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International Trends in the Quantity and Quality of Entrants to Computer Science Courses in Higher Education

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Summary

The paper presents evidence of serious skill shortages in the information technology (IT) sector and in IT-related occupations in France, Germany, Singapore the UK and the US. The extent to which higher education (HE) has responded to the increased demand for skills by providing an increasing number of study places in computer science courses, is examined. In Europe and Singapore the proportion of the age group entering IT courses has increased since 1990. Germany shows a rapid increase since 1995. The US shows a downward trend after an increase in the early 1980s. In Europe, expansion of entrants to IT took place when participation rates were flattening out after growth in the 80s and early 90s. Expansion indicates that entrants were switching to IT from other subject areas. The quality of entrants to IT HE was measured by performance on pre-requisites. In 1998, in all countries except France and Singapore, the quality of entrants to computer science courses was below the average for all HE entrants.

1. Introduction

In the countries considered in this paper — France, Germany, Singapore, the UK and the US, employment in the information technology industries and IT-related occupations is evolving and changing rapidly. Numbers employed have increased, job content has changed and new occupations (e.g. Webmaster) have emerged. Many of these changes have taken place within the past five years. Some IT occupations have, apparently, already 'peaked' and numbers have started to decline — for example, numbers of computer programmers peaked in France in 1993 and declined thereafter. By contrast, numbers of IT engineering/computing IT professionals in France increased nearly 200 per cent between 1985 and the present. In most countries though, there have been growing concerns about skill shortages in all areas of IT-related activity. The scale and rapidity of these changes has given rise to government/industry action in all the countries studied here to monitor and make recommendations to meet skill shortfalls.

This paper is based on the first phase of a project commissioned by the Department for Education and Employment (DfEE) for England and Wales. The original project examined trends over time in numbers and quality of entrants to post-secondary courses in engineering and computer science in five countries. This paper reports our findings relating to computer science for the same five countries — France, Germany, Singapore, the UK and the US and situates them in the wider context of skill shortages and responsiveness of public institutions.[1]

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[1] In the first phase of this work trends in HE enrolments in engineering and computer science in five countries — France, Germany, Singapore, the UK and the US — were examined and country reports prepared. This paper draws on the data and conclusions presented in the individual country reports to compare trends in enrolments and to ascertain whether, in each country, the quality of entrants in these two subject areas is higher or lower relative to the average for all entrants. Where possible a trend in quality of enrolments is presented for a series of recent years. For each country chosen a separate report has been prepared. These country reports are: France (Bruniaux 2000), Germany (Wagner 2000), Singapore (Steedman 2000), the UK (Hansen and Vignoles 2000), the US (Vignoles and Hansen 2000). The reports are available at *http://cep.lse.ac.uk/cee/papers/rrp/*

The paper is structured as follows. Section 2 describes the extent of IT shortages in the various countries and provides definitions and brief descriptions of methods used. Section 3 examines some trends in qualifications giving access to higher education (henceforth HE) and presents some general trends in HE participation rates. Section 4 examines trends for entry into and completion of computer science HE courses and Section 5 compares entrants to computer science degree courses. Section 6 provides evidence on trends in the quality of entrants. Section 7 summarises and points to some policy conclusions.

2. The extent of skill shortages of IT qualified personnel

2.1 France

A recent somewhat conservative estimate (*Commissariat General au Plan* 1999) put the number working in the IT sector in France at around 300,000 — 1.2 per cent of the active population. However, a somewhat broader definition of IT-related occupations might result in a doubling of this number. In 1998 the French government, together with representatives of the IT industry set up an Observatory (*Observatoire des formations et des métiers en informatique et technologies de l'information et de la communication* (OFMI)) to monitor higher education supply in computer science and evaluate demand for this skill area. The French government also commissioned several studies to improve knowledge of this changing area. In 1994, in a trough of the economic cycle it was unemployment in the IT occupations that concerned the authorities. By 1998 the reverse was true, and skill shortages were the main area of concern. In 1998 the ratio of vacancies to registered unemployed was 3:1 with regard to engineers, and 2:1 relating to technicians in IT occupations.

2.2 Germany

Estimates of employment in IT in Germany vary between two and nine per cent of the active population.[2] Over the last 30 years in Germany the supply of IT qualified individuals has fallen short of demand. About two thirds of the IT professional employment stock comes from outside the sector and has undergone retraining, often financed by the Federal Labour Office. To fill the gap in IT personnel the industry has been demanding the right to employ IT specialists from outside the EU. In 1999 just under 2 per cent of IT employees came from other EU countries and just over 2 per cent from non-EU countries. A recently-passed law which has provoked considerable debate in Germany enables an additional 10,000 non-EU IT-specialists to apply for a "Green Card".[3] There remains the problem that IT specialists are sought after in all countries; in other words, the labour market for IT skills is becoming truly global.[4] Many specialists from non-EU countries for example from India seem to prefer employment in the US or the UK.

2.3 Singapore

Singapore is well-known for the strong co-ordinating role played by government in steering the economic growth of the country. This is achieved by forward planning of the desired balance between low and high tech industry and services. Late in 1999 the Ministry of Manpower published an outline for industrial strategy for the next decade and beyond (Ministry of Manpower 1999). Briefly, the aim is to develop Singapore into a high-tech 'hub' providing specialised technical and financial services to the South East Asia Pacific region. The strategy recognises that Singapore's HE graduate output alone will not be sufficient to meet the demand for highly skilled specialists, including computer specialists. In addition a major drive has been launched to encourage flexible working combined with part-time study to upgrade the skills of adult Singaporeans to meet the new demand. But Singapore will continue as now to recruit from outside the country those skills that are in short supply. Far from seeing this policy as a threat to the living standards of Singaporeans, the government sees the competition from highly-skilled non-Singaporean workers as providing a stimulus for lifelong learning by the indigenous population.

2.4 The United Kingdom

The information technology sector is one of the fastest growing sectors in the UK, particularly since the recent "internet boom". The work force in IT has grown from just over half a million workers in 1994, to around three-quar-

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[2] In Germany, estimates of IT employment and skill shortages vary considerably depending on definitions. According to an estimate of the German Federal Labour Office about 360,000 persons were employed in IT-related occupations in 1999 and a further 22,000 were unemployed. In contrast the IT industry association (*Bundesverband Informationswirtschaft, Telekommunikation und neue Medien*) estimates for the same year that employment in hardware, software and IT services was over 1,000,000 with an unfilled demand of 75,000. Other calculations which include software development, professional operating of IT systems, consultancy and trainers result in 3,000,000 persons which represents 9 per cent of the labour force (Dostal 2000). A fifth of these are found in the manufacturing sector. To get more precise figures about the actual demand a working group under the Federal Ministry of Labour was set up in February 2000 (Federal Ministry of Labour 2000).

[3] In case that further needs exist an enlargement to 20 000 or 30 000 IT-specialists might be possible.

[4] In a recent speech (Speech By Dr Lee Boon Yang, Minister For Manpower, Singapore, 27 May 2000) the minister spoke at length of the 'global war for talent' which characterizes the development of the 'knowledge economy' and related sectors.

ters of a million in 1998 (AISS 1999).[5] IT workers now constitute around four per cent of the total UK workforce.[6] With the strong growth in the UK IT sector, has come a growing awareness, amongst employers and policy-makers alike, of a skill shortage in this area.[7]

Around one third of those working in the IT sector are graduates/have an HE qualification, and of those with a degree, only around one third studied a predominantly IT related subject (AISS *ibid*). Thus, graduates with subjects other than computer science are an important source of skills for the IT sector. There is evidence that skills and qualifications acquired outside the recognized HE framework, such as Microsoft awarded certificates, are perceived to be as important as formal academic qualifications. Computer science graduates in the UK earn a relatively large wage premium, compared to some other degree subjects, and similar in magnitude to the wage premium for physical science, social science and business/administration degrees. However, medicine and mathematics, rather than computer science, are the top earning degree subjects. It may be that a large proportion of mathematics graduates are working in computer related jobs and, thus the high wage premium associated with a mathematics degree may in part reflect high relative wages in the computer skills market. The relative wage premium for computer science degrees did not increase during the 1990s. This may indicate that in the UK firms are turning to graduates from other specialisations to meet recruitment needs and skills gaps and that this has helped to halt upward pressure on the earnings of graduates with degrees in computer science.

2.5 The United States

The Current Population Survey shows 1,597,000 employed in the computer and related industry in 1998. This represents about 4 per cent of the total workforce. Additional to this around 8,632,000 were in work which involved the use of a computer in a range of occupations, accounting for roughly 20 per cent of the total US workforce.[8]

As discussed in this paper the participation rate in HE in the United States is one of the highest in the world. However, we will also show that the numbers studying for computer science degrees have declined over the last ten years, and that computer science students are of a lower standard in terms of academic ability than many other graduates. These trends have contributed to a shortage of suitably qualified staff in the IT industry in the US in recent years.

A recent report submitted to the US House of Representatives Education and Employment Oversight Committee found on average three vacancies in every company in the high tech sector and one vacancy for every ten employees in IT.[9] Another indicator of the high level of skills shortage is the fact that in 1996 wages in the high-tech sector grew by five times the national average. The acute skills shortage in the sector has led the Federal government to authorise a dramatic increase in the H-1B visa cap [i. e. the liberalisation of immigration laws for those with IT skills].[10] The report to the House of Representatives Committee concludes that 'despite promising job opportunities and high wages offered by the high-tech industry, today's students … are not acquiring the skills necessary to take advantage of it'.

2.6 The definition of HE

In all the countries examined here the HE sector consists of more than one type of course/diploma, as indicated by length of study period and, in the case of all but the UK, by institutional separation. In this report the HE sector is defined as all certificate courses of study for which the minimum entrance qualification is successful completion of a Level 3 qualification (university entrance level). This definition embraces the shorter (usually two-year) courses and all courses leading to first degree and higher levels of university education. Whenever possible, sector data are disaggregated to show the shorter (usually two-year) courses separately from the longer degree courses.

However, equivalence across countries of degree and sub-degree courses is still problematic. Length of study period is an important criterion used in international classification. However, the countries in our study have HE courses of differing duration. This should be borne in mind when comparing inputs and subsequent outputs. Degree courses of five years or longer not only require considerably more investment from the student but should normally produce a higher level of knowledge and skill than a shorter course. The UK and Singapore have the shortest

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5 The AISS (1999) report suggests these figures, from the UK Labour Force Survey, may underestimate the true size of the workforce in IT.

6 This includes computer-based work within a range of occupations including: computer systems and data processing managers, computer analysts and programmers, information managers, computer clerks, computer operators and data processing operators.

7 Annual staff turnover (15–20 per cent) is higher in the IT sector than average (AISS 1999). Second, numerous surveys of employers indicate that they face difficulties recruiting due to skill shortages. Third, some wage data, derived from the salaries cited in job advertisements, indicate that the price of IT skills is rising at a rate that is well above the average.

8 Occupations include: computer systems analysts and scientists, operations and systems researchers and analysts, computer science teachers, computer equipment operators, data entry, data processing and repairs.

9 'The Emerging High-Tech Industry: the Jobs Keep Coming' http://www.house.gov/ed_workforce/oversight/awp/awpreport/hightech.pdf

10 It was recently reported that the US will raise the limit to 200,000 visas in the coming year (see footnote 4).

HE degree courses, normally three years, reflecting the fact that new entrants have usually specialised intensively in their chosen subjects in the last two years of upper secondary education when studying for A-levels. In France and Germany computer science students in universities rarely study for less than four years and many study for five or more years. In the US the Associate Degree normally requires two years full-time study following High School Graduation and the Bachelor Degree awarded by universities normally requires a minimum four-year study period.

France, Singapore, the UK and the US all have recognised 'short' HE courses leading to a qualification recognised as below first degree level. These can be fairly readily classed as equivalent on the basis of entrance requirements and length of study. Germany presents a special problem, however. The *Fachhochschule* (FHS) qualification which is at a lower level than the university degree (normally 5+ years of study), has a slightly lower minimum entrance requirement (*Fachhochschulreife*) in comparison to the *Hochschulreife* for a university degree and lasts for four years of which half a year is spent in work experience.[11] This puts it very much on a level equivalent to, e.g., the UK three year degree. For the purposes of this study, therefore, we show German degree entrant numbers both with and without the FHS numbers.

2.7 Measures of entrant quality

No internationally consistent quality measure was available. Instead, for France, Germany, Singapore and the UK, performance on the examinations leading directly to HE entrance was taken as an indicator of quality. Within the group gaining a qualification leading to HE enrolment it was necessary to further distinguish those students whose performance was judged to be above the mean. Different solutions to this requirement were adopted dependent on the system of grading of performance in place and the availability of data. In the UK A-level grades were used. In France performance (pass/fail) on the scientific *Baccalauréat* (Bac S) was used to proxy above average performance at the end of upper secondary school and evidence supporting this choice is presented in the country report for France (Bruniaux 2000). In Germany, a grading measure — 'very good' or 'good' marks in the *Hochschulreife resp. Fachhochschulreife* examination — was used. Students in Singapore study for A-level examinations set by an English examining board so that issues of comparability with the UK are minimised. However, the A-level grades of entrants to university courses in Singapore are not publicly divulged and no firm indication of relative quality could be obtained. In the US, where the nominal requirement for university entrance is the High School Diploma, no reliable and nationally comparable measure of performance was available; graded outcomes on the Scholastic Aptitude Test (SAT) were adopted as the indicator of quality.

2.8 Definitions of computer science courses in HE

Computer science is a younger and less institutionalised discipline than, for example, engineering. Formal accreditation by professional bodies is not the norm. HE institutions have therefore enjoyed considerable freedom to develop courses in this area in response to rapidly rising labour-market demand. They have also needed to respond to the almost unheard of pace of technological change in their discipline. One result of this is that the definition of the discipline itself is fuzzy at the edges and shifting rapidly, and HE degree courses which combine computer science with other disciplines, are more common than, for example, in engineering. For the purposes of this study we have included in our definition of computer science entrants those entering courses where computer science is the sole or principal area of study. This means that we have excluded those studying computer science in courses where a second or even a third discipline has equal weight. By adopting a restrictive definition across countries we can have more confidence that our comparisons are valid.

As we have already indicated in the comparison of the demand for skills in Germany and the UK, the absolute numbers of entrants may understate the true numbers produced by HE capable of taking employment in a specialist IT capacity. Ultimately this will depend upon the flexibility of both employers and new entrants to IT occupations. However, we would argue that a comparison of HE output of IT specialist skills in each country provides an important indication of the extent to which each country's HE system can react to and meet core skill demands in this sector.

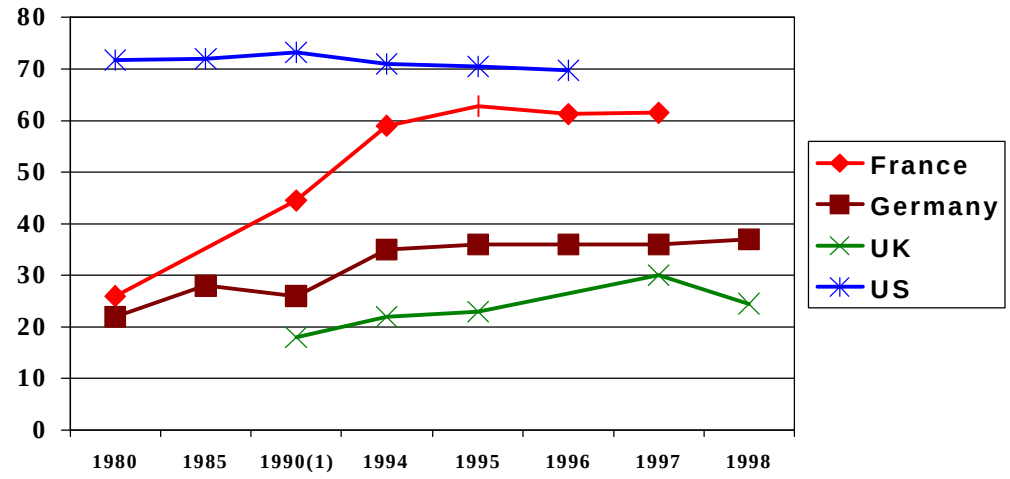
3. Trends in qualifications giving access to HE and in HE participation

3.1 All qualifications giving access to HE

In the 1980s and up to the middle of the 1990s all countries except the US experienced a strong increase in the proportion of the 18/19/20 year-old age group gaining entrance pre-requisites to HE. In contrast to the 1980s, these proportions remained stable or declined in the second half of the 1990s (Figure 1). (See country reports, France: Bruniaux (2000), Germany: Wagner (2000), Singapore: Steedman (2000), the UK : Hansen and

[11] Half of the entrants to Fachhochschule have passed the Hochschulreife which is the minimum entrance requirement to university but also provides access to FHS.

Figure 1



Notes: (1) UK 1992. Germany, 1980, 1985, 1990 1994 Federal Republic only, UK = 2 A-levels only, US = High School Diploma, Germany = *Hochschulreife* and *Fachhochschulreife,* France = General, Technological and Vocational *Baccalauréat*

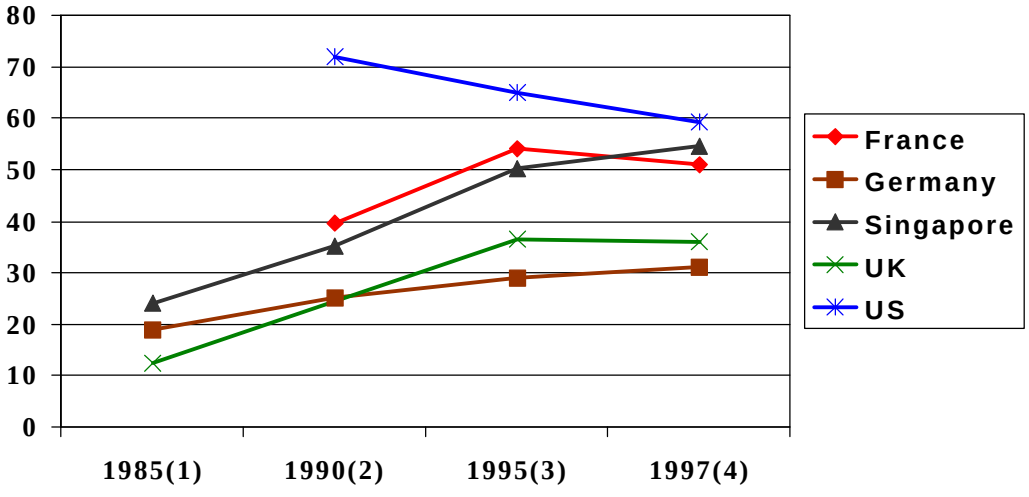
Vignoles (2000), the US: Vignoles and Hansen (2000) for a more detailed account of these trends).

3.2 Trends in entrants to HE

Trends in HE enrolment are presented as percentages of the relevant age cohorts to allow for differences in population size and for changes in cohort size from year to year (Figure 2).[12] For Singapore, data on numbers of entrants to HE courses were not available, and we have therefore used numbers gaining polytechnik diplomas

[12] This measure is an imperfect one, especially in countries such as the US and the UK where a substantial proportion of entrants are aged > 25. For example, in the US only 53 per cent of HE entrants were aged < 25 in 1995–6. In 1995-6 in Germany the

Figure 2



Notes: [a)] see footnote 12 for Germany; (1) Singapore 1984, UK 1987 (2) Germany 1988 (3) France 1994 (4) UK, Singapore 1998

and first degrees. It is considered that this measure can act as a good proxy for entrants since entrants are quite highly selected and there is very little drop-out. Although proportions gaining qualifications giving access to HE in the five countries have stabilised in the 1990s, a higher transfer rate to HE could produce a rising trend in HE enrolments. Until 1995, on the measure used here, all countries except the US show a trend of increased participation in HE. Since 1995 all countries except Singapore and Germany show a flattening out of growth. Growth in France has been faster and participation higher than in the two other European countries, Germany and the UK. Growth in the participation rate in Singapore has outstripped that of any other country. The US participation rate has fallen recently but remains slightly above that of Singapore and France. France also shows a slight fall between 1995 and 1997. In Germany growth is slight but continuous from 1985 onwards. In the UK rapid growth to 1995 has also been followed by a period of stabilisation of the participation rate.

The HE participation rate in the US was, for many years, higher than in the European countries and Singapore. However, a decline in the US and rapid growth in France and Singapore have brought the three countries close together. Singapore has the highest HE participation rate having overtaken France in the mid-1990s. Like France, Singapore has high proportions participating in 'short' HE courses. For the three European countries and the US it appears that, in the short term, increased numbers entering computer science HE courses will only be achieved by students switching from other HE courses since there can be no assurance of continuing rapid expansion of HE participation.

4. Entrance and exit trends in HE courses in computer science

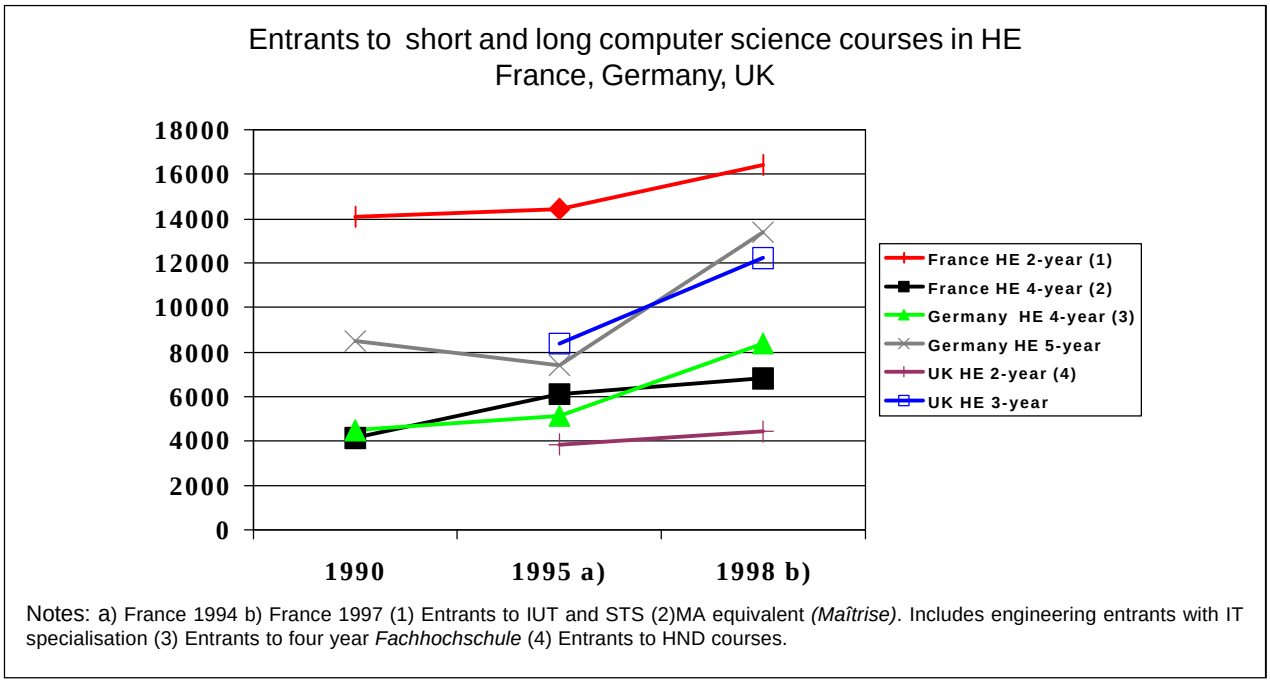
France, Germany and the UK have populations of a roughly similar size and for these three countries we show recent trends in numbers entering, HE computer science courses and provide some information on attrition rates (Figure 3).

4.1 France

In France, estimating quantitative trends in Higher Education is not an easy task. Those who gain an HE qualification in computer science on both 'short' and 'long' routes frequently continue to higher levels and leave with more than one level of qualification. Not only do a proportion of students on 'short' two-year courses (*Brevet de Technicien Supérieur* — BTS and *Diplôme Universitaire de Technologie* — DUT) continue to degree level but university students from other disciplines may 'switch into' computer science courses while part-way through their studies. It is therefore not possible to match entrants with completers in computer science. It is estimated that in total about

entrance to higher education was on average 2.9 years after school graduation. Therefore the age group of 22–23 year olds was taken as a basis for calculation.

Figure 3



Notes: a) France 1994 b) France 1997 (1) Entrants to IUT and STS (2)MA equivalent *(Maîtrise)*. Includes engineering entrants with IT specialisation (3) Entrants to four year *Fachhochschule* (4) Entrants to HND courses.

15,000 leave higher education annually with a computer science qualification, of whom some 6,500 are at a sub-degree level. This total is 28 per cent higher than in 1990, and the increase is the result of more graduates and post-graduates (+ 63 per cent); this is consistent with the fact that there is currently higher demand for graduates than for technician-level (BTS/DUT) qualifications. These figures are consistent with OFMI's calculations with the same method and with the results of the *Direction de l'Animation de la Recherche, de l'Evaluation et des Statistiques* (DARES) of the Ministry of Employment and Solidarity. Their results indicate that of those who leave the education system about 14,000 annually find a job in this area, of whom 9,000 have a bac+3 diploma or more. But OFMI asserts that this estimate is on the low side.

We could also include a further 1,000 new entrants trained in electronic trade and in information system management from business schools. Moreover, when there is a shortage on the labour market, as in 1998 or 1999, about 7,000 people can be added from non-IT HE courses. These are re-trained by their employers in a few months: many engineers, for example, have acquired more computer science knowledge than might be indicated by the title of their degree. In total, OFMI arrives at an estimate of 18,200 to 25,600 entering IT occupations from HE in 1997.

4.2 Germany

In Germany the rise in degree numbers in computer science has been dramatic since 1995, bearing in mind the demographic downturn since 1995 and weak growth in HE enrolments. If FHS and university entrants´ numbers entering computer science courses are added together, this puts Germany ahead of the other countries in this study with a comparable population size (table 1).

Between 1995 and 1998 entrants to computer science courses in universities increased by 80 per cent and at FHS by 65 per cent.[13] The participation rate of females is relatively low with just 17 per cent in 1998. However, it has increased from 1995 when the rate amounted to just 14 per cent. The extent to which IT skill needs are met also depends on the attrition rate within HE. In 1998 3,270 students passed their *Diplom* in computer science (long university degree). Their average age was 28.2 years and average study duration was 6.7 years. For the shorter FHS degree 2,692 students passed in computer science — also aged 28.2 years. Their average study duration was 4.7 years.[14].To calculate the drop-out rate we compare their numbers with those of the HE starters in this subject seven (university courses) and five (FHS courses) years ago.

Table 2 shows an enormous attrition rate at university of 58 per cent. Although Germany has relatively high entrance rates in computer science in comparison to all other countries in the sample, the output rate is relatively meagre. The shorter FHS course shows a higher success rate but with 45 per cent the attrition rate is still very high. Even if the entrance statistics are slightly overestimated and the statistics of degrees underestimated, the data reflect a high drop out rate. A comparison for 1995 shows similar results.

At sub-degree level newly created apprenticeships for IT-occupations are entered by many school-leavers with university entrance qualification. From the end of the 1960s two apprenticeships in the IT area existed, the data processing clerk (*Datenverarbeitungskaufmann*) and the mathematical technical assistant, which have become

[13] Some universities have restricted access to their computer science courses by setting a *numerus clausus*. This reflects the problem that for a further increase in supply the capacity of HE institutions has to be supported by additional financial means.

[14] The similar age level for FHS and university graduates results from the requirement for FHS students to gain practical experience (e. g. internship or apprenticeship) before starting an FHS course.

Table 1

Entrants[1] to computer science courses at universities and FHS as percentage of their age group

Year	Age group 22–23 year olds in '000	Comp. Sc. university entrants	Comp. Sc. university entrants as per cent of all University entrants	Comp. Sc. FHS entrants	Comp. Sc. FHS entrants as per cent all FHS entrants	Total comp.sc. entrants as per cent of age group
1985[2]	1 085	6 296	3.35	2 439	3.25	0.8
1990[2]	1 286	8 496	3.64	4 457	4.69	1.0
1995	902	7 436	3.10	5 073	5.12	1.4
1998	872	13 379	5.16	8 371	7.97	2.4

The age group 22–23 years was taken as the average student enters HE with a delay of 3 years

[1] First semester in computer science was chosen for international comparability. — [2] West Germany.

Source: BMBF, Grund- und Strukturdaten; Federal Statistical Office.

Table 2

Number of degrees in 1998, study period, age at exam and attrition rates from university and FHS computer science courses in Germany

	Entrants	Study period in years	Age at exam	Degrees 1998	Est. drop-out rate per cent
University	7,881[1]	6.7	28.2	3,270	58
FHS	4 964[2]	4.7	28.2	2,692	45

[1] West Germany 1991. — [2] United Germany 1993.

Source: Federal Statistical Office and Grund-und Strukturdaten (1999).

antiquated, and a strong contraction occurred in the numbers of these apprenticeships. In 1997 new regulations were published for four new apprenticeships: All four occupations have a common basic training for about half of the training period of three years which includes joint key qualifications in the areas of electric, electronics, computer science and business. This flexibility allows training in different sizes and types of companies, industries and organisations and to comply with a customer-oriented service. In the year 2000 about 7,000 persons will achieve this certificate. This number is expected to double by 2003. A further 2000 students will qualify from two-year colleges (*Fachschulen*).

In 1999 the Federal Labour Office spent one billion DM for retraining in the IT sector. Some 32,000 persons will be retrained by the Federal Labour Office in 2000. Many of these are unemployed university graduates who studied subjects like mathematics, science and engineering (Dostal 2000). Initially at least it is expected that they will be less qualified than an IT graduate.

4.3 The United Kingdom

The changes in the overall supply of A-level students have been reflected in the rising numbers entering higher education. The percentage of the cohort entering the first year of a degree or two year diploma course in HE in the UK is now more than 30 per cent (Figure 2). The total number of students accepted to study degree courses has increased by 23 per cent since the mid-1990s (from 263,933 in 1994/5 to 323,763 in 1998/9). The numbers accepted to study computer science have increased faster than the aggregate rate, by 78 per cent over the same period. However, numbers entering two-year HND/HNC courses in computer science in the UK are much lower than those entering comparable courses in France.

The upward trend in the numbers studying computer science have been even greater for women, although only just under 20 per cent of those studying computer science are women. This is consistent with the fact that only 25 per cent of those working in IT are women, and at 16 per cent the proportion is even lower at the professional (degree or above) level (AISS 1999).[15] We found that women are slightly less likely to take an A-level curriculum that enables them to study subjects such as computer science and even women who are eligible to study computer sciences by and large choose not to. Given the massive expansion of higher education participation by women over the last 30 years, it is obviously of great concern that certain subjects remain male-dominated, particularly in an industry potentially facing skill shortages. Completion rates for those entering HE courses in the UK are high relative to some other countries considered here. A recent estimate suggests that in the mid-1990s between 14 and 18 per cent of those enrolling failed to gain a qualification.[16]

5. Entrants to 'long' computer science courses as a percentage of age group

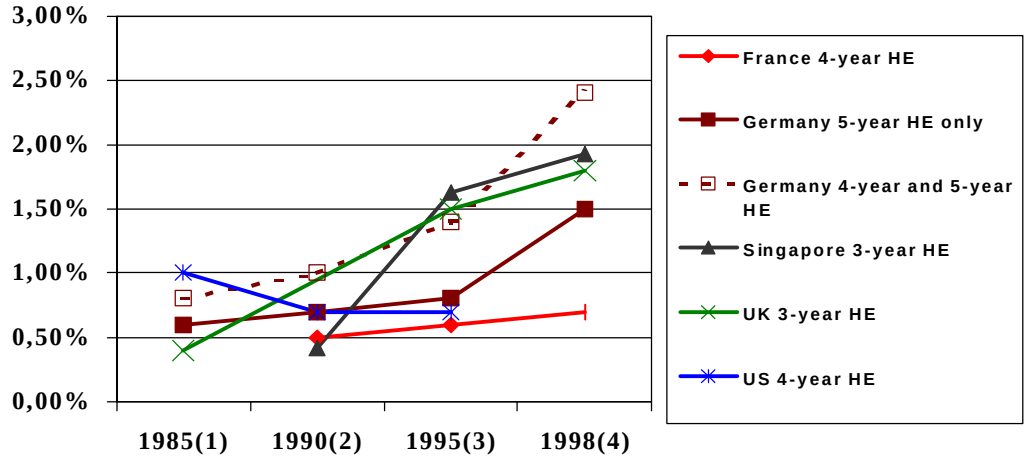
Enrolment rates in HE courses differ from country to country and different demographic trends and population size combine to make the interpretation of absolute numbers entering computer science courses difficult across a wide range of countries. By showing entrants to computer science courses in HE as a percentage of the age group these variables are controlled for, and it is possible to judge whether each country is producing similar numbers of computer science students relative to the population.

In this comparison we control for population size and year on year changes in cohort size. Data on Singapore and the US can therefore be included on a comparable basis to France, Germany and the UK (Figure 4).

[15] In fact the proportion of women working in IT as a whole has actually declined in recent years, as the proportion of lower level computer operators has fallen.

[16] Report of the National Committee of Inquiry into Higher Education (Dearing Report) July 1997 para. 3.22.

Figure 4



Notes: (1) UK 1987 (2) Singapore, Germany 1988 (3) France 1994, US 1996 (4) France 1997 Germany 1985 and 1990 former Federal Republic only (a) Singapore = graduates, France = Bac + 4, end entgineering schools

5.1 Singapore

For Singapore data on numbers of entrants to computer science courses were not available, and we have therefore used numbers gaining degrees in computer science. It is considered that this measure can act as a good proxy for entrants since entrants are quite highly selected and there is very little drop-out. The percentage of the cohort completing computer science degree courses in Singapore increased faster between 1990 and 1995 than in any other country. Relative the to size of the population Singapore produces more IT graduates than any other country examined here. The growth in IT graduates was considerably greater than that of all graduates over a similar period. While numbers of first degree holders leaving Singapore universities roughly doubled between 1988 and 1998, numbers graduating in IT increased nearly five-fold over the same period.

While places on university undergraduate degree courses provide for around one fifth of the 18 year old age cohort in Singapore, opportunities also exist for those with at least five O-level passes to enter a three-year course at one of Singapore's four polytechnic institutions. The three-year course leads to a Diploma award considered equivalent to the British HND/HNC award.[17] Computer science courses are offered at all four polytechnics; in 1998 around two thirds of those gaining a diploma qualified in the engineering or computing field. In 1998 just under 2 per cent of the age group gained a degree in computer science. An additional two per cent of the age group qualifies annually at the sub-degree level in computer science in Singapore.

5.2 The United States

As already shown (Figure 1), educational participation post-16 is much higher in the US than in countries such as the UK. Around 70 per cent of US 17 year olds graduate from high school (Vignoles and Hansen, 2000). These data underestimate the true graduation rate however, since many individuals graduate after the age of 18 or gain a High School Equivalency Certificate (GED) at a later age. Around 90 per cent of 25-29 year olds have a high school diploma or equivalent certificate.

We can broadly say that around 90 per cent of each age cohort in the US is 'eligible' to go on to study for a degree (although in reality we know this depends upon the quality of a student's high school diploma, in terms of mean grade point average, and her/his aptitude test scores). The percentage of high school graduates (aged 16–24) actually enrolled in a higher education institution after completing high school is somewhat lower. In 1997, some two-thirds of the 18 year-old cohort enrolled in a community college or university. This represents a 34 per cent increase since

[17] Some Singapore engineering polytechnic graduates subsequently enrol at British universities on first degree courses and are normally admitted onto the second year of the course (Steedman, Green et al.1996).

1972 when it was around 50 per cent. A proportion of these enrol on short vocational or 'remedial' type courses.

However, attrition rates (average for all disciplines) in the US are high so that for degrees achieved the rise is less impressive. In 1971 22 per cent of 25–29 year olds had a bachelor's degree or higher. By 1998 this percentage had increased to just under a third. Of those starting on a two year college course in 1989/90 37 per cent had attained a qualification by 1994, 14 per cent were stilled enrolled but had no qualification and 49 per cent had no qualification and were no longer enrolled. Of those starting bachelor degrees in the same year 54 per cent had gained a qualification, 18 per cent were still enrolled but had no qualification and 28 per cent had no degree and were no longer enrolled. It therefore appears that attrition rates in the US are relatively high and are closer to those in continental Europe than in the UK.

Numbers entering four-year computer science courses in the US rose sharply in the mid-1980s. Since then numbers have fallen. The overall rise, both in new entrants and in degrees awarded masks the decline seen within computer science. Figure 4 shows the fall in new entrants to computer science degrees measured as a percentage of the relevant cohort since the peak reached in the mid-1980s. But despite this recent decline, the total number of computer science degrees awarded in 1996 was 60 per cent higher than in 1981.

5.3 Summary

Figure 4 shows for all five countries the change in the percentage of the age cohort with a HE computer science long qualification (degree) 1985-1998. This figure therefore takes into account any demographic changes that might have occurred over this period and controls for population size. France has experienced relatively little growth from a low base. Germany, Singapore and the UK have all experienced very considerable increases in the percentage of the age-group entering a computer science degree course. In Germany and the UK the percentage entering has trebled over the period 1985-1998. In Singapore the percentage has trebled over a shorter (8-year) period and the 1998 level is higher than in all other countries. However, if we combine the four-year and five-year degree courses in Germany, the percentage of the cohort in these two types of computer science courses from 1995 onwards is higher even than in Singapore.

The US is the exception in this comparison with a fall between 1985 and 1995. In the US a peak in the percentage of the cohort gaining a computer science degree occurred in 1985/86 but this figurre had almost halved by the beginning of the 1990s. Later growth in Europe could simply reflect catch-up in computer use relative to the US. The sharp fall in the US is difficult to interpret considering the continuing expansion of electronic media and data processing in US business. Controlling for population size, the UK has the second highest and Singapore again has the highest percentage of the age cohort enrolled in computer science degree courses. Germany is very close to the UK and Singapore, and comfortably overtakes both countries if degree and FHS entrants are aggregated. We should recall, however, the very long study period for German university students — an average of nearly seven years. Long study periods mean that Germany will not begin to benefit from increased numbers enrolling in universities in 1995 and subsequent years until 2002 at the earliest.

6. Quality of entrants to HE computer science degree courses

In order to address this issue we tried to determine how the mean score of students admitted onto computer science degree courses compared with the mean score of all students admitted to HE and to track trends over time.

With respect to France we used the Bac S, obtained by individuals from the top 20-25 per cent of the cohort. For Germany we used the measure of "very good" and "good" marks in the Abitur examination, for the UK we used A-level points score and for the US we used scores on the SAT examination (See Section 2.4 above and individual country reports (op. cit.) for more detailed explanation).[18] It was not possible to compare the mean A-level score of computer science students in Singapore with all students in Singapore.

As shown in 2.4 above, different measures of student quality were used in each country since HE pre-requisites are normally country-specific. These allow us to ascertain whether the mean performance on HE pre-requisites of computer science students is above or below the mean for all HE entrants and, following this analysis, to compare quality relative to the overall mean across the countries concerned. Measures of quality relative to the mean were obtained for all countries except Singapore (Steedman 2000). In this section we present data country by country.

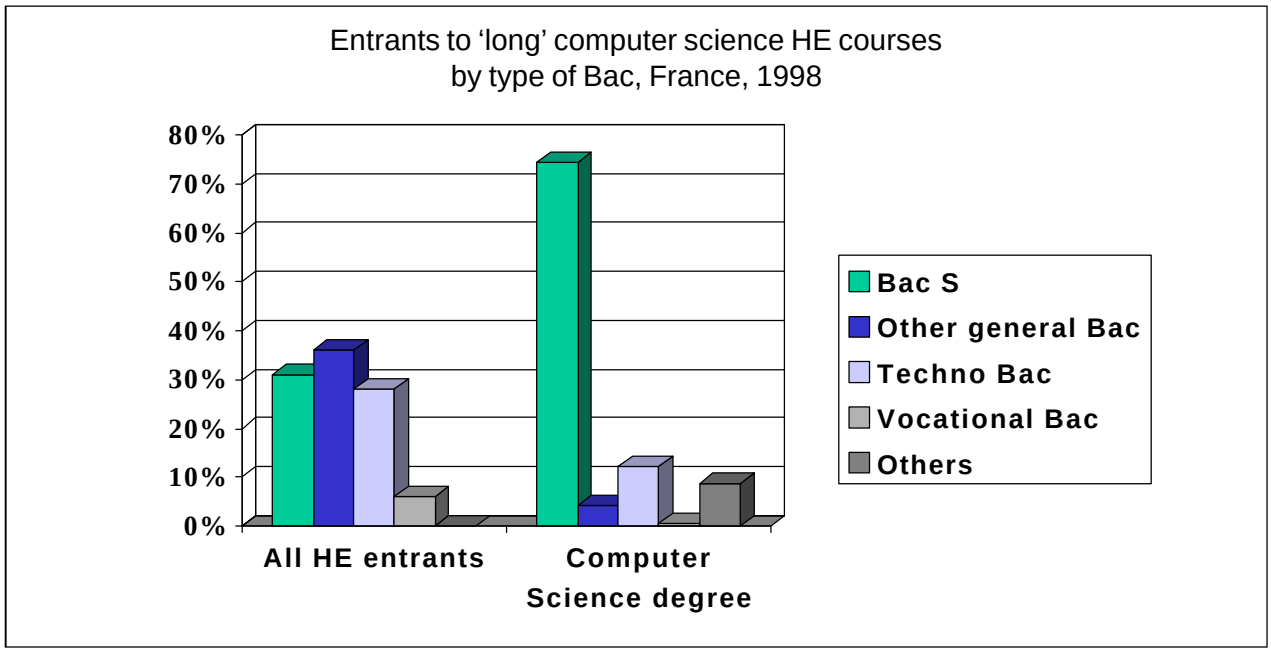
For France, Germany and the UK we have quality measures for both short and long computer science courses in universities or similar HE institutions.

6.1 France

In the country report on France (Bruniaux 2000), evidence is presented to show that the most prestigious Bac, the Bac S, effectively identifies the top two deciles of the cohort who perform best on academic measures in the school system. We have therefore used the Bac S

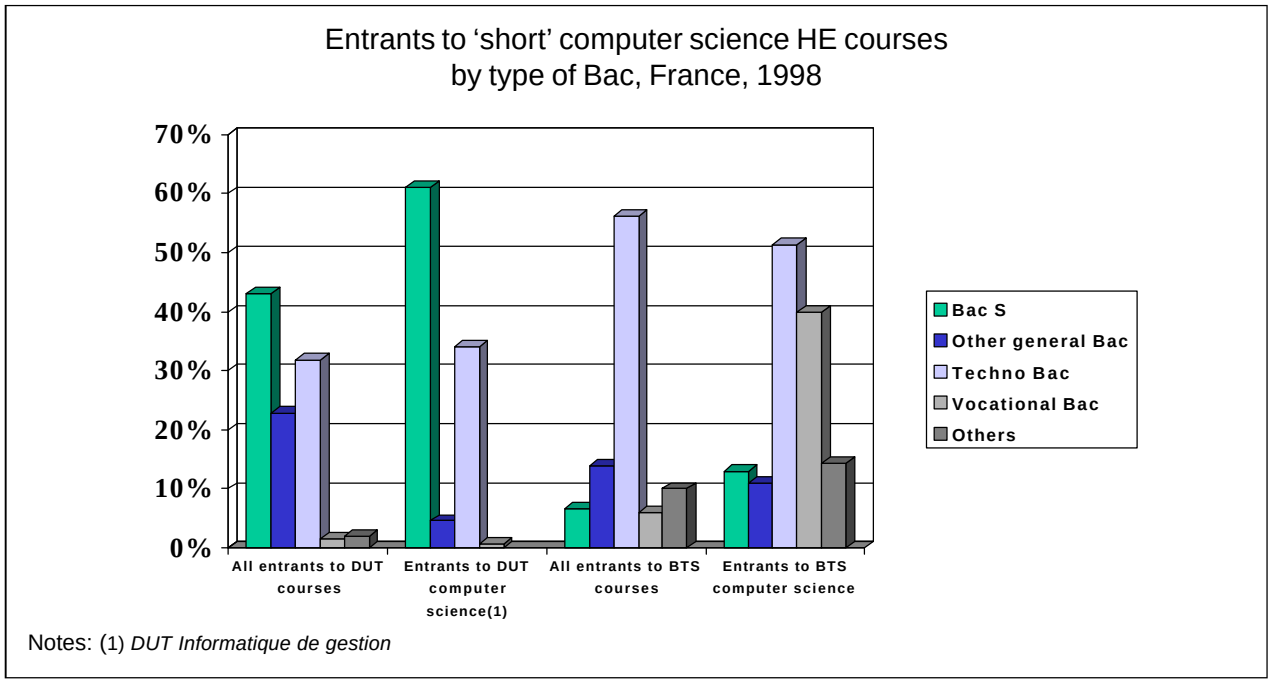
[18] The scale used in England is A = 10 to E = 2.

Figure 5



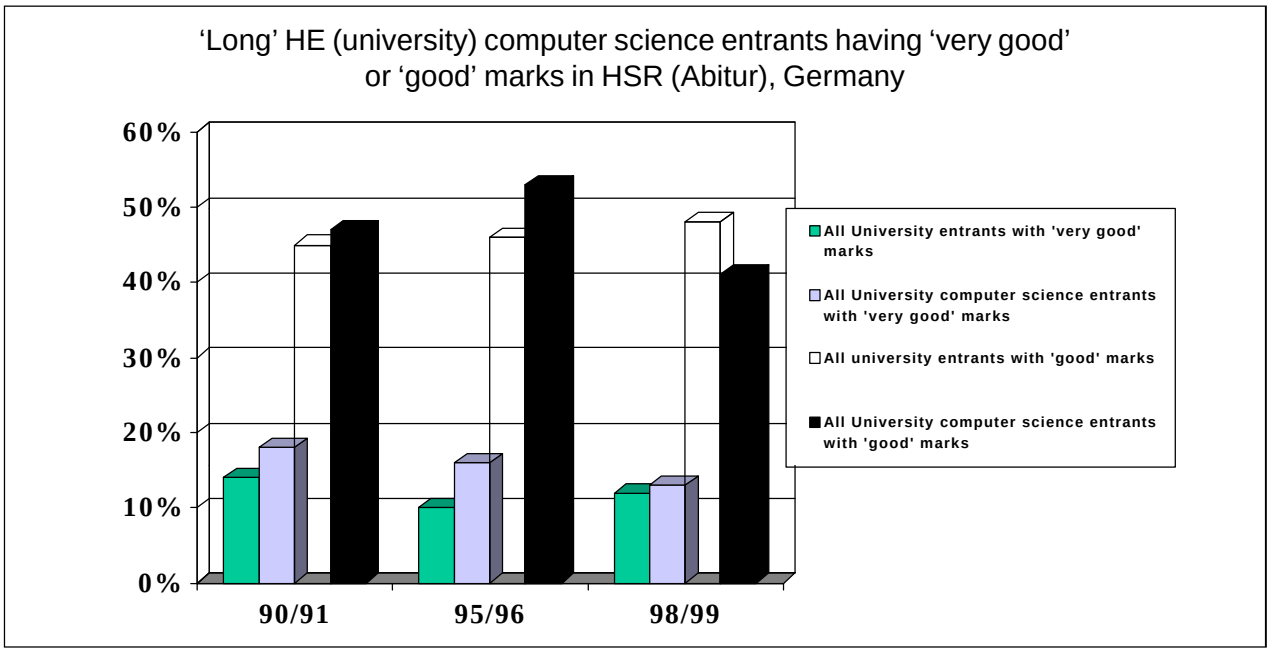
as an indicator of quality of HE entrants. Around three-quarters of all entrants to computer science long degree courses have obtained a pass in the Bac S. Those studying computer science in engineering schools are not included here but almost certainly the proportion with the Bac S is even higher. For all HE entrants the relevant proportion is 30 per cent. Probably because numbers entering computer science courses are still low in France relative to other countries and because most are expected to study for at least four years, quality has remained high (Figure 5). Of those entering short HE courses in computer science (BTS and DUT), the proportions having the Bac S are 13 and 61 per cent respectively. This compares with seven per cent of all BTS students having the Bac S and 43 per cent of DUT students (Figure 6).

Figure 6



Notes: (1) *DUT Informatique de gestion*

Figure 7

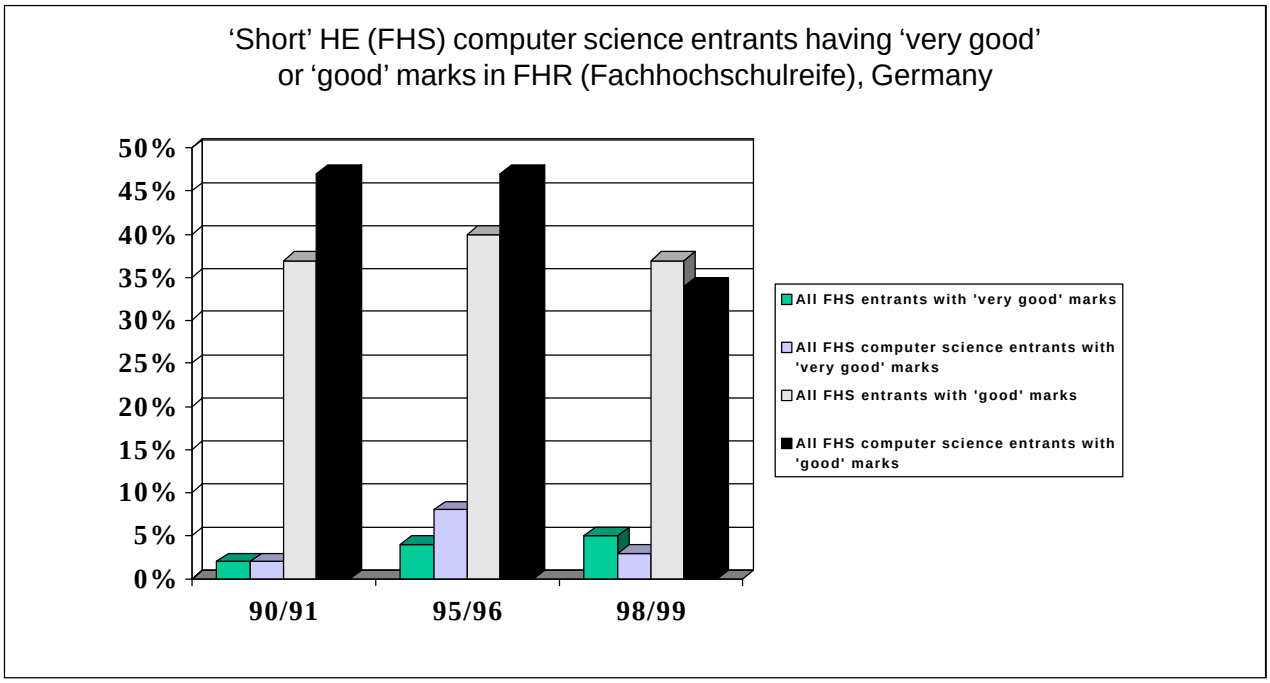


6.2 Germany

For Germany we were able to obtain information concerning the graded performance of students in the *Hochschulreife* (Abitur) examination. The percentages of all university entrants obtaining a pass in the Abitur with 'very good' or 'good' marks is compared with the grades of computer science students (Figure 7). Overall, just under two thirds of university entrants in Germany pass the Abitur with 'good' or 'very good' marks. The percentage passing with 'very good' marks is quite small, a little over ten per cent. Figure 7 shows a changing picture over time.

Computer science students in universities have declining proportions with 'very good' marks but stay well above the average until 1998/99 when there is little difference with the average entrant. In 1998/99 the percentage of computer science students with 'good' marks is well

Figure 8



below the average (Figure 7). Students in the FHS have much lower proportions of 'very good' and 'good' marks than those in university — under half — (Figure 8). The marks of computer science entrants in the most recent year (1998) are below the average for all FHS students and thus mirror the decline noted for entrants to computer science in universities in that year. However, numbers entering computer science courses since 1995/96 in Germany have almost doubled and this rapid expansion probably explains the fall in relative quality.[19]

6.3 Singapore

It is not possible to obtain data showing the mean A-level score of university entrants in Singapore, and therefore no detailed comparisons with computer science entrants can be made. Sources consulted in Singapore considered that the mean score of computer science degree course entrants would be similar to the mean for all university entrants.

6.4 The United Kingdom

The UK country report (Hansen and Vignoles 2000) shows rising numbers of A-level awards and rising grade score attainment at A-level over the 1990s; this explains the rising mean A-level score of entrants at a time of increases in HE participation. Figure 9 shows mean A-level scores for all entrants to HE. Numbers of computer science entrants have increased very rapidly in the UK over this period (Figures 3 and 4) and mean A-level grade score is well below that for all entrants and that for engineering entrants. However, the mean grade score of computer science entrants has also improved at a faster rate than the average for all entrants indicating that the courses are increasingly attracting more able students. The grades of 'short' HNC/HND course students are not given here since numbers are very small.

6.5 The United States

Most college-bound High School students in the US enter for the Scholastic Aptitude Test (SAT). Two scores, for verbal and mathematical reasoning are published by students' intended area of study. Computer science students perform well below the average for all entrants. The proportion of the age-group entering computer science courses has not changed significantly over the period 1990-1995. Thus, there has been a quantitative decline in the total supply of computer science graduates, but this says nothing about changes in the quality of graduates in this subject. To do this we look at Scholastic Aptitude Tests or SATs.

More specifically we use pupils' scores from the SAT I: Reasoning Test to evaluate their achievement. The SAT I

[19] 64 per cent of German computer science students at university have taken mathematics specialisation courses at school whereas the average is just 30 per cent in 1998 (special computation by the *Hochschulinformationssystem* GmbH, Hanover, provided by Mr. Lewin for the survey in 1998).

Figure 9

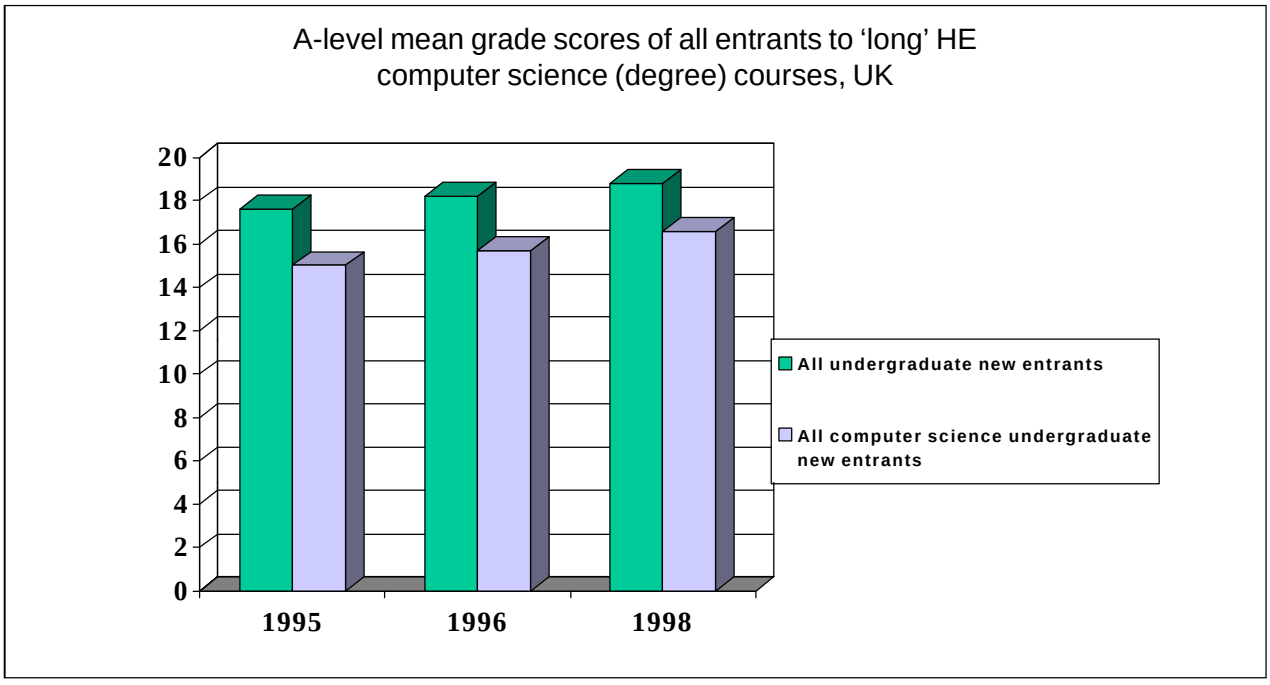
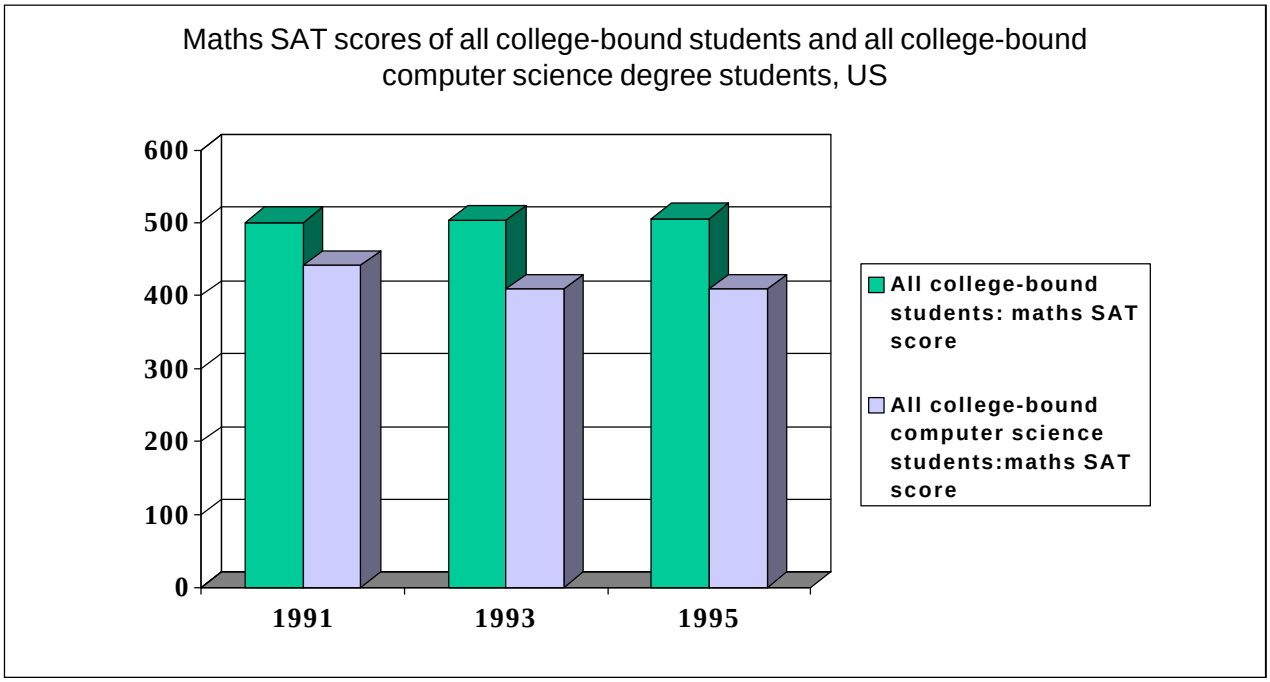


Figure 10



consists of two tests of verbal and mathematical reasoning ability. The tests are reasonably lengthy, lasting an hour and fifteen minutes each and consist of 150, largely multiple choice, questions. Last year in the US around 1.3 million US students took an SAT test. Most US students sit the test once, or more commonly twice, in their Junior or Senior year of high school (last two years of high school: aged 16-18). Re-taking the test is allowed, as is 'coaching' for these tests. The tests are voluntary, although an increasing proportion of high school students chooses to take them.

We can compare the standard of achievement on the verbal and mathematics SAT tests by intended subject of degree for college bound students by data from the US Digest of Education Statistics (1997). Data from 1995, shows that students intending to study computing science at degree level are considerably less able, on average, in terms of both their verbal and mathematical skills; they have 20 per cent lower verbal scores, compared to the average for all subjects, and 12 per cent lower mathematics scores. Furthermore, the achievement of those intending to take a computer science major has barely changed during the 1990s.

Another way to consider this problem is to compare the SAT scores of computer science students with the scores achieved by the entire distribution of US students who took SATs (Vignoles and Hansen, 2000). The data indicate that the mean verbal SAT score achieved by computer science students was 409, which was achieved by 60 per cent of US students who took SATs. The mean mathematics SAT score achieved by computer science students (446) was achieved by between 60 and 70 per cent of all those who took SATs. In other words, computer science students tend to come from the lower half of the ability distribution.

7. Summary and conclusions

There is strong evidence of skill shortages in the IT sector and in IT-related occupations in France, Germany, the UK and the US. In Singapore the evidence for skill shortages is less strong. The situation with respect to the supply of qualified recruits to this sector is considered sufficiently serious in the US and the three European countries for official government and/or industry action to have been taken to analyse the situation of the IT sector with respect to skill needs. Relative to most other sectors and occupations IT employs a high proportion of graduates from the HE sector. This study examines the extent to which the combined effect of student choice of subject in HE and HE provision has responded to the increased demand for skills by increasing the numbers studying on computer science courses.

In Europe and Singapore the proportion of the age group entering IT courses has increased substantially since 1990. Germany shows a particularly rapid increase since 1995. Only the US shows a slight downward trend after a strong increase in the early 1980s. The composition of entrants to HE IT qualifications varies across countries. In France twice as many enter short (two-year) HE

IT courses as enter the longer degree course; the ratio in Singapore is very similar. In Germany, entrants to five-year courses outnumber entrants to four-year FHS courses by nearly two to one, although this gap has been narrowing since 1990. In the UK, numbers entering short (two-year) courses are very low, while in the US entrants to HE are divided more or less equally between 'long' four year courses and 'short' two-year courses. In Europe and the US this expansion of entrants to IT took place during a period in which participation rates in HE were flattening out after a period of growth in the 80s and early 90s. Expansion in entrants to IT therefore indicates that entrants were switching to IT out of other subject areas.

The quality of entrants to IT HE was measured by performance on pre-requisites. In Germany, the UK and the US, evidence of trends in quality over time is available. In Germany, the quality of entrants has declined slightly during the most recent period of rapid expansion of numbers of entrants, but remains close to the mean for all HE entrants. In the UK, entrant quality was below the average for all university entrants but showed recent improvement. In the US, entrant quality was also below the mean for all entrants and showed a slight decline since 1993 despite the lack of expansion in entrants. In France in 1998 entrants to IT were substantially better qualified than all entrants to university courses.

Until now, the IT sector has relied heavily on the (predominantly) state-financed HE sector to provide new recruits to meet the skill needs of the industry. Industry complaints of shortfall in meeting skill needs have largely been directed at HE as the main source of supply. Complaints from the industry are not just that the supply from HE is inadequate but also that the courses on offer lag behind the skills required or that skills and knowledge acquired in HE are not directly relevant to the industry. From a purely quantitative point of view, however, it can be seen that, except in the US, HE institutions have responded to demand by allocating to IT an increasing share of student places over the past five to ten years. It is clear however, from continuing concern over skill shortages that this response has been inadequate. At the same time and on the evidence available, indications are that — except in France — the quality of IT entrants is typically somewhat below the mean for all HE entrants and that more rapid expansion still might seriously jeopardise the quality of the output.

This study has shown that countries vary considerably in terms of length of study period in HE and in attrition rates. Together these will determine the speed and adequacy of the HE response to IT skill requirements. The UK and Singapore are characterised by short study length and low attrition while Germany lies at the other extreme with long study requirements and high attrition.

France and the US lie between the two extremes. German university students take, on average, almost seven years to complete their studies and FHS students take, on average, five years. Thus the rapid expansion of entrants to German university and FHS computer science courses which started in 1995 will not produce a larger number of qualified persons until 2000/2002 at the earliest. Furthermore, a high proportion can be expected to abandon their courses before completing. UK and Singapore students entering in 1995 would normally have entered the labour market in 1998 with few drop-outs.

Another point of contrast between Germany and other countries included in this study concerns the extent to which employers in the IT sector and newly-qualified graduates are prepared to be flexible in their hiring and job-seeking behaviour. In France, the UK and the US, IT companies routinely hire graduates from disciplines other than IT and provide training to equip new recruits with specialist IT skills needed by the company. It appears that in Germany employers are less prepared to undertake the required retraining but often depend on new recruits for whom the retraining has been financed (with no costs for the firm) by the Federal Employment Office. Recruiting these trainees can even be cheaper for the firms than training apprentices.

The IT sector is characterised by an almost unprecedented pace of technological change and development. New occupations and new skill needs can arise — and disappear — within the space of a few years. Universities, by contrast, are large national institutions with a wide responsibility for advanced education and research. While they can and should respond to technological and occupational change, it would be unrealistic to expect them to adapt their standard programmes with the rapidity required by the IT sector.

Companies are, of course, much attracted to universities as a source of highly-skilled recruits. The cost of acquiring these skills has been met largely out of general taxation and the pocket of the individual and his/her parents. In employing graduates the company benefits but does not directly contribute to the cost of acquiring the skills the company needs.[20] This system has worked reasonably well with respect to the professions and the public sector and even for much of the 'old economy'. It is, however, difficult to see how universities can provide for the whole range of skill requirements of a fast-changing 'high-tech' industry, nor is it clear that they should attempt to do so if this means sacrificing their wider educational mission.

Three alternative solutions to exclusive reliance on HE skill outputs have emerged from the evidence assembled

[20] Of course in the long run companies will pay through higher wages but are not at risk of losing their investment in training from externalities associated with the poaching of skills by other companies.

in this paper. First, as happens to some extent already in France, the UK and the US, companies will need to invest their own resources in providing to new and existing employees the specialist training required to work in many IT-related occupations. It should not be beyond the capability of such an innovative and profitable sector to devise ways of overcoming the accompanying externality issue. A second alternative strategy already being developed in Germany is to promote an apprenticeship model which allows companies to re-coup training costs within the duration of the period of apprenticeship and thus minimises the externality problem. A third strategy, used extensively in the United States and Singapore is to out-source IT work to consultants in other countries and/or to import from other countries the skills required. This is the solution currently proposed to tackle the immediate skill crisis in Germany. However, the global market in IT skills may also create problems, particularly for countries in less-developed regions. If high-wage economies in Europe and the US turn to extensive 'poaching' of IT skills from less-developed regions, the capacity of countries in less-developed regions to develop a knowledge-based economy will be damaged.

While the solutions outlined above may help to meet skill needs in the short term, it seems clear that a new relationship between institutions of higher education and the IT sector needs to be developed. We have suggested that the standard HE provision cannot respond rapidly enough to meet the IT industry's skill needs. But universities could and should become more flexible in the types of courses offered, the means of delivery and sources of finance. Short courses aimed at those already employed in IT — or those who wish to enter from another discipline — could be provided by universities on a larger scale than is currently the case. Full advantage should be taken of the Internet for teaching purposes and industry practitioners need to be brought into HE to help ensure that courses are leading edge. Such courses could be charged at full cost with students taking out loans or obtaining a subsidy from their employers. The IT industry will in future need to be more pro-active in bringing about change and greater flexibility in publicly-financed HE if the industry wishes to see an improvement in the supply of skills.

Acknowledgements

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Zusammenfassung

Internationale Trends in der Qualität und Quantität von Informatik-Studienanfängern

Ein klarer Fachkräftemangel behindert das Wachstum der Informationstechnik (IT)-Branche nicht nur in Deutschland, sondern auch in anderen Ländern. In dieser Studie wird untersucht, in welchem Ausmaß Schulabgänger mit einem Studium der Informatik in fünf industrialisierten Ländern, den USA, Großbritannien, Frankreich, Singapur und Deutschland, auf die steigende Nachfrage reagiert haben. Seit 1985 stieg in Europa und Singapur der Anteil der Altersgruppe, die sich für ein Studium in Informatik entschieden haben, beträchtlich an, obwohl in Deutschland die gesamten Studienanfängerzahlen zurückgingen. In Deutschland war ein starker Anstieg an Studienanfängern seit 1995 in diesem Fach zu verzeichnen. In den USA zeigt sich dagegen ein Abwärtstrend, nachdem die Zahlen in den 80erJahren beachtlich zugenommen hatten. Die Qualität der Studienanfänger wurden an ihren Schulabgangsqualifikationen bzw. -tests gemessen. Außer in Frankreich und Singapur lag das Qualitätsniveau der Studienanfänger für Informatik im Jahr 1998 unterhalb des durchschnittlichen Niveaus aller Studienanfänger.