Section V Encouraging Women into S&T

As shown in the previous section, attracting students and researchers from abroad is one way of increasing the number of highly qualified human resources in society. Another means of meeting the increasing demand for human resources in S&T is to encourage and increase the participation of women in S&T education, training and careers.

In recent years, the issue of 'gender mainstreaming'[20] has left the realm of being only an 'emancipation' issue and entered the domain of 'economics'. Economic dimensions of gender inequality are now beginning to have an impact at the macro level and are receiving attention. It seems improbable that the transition to a knowledge-based economy will be made successfully while a large part of half of the available human resources are not actively engaged in the process.

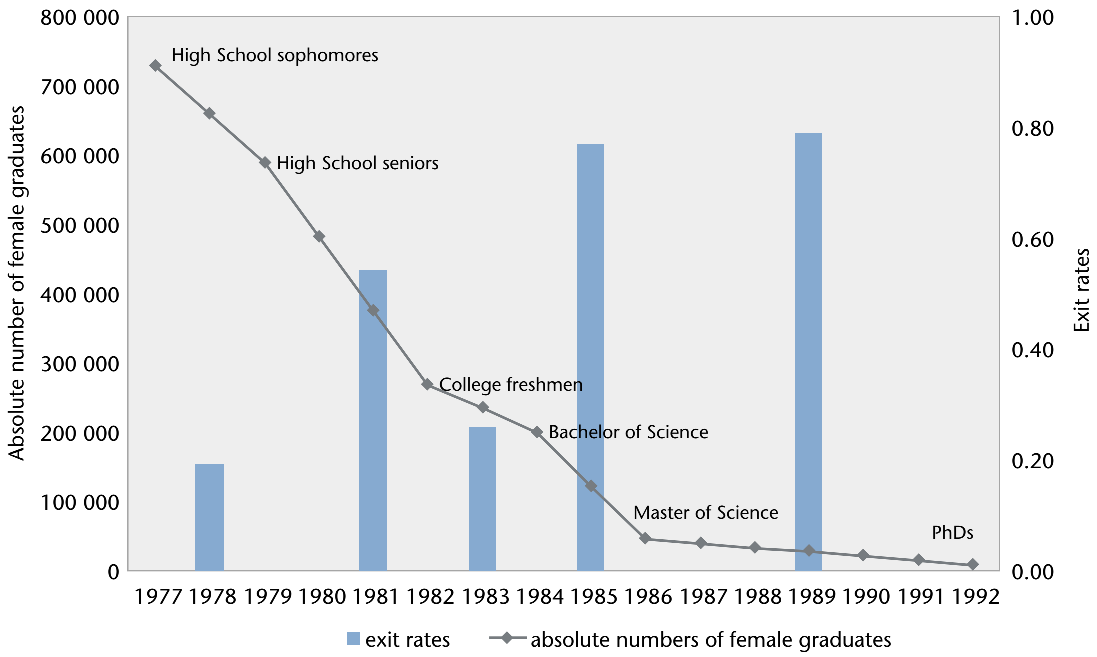
This section sets out to show the potential of women to compensate for the foreseen lack of human resources in S&T. First, some education data on female participation in S&E fields of study are analysed. A breakdown by levels of study and by disciplines will show the gender specificities, such as the high exit rates in the education pipeline and the bias towards non-S&E fields of study. Then secondly, the involvement of women in R&D on the basis of numbers of researchers, is analysed; the breakdown by sectors gives interesting insights. Thirdly, this section ends by looking at some of the data on S&T employment patterns of women, i.e. occupations as professionals and technicians, which pick up again the differences in education levels.

All these analyses suffer from the limited availability of gender specific data on human resources in S&T. In the Dossier on "Women in Science" which follows this chapter, measurement problems are addressed and the discussion on reasons for gender inequalities in S&T careers are looked at in depth.

1. Women's participation in S&T education

Before women can become part of the S&T labour force, they need to be appropriately and adequately qualified. Qualification status is determined by the level of education and the choice of field of study. What are the recent trends in women's participation in S&T education?

Figure 4.5.1 Female S&E students and graduates in the US 1977-1992



Source: World Science Report 1996, UNESCO; own calculations
Data: NSF
Note: Exit rates reflect the ratio between the number of graduates on one level and graduates of next higher degree. The exit rates include therefore the students who did not continue following the education pipeline as well as those who did not finish the next step.

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[20] *European Commission, 2000 (ETAN report), 'Science Policies in the European Union: Promoting excellence through mainstreaming gender equality'*

S&T education trends

Figure 4.5.1 shows some interesting data on the so-called 'education pipeline' for women over a 15-year period in the United States, where the minimum level of education required for an S&T job is an MSc (Master of Science) degree.

Of the 730 000 female students who finished high school in the US in 1977, only 46 000 or 6.3% obtained an MSc degree and only 9 700 (1.4%) completed a PhD. This translates into an exit rate of almost 94% at master's level and of more than 98% at PhD level. The highest exit rates occur after the BSc (Bachelor of Science) and MSc degrees, when almost 80% of female students decide to discontinue their academic careers. When these data are compared to the typical science career of male students, the exit rates of women turn out to be much higher.

Differences in professional careers can also be related to the choice of subject studied at university. Figure 4.5.2 shows the average percentages in 1998 for male and female graduates in the EU in different fields of study, such as natural sciences, mathematics and computing, engineering, health and food sciences, social sciences, arts and humanities, educational sciences and others.

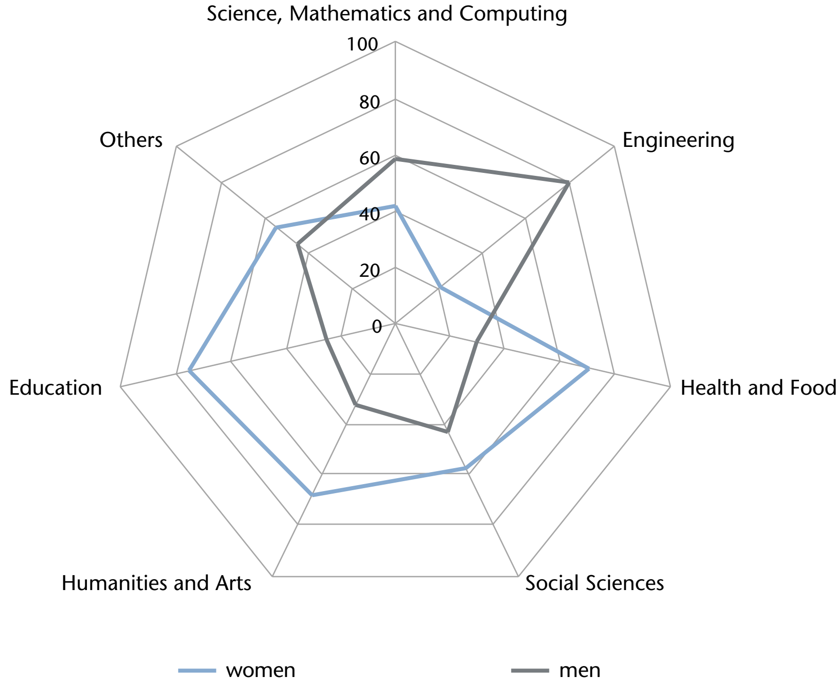
With more than 60% of graduates being female, the fields of education, arts and humanities and the health and food sciences are clearly dominated by women. In contrast, men tend to dominate in engineering and natural sciences, mathematics and computing, with shares of 80% and 59% respectively.[21] The social sciences, which also include economics and law, and the other disciplines show a more equal gender participation.

Overall in S&E (which comprises the natural sciences, mathematics and computing and engineering), women represent 30% of the graduates, while in all disciplines their representation is much higher at 55%. This discrepancy is one that continues to puzzle researchers – is it a question of access or one of interest and priority? Does this trend also apply in individual EU Member States?

Female S&E graduates compared by country and S&E disciplines

Figure 4.5.3 shows the shares of female graduates in S&E and in science and engineering for the EU Member States, the US and Japan.

Figure 4.5.2 Shares (%) of male and female of graduates by field of study 2000, EU averages



Source: DG Research
Data: Eurostat/OECD
Note: No data were available for EL or P, which are therefore not included in the EU averages.

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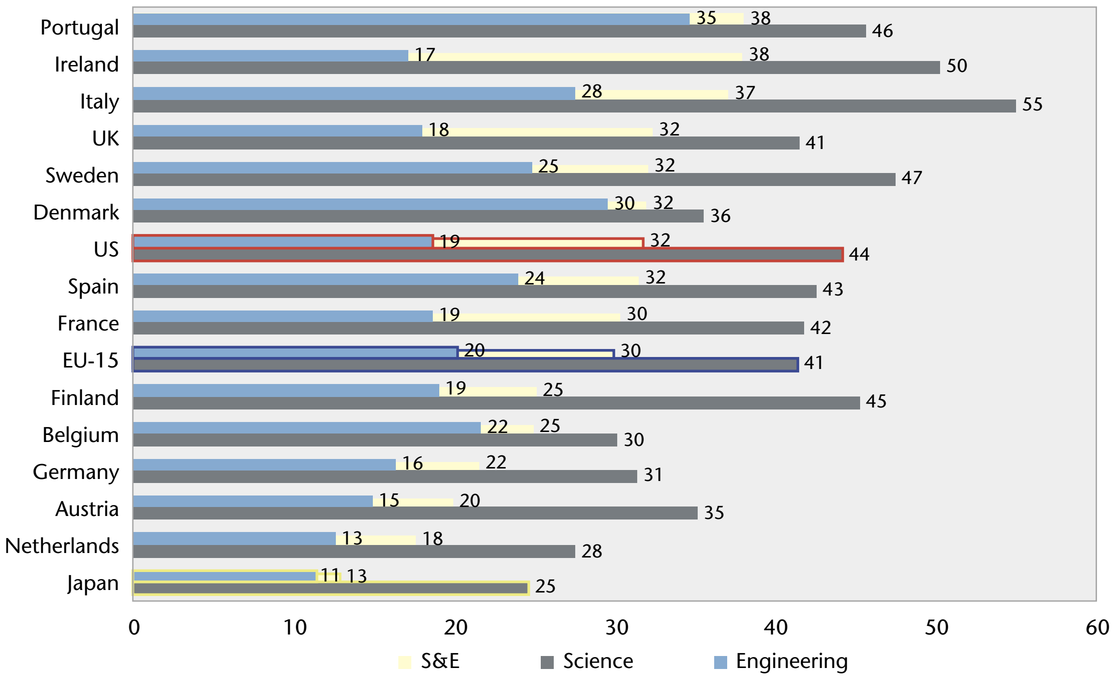
[21] *In the data for 1998, where natural sciences on the one hand, and mathematics and computing on the other hand, were given separately, the share of natural sciences were almost equal between women and man, but mathematics and computing were dominated by 70% male graduates.*

Figure 4.5.3 Percentages of female graduates in S&E: 2000



Source: DG Research
Data: Eurostat/OECD
Note: No data for EL or L which are not in the EU average.

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In 2000, in nearly all EU Member States, more than half of the graduates are women. However, the EU average share of women S&E graduates is only about 30%. This is slightly below the US average of 32% but much higher than Japan's average of 13%. In the EU, Portugal leads with an average of some 38%, while the Dutch with about 18% are below all the other countries.

Overall, across the EU, the end of the 1990s saw the share of women S&E graduates increase from 25% to 30%. The highest growth rates were in the Nordic countries, followed by Ireland and Germany. In these countries, significant progress was made towards equal gender representation during the 1990s. Interestingly, in Italy the growth rate of numbers of women in S&E for the decade is negative, which suggests that this high representation of women among S&E graduates in this country might not be a recent development.

There are striking differences in the representation of women in science and engineering. In the sciences, the representation of women is much higher than in engineering (which also includes town planning and architecture). In the EU, about 41% of the science graduates are women, but in engineering their share is half that at 20%. In the US and Japan this proportion is similar, with lower shares reported for Japan.

So women are generally more strongly represented in the sciences than in engineering at graduate level. With the exception of Italy and Ireland, which both show a somewhat stronger representation of women in the sciences at graduate level, women still account for less than half of the science graduates across the EU. The examples of Italy and Ireland show that equal achievement is possible in science. In engineering, equal representation of women and men remains a challenge. Even in countries with a higher representation of women in engineering, such as Portugal and Denmark, still only a third or so of the graduates are women.

Factors in increasing participation of women in S&E fields of study

An increasing proportion of female graduates in S&E is an important indicator of a narrowing gap between the levels of male and female participation in S&T. However, this does not say anything about the absolute numbers of female S&E graduates. An increase in the share can result from 1) the numbers of women increasing and the numbers of men staying the same, or from 2) the number of female graduates staying the same and the number of male graduates decreasing. Section 4.1 showed that the total number of S&E graduates had increased in most of the EU Member States. So the first of the previous scenarios must apply here for most of the countries under consideration, – the total number of female graduates has increased during the 1990s.

In light of the data presented here, it could be concluded that the low representation of women in some of the S&E fields is the result of insufficient recognition of the potential of this segment of the population to contribute to the human resource pool. Wouldn't a higher level of participation by women help to close the upcoming gaps in the skills supply chain? Science is better gender-balanced than engineering, so the potential for drawing more female graduates into engineering is considerable. There are striking differences between countries in this regard, and their potential to increase the number of women S&E graduates also varies.

It is not certain to what extent policy can influence the current situation in order to make the engineering field more attractive to women and to increase the access of women to S&T programmes in general. However, it is clear that policy alone will not bring about all the changes that are required to tap this potential skills pool. It could well be that the choice of field of study is still rooted in perceptions of these fields and of career options. Cultural and social influences might also still strongly influence choice of field of study. Moreover, it is not just a matter of attracting women into science and engineering at university level but also of keeping female graduates on an S&T career path.

Table 4.5.1 Percentages of female R&D personnel by sector in nine EU Member States: latest available year (1997-1999)

	Business Enterprise		Government		Higher education	
	HC	FTE	HC	FTE	HC	FTE
Denmark	28	25	48	47	40	39
Germany	:	17	:	35	:	35
Greece	:	:	37	40	50	50
Spain	22	22	41	41	37	38
Italy	17	16	36	37	:	:
Austria	15	14	43	40	39	36
Finland	22		46	:	45	:
Sweden	23	25	29	33	43	37
UK	:	:	34	:	:	:

Source: DG Research
Data: Eurostat NewCronos
Note: No data were available for B, F, IRL, L, NL and P
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2. Women in R&D

Lack of data on researchers and personnel makes the analysis of female participation in R&D in EU Member States quite a challenge. Attempts are being made to assemble more complete data on women in R&D, through initiatives such as the Helsinki group on Women and Science and various initiatives of the European Commission (see the dossier, below, on 'Women in Science' for more detail). Fortunately, some data for EU Member States are available from the Research DG's 'Women and Science' unit.

Comparisons of employment and sectors by country

As a first step, some of the data from the NewCronos database on R&D personnel by gender are analysed. Although the data are incomplete, it is worth examining what there is, especially given the differences between full-time equivalents (FTE) and headcounts (HC), and between the business enterprise, government and higher education sectors. Table 4.5.1 shows the share of women in R&D personnel by sector.

Women's participation in R&D varies greatly from sector to sector. In the countries examined, the lowest shares of women are in the business sector, ranging from 28% in Denmark to 15% in Austria in terms of headcount. In contrast, the public sectors show much higher shares, ranging, in headcounts, between 50% in the higher education sector in Greece and 29% in the government sector in Sweden.

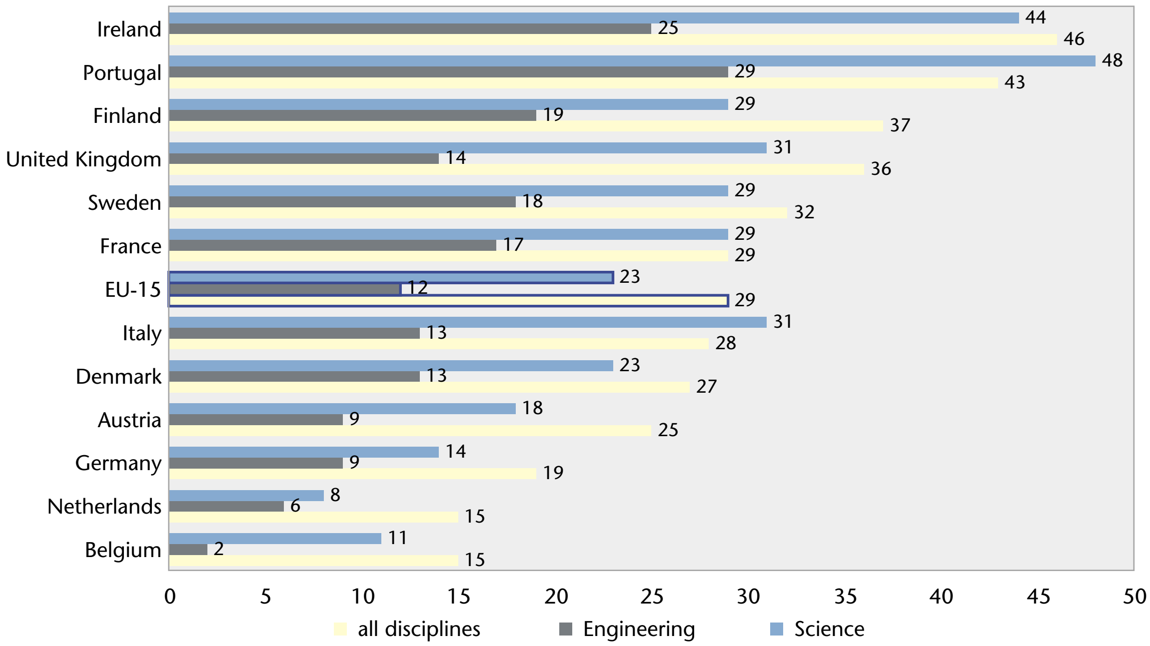
The differences between the HCs and the FTEs, which are indicative of lower numbers of full-time employed female R&D personnel if the HCs are higher than the FTEs and vice versa, are not very large.[22] Only in Sweden are there significant differences in terms of higher FTE shares in the government sector and higher HC shares in the higher education sector. Because these variations go in different directions, it is not possible to reach any conclusions relating to gender specific patterns on full-time or part-time employment in the Swedish sectors. This is even more so in the cases of the other countries under consideration.

The total numbers of R&D personnel are of little use in measuring R&D personnel with higher qualifications by gender. The data on researchers in higher education provided by the DG Research Women in Science unit have more detail in terms of fields of study but these are not complete for all the Member States. Furthermore, because they use a different data source, they are not comparable with the Eurostat NewCronos data on R&D personnel.

Figure 4.5.4 shows the shares of female researchers working in higher education in science, engineering and all disciplines. In all countries the figures for all disciplines show that the proportion of women researchers in higher education is smaller than that of women S&E graduates. In the EU on average fewer than 30% of the researchers employed in higher education were women. The shares of women working

[22] *For interpretation of HC versus FTE, see also the Box at the end of Section 4.1.3.*

Figure 4.5.4 Higher education researchers in science, engineering and all disciplines: Percentages of women, last available year



Source: DG Research
Data: DG Research, C 5, WIS database
Note: Years to which the data refer: D, P, FIN, UK: 1997; A: 1999; all other countries: 1998. No data were available for EL, E or L so they are not included in the EU average.

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in the fields of science or engineering are even less with 23% in science and 13% in engineering.

Portugal and Ireland are in the lead with, respectively, 43% and 47% of higher education researchers in all disciplines being women, 48% and 44% in science and 29% and 25% in engineering. The smallest shares of women researchers in relation to men researchers are found in Belgium, the Netherlands and Germany, with shares ranging between 15% and 19% in all disciplines, 8% and 13% in science and 2% and 9% in engineering. Interestingly, Italy comes out with values near to the average, which seemingly implies that the high shares of women S&E graduates are not pursuing careers in S&T.

If the labour force figures are compared to the data on graduates, it emerges that women on average lose a share of about 18% in science and 5% in engineering. Even for PhD graduates there is a drop of about 10% in science and 4% in engineering.

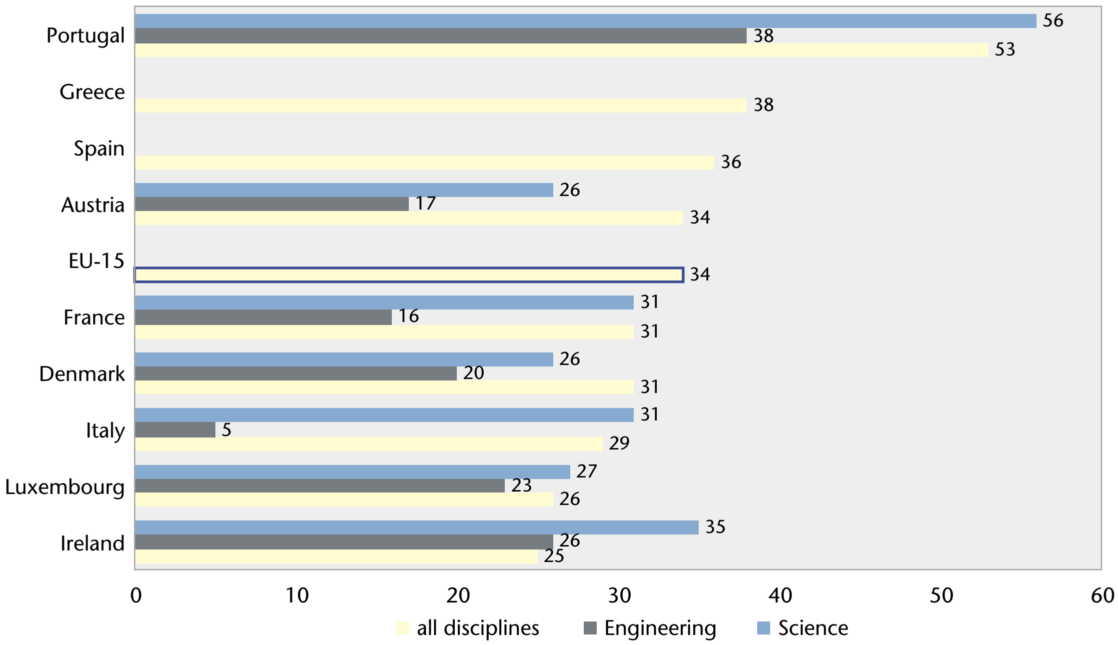
Assuming that a career as a researcher in a higher education or government institution is the most likely occupation for women, the gaps between women S&E graduates and employees in the business sector must be even more substantial. Unfortunately, there is no data for the business sector to prove this, but some government data are available – at least for certain countries. Figure 4.5.5 shows the shares of female government researchers in S&T for a few countries.

As in the higher education sector, Portugal is also in the leading position in the government sector, but Ireland has fallen back. In Portugal the share of women researchers in government institutions is extraordinarily high – more than 50% in all disciplines and in science, and still a high 38% in engineering. The other countries have shares of around 30% in all disciplines and in science, and shares of between 5% and 25% in engineering.

What is striking is that the northern European countries like Denmark or Austria, that feature most prominently in the education data, have nearly caught up with the better balanced southern countries like France, Italy, Spain and Greece. Unfortunately, no data for the Netherlands, Belgium, Germany, the UK, Sweden or Finland are available, so this assumption cannot be tested. Furthermore, the EU average should not be over-relied upon given the narrow statistical base.

Another career path for the graduate is in higher education. Figure 4.5.6 shows the shares of women with full professorships in all disciplines. In the EU, only 11% of full professors are women, which is considerably lower than the representation shown for women graduates in data on all disciplines. Finland, reporting 18% of women in full professorships, has the highest representation at this level, followed by Spain, France and Italy. The lowest shares of between 5% and 6%

Figure 4.5.5 Government employed researchers in science, engineering and all disciplines: Percentages of women last available year



Source: DG Research
Data: DG Research, C 5, WIS database
Note: Years to which the data refer: A: 1993; P: 1997; L: 2000; all other countries: 1999. No data were available for B, D, NL, FIN, S or UK so they are not included in the EU average.

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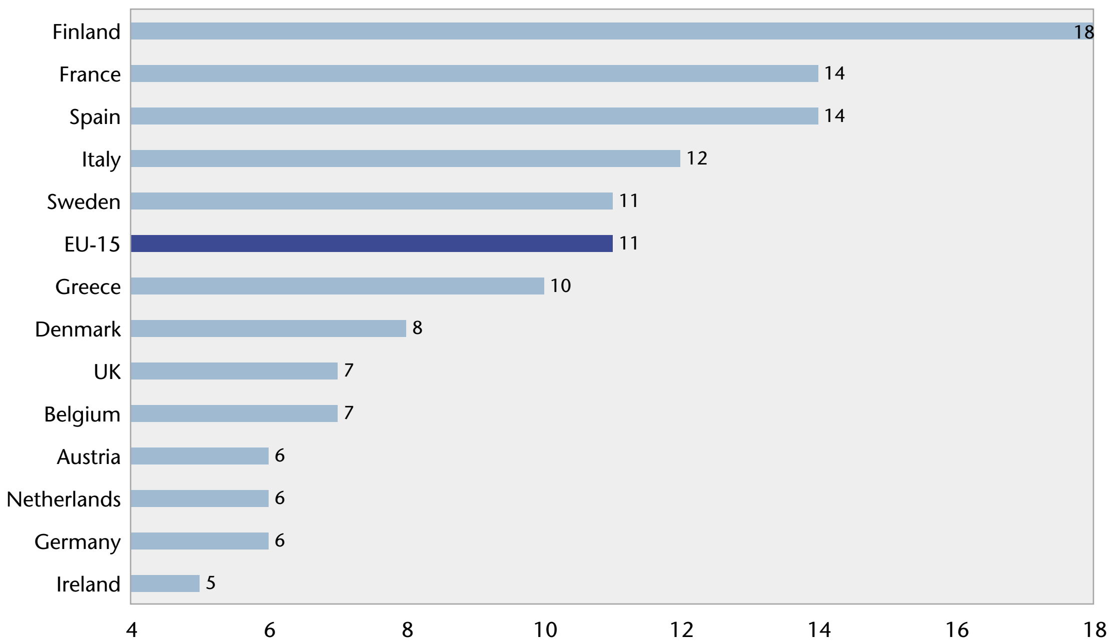
Figure 4.5.6 Full professors in all disciplines: Percentages of women last available year



Source: DG Research
Data: DG Research, C 5, WIS database
Note: Years to which the data refer: EL, E, FIN and UK: 1997; D, IRL, A and S: 1998; all other countries: 1999. No data were available for P and L so they are not included in the EU average.

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were reported in Ireland, the Netherlands, Austria and Germany.

Scenarios for more women in S&T

It is worth considering some possible scenarios regarding the contribution of women to the human resource base in S&T should their increased participation in S&T careers be successfully achieved. Figure 4.5.7 presents a commonly used approach to gender differences in careers: the scissors diagram shows the shares of women and men in the target population, which are students enrolled in upper tertiary education (ISCED 5A) and in postgraduate studies (ISCED 6), the PhD graduates and professors on three different levels (assistant, associates and full professors).

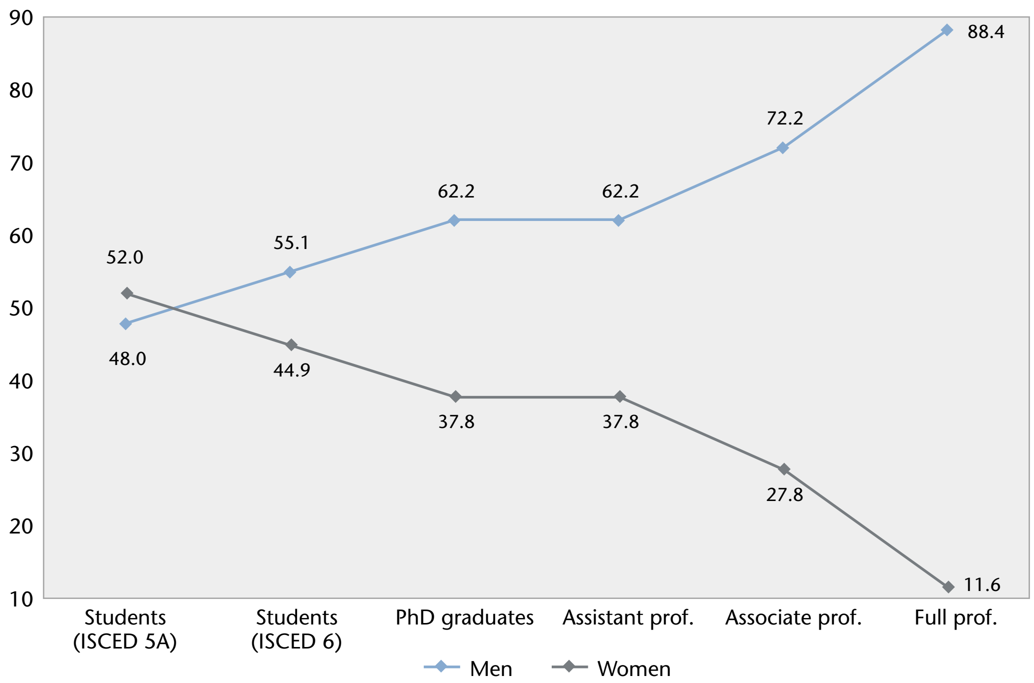
Starting on the same level with slightly more women students, the proportion of men steadily increases to reach 62% of PhDs and 88% of full professorships. In S&E disciplines, lower shares of women can be expected from the outset and become ever more likely on the highest rungs of the career ladder. Making simple calculations based on the data for all disciplines in higher education, the absolute numbers of women assistant professors could be 50% higher if women students followed scientific careers resembling those of male S&E students. At the level of associated professors, the numbers would increase by 150% and for full professors the increase could be as high as 800%.

In absolute figures this translates into a potential 180 000 additional (women) professors in the EU. Other examples are an additional 55 000 women researchers for the government sector and 200 000 women researchers for the business sector. These numbers are hypothetical but indicative of the scale of possible changes in the skills pool if the participation of women in the EU could be canvassed and fully realised.

3. Employment of women

The overall employment figures give also a good impression about women's careers in S&T related occupations. The following analyses are related to the occupations as professionals and as technicians.[23]

Figure 4.5.7 Scissors diagram for EU average in % (1998-1999)



Source: DG Research
Data: DG Research, C 5, WIS database
Note: EU average for PhD graduates does not contain D and L, while the average for professors does not contain L and P. Exceptions to the reference year: EL (students), IRL (PhD gr.): 1997/1998; B (PhDs), P (PhDs), S (PhDs): 1999/2000.

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[23] *For the definitions of professionals and technicians and of levels of education, according to the "Manual on the measurement of human resources devoted to S&T" (OECD Canberra Manual), see the methodological annex of chapter 4 at the end of this report.*

Professionals and technicians compared by education levels

Across the EU, almost 45% of professionals (in the wider than usual definition of ISCO–88 major group 2 which is equivalent to graduate level employees) are women**.** Among people employed as technicians about half are women. In both groups, there are differences when it comes to education, as illustrated in figure 4.5.8. The majority (63%) of lower qualified professionals are men, while men make up only 53% of technicians. Among higher qualified (upper secondary or tertiary level education) professionals, around 45% are women. However, among the higher qualified technicians, more than half (53%) are women.

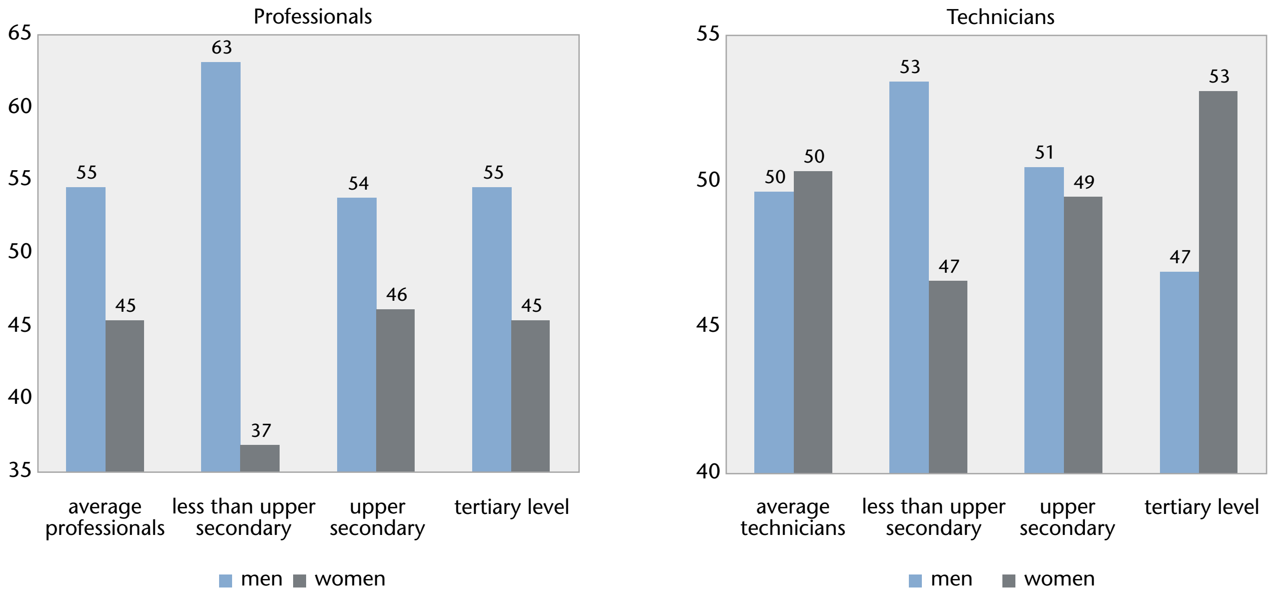
What does this mean? In the "Canberra Manual", the definition of the role of technicians covers support, but not administrative work, that requires a lower qualification level. This may well explain the higher representation of women in the technician group. Similarly, the high share of tertiary level educated women technicians could indicate that, compared to their male colleagues, highly educated women may be occupying positions that undervalue their skills levels. This assertion is supported by the opposite tendency seen in the education levels of male professionals, the majority of whom have lower education levels. Men more often are capable of landing professional positions without the required educational qualification. Typical examples are the male computer experts without formal higher education in contrast to the female secretary with a university degree in social sciences.

Professionals and technicians: EU Member States compared

Figure 4.5.9 shows the shares of women professionals and technicians in the EU Member States by their level of educational attainment.[24]

The participation of women in the two occupational groups varies for the different EU Member States. The shares of women professionals are above the EU average in Finland, Portugal, Belgium, Italy, Ireland, Austria and Sweden, with shares of between 58% and 51%. Lower representation of women in the professionals group is reported by countries such as Luxembourg, Germany and France, ranging between 37% and 38%. Women account for higher shares of the technicians in Germany, Finland and Denmark, each with between 55% and 58%, compared to the lower shares of women technicians – between 39% and 42% – in Belgium, Italy, Spain and Ireland.

Figure 4.5.8 Shares of population aged 15 to 59 occupied as professionals or technicians in 2000 by educational attainment level: EU average



Source: DG Research
Data: Eurostat, CLFS 2000
Note: No data was available for IRL which is not included in the EU average.

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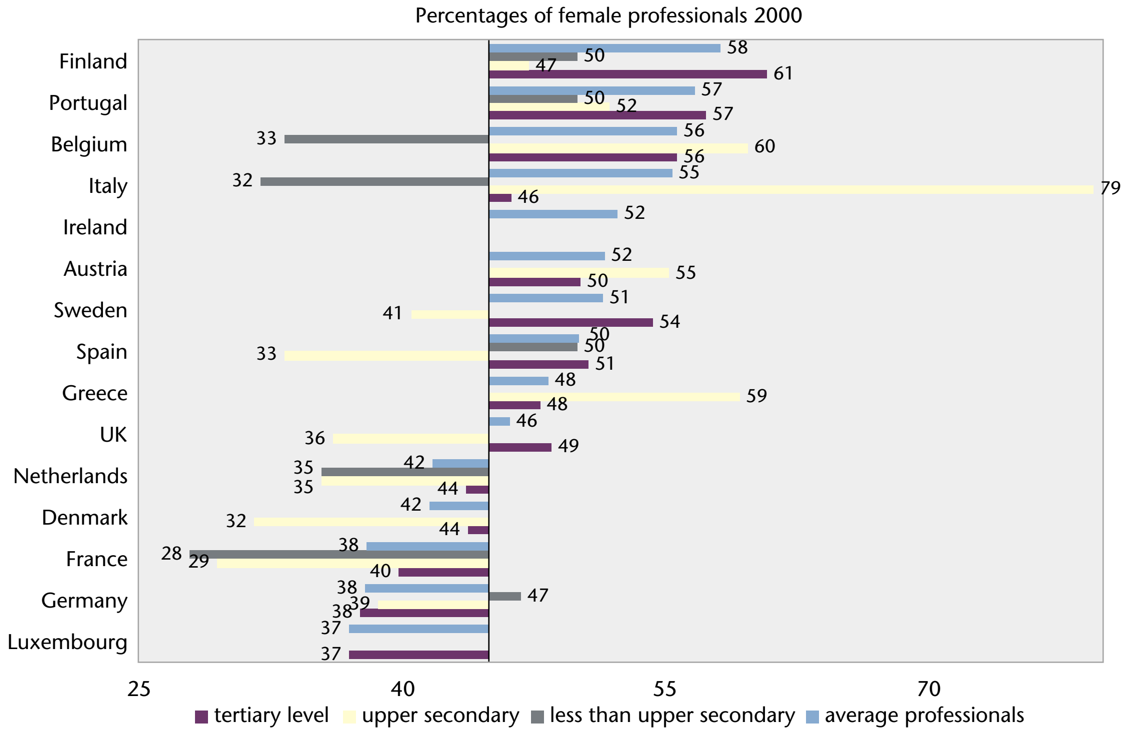
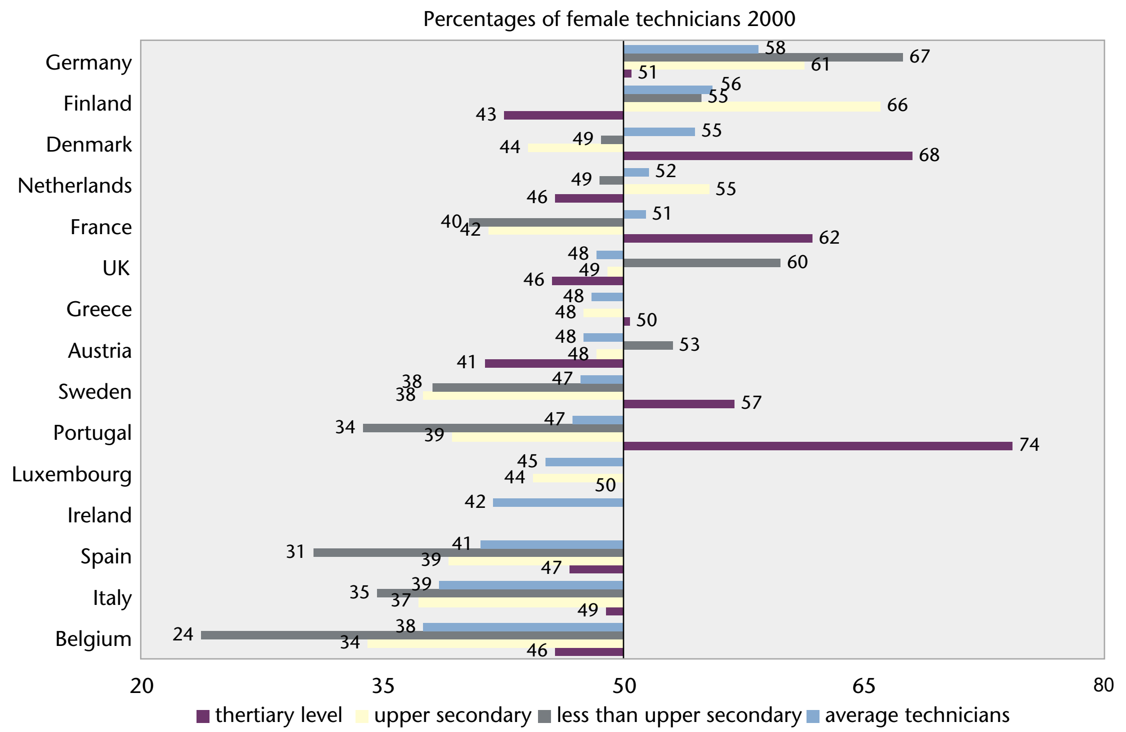
[24] *The EU average for the categories of professionals and technicians is represented by the middle axis for a better interpretation of deviations.*

Figure 4.5.9 Shares of women aged 15 to 59 occupied as professionals or technicians in 2000 by educational attainment level: EU Member States





Source: DG Research
Data: Eurostat, CLFS 2000
Note: No breakdown by educational attainment level for IRL.

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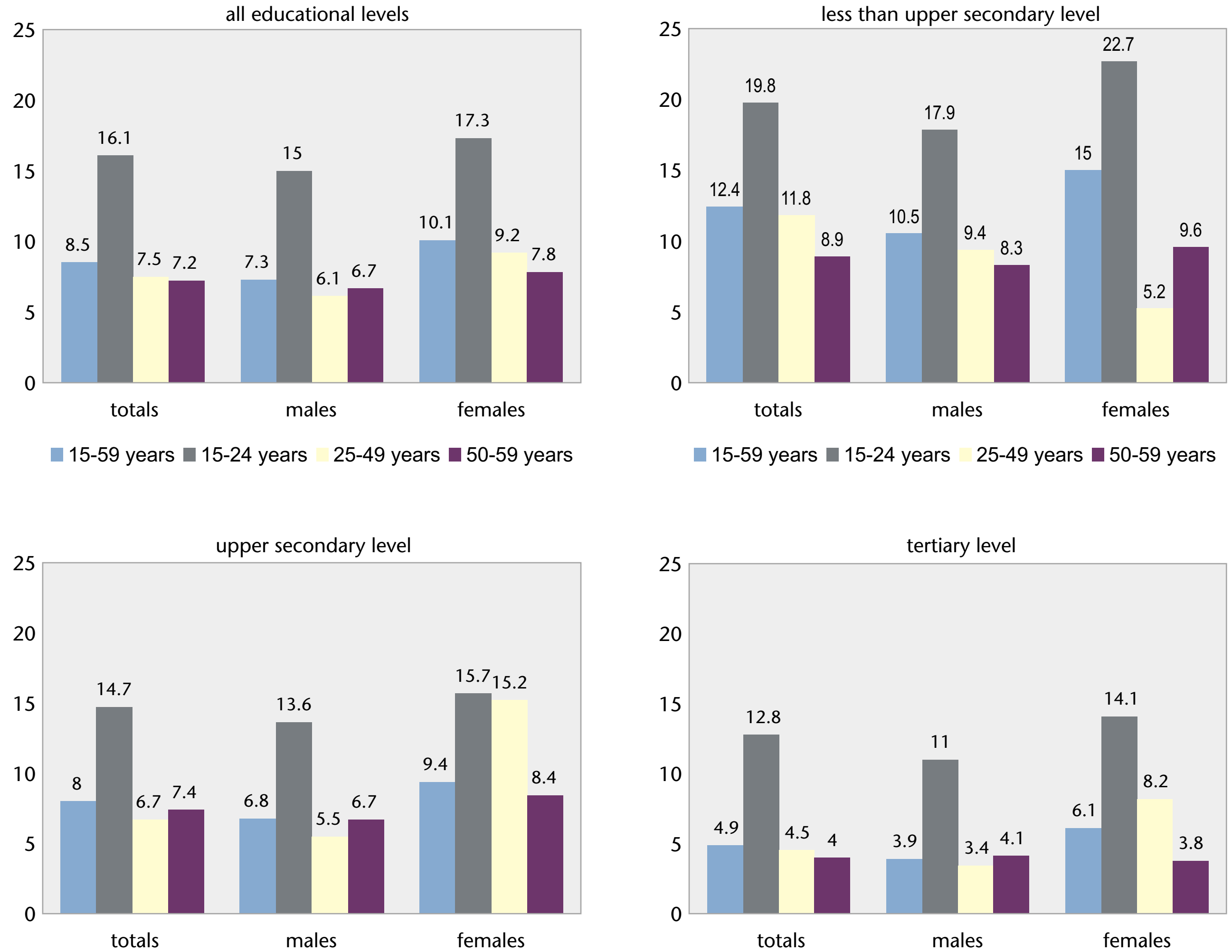
When the levels of educational qualification are taken into account, the biggest differences are found among women professionals with upper secondary education and women technicians educated below upper secondary level. In Italy, around 80% of the upper secondary educated professionals are women. In Belgium and Greece their share is around 60% while France, Denmark and Spain show low shares of around one third. Among women technicians with less than an upper secondary education, the range has Germany at the top with 67% and Belgium at the bottom with 24%.

The largest shares of tertiary educated women professionals are in Finland, Portugal and Belgium and range between 56% and 61%, all significantly higher than the EU average of 45%. Luxembourg, Germany and France have the lowest shares, below 40%. The biggest shares of tertiary educated female technicians are in Portugal, Denmark and France, ranging between 56% and 74%. Austria and Finland are at the opposite end with 41% and 42% respectively.

Unemployment compared to education levels

How do unemployment rates vary for men and women when educational qualifications and age are taken into consideration? Perhaps disturbingly, the youngest age group between 15 and 24 report the highest unemployment rates, as illustrated in figure 4.5.10. The older age groups also show higher unemployment rates, although they do vary according to education qualification levels. As one might expect, unemployment rates decline with higher levels of education. The highest unemployment rates for all age groups are found in the population with less than upper secondary education and the

Figure 4.5.10 Unemployment rates by educational attainment level, age group and gender: EU average 2000



Source: DG Research
Data: Eurostat, CLFS 2000

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lowest unemployment rates in the population with tertiary education.

Interestingly, this does not hold true for the age groups across genders. Among women aged 25-49, the unemployment rate of those with less than an upper secondary education is about 5%, which is very low compared to the 15% unemployment rate of those with upper secondary education. Even among women aged 25-49 with tertiary education, an unemployment rate of 8% is reported, which is higher than the overall figure for people with this level of educational qualification. Overall, the unemployment rates of women are higher than for men, the exceptions being middle-aged people with low educational qualifications and highly educated elderly people. Within these categories the unemployment rates for the men are slightly higher than for women.

The data examined in this section support the notion of the enormous potential of women in providing human resources for S&T. That there is potential waiting to be realised is abundantly clear. It is illustrated by the substantial numbers of female graduates in S&E disciplines, from the ranks of those pursuing academic careers to the level of PhDs and professorships and also in the unemployment figures for higher qualified women.

Conclusions

One of the objectives of Chapter 4 was to illustrate the importance of human resources for S&T in the EU, and the implications of growing international pressures and demand for highly skilled S&T personnel. Key statistics on human resources in S&T show that the numbers of researchers have increased in all EU Member States. Even so, the European Union is not homogeneous and there are notable differences between the bigger and smaller countries. Concerns about a possible polarisation of skills and technology between the northern Member States and the southern Member States do have an empirical basis. A number of trends in the EU may be evaluated, and compared with developments in the US and Japan.

Almost all the Member States of the EU lag behind the US and Japan in terms of their ratio of researchers to labour force, and it will be difficult to catch up with these two countries. The typical requirements of a knowledge-based economy are not notably reflected in European countries with small pools of researchers. Recent developments in Sweden and Finland, which pushed up their shares of researchers from an already high level, are a good example of how to cultivate highly qualified human resources in science and technology. Portugal is progressing well too, albeit at a lower intensity. A closer examination of the policies in countries which promote higher numbers of researchers in the work force, could be useful in finding policy instruments for other Member States to consider.

In the public sector but particularly in the business sector there is a need to create more opportunities for highly qualified research personnel. The data show that European companies employ half of the researchers. This is well below the figure in the US and Japan, where the private sector employs up to 80% of researchers.

Why is the business sector in the EU lagging behind the US and Japan in creating opportunities for researchers? The challenge for the EU to extract greater economic and social benefit from its research and development achievements remains. The data suggest that the EU has not yet embarked sufficiently on activity to translate the benefits of research into private sector initiatives and start-ups. Proof of this hypothesis is the fact that countries with low overall numbers of researchers also show a low share of researchers in their business sectors. In this sense, the fundamental ideals of the knowledge-based economy have not fully dawned on Europe's private sector.

In contrast to the number of researchers, the number of graduates who are qualified for high-level occupations in S&T haves grown satisfactorily in the EU. In nearly all Member States the number of S&E graduates increased in the 1990s, although once more the differences between individual countries are striking. Countries such as Ireland, France and the UK are performing well, while others such as Belgium and Denmark have very low shares of highly qualified people in their younger populations. With regard to producing PhDs, Sweden and Finland lead the field, while most other Member States are keeping pace with the US and Japan.

The number of people qualified for S&T produced by the education system in the EU appears adequate, but it could lead to a false sense of security. Shortages may result, for instance, if education policy fails to enhance the appeal of S&T to students entering the education system, and to those on a career path. It is also clear that people with S&T skills are afforded flexibility in terms of opportunities and mobility across occupations and sectors in the economy. In addition, there is the global nature of the S&T labour market and the drawing power of competitors, for example the US. The knowledge-based economy will not reduce the need for people with scientific, technical, analytical and communication skills, as defined by S&E.

Section II identified possible shortages in the future by establishing a link between the production of human resources in S&T through education, and their occupation as researchers. Reasons for the shortage of human resources in S&T have been analysed by focusing on the phenomenon of an ageing population, the educational attainments of the population, age structures, the appeal of S&T in the population, and the employment situation of people with higher education qualifications.

The ageing of the population will not affect the total number of the potential labour force, aged 25 to 64, during the present decade. Nevertheless it will already begin to impact on the number of young people in S&T – which as a section of the population forms the human base for S&E graduates and young researchers. An important factor is the constant renewal of knowledge and skills. It is estimated that the ageing population phenomenon could reduce the human resources in S&T by up to one million young researchers, which is a potentially serious problem for the dynamics of the emerging knowledge-based economies. Again, differences between the EU Member States should be taken into consideration.

According to the results of Eurobarometer, S&T is respected by the population at large, but compared to other fields of interest, it is not rated among the top. The most S&T interest is shown in the medical or environmental sciences, which are important for societal well-being. Scientists and engineers enjoy a good reputation and the importance of S&T is recognised. It cannot be concluded from these results that lack of appeal is a major obstacle to students opting for S&E fields of study.

The education of the majority of the population in a broader knowledge-based society, and higher education for specialised R&D occupation, are both crucial factors in the development of a knowledge-based economy. Traditionally, European countries have understood this and made investments in all levels of education. Investment in tertiary education is not linked directly to output of graduates in higher education.

The share of total population of higher qualified R&D personnel with higher education differs among the Member States. Despite these differences, it cannot be concluded that in some countries, as opposed to others, it is more appealing to work in R&D with an adequate qualification. Some countries have more success than others in exploiting that part of the population with higher education qualifications. In other cases, the appeal of non-S&T jobs and factors such as unemployment or inactivity may be more important.

The unemployment data reveal insufficient use of current human resources in S&T. In the EU, there are up to two million unemployed people with appropriate educational qualifications or job experience who are potentially available for S&T posts. Comparative figures tell a different story. When compared with the rest of the unemployed part of the population, the unemployment of higher qualified people does not seem to be a major problem, due to the larger and growing demand for knowledge workers. The main pattern emerging from the analysed unemployment data is that existing human resources are well exploited in terms of S&T. Shortages may occur on the production side in turning out adequate numbers of S&E graduates.

Investment in education, especially tertiary education, was analysed in section III. Huge differences between the EU and the US are identified. The US is investing a far higher proportion of its educational budget and its GDP on tertiary education than most EU countries. Owing to major efforts made by all EU countries, especially during the first half of the 1990s, the gap between Europe and the US decreased between 1990 and 1998. Europe's overall gain in educational expenditure on the US during the 1990s occurred primarily in respect of secondary, intermediate education, with a much smaller gain at tertiary level. The growth in tertiary education expenditure during the 1990s took place at more or less the same rate as the overall GDP growth. In 1995, as in 1998, the same proportion of EU GDP was devoted to the financing of tertiary education.

The immigration of students and highly qualified people has potential for satisfying the growing demand for researchers (Section IV). International mobility, which is not a new phenomenon, is increasingly seen as representing the enhancement of skills and flow of knowledge. Still, there are real fears of talented R&D personnel not returning to their countries of origin once they have practised S&T in foreign countries. An obvious example is the drawing power of the US for foreign-born skilled people from all parts of the globe.

A second significant method for increasing the number of researchers is stimulating greater participation by women in S&T by drawing more female students into university programmes and careers in S&T (Section V). At the same time, the employment opportunities for women have to be expanded and issues of exclusion investigated. Some more aspects on this will be discussed in the subsequent dossier on 'Women in Science'.

A keen awareness of the problems the EU faces today, and may face in the future, is crucial in achieving the goal of transformation into a knowledge-based economy. Researchers need to continue exploring the links between human resources and innovation, and mobility of human resources between occupations, sectors and countries around the world. Only on the basis of empirical evidence can discussions result in positive policy actions to ensure that Europe has sufficient numbers of highly skilled people in S&T.

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DOSSIER III

Women in Science: What do the indicators reveal?

Although female participation in science has increased in recent decades, women are still rarely seen in top scientific positions, such as professorships or other high-level research positions. Career opportunities in science are determined by a number of complex factors, which cannot easily be described using simple statistical indicators. 'Internal' factors – those that depend on the organisation, operation, and structuring of the scientific community itself – form an essential part of the explanation. The internal factors interact with 'external' factors, which are determined and shaped by society at large – such as existing gender roles inside and outside the family, the changing status of women with regard to education and the labour market, and the political frameworks that support equal opportunities[1].

In this dossier,[2] a set of established and new indicators will be presented to evaluate whether there is a gender bias in science[3] that prevents European women scientists from realising their full human and intellectual potential. The dossier does not address the questions of whether the contributing factors are specific to science, or part of a wider problem in society as a whole; or whether the problem is of greater or lesser importance in science than in other domains. What it does attempt, using established and new indicators, is to present an overview of the presence and participation of women in science, and to show gender-specific patterns of both presence and career opportunities.

Section I Measuring gender in Science and Technology

Giving prominence to the inclusion of a sex variable in data collection on science and technology (S&T) personnel and in the analysis of an S&T personnel profile has been identified as a priority at the European level.[4] Proposals to include the gender dimension in the revision of the current Frascati Manual (OECD, 1993) are widely supported by the European Union Member States. Recent Europe-wide initiatives to compare and contrast national policies and their outcomes have become more sensitive to issues of gender. The EU's exercise'Structural Indicators' include a measure for the gender pay gap, and the 'Benchmarking Exercise for National Research Policies' includes a sex breakdown for all human resource indicators. It also includes a specific indicator that reflects the presence of women in publicly funded research.

However, these initiatives are all very recent. In the past, science claimed to be gender-neutral. In spite of a recommendation by UNESCO's Division of Statistics on Science and Technology that all research personnel be classified by sex as early as 1984, sex-disaggregated data on S&T in Europe have only been collected at supra-national level since 2001. Previous editions of the European Report on S&T indicators and the World Science Report have underlined both the importance and the difficulty of obtaining appropriate statistical data and analysis for human resources in science and technology (Harding & Mc Gregor, 1996; Papon & Barré, 1996). The sex-disaggregation of information on scientific personnel in Europe was identified as a priority during the late 1990s[5]. Subsequently, efforts within Member States have yielded significant results[6], most notably the first statistical evidence that women are underrepresented in European research, especially in top academic positions.

[1] *It has been shown in chapter 4 that the goal of gender equity is not only an ethical one. For a variety of economic and technological reasons, the under-exploitation of women as human resources in science could become a serious obstacle to the future competitiveness of countries with higher levels of gender inequality. The emancipation and active empowerment of women in science, as well as in other sectors of society, on the other hand, present an opportunity to reduce potential future problems of scarcity of human resources, which should not be ignored by the European Union Member States.*

[2] *This dossier is a contribution of unit C5 "Women and Science" of directorate C "Science and Society" of the Research DG of the European Commission.*

[3] *In this dossier, the term is used in a very broad sense and includes the social sciences and humanities.*

[4] *Cf. the Communication from the Commission entitled: "Women and science: Mobilising women to enrich European research" – Brussels (COM [1999] 76 ferial of 17.12.1999); and Council resolution on "Science and Society and Women and science" Brussels, 01/06/99 (OR. En) 8565/99; Action Plan on Science and Society, COM (2001) 714 final of 4.12.2001, (Action 21), "A set of gender indicators will be produced in co-operation with the statistical correspondents of the Helsinki Group of Women and Science to measure progress towards gender equality in European research."*

[5] *Cf. European Commission (ETAN Report) (2000) Chapter 8, Gender statistics in science: measuring inequality.*

[6] *See the European Commission"National policies on Women and Science in Europe" (2002), the Helsinki Group on Women and Science.*

The Commission has adopted a two-pronged approach to data collection at a European level. The first, referred to as the 'Top Down approach', aims to promote the breakdown by sex of data collections at institutional, national and international level in order to obtain comparable data. This approach, although more comprehensive, is relatively slow. In order to obtain an informed overview of the situation in the meantime, it has been decided to implement a simultaneous 'Bottom Up approach' – i.e. a collection of existing data at national level in Member States.

Although indicators on R&D personnel and S&T education are mainly input oriented, it is also possible to analyse the output of research by gender. Two feasibility studies on bibliometric and patent indicators by gender have been funded by the Commission's Research DG within the CBSTII[7] activity. It has been established that collecting bibliometric data by gender is difficult, time-consuming and expensive, as the sex of authors and inventors could only be identified by their first names. Furthermore, the authors' first names are often indicated by initials only (Biosoft, 2001). Tracing them is time-consuming, and contains a margin of error. However, the Biosoft feasibility studies have shown that at present, first name analysis is probably the only solution for obtaining retrospective output data by gender. If further and meaningful analyses of women's patterns of productivity are to be undertaken, a sex breakdown should be given prominence in the major cross-national patent and bibliometric databases.

A mapping exercise of available data and sources in the European countries has demonstrated the need for comparable data concerning women in science, both at macro and micro level (Glover & Bebbington, 1999). However, the harmonisation of data to ensure comparability is a problem and tends to come to the fore only at the analysis stage. The lack of comparable data between countries, disciplines, occupational grades and career pathways, resulting from the different national academic, institutional, scientific and educational systems, should not block the on-going process of making the empowerment of women in science an important issue for society.

The data presented in this dossier, unless otherwise indicated, are based on national information provided on a goodwill basis by the Statistical Correspondents of the Helsinki Group on Women and Science. The data are validated by Eurogramme[8] for consistency and conformity, where relevant, to the International Standard Classification of Education (ISCED), the International Standard Classification of Occupation (ISCO) and the Frascati (OECD, 1993) and Canberra (OECD, 1994) manuals. Data on the US and Japan were obtained from "Women, Minorities and Persons with Disabilities in S&E" (National Science Foundation, 2000) and Kissho (2002) respectively. The sources of other analyses used in this dossier, such as on the family situations of women scientists or on productivity, are fully cited and listed in the references. All the data presented refer only to the two public sectors: the Higher Education Sector and the Government Sector.

Section II New concepts, initiatives and indicators

The most resourceful and logical way to approach the measurement of sex differences in science is to draw upon the wealth of work that has already been accomplished in employment at large.

Indicators of 'occupational segregation' are well established for highlighting differences between sub-groups, such as sex or ethnicity, in employment (Siltanen et al., 1995). Overall occupational segregation is composed of horizontal segregation and vertical segregation. Only vertical segregation is sensitive to vertical inequality, since it represents the extent of the differences between sub-groups throughout the entirety of a hierarchy or hierarchical system (Blackburn and Jarman, 2002). Horizontal segregation, on the other hand, is a measure of the differences between groups across sectors, fields or disciplines.

In the current absence of an agreed international methodology for quantifying overall, vertical and horizontal segregation in a comparable way, there are, fortunately, other kinds of indicator that still tell us something about the patterns of vertical and horizontal differences between the sexes in European science.

1. Horizontal differences between women and men in S&T sectors and fields

At the end of the 20th century approximately 722 000 people, of whom 31% were women, were working as researchers in the Higher Education Sector (HES) and in the Government Sector (GOV) in the 15 EU Member States.[9] The sex composition of the labour force is often taken as a baseline for determining a point of equality. Figure D3.2.1 compare the share of women researchers in each of the two public sectors (HES and GOV) with the overall share for the labour force.

In 11 of the 14 applicable European Member States – Portugal, Ireland and Greece being the exceptions – the percentage of women working in science in the public sector is below the average for the total labour force. However, there is nothing

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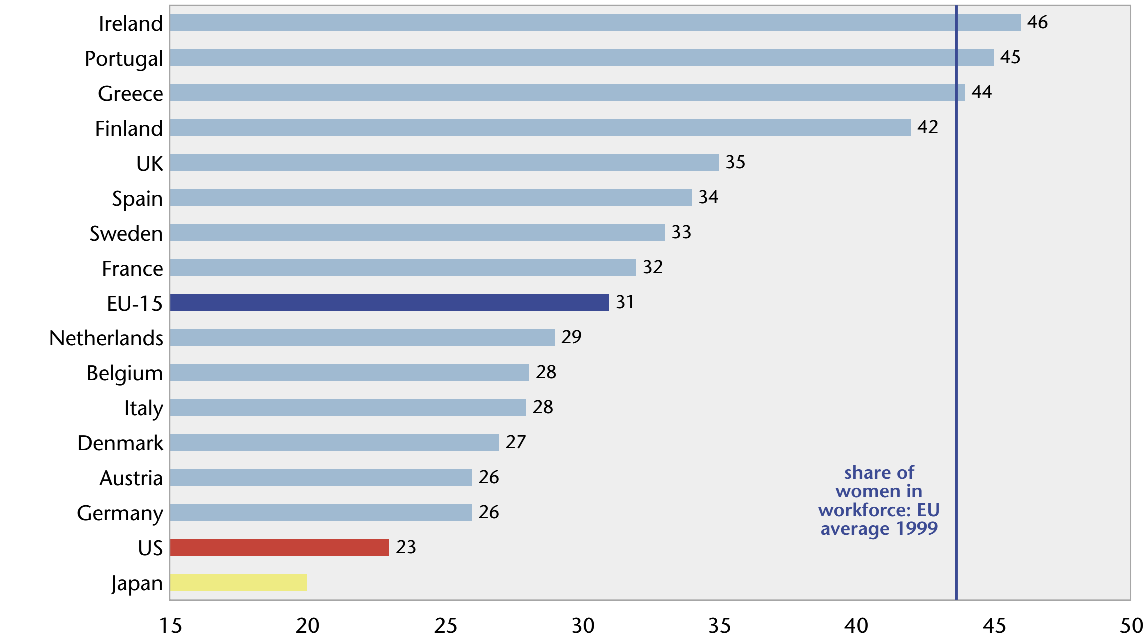
[7] *Common Basis for Science, Technology and Innovation Indicators.*

[8] *A statistical consultancy based in Luxembourg, contractors to Unit C5, Women & Science, at DG Research, in co-operation with Unit A4, Eurostat.*

[9] *"National policies on Women and Science in Europe in 2002", the Helsinki Group on Women and Science. This figure is presented in head count, and therefore differs from the OECD total, which is presented in full time equivalent. cf. Chapter 4 of this report for general data on human resources.*

Figure D3.2.1a Share of women in the labour force and as researchers in HES (in %, 1999)



Source: DG Research
Data: WiS database
Notes: Exceptions to the reference year: 1998: A, UK (GOV); 2000: B (French speaking part); D (HES), LU. Exceptions to the Frascati Manual definition of researchers: B, IRL, NL, UK (HES). Estimated data: B, NL (HES); D, IRL, S (GOV); EU (HES and GOV).
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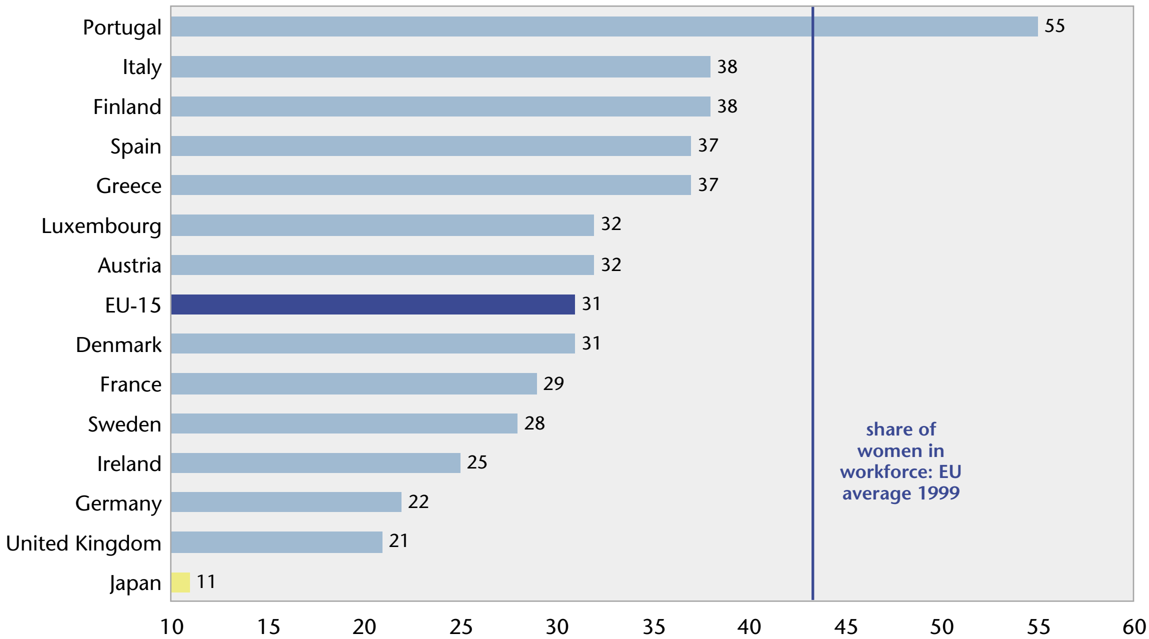
Figure D3.2.1b Share of women in the labour force and as researchers in GOV (in %, 1999)



Source: DG Research
Data: WiS database
Notes: Exceptions to the reference year: 1998: A, UK (GOV); 2000: B (French speaking part); D (HES), LU. Exceptions to the Frascati Manual definition of researchers: B, IRL, NL, UK (HES). Estimated data: B, NL (HES); D, IRL, S (GOV); EU (HES and GOV).
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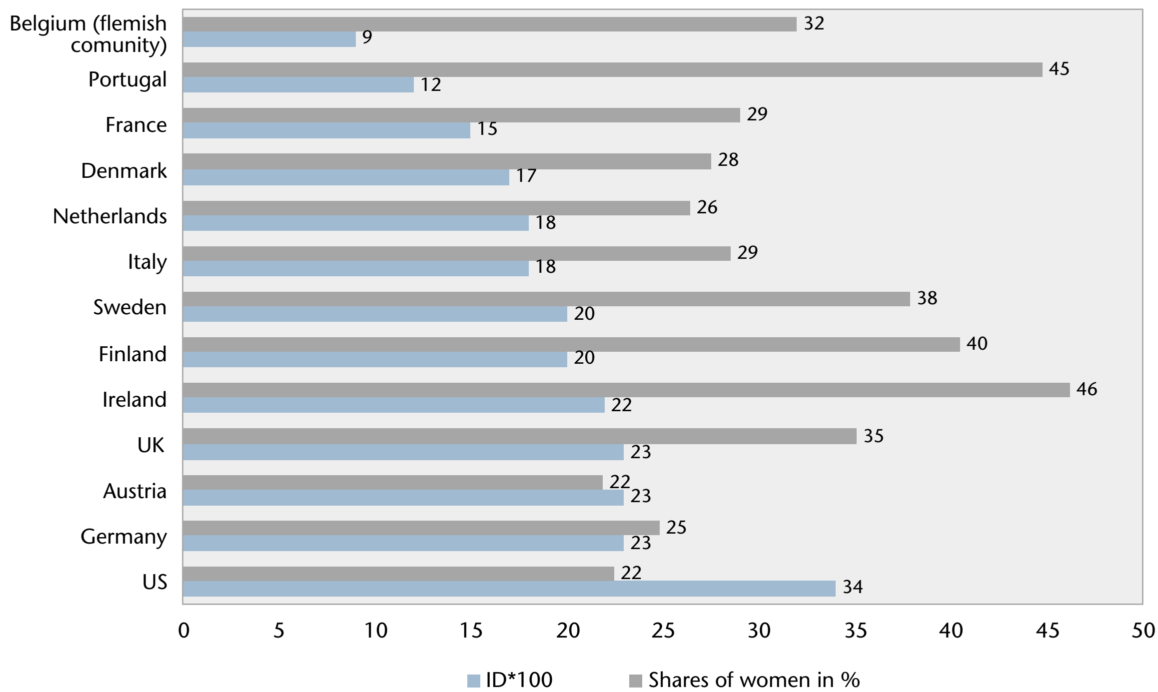
to suggest that there are any major disparities in this respect between HES and GOV.

Four countries – Greece, Ireland, Portugal and Finland – have more than 40% women researchers. Finland has a tradition of sensitivity towards gender issues. It appears that women are better represented in the countries in which the scientific professions are less developed and where the institutions are relatively new. In countries where the research system is more developed, larger numbers of women only started entering the labour market in an established system where men far outnumbered women. These findings demonstrate that in most EU Member States, it is likely to be easier for women to remain in non-scientific than to enter scientific professions. It is also interesting that the percentage of female scientists and engineers in the US and Japan are not only below the European average, but also below those of all EU Member States.

When measuring horizontal differences in science, the implicit assumption is that a more balanced distribution of women within disciplines may be a good result in terms of gender equity. A statistical measurement which is commonly used is the *Index of Dissimilarity* (ID)[10], which expresses the percentage of scientists and engineers who would have to switch occupational fields to match the percentage distribution by occupation of a referent group. This index is calculated as the sum of the absolute difference between the percentage of engineers and scientists working in a particular group working in each occupational field, and the percentage of engineers and scientists in the reference group working in each occupational field. The reference for women is men. Furthermore, the index of dissimilarity must be interpreted alongside the proportions of sexes in the analysed population to ascertain whether the dissimilarity favours women or men. The Organisation for Economic Coorporation and Development (OECD) and the National Science Foundation in the US (NSF) both use these indicators to highlight existing inequalities between the sexes.

From the horizontal perspective, a low ID score shows that men and women are equally distributed between disciplines with regard to the overall presence across all disciplines. In their report on indicators on gender equality in European employment, Rubery et al. (2001) remarked that differences between men and women are found in countries with high levels of female employment. This is confirmed by the results shown in figure D3.2.2, but is not necessarily always the case

Figure D3.2.2 The ID and shares of women by country for researchers in HES (1999)



Source: DG Research, Unit C5
Data: WiS database
Notes: Exceptions to the Frascati Manual definition of researchers: IRL, I, NL, FIN and UK. Exceptions to the reference year 1993: A.
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[10] *The Index of Dissimilarity has some limits since the basic hypothesis is that there should be an even distribution by gender in every disciplinary group. This is clearly unrealistic, allowing for no element of variation in the processes that match people to occupations (Hakim, 1998, p. 8). It is, nevertheless, useful for promoting the concept of gender in the scientific community. It should be borne in mind that the greater the aggregation by disciplines, the lesser the difference, since the overall variability decreases.*

for science. The figure shows that Austria and the Netherlands, with an ID of 22, have the least equitable distribution of women by field. In comparison, the US has a score of 34. Not surprisingly, Austria and the Netherlands also have comparatively low shares of women. However, Ireland and Portugal, which appear to be the most highly feminised countries, have significantly different levels of horizontal inequality, emphasising the need to make careful interpretation of simple percentages.

Table 3.2.2 shows that in 12 EU Member States, there are clear imbalances in the share of women researchers between the different scientific disciplines. The share of women among all researchers is a good indicator – if the data can be provided for each field – as this information is simple to construct and interpret. The representation of such an indicator where it refers only to part of a system, such as a single discipline, is termed 'concentration' (Siltanen et al., 1995).

Although the representation of women varies across countries, table D3.2.1 reveals that the patterns of concentration are surprisingly similar. In other words, there are scientific fields where women are scarcely present (engineering, in particular), and others where they occasionally form the majority, as in the medical sciences. As a general rule, the data show that women are more concentrated in medical sciences, social sciences and humanities than in engineering and the natural sciences. Case studies show that these disparities are also pronounced within more detailed fields, such as biology or computing, but these data are not yet collected at cross-national level.

Horizontal gender inequality is important because it has an impact on the different career choices and opportunities available to women and men. In a study of the attrition of female and male natural and health scientists carried out in the UK, based on longitudinal data, Blackwell (2001) observed that horizontal inequality resulted in distinctive employment patterns within each of the two discipline areas. The study looked at whether women are feminising their working environment, or whether they are choosing disciplines that are known to be 'friendlier' to women's work/life balance. Overall, men are more likely to be employed and less likely to be unemployed than their female counterparts. However, within each field and for each employment scenario, both sexes are subject to the vagaries of change over time.

When measuring horizontal inequality in science, the implicit assumption is that a more balanced distribution of women within disciplines may be advantageous in terms of gender equity. However, in European universities and scientific institutions, women and men share many aspects of working together, collaborate with each other in various and complex ways, and yet often end up with very different rewards and recognition (ETAN, 2000; Harding & McGregor, 1996; Siltanen et al., 1995; Wirth, 2001).

2. Vertical inequality: careers and empowerment of women in S&T

The measurement of vertical inequality reflects a country's ability to make optimal use of its female human resources. It investigates the distribution of women throughout the scientific career ladders, and indicates the level of female partici-

Table D3.2.1 Shares of female researchers in HES by main fields of science in some European Member States (1999)

	Natural sciences	Engineering	Medical sciences	Agricultural Sciences	Social Sciences and Humanities
Belgium (Flemish comunity)	0.30	0.22	0.39	0.35	0.36
Denmark	0.23	0.13	0.32	0.43	0.32
Germany	0.17	0.11	0.33	0.31	0.30
France	0.29	0.17	0.21	(incl. in med. sc.)	0.38
Ireland	0.45	0.26	0.68	0.12	0.55
Italy	0.31	0.14	0.23	0.24	0.36
Netherlands	0.20	0.14	0.37	0.26	0.30
Austria	0.15	0.06	0.27	0.26	0.30
Portugal	0.49	0.29	0.50	0.44	0.49
Finland	0.34	0.22	0.52	0.36	0.48
Sweden	0.31	0.19	0.51	0.41	0.44
UK	0.25	0.15	0.52	0.33	0.39

Source: DG Research, Unit C5
Data: WiS database
Note: F: Agricultural sciences are included in Medical Sciences. Exception to the Frascati Manual definition of researchers: IRL, I, NL, FIN, UK. Exception to the reference year: 1993: A. Data for NL are estimated

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pation at the highest decision-making levels. A European Commission *ETAN* report (European Commission, 2000) on women in the sciences has shown that across all European countries, there are few women in top university and research positions. It stresses that this under-representation of women compromises the attainment of excellence in scientific work. Furthermore, it represents a waste of talent because women's potencial in being under-untilised.

A comparison of the percentages of women in senior grades and those in junior positions is a useful indicator of the real presence of inequality, particularly if this percentage gap is significantly different from the one that applies to men (figure D3.2.3).

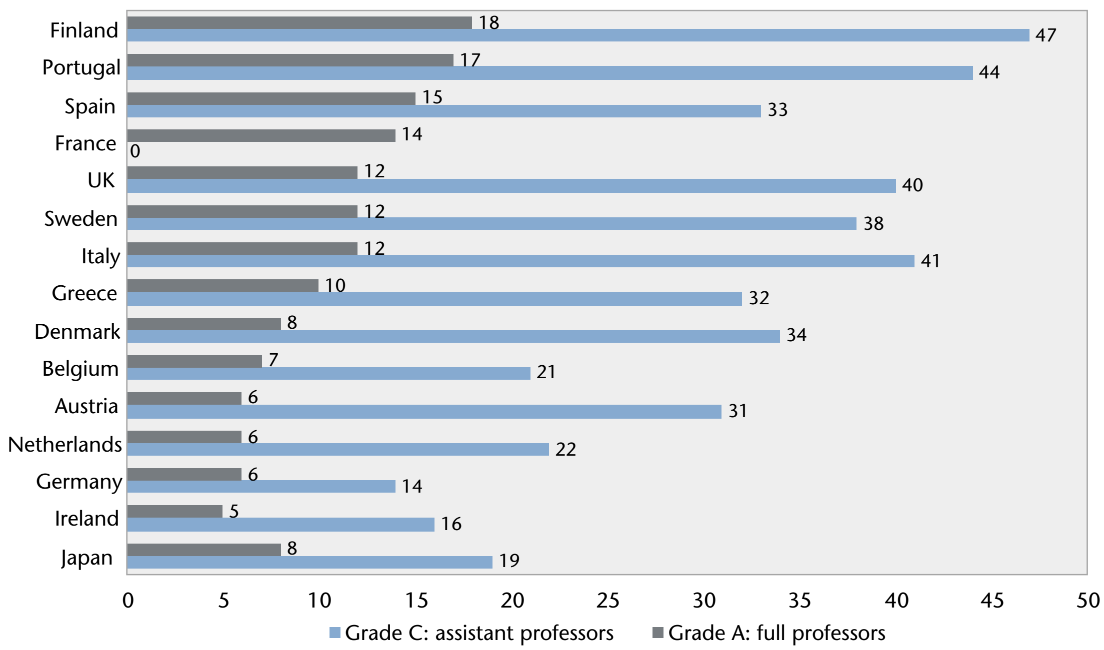
Existing inter-country differences in the grades of career paths in government scientific bodies, academia and other educational systems make comparisons difficult.[11] Notwithstanding these differences, it is clear from the figure that the higher the academic rank, the lower the presence of women.

To identify the point between graduation and full professorship at which women are being excluded in a given country, it is useful to look at the broader context of different career patterns by sex. The so-called career "scissors" (figure D3.2.4) refer to the crossover from relatively high graduation rates to low rates of appointment to professorial level. They are one of the most constant and regular phenomena that can be observed statistically. The scissors diagram is a cross-sectional image of the career opportunities available to today's female graduates in a given country under present conditions.

The figures show that in spite of the healthy representation of women at entry level, the differences between the numbers of men and women increase progressively up the hierarchy. With the rise in the rank (and in importance and salary), the number of women decreases considerably, until they become a distinct minority at the top. As status in contemporary society – science being no exception – is often equated with income-earning capacity, women are undervalued both socially and economically through the lack of recognition of their contribution to the advancement of science.

The scissors diagrams show that in Europe an overwhelming majority of men occupy the top academic positions. Two distinct career models can be discerned (Palomba, 2000). The first model, called 'The Overtaking', characterises countries

Figure D3.2.3 Share of female professors at academic grade C and A in some European Member States and Japan (in %, 1999)



Source: DG Research, Unit C5
Data: WiS database
Notes: Exceptions to the reference year 1997: EL, P; 1998: E, IRL, A; 2000: JP.

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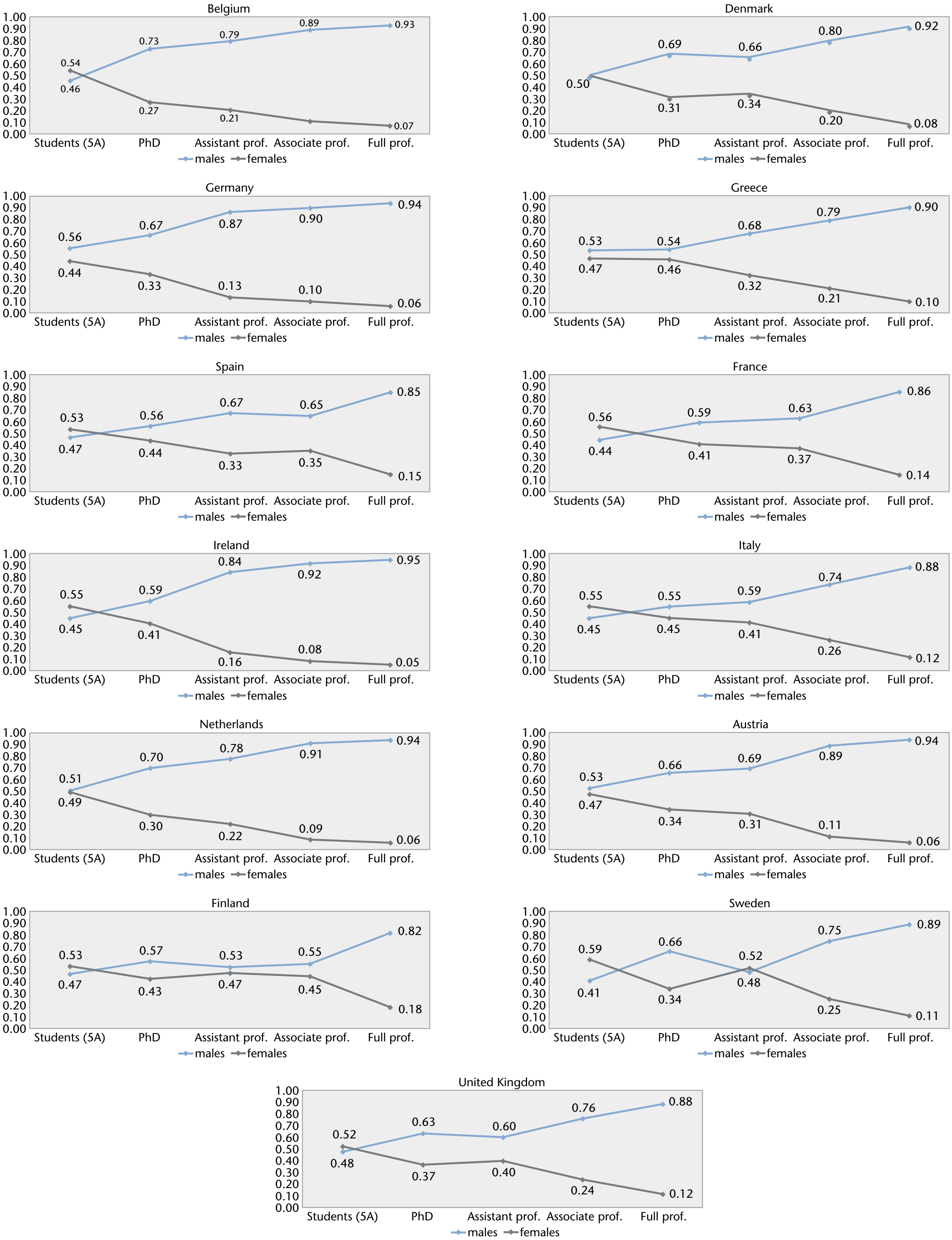
[11] *The grades used here are drawn from the three categories of professor proposed in the ETAN Report: C, B, and A (European Comission, 2000). A is equivalent to full professor, B to associated professor and C to assistant professor. They identify the junior, mid-term and senior posts in a typical path for each national junior academic system. Although tests have shown that comparability is good for grade A and reasonable for B, there are major differences between countries for the coverage of grade C.*

Figure D3.2.4 Scissors diagrams for 13 EU Member States



Source: DG Research, Unit C5
Data: WiS database
Note: Exception to the reference year 1997: EL; 1998: E, IRL, A; head counts for NL are estimated. No data for full professors for F. No data for P or L.

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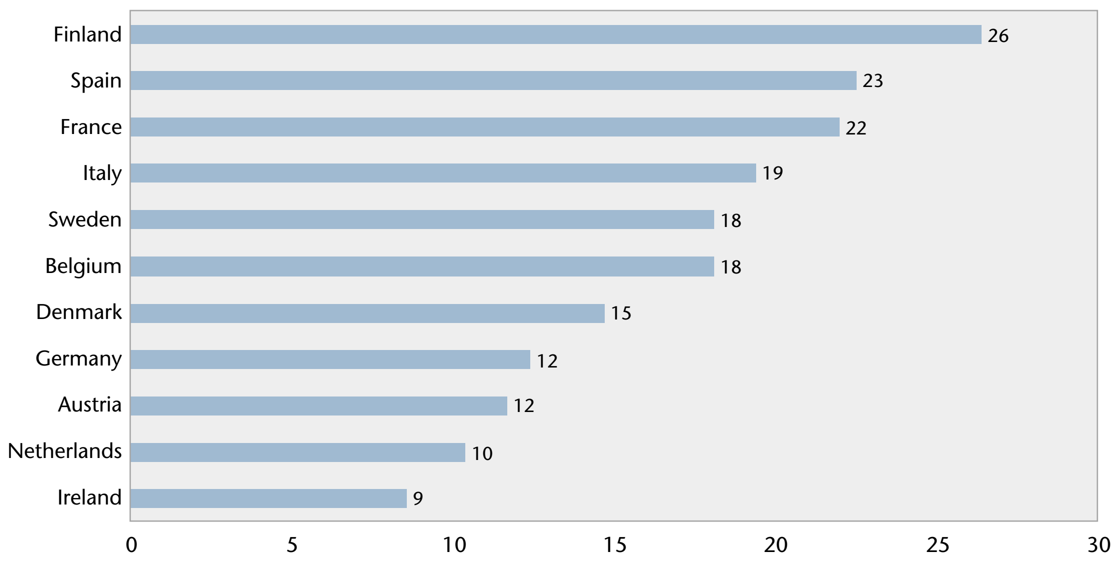
such as Belgium, Spain, France, Ireland, Italy, Finland, Sweden) and the UK. In this scenario, women researchers start with a considerable advantage (in terms of numbers) over men, but progressively lose ground until they end up as a distinct minority in the top positions. The second model, called 'The Impossible Pursuit', characterises Denmark, Germany, Greece, Austria and the Netherlands, where it is impossible for women to recover from, or even to maintain, the minimal numbers in which they begin at student level. Within the different national academic career structures, there is clearly some diversity in the stages at which the gender difference takes effect, but the overall picture is alarmingly homogeneous for all 15 Member States.

The Equally Distributed Equivalent Percentage (EDEP) is another way of illustrating the extent to which women are being utilised as a human resource in science. This single indicator is a component of the UN Gender Empowerment Measure (GEM) (cf. UNDP, 2001). The objective of the GEM is to concentrate on the professional participation of women, and in particular the degree to which they have been empowered within national systems in comparison to men.

The advantage of calculating the EDEP is that potentially different national situations can be compared, in spite of the differences in the educational systems and career pathways. This is relevant, because when comparing different countries, it is useful to be able to simultaneously take into account the extent to which achievements can be attributed to the background context. The EDEP is the harmonic mean calculated by taking the reciprocal of the population-weighted mean of female and male achievements in the top career grades. The harmonic mean has the property of taking into account both the value of the overall ratio and, to a certain extent, the disparity between men and women (UNESCO, 1997). Using the percentages of female students in each country to derive the weighting for the full professors, an EDEP for the participation of women in science[12] was estimated for 11 EU countries (figure D3.2.5).

From figure D3.2.5, it is clear that no country is anywhere near the EDEP equality score of 50%. In Finland, with a score of 26%, women students only have half as much chance of

Figure D3.2.5 Equally Distributed Equivalent Percentage (EDEP) for scientific participation in some European Member States (1999)



Source: DG Research, Unit C5
Data: WiS database
Notes: Exception to the reference year: 1998: ES, IRL, A and S. The formula is EDEP = 1/(SF/DF+SM/DM) where: SF = % of women in the 'source' population (i.e. students) expressed as a fraction (i.e. 0.1); DF = % of women in the 'destination' population (i.e. Grade A researchers) expressed as a whole number (i.e.10); SM = % of men in the 'source' population (i.e. students) expressed as a fraction (i.e. 0.9); DM = % of men in the 'destination' population (i. e. Grade A researchers) expressed as a whole number (i.e. 90).

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[12] *The indicator varies between 50% and 0%. If there is total equity in career pathways, the EDEP score is 50%; the greater the disparity between female and male shares, the lower the EDEP will be. The weights are the female and male percentage shares in the bottom grade of the career ladder. For the reference population in each country the ISCED 5A students (Master's and Bachelor's degrees) are selected. ISCED 5A was selected because it eliminates bias emanating from the 'cross-over' point in the scissors diagram. It also considers the complete potential pool of researchers.*

becoming a professor as male students. For the four countries with scores of less than 12.5%, young men are four times more likely to achieve the top level of recognition and rewards than young women, if no change occurs in the gendered patterns of career trajectories.

Section III The debate on Women in Science: Does the evidence confirm general opinions?

In this section, three stereotyped perceptions on gender differences in professional life are analysed:

- *The situation will redress itself naturally as more women qualify in science*. Underlying this perception is the idea that “women have to be patient and wait.” The belief that their under-representation at the top of the scientific hierarchy will eventually disappear “naturally” over time as their numbers increase at the entry level, is examined by analysing the careers of women in S&T occupations, relative to men.
- *Women are more affected by the ongoing double standard in family and domestic responsibilities*. This perception reflects the opinion that “family and children are a handicap for female scientists, because science and raising a family are both totally demanding (and therefore mutually exclusive) jobs”. The family status of women in S&T in comparison with those of men is a focal point of the analysis.
- *Women are less productive than men*. The perception that “women publish less than men and that it is therefore normal that they fail to arrive at the top level”, is examined by presenting some gender-related activity indicators.

1. Is “natural redress” sufficient?

Most of the measurements presented in the previous section concerning the paucity of women at the top of the academic and scientific hierarchy, are cross-sectional period indicators. Because of observed changes in the numbers of men and women entering science, it could be argued that it is simply a matter of time before gender equity is achieved.

Assuming that there is no active gender discrimination, and women must simply wait patiently for their turn to have a more equitable career structure, a new question arises: how long will this take? The Gender Segregation Index (GSI)[13] by position presents the number of men who would have to leave their posts, in favour of the same number of women, to equalise the presence of men and women in the career grades. Examination of the GSI in the EU concerning the top grade A reveals that natural recovery is in many cases impossible in the short term. For example, in France this would require at least 5 980 male full professors to retire. In all the countries, 31 305 grade A male professors (more than 30%) would have to be substituted by the same number of women before achieving quantitative equality.

The number of years to equality can be calculated by applying recently observed growth trends to current data. In Belgium, for example, if women’s shares in the different grades continue to increase at the current annual rate, it will take 40 years to reach equality in the C grade, 140 years in the B grade and 211 years in the A grade (De Henau & Meulders, 2001). In Italy, equality in the A grade could only be reached in 79 years if full professors continue to increase at the current rates. Considering the annual growth rate of the C grade pool, where the male rate of increase is higher than that of women, gender equality will never occur. It is clear that “simply waiting one’s turn” is not on option for today’s women. Moreover, merely condoning a short wait would also be symptomatic of a patronising attitude towards the question of women’s participation in science.

Does this mean that vertical equality is unobtainable? To answer this question, longitudinal studies on the careers of men and women who have all entered academies and/or research organisations during a given year would have to be undertaken. If gender inequalities persist, when seniority and other related factors are held constant, the option of waiting patiently cannot be regarded as valid.

If an eventual “natural” recovery in vertical gender inequality can be expected, this can be confirmed by comparing longevity in each grade of the career ladder. The hypothesis would be that there is a relationship between promotion and longevity in that women and men with the same length of service in a certain career grade, and the same capacities and merit, have the same probability of being promoted to the upper level. Without gender discrimination in career paths, and assuming that the quality of the scientific work done by women is equal to that of men, the increase in the female presence at the entry level should result in an increasing female share in the top scientific grades.

The existence of vertical gender inequality was the subject of a survival analysis in Italy (Palomba, 2000). A cohort of 1 022 scientists – 224 women and 798 men – who entered the B grade at the National Research Centre (CNR) in the same year was studied. The results showed a relationship between the length of stay in the B grade and the probability of being promoted to the A grade – the longer the duration of stay, the higher the probability of being promoted. Although this was the case for both sexes, women appeared to be spending more time in the be grade that men. For example, after 11 years in

[13] *In UNESCO, 1997 it is defined as the percentage of all persons enrolled in a given occupational grade, who would need to be replaced by the other sex to achieve the 50% ratio of men and women, assuming that there is no change in the total enrolment.*

the B grade, women had a 16% probability of being promoted, whereas their male colleagues had a 39% probability.

Although longevity was not the only factor affecting the possibility of being promoted, it still played a role when other factors were considered[14]. For example, after seven years in the B grade, men had a 23% probability of being promoted to A grade, whereas women only had a probability of 11.9%. After 11 years in the B grade, men had a 28% probability of being promoted. Women had less than half the chance, at 13.5%. The same analysis carried out for university professors again showed that men are twice as likely as women to become associate professors and hence have a 30% better chance of becoming full professors (Micali, 2001).

In conclusion, the results showed that factors such as age at promotion, field of science and number of publications only partially explain the gender differences in the science hierarchy. The main explanatory factor is, and remains, gender. Accordingly, it can be stated with some confidence that gender discrimination against women still exists. Possible solutions are discussed in the concluding section of this dossier.

2. Are women more affected by the family double standard?

Throughout Europe, high birth rates, which have severely restricted women's freedom of choice of a career in the past, have fallen drastically. In Spain and Italy, for example, fertility rates are the lowest in the world (UNFPA, 2001). In spite of this general reduction in the birth rate, women scientists striving for career advancement are expected to choose between their female identity and social role, and adopting the "male model" of total involvement in work.

Careers and promotions in highly professional and qualified jobs require heavy investments in terms of time (unlimited working hours, unforeseen commitments, high levels of productivity, etc.), availability, and geographical mobility. Even in the most flexible work situations, such aspects may be hard to reconcile with family responsibilities, which are still largely left to women to shoulder (Arve-Parès, 1996).

Thus, for women the lack of career upgrading is often explained by their 'life choices'. Female scientists are confronted with a 'choose-or-lose' dilemma. They can choose to have a family and children or to strive to achieve a top position in their scientific career. The choice may have a symbolic value rather than a concrete effect on their careers. Moreover, from the empirical studies outlined below it emerges that there is no evidence that being childless will produce positive results in terms of career mobility. No one questions whether men, who remain at lower levels on the career 'ladder', do so by "choice" with respect to other social dimensions, or whether successful male scientists have ever been confronted with the same 'choose-or-lose' dilemma.

In EU countries, existing data concerning marital status and number of children of male and female researchers are fragmented. Such studies are undertaken by disciplinary associations, as a result of personal initiatives by women researchers, contingent curiosity and general interest, and do not facilitate cross-national comparisons. In many cases, they are related to specific science sectors. However, case studies from six EU Member States on this topic reveal similar results.

The family formation patterns of highly qualified women scientists in a UK longitudinal study was analysed quantitatively, using 1971 and 1991 cross-sectional information and cohort comparisons (Blackwell, 2001). The results confirmed that scientifically qualified women have distinctive patterns of marriage, cohabitation and childbearing. Women with health-related qualifications were compared with natural scientists (including those with qualifications in mathematics), technologists, women with non-S&T qualifications (degree level and above) and women with no degree-level qualifications.

High proportions of women aged 25-44 years in 1991 had never been married. The highly qualified were less likely to be married than those with no degree-level qualifications. The technologists were more likely than other graduates to be single, and more than twice as likely as non-graduates to have never married. Among the highly qualified, those qualified in health-related subjects were the most likely group to have married and had children. The author suggests that women within the health fields have more children because these are more flexible working environments. However, it cannot be ruled out that women choose health fields because they are perceived to be more family friendly.

The ages at which women in different types of occupation entered motherhood were subject to a survival analysis (Blackwell et al., 2001). The obstacles to women remaining in their profession becoming a mother, was determined for each year between the ages of 15 and 49. Clear differences emerged between the different occupations, with those working in technology and in natural sciences least likely to have children.

Another study conducted in the UK on women in engineering careers (Evetts, 1994) found that the efforts of women engineers to balance their professional and family roles limited their prospects of promotion. An obvious way to avoid the difficulties of trying to combine engineering and motherhood was not to have children.

In Sweden[15], male and female professors differ with regard to their marital/reproductive behaviour and the fulfilment of successful scientific careers. Among A grade professors, the percentage of married men is significantly higher in the sci-

[14] *The factors considered were age at entrance into B grade, age at recruitment, number of publications, disciplinary field, and geographic area.*
[15] *Data provided by Higher Education Statistics Unit, Statistics Sweden.*

ences (81%), than in the economically active population (47%). This also applies to women, but to a lesser extent (59% of A grade professors are married, compared to 50% of economically active females). Furthermore, the percentage of unmarried women among all A grade professors is twice the percentage of men (14% and 7% respectively).

With regard to parental status, at every grade the percentage of childless women among professors exceeds that of the total for economically active women. This is especially evident in the A grade. For men, no relevant differences emerge apart from a reduction of childless male professors in the B grade. It can be concluded that for Swedish women, there is a trade-off between having children and advancing their careers.

These results are reinforced by a recent study conducted among French engineers (Gadéa and Marry, 2001). When comparing the family situations of men and women in the top career grades (director or president), an 'inverted stairway' emerges. Men with four or more children are more likely to appear in the top grades than men who remain unmarried and childless. Women with four or more children are less likely to appear in the top grades and more likely to appear in the lowest grades. Although this is possibly due to an age effect, it may be concluded that if women scientists are not having remarkably fewer children than their male counterparts, they are waiting longer to have them.

A German study of women and men in physics (Krais, 2001) showed that, whereas men prefer traditional family settings, 71% of women physicists do not have children, and do not intend to have children in the future. An Italian study of female economists showed that 29% female professors were unmarried compared to 16% of women of the same age in the labour force. 39% of female professors aged 39 or more were married and childless as opposed to 11% in the corresponding age/sex sector of the work force (Bettio, 1999). In Ireland, 49% of female academic personnel were childless, compared to 25% of men (O'Connor, 1993).

Although it is too early to draw any definite conclusions from this data, the evidence suggests three different hypotheses concerning the existing gender relationships between family, children and the scientific profession:

- in several European countries, women scientists are less likely to have a family;
- women appear to be paying the price of their fertility themselves, either by deciding not to have children, or by placing their family before their careers;
- the presence of wives and children appears to have a positive impact on the career opportunities of men.

3. Are women less productive than men?

One of the criteria widely used by the scientific community to evaluate the merit of researchers is the quantity and impact of their scientific and technological productivity. This is usually measured by the numbers of publications and patents (cf. the paragraph on bibliometric and patent indicators by gender at the beginning of this dossier).

The number of publications and citation rates are the most commonly used measures of scientific performance (cf. chapter 5) because it is extremely difficult to measure the quality of scientific work statistically. In order to quantify women's productivity, it is necessary to identify the sex of an author. However, this is not easy as very few scientific institutions have a database of publications by gender. The results of the Biosoft feasibility study on bibliometric indicators by gender show that the share of female authors in terms of total numbers was about 15% to 30% in the six countries covered (Biosoft, 2001). As the feasibility study did not put an emphasis on representation but on feasibility, the results are only indicative, but still representative enough to identify a south-north bias between the countries studied. The southern European countries of Italy, Spain and France have a significantly higher share of female authors than the northern European countries of Germany, the UK and Sweden. There are also notable differences between the different disciplines. The highest share of female authors is found in publications within biology, earth and space sciences and biomedicine, and the lowest in mathematics.

Besides the feasibility study, information on gender differences in publishing comes mainly from studies which cover a particular scientific field. An American study on biochemists (Long, 1992) showed that the average lower productivity of females resulted from their over-representation among non-publishers and their under-representation among the extremely productive. However, if the extreme cases are not taken into account, women and men showed comparable levels of productivity. In addition, papers written by women on average receive more citations than those written by men. American data on the number of publications by full-time scientists and engineers point in the same direction, although with some differences (NRC, 2000). The data show that on average women publish less than men (5.8 for women and 7.3 for men). However, the difference depends on the over-representation of men in the extremely productive group and takes no account of women's participation as part-time employees.

A subsequent study carried out by Long (2001) in the US shows that differences in the positions held by men and women are likely to cause differences in productivity. There is a strong correlation between career stage and publication rate for men. Full-time male professors published 30% more papers than women in the same grade. Differences in productivity appear to decrease as the prestige connected to the position declines. Holding a position of responsibility tends to multiply men's publications, whereas for women this is less true. The under-representation of women in the top grades of scientific careers is therefore not the only factor in explaining their lower productivity figures.

It is also important to understand if and how differences between the productivity of men and women may change over time. Analysing scientific productivity, using national surveys from 1969 to 1993, Xie and Shauman (1998) found that gender differences in productivity had declined.

In summing up the results of the studies presented, there does not seem to be any proof that women are a priori less productive. Lower productivity of women is mainly due to structural circumstances such as their under-representation in science, but also due to the inequalities in career opportunities. It is important to stress that a lower hierarchical position appears to cause lower productivity, and not vice versa. Some results indicate that women have to outperform their male counterparts to establish a scientific career and to receive the necessary recognition for their work.

Conclusions

The studies that have been reviewed, identify a stratified system in which men are favoured in career advancement in science at the expense of women. Women do not share equally with men in the opportunities, benefits and responsibilities of scientific development and citizenship. In the long run this triggers a mechanism of exclusion that appears to exclude them from the same reward systems and deprives science of their input. All the indicators presented here illustrate the existence of inequalities and gender bias in the mechanisms underlying scientific excellence. These inequalities, which are produced through a wide variety of small differences, make the discrimination mechanism less visible, harder to identify and therefore more insidious.

The goals of equal opportunities in science differ from one country to another, depending on the social, economic and cultural context. Thus, in striving for gender equality, different European countries may set different priorities, including encouraging more young women into S&T disciplines, reserving more high-level posts for female scientists and ensuring that existing recruitment and promotion mechanisms are fair and transparent. Fundamental to all the above priorities is that women must have an equal share in all aspects of scientific decision-making. The limited participation of women in drafting programmes for the national research system, assigning funds for projects, and generally managing resources is an issue of great importance (European Commission, 2000).

The achievement of gender equality in science is a long-term process in which existing social and political norms and rules must undergo profound changes. It also implies a new way of thinking in which the stereotyping of women and men no longer limits their opportunities, or continues to reward only one of the sexes. This dossier has pointed out the pointlessness and wastefulness of “waiting for equality” and the impossibility of a ‘natural’ recovery. It has been argued that until the gender dimension is given prominence in bibliometric and patent measurements, there is no firm evidence to support the myth that women are less productive. Paradoxically, the utility of the main output indicators for gender analysis is shown to be fundamentally flawed.

The responsibility for family and children still represents an obstacle to women’s careers in science as well in society at large. Several studies presented show that having families is detrimental to women in their careers, whereas men benefit from the presence of wives and children. Finding equitable solutions to this situation means challenging long-held stereotypes (such as the prevailing gendered division of domestic work) that underlie the power relationships and define the status of women and men in society. It is important to stress that science should no longer be considered immune, either from gender inequalities in power structures, or from job and family reconciliation responsibilities.

In Europe, as indeed worldwide, much remains to be done to improve gender equity in science. Women remain a rare commodity in the corridors of scientific decision-making. The development of indicators suitable for highlighting gender differences, for measuring equity-sensitivity, and for monitoring changes over time, depends largely upon the awareness of the value of gender statistics as a tool for policy-makers in the management of science. Women are increasingly regarded as essential agents of change, and so the measurement and analysis of gender gaps in science are a necessary tool for designing and adjusting policy actions (European Commission, 2002).

The collection of new gender-sensitive data and the construction of good indicators are also essential. Subjects such as the impact of the family on scientific careers need to be investigated extensively from a gender perspective through comparative and longitudinal surveys. Other topics, such as scientific productivity by gender, and understanding patterns of productivity in terms of both patents and number of publications by gender, remain an essential element if European science is to be competitive and sustainable. Further analysis is necessary to ensure that obstacles to women’s productivity are identified and removed through policy measures.

For women to share equally in developing scientific knowledge, regulatory mechanisms conceived for a male-dominated work environment must be corrected. Rethinking the rules of scientific engagement from the point of view of equal opportunities, means creating the conditions for an increase in the number of women scientists in positions of excellence and leadership. As their numbers grow, they will serve as positive role models for the next generation.

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