahead of both Europe and Canada since 1995, which is main the topic of the next section.

In conclusion there are at least two reasons that may contribute to slower income growth in Europe and Canada relative to the United States during the 1990s. The first reason is different labor market arrangements that led to an underutilization of the labor potential in Europe and Canada. This explanation dominated the differences in income trends until the mid 1990s. The second reason is slower productivity growth in Europe and Canada. This has been the main explanation for better income performance in the United States since the mid 1990s. The search for an explanation for recent differences in per capita income performance should therefore concentrate on the reasons for the differences in productivity growth since 1995.

3. The Role of ICT Capital

The rapid increase in investment in information and communication technology (ICT) is seen by many as a key explanation for the acceleration of productivity growth in the United States (OECD 2000a, 2001a). Some have stressed that this growth acceleration is to a large extent due to improved productivity growth in the ICT-producing sector (Jorgenson and Stiroh, 2000; Jorgenson, 2001). Others have demonstrated an increasingly productive use of ICT-goods and services elsewhere in the economy (Oliner and Sichel, 2000; Baily and Lawrence, 2001). Most authors, however, agree that investment in ICT has been high and widespread in the United States.[5]

Although the international evidence on the impact of ICT capital on growth is still sparse, there are some comparative growth accounting studies that compiled ICT investment as separate factor input. These studies mostly derive information on ICT expenditure from (private) data sources (e.g., Schreyer, 2000; Goldman Sachs, 2000; Daveri, 2001). The latter include consumer expenditure, which needs to taken out on the basis of crude assumptions to arrive at proxies for ICT investment.

Only recently first attempts have been undertaken to obtain genuine investment series for ICT (Colecchia and Schreyer, 2001; ECB, 2001). The top panel of Table 3 compares the acceleration of real investment growth in ICT in the United States, Canada and five European countries (Finland, France, Germany, Italy and the UK) between 1990-1995 and 1995-1999.[6] ICT investment includes IT goods, communication equipment and software. The figures show that throughout the 1990s growth in ICT investment was quite high and not only in the United States. Canada even experienced a faster rise in ICT investment than the United States during the second half of the 1990s. Moreover, many countries have been catching rapidly with U.S. investment in ICT, as Canada, Finland, Germany and Italy showed a faster acceleration in ICT investment than the United States.

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[5] However, that there are also critics who argue that ICT does not have the potential to raise growth by as much as the great innovations earlier in the twentieth century, such as the introduction of electricity, the combustion engine, etc. (Gordon, 2000). In addition, Gordon stresses that part of the growth acceleration in the United States is due to the pro-cyclical productivity effect in the upward phase of the business cycle during the second half of the 1990s. It is only after a complete cycle has passed that we can fully evaluate the growth impact of ICT.

[6] Studies on ICT investment and its contribution to growth for the whole of the European Union are not available. See Daveri (2001) for a study of proxy estimates of ICT investment based on expenditure information. See Mulder, Melka and van Ark (2001) for provisional estimates of ICT investment in 12 out of 15 EU member states.

<Table 3 about here>

To compute the contribution of ICT to productivity growth, one needs to transform the ICT investment numbers into a measure of ICT capital. This is usually done by cumulating the investment figures over the years and by applying certain assumptions on the service lives and scrapping patterns of the assets (the "perpetual inventory method"). Service lives of ICT capital goods are substantially shorter than those of other capital goods, which raises the pace at which old capital goods are replaced by new capital goods. Following Schreyer (2000) and Colecchia and Schreyer (2001), output growth (Q) can decomposed into:

$$\hat{Q} = s_L \hat{L} + s_{KC} \hat{K}_C + s_{KN} \hat{K}_N + \hat{A} \tag{3}$$

where L is labor input, K_C is ICT capital, K_N is all other physical capital and A represents total factor productivity with the latter being measured as a residual (the hats on the variables indicate percentage rates of change). Labor and capital services are weighted at the share of their respective revenues in total factor income.[7] The bottom panel of Table 3 shows the contribution of ICT capital (K) to output growth. With the exception of Finland, Colecchia and Schreyer find a higher ICT contribution for the United States than for the other countries.[8] Daveri (2001), who covers a larger group of countries but uses adjusted ICT expenditure proxies for investment, largely confirms these results. He finds that the contribution of ICT capital to GDP growth in European countries varied from between 0.31 and 0.64 percentage point during the period 1991-99, compared to 0.94 percentage points in the USA. In an earlier version of his paper, Daveri (2000) also showed estimates for non-European countries, including Australia and Canada, which

[7] In principle equation (3) can also be rearranged to obtain the rate of change of labor productivity: $\hat{Q} - \hat{L} = s_{KN}(\hat{K}_N - \hat{L}) + s_{KC}(\hat{K}_C - \hat{L}) + \hat{A}$. It is important to recognize that K and K_N represent the annual services that ICT capital and other capital goods deliver to output growth, which are weighted at the user cost of individual assets. The latter consist of the gross rate of return times the current price of the given asset. Gross rates of return on ICT capital are typically high to compensate for the rapid price declines of ICT goods. Hence the rapid growth of individual capital services from ICT and the rapidly increasing weights at which these enter the overall measure of capital services account for the increasing contribution of ICT capital to growth (see Schreyer, 2000; Colecchia and Schreyer, 2001).

[8] Finland, however, is a special case, however, as the production of communication equipment is a dominant feature of Finland's manufacturing sector.

showed ICT contributions as large as those for the leading group of European countries, such as the UK and the Netherlands.[9]

In this paper we do not go into many of the methodological details concerning the calculation of the contribution of factor inputs to growth, and the interpretation of total factor productivity which emerges as a residual from any growth accounting study. These have been the subject of a long debate which is very well summarized in a recent survey article by Hulten (2001). From the perspective of using ICT as a separate capital good in the production function, one of the most fundamental problems are the constant returns that characterize the production function and which assumes there can be no "supra-normal" returns from ICT beyond that of other capital goods.[10]

Another important issue concerns the assumption of Hicks-neutral technical change which assumes that technological progress increases output without changing the proportional distribution between the factor inputs. This viewpoint can be challenged for at least two reasons. Firstly, a distinction may be made between the fraction of investment required to keep the capital-output ratio constant (given the state of technology) and the fraction of investment that is induced by the innovations themselves. The latter represents the part of investment that contributes to the outward shift of the production function, and therefore represents technological change rather than accumulation.[11] Secondly, it is generally asserted that ICT is not neutral to the use of factor inputs, as it is typically characterized by a high capital-skills complementarity (Berman, Bound and Machin, 1998). Although the latter issue is relevant from the perspective of investment in intangible capital, which will be discussed in Section 5 of this paper, I have not tried to resolve the links between the factor inputs that go beyond just measuring but also explaining productivity differentials between countries.

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[9] See van Ark (2002) for a review. At national level, except for the US, growth accounting studies with ICT as a separate input, and based on actual investment data instead of reworked expenditure data, were carried out for Finland (Jalava and Pohjola, 2001), France (Mairesse, Cette and Kocoglu, 2001), the Netherlands (van der Wiel, 2001) and the United Kingdom (Oulton, 2001). The overall picture is one which suggests that most countries show somewhat lower contributions of ICT to economic growth than in the United States, with the exception of Finland.

[10] As a result, if there are any supra-normal returns on ICT capital, these end up in the TFP residual See Schreyer (2000) and Stiroh (2001) for a discussion of this issue.

[11] Here one speaks of an assumption of Harrod-neutral technical change, keeping the capital-output ratio rather than the capital-labor ratio constant. More specifically, following the Harrod-Rymes concept of technical change, the larger investment in ICT will not reduce growth of total factor productivity, but rather raise it as ICT improves the efficiency by which the capital goods themselves are produced.

At this stage if suffices to note that the figures reported in Table 3 suggest we get some way towards identifying ICT investment as one of the causes of slower productivity growth in Europe and Canada compared to the United States. However, even though for most countries the contribution of ICT to output growth is less than in the United States, one would have expected at least some acceleration in labor productivity growth. Instead, despite the acceleration of ICT investment, labor productivity in many European countries and Canada in fact *de*celerated.

4. The ICT-Use Differential

As many countries still lack the necessary statistics, disaggregation of ICT investment by industry is not possible in the framework of international comparisons. An alternative approach is to focus on labor productivity, which only requires output and employment data by industry. Van Ark (2001b) compares the contributions to overall labor productivity growth from three groups of industries, i.e. ICT producing industries, intensive ICT using industries, and industries that use ICT less intensively, hereafter referred to as "non-ICT" industries. This approach can shed light on the role of ICT in growth for several reasons. Firstly, a strong presence of ICT-producing industries (i.e. hardware and software producers), as is the case in the United States and Finland, is in itself an important explanation for a greater contribution of ICT investment to growth. Secondly, a large ICT-producing sector may facilitate the process of diffusion of ICT to industries that are major users. Thirdly, some industries in the economy are much more intensive ICT users than other industries. Big users of ICT are in particular found in business and producer services (McGuckin and Stiroh, 2001). These are relatively large industries, in which most of the employment creation of the past decade was concentrated, and which are therefore an important key to the acceleration of productivity growth. This also implies that a sectoral composition that is biased against those industries may be an important reason for slower productivity growth at the aggregate level.

The precise shares of the three ICT categories in total output depend on the definitions of ICT-producing industries and on the empirical distinction between ICT-using industries and non-ICT industries. ICT-producing industries are defined by OECD, and include computer hardware and software producers, computer services and telecommunication equipment and services (OECD, 2000b). For the definition of ICT-using industries, we used estimates of ICT-investment-output ratios by industry as well as the industry shares of ICT capital for two countries, i.e., the United States and the Netherlands.[12] About one third of industries with the highest ICT-intensity and/or the highest shares in the ICT capital stock are defined as ICT-using industries.

The first two columns of Table 4 show that the output shares of the ICT-producing sector are quite low across the board. Even for the U.S. the share of ICT production in total economy output is less than 7.5 per cent of current GDP in 1999. With the exception of Finland the shares of the ICT-producing sector in nominal output only slightly increased. The differences in output shares are mainly due to larger shares of ICT-manufacturing industries in Japan, the USA and Finland.

The third and fourth columns of Table 4 show the shares of ICT-using industries in GDP. The United States is again characterized by larger output shares than most other OECD countries except the Netherlands. However, the differences in output shares of the ICT-using sector are smaller than for the ICT-producing sector. The differences in shares between the ICT-using sector are due to differences in industry composition across countries. For example, the relatively high output share for the Netherlands is due to the larger share of chemicals in ICT-using manufacturing and of business services in ICT-using services.

<Table 4 about here>

To measure the contribution of the ICT-producing sector, the ICT-using sector and the "non-ICT sector" to the growth of labor productivity a traditional shift-share analysis was employed. This implies that labor productivity for the total economy (P) can be perceived as the

[12] The distinction between intensive ICT using industries and “non-ICT” industries is largely based on studies by McGuckin and Stiroh (2001) and the National Science Foundation (2000) for the United States. See Tables 4 below and van Ark (2001b) for the exact classification used here. Even though ICT-producing industries are also ICT-using industries (as the producers themselves also invest heavily in ICT), ICT-producing industries are excluded from the ICT-using sector in the analysis below. The distinction between ICT-using industries and “non-ICT” industries has two important limitations. Firstly, even though we use one and the same classification for all countries, ICT investment-output ratios and ICT capital shares are not distributed in the same way across countries. For example, even though retailing is within the non-ICT category in our classification, it would in fact fall within the ICT-using category in the United States. Secondly, ICT investment intensity may not always be the best criterion for determining the potential impact of ICT on productivity. In some industries even a small amount of ICT can generate high returns because of its leverage on existing activities. For example, in the oil extraction industry a small investment in ICT has fundamentally changed the methods by which this industry explores new oil reserves (Olewiler, 2002). Obviously the classification used here can be further tested for its sensitivity for other distributions, which is a topic for further research.

sum of the productivity contributions of three sectors (i) distinguished above weighted at their labor share ($L_i/L=S_i$):[13]

$$P = \frac{Y}{L} = \sum_{i=1}^{n}\left(\frac{Y_i}{L_i}\right)\left(\frac{L_i}{L}\right) = \sum_{i=1}^{n}(P_i S_i) \qquad (4)$$

Table 5 shows the contribution of the ICT-producing sector, the ICT-using sector and the "non-ICT sector" to the growth of labor productivity from 1990 to 1999, with the period being divided into two subperiods, 1990-1995 and 1995-1999.[14] In the United States, the ICT-producing sector and the ICT-using sector together accounted for almost two thirds of labor productivity growth during the most recent period 1995-1999 (0.6 + 1.4 as a share of 2.5). In all other countries, except Finland, the combined contribution of ICT production and ICT use was lower in absolute terms.[15] Table 5 also shows that in almost all countries ICT-production (with the exception of Denmark) and ICT-use (with the exception of Italy, and to a lesser extent Japan and the United Kingdom) contributed positively to the *acceleration* in labor productivity growth during the second half of the 1990s over the first half of the decade. However, in several European countries, notably in Denmark, Finland, Germany, Italy, the Netherlands and the United Kingdom, the non-ICT sector contributed negatively to labor productivity acceleration offsetting the positive effects from ICT-production and ICT-use. The mirror-image of the slowdown in productivity growth in the non-ICT sector is the rapid acceleration in employment growth in this part of the economy during the period 1995-99. Only in the U.S., employment expansion went together with a substantial labor productivity gain. These effects may relate to differences in the pace structural reforms in labor and product markets (McGuckin and van Ark, 2001).

<Table 5 about here>

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[13] In fact seven sectors instead of three are distinguished in the weighting scheme, i.e. ICT-producing manufacturing, ICT-producing services, ICT-using manufacturing, ICT-using services, other manufacturing, other services and remaining sectors (such as agriculture, mining, construction and public utilities). See Van Ark (2001b)

[14] For France, Germany and Japan the last period ended in 1998; for Germany the first period started in 1991.

[15] In Denmark, Italy, Japan, the Netherlands and the United Kingdom the *relative* contribution of ICT production and ICT use was higher than the two-third contribution in the U.S., but overall labor productivity growth in these countries was much slower. The relatively rapid productivity growth in Finland was largely accounted for by ICT-production.

In conclusion, this section shows that despite a somewhat smaller role for ICT-producing industries and a moderate positive growth effect from intensive ICT-using industries, the core of the productivity problem in Europe, Canada and Japan seems to be located as much in the non-ICT sector of the economy as in the intensive ICT using industries. The recent employment expansion in Europe has not been accompanied by the creation of productive activity in the same way as in the United States. Hence the focus of our analysis now needs to be directed to another type of investment which is currently seen as an important engine of growth, i.e. the creation of intangible capital.

5. Is Intangible Capital the Missing Link?

The creation of the knowledge-based economy is now at the top of the economy policy agenda of many industrialized nations. For example, the Lisbon declaration of the European Union in Spring 2000 identified the knowledge-based economy as the key for the creation of a competitive economy.[16] Policy-oriented research organizations, such as the OECD, have made research into knowledge creation a major priority on their research agenda.[17] The academic literature has also given renewed attention to the contribution of intangible capital to growth, even though the topic is not at all new.[18] The renewed urgency to deal with the issue is partly related to the rise of ICT. ICT is a typical general purpose technology, characterized by its broad scope of applications across the economy and its ability to generate a continuous stream of cost-reducing innovation (Bresnahan and Trajtenberg, 1995). Its successful diffusion is facilitated by investment in human capital, knowledge capital and organizational capital, together labeled as investment in intangible capital (Brynjolfsson and Hitt, 2000).

Despite its recognized importance, the problems concerning the conceptualization of intangible capital, its measurement and integration into a production function or growth accounting framework are still huge and largely unresolved. Various definitions of intangible capital are possible with different coverage but most definitions are offsprings from Schumpeter's

[16] See http://ue.eu.int/Newsroom/LoadDoc.asp?BID=76&DID=60917&LANG=1.
[17] For example, the OECD Growth Project has targeted knowledge creation as a pillar for sustainable growth. See also OECD, *Science, Technology and Industry Scoreboard* 2001and *STI Review* No. 27 (2001).
[18] See Ducharme (1998) for an overview of theory related to intangible capital which is rooted in human capital theory, theory on technical change, intellectual capital and new growth theory. Howitt (1996) and Diewert (2000) deal with the conceptualization of knowledge capital in a production function framework. Mortensen (2000) also discusses the growth accounting work related to intangible capital.

classification including the development of new products and production processes, organizational change, management, marketing and finance (Schumpeter, 1943). An important distinction can be made between a narrow and broad concept of intangible capital. The narrow concept mainly deals with human capital and knowledge capital (see Table 6). With the rise of the "new growth theory" during the 1980s and 1990s, these components can be rooted in mainstream neoclassical growth theory. New growth models have improved the modeling of increasing returns and interactions between input variables which are typical of intangible assets. The broader encompassing concept of intangible capital emphasizes the facilitating role of intangible capital in the search process for new technologies. It provides a clear role to the attributes of the entrepreneur and his ability to raise organizational capital.[19]

<Table 6 about here>

From a growth accounting perspective, which is pursued in this paper, the narrower concept of intangible capital is more attractive because of its roots in the production function and its focus on measurement of human capital and knowledge capital at the macroeconomic or industry level.[20] Howitt (1996) argues that knowledge creation can be treated as capital formation, because "(I)t can be produced, exchanged and used in the production of other goods, or in the production of itself. It can also be stored, although subject to depreciation, as when people forget or let their skills deteriorate, and subject also to obsolescence, as when new knowledge comes along to supersede it" (pp. 99-100). Diewert (2001) clearly defines knowledge in the context of production theory as "the set of input and output combinations that a local establishment could produce […] at […] given time period *t*" (p. 93). Hence investment in knowledge capital refers to an outward shift of the traditional production function referred to in Section 3 above.

Both Howitt (1996) and Diewert (2001) emphasize that the inherent measurement difficulties of intangible capital go, despite similar characteristics, beyond those of tangible capital. Howitt classifies those measurement problems as follows:

[19] The latter has its roots more strongly in evolutionary theory (see, e.g. Clement, Hammerer and Schwarz, 1998). Recently, the literature on the sources of growth has moved a step further by not only looking at organizational capital creation within the firm but also within the society as a whole, so-called social capital (see, for example, Helliwell, 2001; OECD, 2001b). Here I abstain from dealing with social capital as the problems concerning its conceptualization and measurement go beyond what can be accomplished in the analytical framework I am using for this paper. It should be noted, however, that as far as OECD countries are concerned, the empirical work has so far not shown large differences in the effect of social capital on growth (Temple, 1999).

[20] See Mortensen (2000) for an overview of growth accounting work including intangibles.

1) The knowledge-input problem, which concerns the measurement of the resources devoted to the creation of knowledge which can often not be distinguished unambiguously from other inputs, such as labor and capital.
2) The knowledge-investment problem, which refers to the output of the process of knowledge creation which is typically not measured at all because knowledge mostly does not directly produce a commodity or service.
3) The quality improvement problem, which relates to the need to pick up the improvement of the goods and services which results from knowledge creation. The latter is an inherent part of criticism at official statistical measures of prices and real output growth, and have induced major statistical programs to improve measurement methods.[21]
4) The obsolescence problem which stresses the need with any type of capital to find a measure of depreciation, which is very difficult for intangible capital measures.

So far there has been little attempt to measure intangible capital beyond human capital measures.[22] Measures of knowledge capital have not gone much beyond the accumulation of R&D expenditure combined with some rough assumptions on its price and depreciation pattern (Griliches, 1988). International comparisons of organizational capital are, to my knowledge, not available. Moreover investment is difficult to distinguish from operating expenses on intangibles. Finally, measurement problems also arise because intangible investments relate to services rather than goods. In conclusion, the stock or flow of intangible assets is not easily measured.

The latest efforts in international comparisons of intangible expenditure – rather than investment or capital – are undertaken under auspices of OECD by Croes (2000) and Khan (2001). But even Khan's work, which probably represents the state of the art in this area, applies a fairly "narrow concept" of intangible capital, which includes measures of investment in higher education (including private expenditure), in R&D (including the capital expenditure component)

[21] Much of the criticism on official accounts, and in particular price index measurement, stems from the work of Griliches (1992, 1994) and the U.S. Advisory Commission to Study the Consumer Price Index in 1996. Recent attempts at the Bureau of Labor Statistics and the Bureau of Economic Analysis, supported by a range of studies at The Brookings Institutions in the USA, and new work at national statistical office across the OECD and at Eurostat have contributed to many improvements in measurement of prices and real output to deal with quality issues, even though many issues remain to be resolved. See Dean and Harper (2001) for a review of US work. See van Ark (2002) for references to other work in particular in Europe.
[22] See OECD (1998) for a review of international comparisons of human capital. Kendrick (1976, 1994) is one of the first encompassing studies to measure intangible capital beyond human capital.

and software.[23] Khan adjusted the estimates for the overlap between some expenditure categories, such as the overlap between investment in higher education and R&D, between higher education and software, and between R&D and software.

One simple way to observe the extent to which international differences in investment in intangible capital can be related to diversity in productivity performance is to compare rankings of productivity level estimates, the share of ICT-producing and ICT-using industries in GDP and the share of knowledge investment shown in this paper (Table 7). As mentioned above in Section 2, minor differences in relative levels should not be reflected as different rankings. The rankings in Table 7 are therefore indifferent for differences in productivity levels between countries of less than 2.0 percentage points, differences in the combined ICT production and –use share of less than 1.0 percentage point and differences in the share of knowledge expenditure in total GDP of less than 0.3 percentage points.

The rankings show some relation, in particular as the United States scores second in terms of intangible investment intensity and between 3rd and 6th rank in terms of productivity (i.e., the US productivity ranking cannot be distinguished from that of France, the Netherlands and Ireland). The US measure is particularly high because of its high expenditure on higher education (1.9% against 1.2% for the OECD as a whole and 0.7% for the European Union). Moreover the United States also stands out in terms of the highest share of ICT-producing and intensive ICT-using industries in total GDP. But the relation between relative productivity levels and intangible investment is far from perfect. Indeed the country with the highest level of intangible capital, Sweden, ranks only between 13th and 15th in terms of its productivity level. Moreover, the two other countries at similar productivity levels as Sweden (Canada and Australia) had much lower knowledge intensity levels. The high R&D intensity of Sweden is the main reason for its high ranking, which can also be said of Finland and Korea. Canada's 6th to 8th position on the ladder of intangible expenditures is – as with the US – due to its high expenditure on higher education.

<Table 7 about here>

Table 8 looks at the dynamics of the relation between the acceleration in productivity growth, the combined contribution of ICT-production and ICT-use to labor productivity growth,

[23] Croes (2000) uses a broader concept including expenditure on private and secondary education and marketing.

and the growth in knowledge expenditure. At first sight the picture looks somewhat better than for levels. Two countries, Greece and Ireland, which were among those with the greatest accelerations in labor productivity during the second half of the 1990s also showed the fastest growth in intangibles. However, Greece and Ireland are both typical catching-up countries, so that their rapid growth performance on both indicators – starting from relatively low levels – comes as no surprise. The United States, which scored between 5th and 7th in terms of productivity acceleration, ranked in between 9th and 15th in terms of growth in knowledge expenditure. Indeed many Scandinavian countries scored high on growth in knowledge expenditure (Sweden, Finland and Denmark ranked all in between the 3rd and 8th ranks) but much lower on acceleration of productivity growth during the second half of the 1990s.

<Table 8 about here>

It can be concluded that the crude comparisons shown here do not suggest a clear-cut story on the role of intangibles explaining the recent growth differentials among OECD countries. However, it should be emphasized that these measures only relate to those components of intangible capital which are most easy to quantify (R&D, software, education). More importantly, these measures are likely to be most strongly related to tangible investment in new high-tech equipment, such as IT and communication equipment which complicates the explanatory growth story – an issue already briefly touched upon in Section 3.

The measures on intangible expenditure used so far do not take on board various other components of the broad definition of intangible capital, especially organizational capital. Indeed micro research suggests that the successful implementation of ICT is strongly facilitated by investment in organizational capital. For example, a Danish study done in 1996 showed that the growth in productivity brought about by ICT is four or five times greater if it also involves changes in work-floor methods than if it does not. Norwegian research has shown that the returns on physical capital are 50% higher if the investment in ICT is accompanied by a complete ICT strategy within the particular organisation (UNICE, 2001). A recent study by Brynjolfsson and Hitt (2000) on 800 U.S. firms stated that the overall expenditure on non-material capital that firms have to make when ICT is introduced is at least ten times greater than the expenditure on ICT itself.

More recently, Yang and Brynjolfsson (2001) have argued that the omission from the growth accounts of expenditure associated with the creation of intangible assets is a main reason explaining the productivity slowdown since 1973. If these expenses relative to ICT investment have remained constant, it would also imply an underestimation of the recent productivity surge. To make their case, Yang and Brynjolfsson combine traditional growth accounting with the q-theory of investment. In this way the market valuation of the assets represents the tangible and intangible value of those assets. This methodology has not yet been applied for international comparisons.

5. Conclusions

The aim of the present paper was to review some of the reasons for differences in growth performance and changes in the income and productivity gaps between OECD countries. Compared to the United States, which has continued to enjoy the highest per capita income within the OECD area until today, and despite faster GDP growth most countries have seen little to no closing in their per capita income gap over the past decade. Before the mid-1990s the reasons for the failure to narrow the income gap relative to the US were related to the underperformance of the labor market which offset the catch-up effects in terms of productivity growth in the follower countries. However, since the mid-1990s sluggish productivity growth seems to one of the main causes of slower growth in Europe, Japan and Canada.

Using a conceptual framework, which is rooted in a traditional growth accounting framework – but with several extensions –, the analysis in this paper was focused on two sources of growth differentials. Firstly I looked at the role of the “new economy” as such – in the sense that ICT has been a source of faster productivity growth in the United States on itself. Secondly I looked at the impact of the creation of intangible capital which has been identified as a necessary condition to exploit the productivity advantages from ICT investment.

The analysis suggests that differences in realization of the potential to generate productivity accelerations from ICT is likely to have contributed to the differential economic growth performance within the OECD area. At the same time, it is difficult to measure the contribution of the various explanatory factors at the macroeconomic level very precisely. One may even argue that the traditional methods to analyze and measure the relation between inputs and output at the macroeconomic level are increasingly failing to describe the processes that drive changes and differences in growth performance. Nevertheless over the past years significant advances in growth theory and improvements in measurement methods have been made, even though it is probably true that formal theory is ahead of conceptual clarity and reliable measurement (Howitt, 1996). Some areas for further research are identified in this paper, such as the need to improve the measurement of ICT capital as well as the analysis of its contribution to growth, to extend measures of intangible capital towards organizational capital, and to disaggregate input and output measures to the level of industries.

Macroeconomic analysis and measurement of sources of growth remains of crucial importance to understand the relation between economic growth, improvement in living standards and social progress. Not only is per capita income a reasonable – though imperfect – proxy for living standards that is fairly comparable across countries. Many sources of economic growth are themselves direct contributors to improvements in living standards and social progress. For example, the creation of human capital and knowledge are important determinants of social progress. And income growth provides an important feedback in raising the demand for such assets. An efficient allocation of such scarce resources is essential to fully exploit this potential to raise living standards and further social progress.

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Table 1: Reconciliation of GDP per Capita and Labor Productivity, 2001 (preliminary estimates)

	GDP per Hour Worked (a)		Effect of Working	Effect of Employment share in Total Population (in % points)				GDP per Head of Population	
	in 1996 US$	as % of US	Hours (a) in % points	Unem-ploy-ment (b)	Labor Force to Population (15-64 yrs)	Population (15-64 yrs) to Total Population	Total (c)	in 1996 US$	as % of USA
United States	36.97	100.0	0.0	0.0	0.0	0.0	0.0	33,538	100.0
Norway	40.55	109.7	-28.9	1.0	3.1	-1.6	2.5	27,940	83.3
Ireland	36.36	98.4	-8.8	0.6	-9.7	1.0	-8.1	27,318	81.5
Switzerland	31.73	85.8	-12.8	2.1	5.5	0.6	8.2	27,236	81.2
Denmark	34.58	93.5	-16.4	0.1	2.4	0.4	2.9	26,857	80.1
Canada	30.53	82.6	-3.5	-2.1	-1.2	1.5	-1.8	25,923	77.3
Australia	30.32	82.0	-3.1	-1.7	-1.7	1.5	-1.9	25,818	77.0
Belgium	41.54	112.4	-18.9	-2.1	-15.4	-0.7	-18.2	25,252	75.3
Netherlands	37.32	100.9	-28.1	1.5	-1.1	1.3	1.7	24,989	74.5
Austria	35.46	95.9	-17.9	0.8	-6.3	1.5	-4.0	24,828	74.0
Japan	26.64	72.1	-2.7	-0.1	1.4	1.7	3.0	24,267	72.4
Finland	31.92	86.3	-10.7	-3.4	-2.2	0.9	-4.7	23,795	71.0
Sweden	30.22	81.7	-10.7	-0.3	1.7	-2.0	-0.5	23,636	70.5
Germany	34.20	92.5	-16.6	-2.5	-5.1	1.0	-6.6	23,247	69.3
France	37.63	101.8	-17.8	-3.6	-9.6	-1.6	-14.8	23,176	69.1
Italy	32.53	88.0	-11.0	-4.1	-5.2	0.9	-8.4	22,991	68.6
United Kingdom	29.40	79.5	-9.2	-0.2	-1.8	-0.6	-2.7	22,696	67.7
Spain	27.93	75.6	-1.8	-6.6	-12.2	0.9	-18.0	18,723	55.8
New Zealand	22.49	60.8	-3.6	-0.3	-0.7	-0.8	-1.9	18,560	55.3
Korea	15.18	41.1	13.6	0.4	-8.4	3.3	-4.7	16,747	49.9
Portugal	19.25	52.1	-3.1	0.3	-1.1	1.2	0.4	16,548	49.3
Greece	21.64	58.5	2.4	-3.9	-10.9	0.7	-14.1	15,696	46.8
Czech Rep.	14.43	39.0	3.2	-1.5	-3.0	2.0	-2.5	13,346	39.8
Hungary	17.44	47.2	-1.8	-0.5	-10.8	1.0	-10.4	11,730	35.0
Poland	11.90	32.2	2.7	-4.8	-4.2	1.1	-7.9	9,021	26.9
Mexico	12.13	32.8	3.0	0.9	-9.6	-2.7	-11.5	8,156	24.3
Turkey	10.16	27.5	1.1	-0.9	-10.2	0.2	-10.9	5,933	17.7
European Union	32.30	87.4	-12.1	-2.4	-6.0	0.2	-8.2	22,511	67.1
OECD excl. US	24.87	67.3	-2.8	-1.5	-7.0	0.1	-8.4	18,818	56.1

(a) calculated on basis of actual hours worked per person per year; (b) calculated on basis of standardized unemployment rates from OECD; (c) sum of previous columns plus rounding differences.

Source: Groningen Growth & Development Center & The Conference Board. Based on *OECD National Accounts*, *Economic Outlook*, *Employment Outlook* and *Labour Force Statistics*, with GDP converted to US$ at 1996 EKS PPPs.

Table 2: Growth of GDP per Capita and Labor Productivity (indexed on US 1990=100) and Labor Market Indicators for Reconciling the Difference

	GDP/Capita (US 1990=100)			GDP/Hour Worked (US 1990=100)		
	Canada	European Union	United States	Canada	European Union	United States
1990	85.2	70.2	100.0	87.4	85.4	100.0
1991	82.5	70.6	98.5	88.9	88.1	101.0
1992	82.3	71.3	100.4	91.8	90.4	104.0
1993	83.4	70.7	102.0	92.1	92.3	104.3
1994	85.7	72.4	105.1	92.0	95.0	105.4
1995	86.5	73.9	107.0	93.4	96.6	105.8
1996	86.7	74.9	109.8	92.9	97.7	108.2
1997	88.0	76.5	113.6	94.4	99.7	109.9
1998	89.9	78.5	117.3	95.8	100.5	112.0
1999	93.1	80.2	121.0	97.2	101.5	114.3
2000	96.4	82.7	124.9	98.3	103.5	117.1
2001*	96.7	84.0	125.1	98.5	104.2	119.2

	Hours per Person Employed			Employment/Population Share		
	Canada	European Union	United States	Canada	European Union	United States
1990	1799	1657	1819	0.468	0.429	0.475
1991	1764	1637	1808	0.455	0.423	0.466
1992	1736	1633	1799	0.447	0.417	0.464
1993	1760	1624	1815	0.445	0.408	0.466
1994	1789	1624	1825	0.449	0.406	0.472
1995	1771	1621	1840	0.452	0.408	0.475
1996	1789	1619	1838	0.451	0.409	0.477
1997	1782	1616	1848	0.452	0.410	0.483
1998	1766	1620	1864	0.459	0.417	0.486
1999	1772	1617	1872	0.467	0.422	0.489
2000	1789	1609	1879	0.474	0.429	0.491
2001*	1789	1609	1868	0.475	0.433	0.486

* Preliminary estimate
Source: Groningen Growth and Development Center & The Conference Board (http://www.eco.rug.nl/GGDC/index-dseries.html)

Table 3: Growth of ICT Investment and Contribution of ICT to Output Growth, 1990-2000

	United States	Canada	Euro-5	of which Finland	France	Germany	Italy	UK
	Growth of ICT investment (incl. IT, comm. eq. and software) in constant prices							
1990-1995	13.5	12.0	11.6	9.4	14.4	8.8	6.9	18.9
1995-2000(a)	21.3	22.8	17.6	21.0	15.7	17.7	16.3	19.8
acceleration	7.8	10.8	5.9	11.6	1.2	8.9	9.4	0.9
	Contribution of ICT services to output growth							
1990-1995	0.43	0.30	0.25	0.24	0.18	0.30	0.21	0.27
1995-2000(a)	0.87	0.57	0.38	0.62	0.33	0.35	0.36	0.47
acceleration	0.44	0.27	0.13	0.38	0.15	0.05	0.15	0.20

(a) For Finland and Italy numbers run only up to 1999.
Source: calculated from Colecchia and Schreyer (2001). European weights from Mulder *et al*. (2001)

Table 4: GDP and Employment Shares of ICT-producing, ICT-using and non-ICT industries, 1990 and 1999

	ICT-producing industries as % of total economy (a)		ICT-using industries as % of total economy (b)		"Non-ICT" sector as % of total economy	
	1990	1999	1990	1999	1990	1999
	as % of GDP at current basic prices					
Canada (c)	4.2	4.8	20.3	20.9	75.5	74.3
Denmark	4.3	4.7	18.5	19.2	77.2	76.1
Finland	4.6	9.6	16.3	16.3	79.1	74.1
France (d)	5.0	5.3	19.6	19.4	75.4	75.3
Germany (e)	5.4	5.3	21.0	20.8	73.6	73.9
Italy	4.4	5.0	21.2	21.6	74.4	73.4
Japan (d)	6.0	6.3	22.0	21.4	72.0	72.3
Netherlands	4.5	5.5	22.9	25.4	72.6	69.1
United Kingdom	5.7	7.0	21.6	22.4	72.7	70.6
United States	6.5	7.3	21.0	25.0	72.5	67.7

(a) The ICT-producing sector consist of IT hardware, radio, television and communication equipment, medical appliances and instruments and appliances for measurement (together the ICT industry) and telecommunication and computer services (together ICT services).
(b) The distinction between intensive ICT using industries and "non-ICT" industries is largely based on studies by McGuckin and Stiroh (2001) and the National Science Foundation (2000) for the United States, making use of ICT investment/output ratios and ICT capital stock shares by industry. These industries include publishing and printing, the chemical industry, electrical and electronic machinery and equipment, medical and measurement appliances (together ICT-using manufacturing), wholesale trade, post and telecommunication, the financial sector, the renting of machinery, computer services, research and development and part of business services (accountants, architectural firms, legal offices, consultants and marketing agencies) (together ICT-using services).
(c) For Canada, value added at current prices for 1999 is derived by extrapolating 1996 current price estimate to 1999 with index in constant prices and using average deflators for 1990-1996.
(d) For France and Japan for 1998
(e) For Germany for 1991 and 1998
Source: van Ark (2001b)

Table 5: %-Point Contribution by Sector to Labour Productivity Growth, 1990-1995 and 1995-1999

	ICT-producing sector	ICT-using sector	non-ICT sector	Total
Canada (1990-1995)	0.2	0.3	0.7	1.2
Canada (1995-1999)	0.3	0.4	0.3	1.0
Acceleration/deceleration	0.1	0.1	-0.4	-0.2
Denmark (1990-1995)	0.3	0.2	1.6	2.0
Denmark (1995-1999)	0.2	0.6	0.2	1.0
Acceleration/deceleration	-0.1	0.4	-1.4	-1.0
Finland (1990-1995)	0.6	0.1	2.7	3.3
Finland (1995-1999)	1.4	0.6	0.7	2.7
Acceleration/deceleration	0.8	0.5	-2.0	-0.6
France (1990-1995)	0.2	0.2	0.8	1.1
France (1995-1998)	0.4	0.2	0.7	1.3
Acceleration/deceleration	0.2	0.0	-0.1	0.2
Germany (1991-1995)	0.1	0.5	1.5	2.1
Germany (1995-1998)	0.4	0.5	0.7	1.7
Acceleration/deceleration	0.3	0.0	-0.7	-0.4
Italy (1990-1995)	0.2	0.5	1.1	1.8
Italy (1995-1999)	0.3	0.2	0.1	0.6
Acceleration/deceleration	0.1	-0.3	-1.0	-1.2
Japan (1990-1995)	0.3	0.4	0.1	0.8
Japan (1995-1998)	0.4	0.3	0.1	0.8
Acceleration/deceleration	0.1	-0.1	0.0	0.0
Netherlands (1990-1995)	0.1	0.3	0.9	1.3
Netherlands (1995-1999)	0.5	0.6	-0.2	0.9
Acceleration/deceleration	0.4	0.3	-1.1	-0.3
United Kingdom (1990-1995)	0.4	0.6	1.5	2.5
United Kingdom (1995-1999)	0.6	0.5	0.1	1.2
Acceleration/deceleration	0.2	-0.1	-1.4	-1.3
United States (1990-1995)	0.3	0.3	0.5	1.2
United States (1995-1999)	0.6	1.4	0.5	2.5
Acceleration/deceleration	0.3	1.1	0.0	1.3

Source: Van Ark (2001b) and McGuckin and van Ark (2001)

Table 6: Classification of Intangible Capita

a) Human Capital
a1) Formal Education
a2) Company training

b) Knowledge Capital
b1) Research and Development
b2) Patents
b3) Licenses, brands, copyrights
b3) Other technological innovations, not related to b1) to b3)
b4) Software
b5) Mineral Exploration
b6) Experience

c) Organizational Capital
c1) Engineering design
c2) Organization design
c3) Construction and use of data bases
c4) Remuneration of innovative ideas

d) Marketing of new products

e) Social Capital

Sources: based on Vosselman (1998) and Young (1998)

Table 7: Rankings of Labour Productivity and Income levels, ICT Output Shares and Knowledge Investment/Output Ratios

	Labour productivity		Output share of ICT producers and users		Investment in Knowledge as % of GDP (1998)				
	2001 (1996 US$)	rank*	%-share 1999	rank**	R&D	software	higher education	total	rank***
Belgium	112.4	1			1.9	1.4	0.4	3.7	13-16
Norway	109.7	2			1.7	1.2	1.0	4.0	9-14
France	101.8	3-4	24.7	9	2.2	1.2	0.8	4.1	9-14
Netherlands	100.9	3-4	30.9	2	2	1.7	0.7	4.3	9-11
United States	100.0	3-6	32.3	1	2.6	1.5	1.9	6.0	2
Ireland	98.4	5-6			1.4	0.5	1.1	3.1	17-18
Austria	95.9	7			1.8	0.9	0.8	3.5	15-17
Denmark	93.5	8-9	23.9	10	1.9	1.5	1.1	4.6	6-8
Germany	92.5	8-9	26.1	6-8	2.3	1.2	0.7	4.2	9-12
Italy	88.0	10-11	27.1	4-5	1	0.5	0.6	2.1	20-21
Finland	86.3	10-12	25.9	6-8	2.9	1.2	1.1	5.2	3-4
Switzerland	85.8	11-12			2.8	1.5	0.5	4.8	5-8
Canada	82.6	13-15	25.7	6-8	1.6	1.6	1.5	4.7	6-8
Australia	82.0	13-15			1.5	1.2	1.2	3.9	11-15
Sweden	81.7	13-15			3.8	1.9	0.8	6.5	1
United Kingdom	79.5	16	29.4	3	1.8	1.3	0.8	3.9	11-15
Spain	75.6	17			0.9	0.5	0.8	2.2	20-21
Japan	72.1	18	27.7	4-5	3	1.1	0.6	4.7	6-8
New Zealand	60.8	19							
Greece	58.5	20			0.6	0.2	0.9	1.7	22-23
Portugal	52.1	21			0.6	0.4	0.8	1.8	22-23
Hungary	47.2	22			0.7	1.0	0.8	2.6	19
Korea	41.1	23			2.6	0.4	2.2	5.2	3-4
Czech Republic	39.0	24			1.3	1.2	0.8	3.3	16-18
Mexico	32.8	25			0.4	0.4	0.7	1.5	24
Poland	32.2	26							
Turkey	27.5	27							
OECD	76.5				2.2	1.2	1.2	4.7	
European Union	87.4				1.8	1.0	0.7	3.6	

* countries within a 2%-point productivity range were ranked the same

** countries within a 1%-point ICT-share range were ranked the same

*** countries within a 0.2%-point knowledge-intensity range were ranked the same

Source: GGDC Total Economy Database, van Ark (2001b), Khan (2001), OECD Science, Technology and Industry Scoreboard, 2001

Knowledge investment includes R&D (including capital expenditure), higher education (including private expenditure) and software.

Table 8: Rankings of Labour Productivity Growth and Acceleration, Acceleration of ICT Contributions to Productivity Growth and Growth in Investment Knowledge

	Acceleration in GDP per hour worked		%-point cont. of ICT producers and users to acceleration of labour productivity		Growth in investment knowledge	
	1995-01 over 1990-95	rank*	1995-99 over 1990-95	rank**	1991-98	rank***
Mexico	3.1	1				
Czech Republic	2.2	2				
Greece	1.9	3			10.1	1-2
Ireland	1.5	4			10.2	1-2
U.S.A	0.9	5-7	1.4	1-2	3.9	9-15
Austria	0.8	5-7			6.3	4-8
Switzerland	0.8	5-7			3.2	10-16
Turkey	0.0	8-14				
Japan	0.0	8-14	0.0	7-10	2.6	14-17
Australia	-0.1	8-14			4.0	9-14
Belgium	-0.1	8-14				
Netherlands	-0.2	8-17	0.7	3	3.8	9-15
Poland	-0.2	8-17				
Sweden	-0.2	8-17			7.6	3-4
New Zealand	-0.3	10-19				
Finland	-0.3	10-19	1.3	1-2	6.8	3-5
Canada	-0.4	12-19	0.2	4-9	2.6	14-17
France	-0.5	12-19	0.2	4-9	3.0	11-17
Hungary	-0.5	12-19			1.6	17-18
U.K.	-0.8	20	0.1	4-9	3.6	9-15
Denmark	-1.2	21-22	0.3	4-8	5.9	4-8
Korea	-1.4	21-23				
Portugal	-1.6	22-25			5.4	5-8
Norway	-1.7	23-25			5.6	5-8
Germany	-1.7	23-25	0.3	4-8	2.2	15-18
Spain	-2.2	26-27			4.3	9-13
Italy	-2.3	26-27	-0.2	9-10	-0.6	19
EU	-1.2				3.1	
OECD	0.1				3.4	

* countries within a 0.2%-point range of productivity acceleration were ranked the same
** countries within a 0.2%-point range of productivity acceleration were ranked the same
*** countries within a 0.2%-point knowledge-intensity growth range were ranked the same
Source: GGDC Total Economy Database, van Ark (2001b) and Kahn (2001)

Knowledge investment includes R&D (including capital expenditure), higher education (including private expenditure) and software. See Khan (2001), Figure 6, for a breakdown by subcategory.

Figure 1 – Analytical Framework of Sources of Growth