Computers and employment: The truth about e-skills

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1. Introduction

When compared to other technological breakthroughs, information and communication technologies (ICT) appear to have at least two unique features. One is the long, unremitting technological improvement that has taken place in these technologies during the post-war period. A second unique feature is the exceptional technological spillovers that are possible throughout the economy.

This paper addresses the particular question of the impact of this "new" digital environment on the labour market. It will investigate in particular how ICT has changed and is changing the labour market and the "old", classical insights into the relationship between technology, employment and skills. We start in Section 2 with a review of the literature on technology and employment. In previous centuries, but also in recent decades, new technologies were often identified with employment "destruction". They were feared to be one of the main causes of unemployment amongst unskilled workers and at the origin of most of the new, so-called "biased" opportunities in favour for more skilled workers. Ever since the so-called Luddites smashed the power looms and spinning jennies that threatened their livelihood in the early 19th century, the popular fear that technological change would increase unemployment has existed and continued even in boom years.

We do not review the currently available evidence surrounding employment growth in Europe and its relationship with the "new" economy. We rather focus here on the skill aspects of the emerging new ICT. These remain controversial, and too often represent an area of meaningless "policy speak".

There is little doubt that most of the jobs being "displaced" as a result of the application of new ICT have been concentrated amongst the lower skilled workforce, whereas many of the new jobs have required, different, sometimes new (or higher), levels of skills. Hence, as the demand for skilled labour has risen relative to the demand for unskilled labour, wage differentials have widened in favour of the higher educated. For example, it is often cited that since 1979, the average weekly earnings of college graduates in the United States have risen by more than 30 percent relative to those of high-school graduates (e.g. Katz and Murphy, 1992). As average real wages rose relatively slowly for much of this period, the real pay of the least educated has actually fallen in the United States over the past 20 years.

Section 3 addresses the computer as the particular prominent example of this process. However, it does not appear to be computer skills *per se* that have particularly led to increasing demand for skilled labour. In this regard, Acemoglu (1998), and Goldin and Katz (1998), suggest that although ICT must have played a part in the widening of wage inequality over the past two decades, slower

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growth in the supply of more educated workers may have been a bigger factor (1). This evidence leads us to review (in Section 4) international data on skill levels to investigate further the differences across countries and the consequences for wages. Following this analysis, we conjecture that the ultimate effect of the computer is to free time for the core tasks of a particular job. This will induce employers to hire more skilled workers.

Concluding, we highlight some features of the current impact of ICT on growth and employment. So far the rapid diffusion of the information communication revolution has been accompanied at the aggregate level, with a predominance of new employment opportunities: in sectors predicted to witness significant employment displacement such as the telecom or financial services sector. But this current pattern gives no guarantees as to future sectoral employment trends. The only clear indication seems to be that demand satiation is more than ever not a factor bringing about technological unemployment.

2. New technology and employment

As long as there are unsatisfied needs and labour and product markets are flexible, technical change does not reduce aggregate employment.

The relationship between technology, growth and employment has been the subject of a large literature in economics. We would distinguish four sets of economic debate on the relationship between technology and employment. The first, and most "classical" in its origins, took place during the economic depression of the 1930s. The second debate focused mainly on the post-war United States and the fear of "automation". In the 1960s, levels of unemployment were higher in the United States than in Europe, and many people blamed technological change. As a result, a National Commission on Automation was appointed and produced a massive six-volume report in 1966. The third debate, which began in the late 1970s, was particularly active in Europe. It focused on the emergence of the combination of computer-based communication, information, and automation techniques associated with microelectronics. These appeared at first glance to have great labour-displacing implications. The fear was that these displacement effects might dominate the compensating job creation effects for quite some time. As with the classical debate, this was a reflection of the times: there was a set of "revolutionary" new technologies and persisting high unemployment. The fourth, and most recent, upsurge in this debate focuses more on the global aspects of ICT, and the possible erosion of employment and living standards in the advanced countries. Originating mainly in the United States, and linked to the political debate surrounding NAFTA, it quickly "globalised", and spread throughout the world (2).

While the subject of intense argument over the last two centuries, the relationship between technical change and employment appears straightforward today, at least from the macroeconomic perspective. Either the introduction of new technologies leads to more efficient production processes, reducing costs by saving on labour, capital, materials, energy, or any other factor of production, or it leads more directly to the development of new products that generate new demand. In either case, more welfare is created: in the first scenario through more efficient production that liberates scarce input resources; in the second case by satisfying new wants. The impact is often a mixture of both effects.

1) In the 1970s, the supply of educated workers surged in America as the baby-boom generation entered the workforce and college enrolment rose. But since then, the educational level of the workforce has improved much more slowly. A comparison made by Murphy, Riddell and Romer (1998), of the United States with Canada supports this argument. During the 1980s and 1990s the ratio between the earnings of university graduates and high-school graduates rose sharply in the United States, but fell in Canada. In both countries the demand for skilled labour rose by similar margins, but the supply of educated workers rose much more rapidly in Canada than in the United States.

2) See Freeman and Soete (1994), and Soete (1987), for an overview of this latter fear.

The extent to which this higher welfare or increased productivity feeds back into employment growth depends on the extent to which firms translate productivity gains into lower prices and new investment, and the pace with which consumers respond to lower prices in terms of greater demand. The job losses that might follow the introduction of a new labour-saving process are compensated by the job creation associated with output growth (following the decline in prices), by additional employment creation in other sectors (and particularly in the new technology-supplying sector), and by the possible substitution of labour for capital (following a downward wage adjustment that clears the labour market). As long as there are unsatisfied needs in the economy and as long as labour and product markets are sufficiently flexible, technological change, even in the form of new labour-saving production processes, does not reduce aggregate employment.

Most of the controversies that have dominated the economics literature on this issue over the last decades have centred on the automatic nature of the various compensation effects described above. Since the functioning and flexibility of product markets depends in part on the firm's market power, the degree of economies of scale and various other factors influencing prices, many contributors have questioned the way in which cost reductions are effectively translated into lower prices and are likely to lead to more output growth. Similar questions can be raised with respect to employment growth and the functioning of labour markets; they range from downward wage inflexibility to the many mismatches typical of (heterogeneous) labour markets. In either case, it is less technology itself that is at the centre of the debate than the pace and clearing function of product and labour markets. The relevant policy issues therefore fall primarily under the heading of improving the functioning of these markets (3).

However, an international "open economy" framework complicates the matter greatly.

Other contributions have questioned the possibility of *ex-post* substitution between labour and other factors of production. At least in the short term, the implications of a more rigid set of production coefficients for analysing technical change and employment are relatively straightforward. Labour-saving technological change embodied in new investment could, if wages adjust slowly, lead to unemployment because of insufficient investment to maintain full-employment; this is the so-called "capital-shortage" unemployment. There was a lively debate during the 1980s on the extent to which the increase in unemployment in European countries could be due to this phenomenon.

Yet other contributions question the automatic nature of the link between input-saving new technologies and productivity gains. Most of these studies were empirically focused and attempted to find reasonable explanations for the disappointing performance of total factor productivity growth in most OECD countries during the late 1970s and 1980s, despite rapid investment in knowledge (in particular, in private sector R&D) and the emergence of the new combination of ICT.

The international "open economy" framework within which most compensation mechanisms are likely to operate, complicates, however, matters greatly. Relatively straightforward linkages between technology, productivity growth, and job creation such as those mentioned above no longer exist. Even the most simple elaboration in terms of employment compensation due to foreign demand (e.g. through export and import elasticities) leads to complex interactions (Stoneman, 1984). More

3) The OECD Jobs Study (1994) can be said to have focused primarily on labour markets emphasising in particular the poor functioning of labour markets in Europe, compared to the US; the McKinsey Global Institute study (1994) on the functioning of product markets.

complete pictures including not only trade, but also the effects of international spillovers of technology on productivity growth or international capital mobility, make it much more difficult to identify the key links between the introduction of a new technology and the ensuing domestic employment impact.

The focus of some of the recent popular concerns about the implications of technological change for employment appear to relate to the way that gains from technological change are distributed internationally. In the gloomy vision of some popular authors, (4)

> *"…wages in the most advanced economies are being eroded owing to the emergence of a global market-place where low-paid workers compete for the few jobs created by footloose global corporations" .* (Rifkin, 1995).

In other words, the globalisation of industry and services casts a new light on the interaction between technology and employment in an open economic framework characterised by low transport and communication costs.

The impact on individual countries is difficult to predict and depends upon a broad range of macroeconomic and microeconomic adjustment mechanisms.

While it is still generally agreed that in a "world" economic framework, input-saving technical change leads, through increases in productivity, to growth and new employment, the impact on individual countries is difficult to predict and depends on a broad range of macroeconomic and microeconomic adjustment mechanisms (e.g. Acemoglu and Zilibotti, 2000 and Berman, 2000). This is especially true because positive and negative effects do not coincide either in time or in space: adjustment takes time, and the industries and types of workers that will benefit from technical change are different from the ones that lose from it.

At the same time, the premium placed on the role of knowledge and on the acquisition of skills in this global environment implies that international differences in the pattern of employment and unemployment depends increasingly on the capacity of national economies to innovate, enter new, unregulated service sectors and / or absorb new technology more rapidly. The emergence of a so-called information society becomes hence crucially dependent on user demand for new information products and services. The "demand articulation" of the latter depends on the existing regulatory institutional framework as well as on the overall macroeconomic climate. Much had already been written about the former. Many studies point e.g. to the existing (over)regulation in Europe in a number of "information society" service sectors. Moreover, in typical cases of information or communication services, marginal costs are a fraction of fixed costs (one may think of movies, software, financial and insurance services, etc.). Commercial success seems to depend critically on the reaping of economies of scale, leaving Europe with its fragmented national service markets and cultural diversity at a disadvantage.

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4) In many ways, such views are reminiscent of the old Prebish-Singer dependencia *arguments, but applied to the advanced countries. In the old core-periphery models, "immiserising" growth in the developing countries would take place because all the benefits of increased efficiency gains in raw materials, agricultural, and labour-intensive manufacturing production were passed on to the advanced economies, e.g. through lower prices or higher repatriated profits. In the current view, the pattern is the opposite: most of the benefits of technological change are passed on to some of the rapidly industrialising countries through more rapid international diffusion of technology from the advanced countries, the reinvestment of profits and relocation of production to those industrialising countries, and the erosion of various monopoly rents in the advanced countries, including wages. In principle though, and in contrast to the Prebisch-Singer model, such a redistribution process should lead, as trade theory would predict, to the convergence of growth and income and not to the "end of work". In this regard, Hodgson (1999), provides an intriguing view on "why the learning economy is not the end of history".*

It is these latter issues which brings the employment concerns about ICT back to the public policy spotlight, despite the many reassuring historical arguments, and the macroeconomic success stories of the United States and some of the smaller European countries. At the core of the current concerns are the distributional aspects of ICT. Various skills, competences and qualifications are likely to be of a much more pervasive and general nature, raising questions about the inherent "skill and competence bias" of new ICT. Hence, we focus the remainder of this paper on the skill content of recent technological change to evaluate those fears.

3. New technology and skills

In the previous section, we described how various forms of technological change could be connected to changing employment structures; here we develop a story connecting ICT to the possibly (changing) level of skill requirements (5). The idea is very straightforward. Suppose a technological revolution takes place requiring the implementation of new equipment. This can only be successful if the labour force can operate the new equipment, and so workers must acquire a set a "machine-specific" skills (6). A technological revolution is "skill-biased" if the new skills are more costly to acquire than the skills required to operate the old machine. On the other hand, it is "de-skilling" if the reverse is true.

Greenwood and Yorukoglu (1997), argue that 1974 is a turning point in the introduction of Information Technology (IT) (7). From this year on, the rate of technological change in the production of IT equipment increased. A sharp rise in the demand for skilled workers followed and so did income inequality in many OECD countries. Table 1 gives an overview of the rise in income inequality in OECD countries from the 1970s onwards.

The IT revolution is often perceived as a skill biased revolution.

From this evidence, the IT-revolution is often perceived as a skill-biased revolution, favouring the labour-market position of the skilled part of the workforce at the expense of the unskilled. Several studies find a substantial positive correlation between skill upgrading and computer investments, employee computer use, and research and development efforts (8). For example, Greenwood and Yorukoglu (1997, pp. 49-50), argue that:

> *"the adoption of new technologies involves a significant cost in terms of learning and that skilled labour has an advantage at learning. Then the advance in technology will be associated with an increase in the demand for skill needed to implement it. Hence, the skill premium will rise and income inequality will widen."*

5) Acemoglu (2000), provides an overview of the effect of technological change on wage inequality and the demand for labour. He argues for the United States that the behaviour of wages and the returns to schooling indicate that technological change has been in favour of skilled workers since 1940. Chennells and Van Reenen (1999), and Sanders and Ter Weel (2000), provide an overview of the micro-econometric evidence of more than 100 studies investigating the effects of skill-biased technological change.

6) Much research has suggested that long-run changes in the distribution of earnings is shaped by a race between the demand for skill, driven by industrial shifts and technological advances, and the supply of skills, altered by changes in educational investments, demographics, and immigration. See, for example, Katz and Murphy (1992), Murphy and Welch (1992), Autor, Katz and Krueger (1998), Acemoglu (1999), and Goldin and Katz (1999).

7) We prefer to use the term IT here as distinguished from ICT, which emphasizes more strongly the importance of communication technologies, such as the Internet and broadband communication.

8) See Berman, Bound and Griliches (1994), and Autor, Katz and Krueger (1998), Berman, Bound and Machin (1998), and Machin and Van Reenen (1998).

Table 1. Pattern of changes in earnings dispersion in the 1970s, 1980s and 1990s

Country	1970s	1980s	1990s
Australia	–	+	..
Austria	–	+	..
Belgium	..	+	..
Canada	0	+	+
Denmark	..	0/+	..
Finland	–	0	..
France	–	–/+	+
Germany	0	–/0	+
Italy	–	0	..
Japan	..	+	..
Netherlands	0	–/+	0
Norway	..	0	..
Portugal	..	+	..
Spain	––/0	+	+
Sweden	0	0/+	..
United Kingdom	–	++	+/–
United States	+	++	+/–

Note: ++: strong increase in dispersion, +: increase in dispersion, 0: no clear change, -: decrease in dispersion, --: strong decrease in dispersion, +/-: increase followed by decrease, ..: no information available.
Source: Sanders and Ter Weel (2000)

Similarly, Caselli (1999, pp. 79-80) argues that:

> *"technological progress has been predominantly incremental in the 1950s and 1960s, and predominantly revolutionary (of the skill-biased variety) in the 1970s and 1980s."*

The main example of IT-investment is, of course, the computer. An eminent paper by Krueger (1993), on the impact of computer usage on wages and the demand for skilled workers, shows (for 1984 and 1989), that workers using a computer receive a wage premium of some 15 percent. Later work by Autor, Katz and Krueger (1998), shows that this computer wage premium has increased to more than 20 percent in 1993. In interpreting his findings, Krueger (p. 34) concludes that

> *"employees who use computers at work earn more as a result of applying their computer skills."*

Based on the argument that workers who are best at using the computer are allotted to jobs, which require these skills most, other researchers also conclude that computer skills have a high pay off (9). This evidence suggest that IT would be a truly skill-biased "revolution" increasing the demand for high-level (computer) skills and leading to persistent wage inequality between workers possessing computer skills, and the rest.

9) See for example Entorf and Kramarz (1997), and Miller and Mulvey (1997).

However, there is also evidence suggesting that IT has not changed the labour market as dramatically as sketched above. For example, the previous argumentation requires that the highest skilled workers have been allotted to the most complex jobs. Many authors therefore conclude that workers using a computer are most qualified to do so. Thus, a major part of the increase in the demand for skilled workers and wage differences can be attributed to the emergence of the computer. The policy solution seems obvious. Education should focus on teaching computer skills much more than it has done so far. This analysis reflects a view on computers that is now popular amongst businessmen and policy makers. Indeed, many people take the odd computer course to familiarise themselves with Windows or the Internet, afraid to lose touch with it all. They often buy a computer to ensure that their children become familiar with the new technology. Policy measures are based on the assumption that all youngsters need to enter the labour market with computer skills, because otherwise there might be a threat of an unbridgeable computer skill gap, the source of a digital divide in society.

These seven points question the traditional view that computer skills are highly rewarded.

Recent research by Borghans and Ter Weel (2000b), however, has illustrated the major shortcomings of such a view. From various perspectives, research results are found that do not fit in this framework (10). They are:

1. The largest premium for e-mail and word processing

If one takes a close look at Krueger's results, it appears that the largest computer wage premium goes to computer tasks such as e-mailing and word processing. These are hardly the skills that are reserved for the higher educated. Surprisingly enough, tasks that are carried out by computer programmers and specialist staff, such as software design, are rewarded with lower computer wage premiums.

2. Many low and intermediately skilled workers use computers

As many low-skilled and intermediately skilled workers use computers, Bresnahan (1999), and Handel (1999), argue that it is unlikely that they are the cause of skill-biased technical change. In particular, many typists use e-mail and word-processing intensively. This does not seem to indicate that the use of new technology requires sophisticated skills.

3. Is it true that computer usage leads to higher wages?

Chennells and Van Reenen (1998), and Entorf, Gollac and Kramarz (1999), studied a data set of employees who started to use computers. They found that they did not receive significantly higher wages than the group who did not use computers.

4. Companies with a high level of computer usage also pay higher wages to employees who do not use computers

The idea that the computer wage premium should first and foremost be regarded as an appreciation of individual computer skills, implies that only those who actually use a computer will get higher wages. However, studies by Doms, Dunne and Troske (1997), and Dunne, Foster, Haltiwanger and Troske (2000), show that the computer wage premium is not an individual, but a company-related effect. They found that companies that work with advanced technology, such as computers, pay their employees more. It is irrelevant whether an employee uses a computer or not. He/she will nevertheless receive a wage premium.

10) See Borghans and Ter Weel (2000c), for an elaborate overview of these arguments.

5. **People who have computer skills, by no means always use computers**
   If computer skills are becoming more and more important in the labour market and increasing use of computers has made these skills a scarce commodity, it can be expected that employers will try to ensure that anyone who has such skills does work in areas where these are important. DiNardo and Pischke (1996), however, show that in Germany it is by no means the case that all those who have computer skills, are working in jobs in which computers are used.

6. **The use of pencils also yields a premium**
   DiNardo and Pischke (1997), took a critical look at Krueger's results by investigating whether it was only computer usage that explained remarkable wage differences. They therefore looked at the use of other tools, such as pencils, calculators, telephones, and whether a person works standing up or sitting down, to see whether any of these aspects could also explain the wage differences. Apart from the computer wage premium, they found a similarly large premium for the use of pencils. From these results, they concluded that Krueger's computer wage premium is probably not an adequate measure for the importance of computer skills.

7. **Rewards appear to be unrelated to computer skills**
   The six types of research results discussed above all cast doubt on the question whether the computer wage premium should be interpreted as a reward for computer skills. The questions that they raise, however, are always based on indirect evidence. One of the few studies based on direct measures of computer skills, by Borghans and Ter Weel (2000a), using evidence from a survey carried out in the United Kingdom in 1997, groups people by computer skills (from very high to very low). It turns out that everyone appears to receive approximately the same computer wage premium (see Table 2). As a matter of fact, individuals with average computer skills receive the highest computer wage premium.

The above seven points question the traditional view that IT skills - limited here to computer skills - are highly rewarded, and that simply operating computers requires special and more highly paid skills. How then can one explain the impact of computers on the composition of skills and the labour force? The most insightful contribution is by Bresnahan (1999), who offers a theory of workplace computerisation focusing on computer use in white-collar bureaucracies, the substitution of machine decision-making for human decision-making in low-skilled white-collar work, and the strategic use of computers by high-skilled workers. Autor, Levy and Murnane (2000), further develop the argument by modelling how the widespread adoption of computers in the workplace might alter skill demands. They argue that not all tasks are equally amenable to computerisation and that computers are an incomplete substitute for both unskilled *and* skilled labour. Their empirical results suggest that computerisation is associated with a declining demand for routine manual and information processing skills and a rising demand for non-routine information processing skills.

An important observation is that high wages themselves are an important factor in explaining the introduction of IT in the workplace.

An important observation is that high wages themselves are an important factor in explaining the introduction of IT at the workplace, because the savings are in this case much greater. Hence, IT use is determined by a combination of the specific tasks of a job and the wage level of a particular worker. As a consequence, when new IT-applications are developed and costs decrease, IT spreads further *both* among relatively skilled and unskilled workers.

Table 2. The returns to computer skills in the United Kingdom in 1997

Computer skills	Estimated computer wage premium (standard error in brackets)
Very high	.312 (.067)
High	.313 (.068)
Intermediate	.315 (.082)
Low	.298 (.089)
Very Low	.308 (.135)

Note: The following equation was estimated: ln $W_i = X_i a + C_i b + e_i$ where ln W_i is the natural logarithm of the hourly wages of individual i, X_i is a vector of the observed personal characteristics of individual i, such as training level, age, working experience, etc. C_i is a matrix for the different levels of importance of computer skills. a and b are estimated parameters. e_i is an error term with the usual assumptions. The equation was estimated using OLS.

Source: Borghans and Ter Weel (2000a)

4. The skill content of recent technological change

The above discussion suggests that the complementarity between ICT and skilled workers is one possible scenario but not the only one. It might also be the case that due to the costs of ICT it is more profitable to start implementing ICT at the highest (wage) segment of the labour market. By eliminating routine tasks, the computer gives more time to workers to use their particular skills.

But how does Europe compare in terms of education and skills, and what is the impact of skill differentials on wages?

Internationally comparable databases are scarce because of measurement problems in comparing educational levels. For example, on-the-job training traditions in some countries (notably Germany and Sweden) make education a biased estimator, the United Kingdom has a complex educational system depending upon profession, and the high-school-college system in the United States is again different. One database in which we are able to compare skills on an international level is the International Adult Literary Survey (IALS) conducted by the OECD and *Statistics Canada* in 1995 (11). The main advantage of IALS is that between 2 000 and 4 500 individuals in each of seven countries have been asked exactly the same questions (12). In this way, a relatively consistent picture of the skills of the workforce in these countries has been obtained. Besides the information on literacy, the survey also included questions on standard labour market variables such as employment status, earnings, education and demographic characteristics. In this section we only use data for males aged 18-65 years who were employed at the moment of the interview.

We distinguish five different skill measures: years of schooling, on-the-job work experience, numerical literacy, prose literacy, and document literacy. The first two skills do not need further

11) For more details on the data used here see the descriptive sections in Murray, Kirsch and Jenkins (1998) and Leuven, Oosterbeek and Van Ophem (2000).

12) These countries are Canada, Germany, the Netherlands, Poland, Sweden, Switzerland and the United States. France took part initially, but subsequently withdrew its support.

The scores for the three dimension of literacy are displayed in columns 5 to 7 of the Table. It turns out that Sweden has the highest relative scores in all three categories. The EU countries are above the scores of the United States for numerical and document literacy, but may perform less well for prose literacy. However, the large standard deviations prevent us from drawing strong conclusions from these three columns.

To say something about the importance of skills within countries, we look at the distribution of these skills. Table 4 computes the difference between the 90th and 10th percentile of the skill distribution. The United States is interesting in this regard in that it has the lowest differential for education (both for years of schooling and work experience), but a larger gap in terms of skills (only Poland performs worse). The question these data raise is whether wage inequalities across countries also reflect these differentials?

Table 4. The 90th - 10th percentile skill differentials

(1) Country	(2) *N*	(3) Years of schooling	(4) On-the-job experience	(5) Numerical literacy	(6) Prose literacy	(7) Document literacy
Canada	1 003	64.5	166.2	49.0	46.5	52.3
Germany	470	64.1	170.0	42.5	44.4	44.8
Netherlands	940	71.3	161.0	36.7	35.9	37.7
Poland	671	57.8	145.5	60.2	53.2	67.6
Sweden	760	71.6	171.8	44.9	46.5	45.6
Switzerland	800	57.0	171.4	36.7	38.7	41.6
United States	789	49.9	150.6	55.4	52.5	59.4

There are high returns to cognitive skills, and this applies to persons of all educational levels. The computer has not been a substitute for these skills.

This issue is further explored in Box 1 with a regression of wages on education (schooling and one-the-job training) and literacy. The interesting feature is the significance that numerical, prose, and document literacy has in determining wages. High returns to these “cognitive” skills have also been underscored by Murnane, Willett and Levy (1995). It applies to persons of all educational levels, showing that a rising demand for basic cognitive skills might be part of the explanation for the rise in wage inequality in the United States since the 1980s.

Returning to the question of the consequences of the computer on labour markets, these results seem in-line with Bresnahan’s (1999), observation that ICT has not been a substitute for high levels of human cognitive skills. As ICT applications take over work from human beings, the importance of various types of skills will undergo major changes in the near future. On the basis of the new production options, employers will reconsider the product range that their companies supply and the working methods used. Under certain circumstances, we expect that there will be more tailor-made work (in those occupations where skills are required) while under other conditions there will be greater standardisation of products (in less skill-intensive jobs).

BOX 1. The relationship between skill inequality and wage inequality

Since there is no direct information on wages in the published version of the IALS, we have to rely on estimates by Leuven, Oosterbeek and Van Ophem (2000), who had access to the wage information before publication, and on other sources. Table 1.1 shows the summary measures of wage inequality for the countries of the IALS.

When we look at the information available over time - and acknowledging that the data are drawn from different sources - we can see that inequality has widened in Canada and Europe. Typically the differential between the 90th and 10th percentile of the wage distribution increased by about 18 percent or so between the late 1980s and mid-1990s. In the United States this ratio is significantly larger, but it increases by only a small amount over this particular period.

Another observation from Table 1.1 is the fact that for some countries the difference between the 90th - 50th percentile of the wage distribution is larger than the 50th - 10th percentile. This indicates that there is larger dispersion towards the top of the wage distribution. These countries are Germany, the Netherlands (1987), Poland, Sweden (1980 and 1992), and Switzerland. On the other hand, there are also countries in which the difference between the 50th - 10th percentile of the wage distribution is larger than the 90th - 50th percentile. This indicates that workers at the lower end of the wage distribution earn relatively little. These countries include Canada, the Netherlands (1995), Sweden (1995), and the United States.

Table 1.1 Inequality measured by percentiles of the wage distribution.

(1) Country	(2) Authors	(3) Year	(4) 90th - 10th	(5) 90th - 50th	(6) 50th - 10th
Canada	G&J	1991	1.337	0.532	0.805
	LO&VO	1995	1.578	0.579	0.999
Germany	B&K	1988	0.995	0.540	0.450
	LO&VO	1995	1.188	0.626	0.562
Netherlands	G&J	1987	0.900	0.549	0.351
	LO&VO	1995	1.256	0.593	0.663
Poland	LO&VO	1995	1.625	0.852	0.773
Sweden	B&K	1980	0.840	0.465	0.395
	G&J	1992	0.834	0.497	0.337
	LO&VO	1995	0.986	0.452	0.534
Switzerland	B&K	1987	1.230	0.790	0.475
	LO&VO	1995	1.171	0.625	0.546
United States	B&K	1989	1.595	0.555	1.005
	G&J	1991	1.625	0.622	1.003
	LO&VO	1995	1.662	0.706	0.956

Note: Authors: B&K: Blau and Kahn (1996, Figure 1), G&J: Gottschalk and Joyce (1998, Table 1), and LO&VO: Leuven, Oosterbeek and Van Ophem (2000, Table 3).

Table 1.2 takes these comparisons further. It gives the results of the following wage regression for each of the seven countries (taken from Leuven, Oosterbeek and Van Ophem, 2000, Table 4):

$$\ln W = C + \alpha SCH + \beta EXP + \chi EXP^2/100 + \delta IALS + \phi IND/OCC + \varepsilon$$

where $\ln W$ is the log of the wage, SCH is years of schooling, EXP is on-the-job work experience, $IALS$ is a simple arithmetic average of the scores on three measures of literacy, IND/OCC are industry and occupational dummies, C is constant and ε, is an error term with the usual properties.

The results of this simple exercise are as follows: First, there are large differences in the returns to schooling. For example, one year of additional education pays under 3 percent of additional wage in the EU, while it pays close to 5 percent in the United States, and as much as 9 percent in Poland. Many scholars have attributed the high returns to education in the United States to skill-biased technical change (see, for example, Katz and Murphy (1992). Columns (3) and (4) of the Table reflect the returns to on-the-job work experience. The coefficient is highest in Switzerland and lowest in Sweden and the United States. In all countries workers face decreasing returns to experience ($EXP^2/100$ is negative and significant in all instances). However, on-the-job work experience is probably not a very good measure for skills and these results should be interpreted with caution.

The most interesting column is column (5), the return on literacy. This is highest in the United States. Germany, the Netherlands, and Switzerland also show relatively large wage premiums. Surprisingly, the coefficient is insignificant in Poland and Sweden. This could be interpreted to mean that these skills do not give workers a wage premium in those countries.

Table 1.2 Ordinary Least Squares wage regression results

(1) Country	(2) SCH	(3) EXP	(4) $EXP^2/100$	(5) $IALS$	(6) R^2
Canada	0.032 **	0.521 **	-0.073 **	0.169 **	0.39
	(0.008)	(0.057)	(0.012)	(0.042)	
Germany	0.022 **	0.491 **	-0.075 **	0.125 *	0.41
	(0.008)	(0.069)	(0.015)	(0,050)	
Netherlands	0.027 **	0.519 **	-0.080 **	0.182 **	0.44
	(0.004)	(0.047)	(0.010)	(0,041)	
Poland	0.088 **	0.364 **	-0.063 **	-0.028	0.18
	(0.013)	(0.095)	(0.020)	(0.047)	
Sweden	0.026 **	0.449 **	-0.070 **	0.056	0.18
	(0.007)	(0.061)	(0.012)	(0.041)	
Switzerland	0.028 **	0.665 **	-0.109 **	0.182 **	0.31
	(0.007)	(0.056)	(0.012)	(0.042)	
United States	0.047 **	0.457 **	-0.074 **	0.213 **	0.43
	(0.008)	(0.062)	(0.014)	(0.038)	

Note: Dependent variable log wage; standard error in brackets. ** is significant at a 1 percent level and * is significant at a 5 percent level.

Source: Leuven, Oosterbeek and Van Ophem (2000, Table 4)

The major effect of ICT is that individuals can concentrate on professional activities, as many secondary tasks can be taken over by the new technology.

Thus, a major effect of greater penetration of ICT is that individuals at work are able to concentrate more on those activities that constitute the essence of their profession. Many secondary tasks will be taken over by the new technology. This means that employers will tend to increase skill requirements. After all, the costs of higher wages will be compensated by the fact that less time is lost on tasks in which these skills are not used. It is in particular this argument that gives rise to the expectation that the demand for higher educated workers will continue to grow. As a result the computerisation of the labour market may then in effect lead to "skill-biased technical change".

5. Concluding comments

The particular employment concerns associated with ICT investment relate ultimately to their likely impact on output and productivity growth and wage premium redistribution across educational and skill levels. We have in this paper focused very much on these latter aspects, highlighting some of the complexities currently involved and insufficiently captured in the simple dichotomy of "skill-biased" versus "de-skilling" revolutions. Let us conclude with some general observations with respect to the growth and productivity impacts.

In attempting to assess the overall employment creation and destruction effects of ICT it is not possible to distinguish the direct negative and positive effects from the indirect effects, if ever this was possible in the past. The direct effects represent as much the new jobs in producing and delivering new products and services, as the old jobs being replaced by new ICT equipment. The indirect effects are the amalgamation of the many positive and negative consequences elsewhere. Thus, while computer terminals are everywhere, it is not always clear whether they are displacing workers or adding additional services and employment (14). The computer industry itself has provided machines that displaced earlier types of electromechanical office equipment, while the microelectronic industry largely displaced the old valve (tube) industry.

Such arguments do not hold only for manufacturing. In services too, it is no longer possible to distinguish clearly direct from indirect employment creation of displacement effects. New digital telephone exchanges require far less labour to manufacture and to maintain than the old electromechanical exchanges and the number of people working in the telephone switch industry has fallen in most industrial countries. Competitive re-structuring of the old monopolistic networks has also resulted in a reduction of the number of employers, even though the number of firms and the number of lines and cells has increased. However, and contrary to initial expectations, the new telecommunication infrastructure provided the basis for many new information service industries, bringing about a significant employment growth rather than the predicted employment loss. Similarly, some of the main ICT-using service sectors, such as financial services and insurances witnessed overall little employment displacement. However, within these sectors a significant restructuring took place amongst different jobs. That restructuring process is far from over. It is likely to be followed in the years to come by a significant employment displacement of clerical "physical presence" jobs in many local branches of banks, insurance offices, even call centres as such jobs are further "automated" through computers and through virtual communication on the Internet. The

14) See Autor, Levy and Murnane (2000) who analyse job creation and destruction in a large US bank following the introduction of an automated cheque processing system. They find it hard to distinguish whether changes took place within the job, or whether new jobs were created as a result of this particular technological change.

unexpected, positive employment trends in these sectors is hence no basis for any prediction of future trends.

To compare the sector balance of gains and losses remains therefore an impossible undertaking as numerous empirical studies of the 1980s and 1990s already confirmed (e.g. Davis, Haltiwanger and Schuh, 1996). What is for sure is that an aggregate output growth which lies - as has been the case over the last decades in a number of OECD countries such as the United States, the Netherlands, Denmark, Ireland and the United Kingdom - substantially above productivity growth will lead to significant declines in unemployment rates, employment growth being sufficient to absorb both new entrants to the labour market and reabsorb displaced workers. As a matter of fact, in the 1990s some of these countries witnessed a significant growth in labour force participation, which itself has been a source of additional growth. Many of those new entrants (women and youth) having relatively high consumption patterns in some of the new ICT areas (mobile communication, Internet use, etc.). All this makes it difficult to argue what the true domestic employment effects of technological change are.

What can be argued nevertheless is that ICT investment's impact on growth depends in the first instance on the new needs and markets the new information service sectors are capable of addressing. In Europe this has been aptly illustrated by the phenomenal rise in mobile telephony use. Whether the recently tendered frequencies for third generation mobile communication (UMTS) will lead to a similar uptake of mobile Internet use remains to be seen, but will again depend crucially on the way telecom operators succeed in identifying possible core "new" mobile needs. The information and communication technologies have undoubtedly opened a new dimension of business and consumer wants. Such new demand led growth does not seem, at least in these early stages of the information communication revolution, to be subject to intrinsic demand satiation effects, as in the case of previous manufacturing consumer needs. Nevertheless, Gordon (2000), has argued that the new information and communication technologies represent ultimately little more than increased substitution possibilities of "free time" ultimately constrained by "the fixed endowment of human time". That might well be so, but such increased substitution possibilities do open up possibilities for an infinity of alternative, individual consumption activities, unlikely to be ever subject to demand satiation. The spectre of "technological unemployment" resulting from demand satiation seems from this perspective more than ever unrealistic.

Demand for skilled labour has undoubtedly risen. But it is not computer skills that are behind the widening of wage differentials: it is the freeing of time so that more skilled workers can get on with their job.

With respect to the distributional aspects of ICT, the demand for skilled labour and in particular the highly specialised IT jobs, has undoubtedly risen relative to the demand for unskilled labour. However, it does not appear to be computer skills per se are behind the widening of wage inequality over the past two decades. Rather the effect of the computer on which we focused in Sections 3 and 4 appears in essence to consist of the freeing of time so that more skilled workers can get on with the core tasks of their job. In this sense computer skills have become pervasive, truly general purpose skills widely used across all skills and all jobs. The freeing of time in the case of the more expensive, skilled work force has not only led to a more rapid diffusion of computer use amongst this particular group of the work force, it has also induced employers to hire more skilled workers.

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