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# Science and Gender Indicators: A Critical Review

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**ABSTRACT**
This article approaches, from a critical perspective, the study of two of the most frequently used science and gender indicators: the glass ceiling index and the dissimilarity index. The former places at a disadvantage those science and technology systems where more women are present, sometimes providing measurements that go against an intuitive interpretation of the data. The measurements provided by the latter index depend on the level at which the indicator is applied, (ISCED levels 5 or 6, or women researchers). The most surprising result is that populations that are initially heterogeneous become homogenous over time. Finally, we propose using as an indicator the number of years needed in each country to achieve equality at each stage of an academic career. The formula combines the growth rate and the percentage of women in each group. This indicator is especially useful in international comparisons. To carry out the analysis, real data were used from various European Union countries, including Spain, Denmark, Sweden, and Germany.

**KEYWORDS**
gender; science; indicators; glass ceiling; index; dissimilarity index.

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## INTRODUCTION

Science and technology indicators are an essential tool in techno-scientific political decision-making. They allow the system to be diagnosed in relation to a previously defined objective, the allocation of the necessary resources for compliance with that objective, and the assessment over time of the impact that the political measures have had on achieving the intended goal.

One of the most important sets of indicators in a science and technology system are indicators of human resources, which together with those of financial resources measure the scientific and technological capability of a country. Throughout the 1990s the assessment of the European science and technology system revealed a profound inefficiency; an important part of human resources in science and technology was being wasted i.e., that of women.

Indeed, the virtual lack of women in top academic posts and on committees where decisions are made is palpable. As a result of this, the General Research Board of the European Union commissioned a report on the situation of women in all aspects relating to scientific policy. This report, (European Commission, 2000), which was carried out by the European Technology Assessment Network (and is known as the ETAN report), concludes that the under-representation of women threatens the aim of science to achieve excellence, and is costly and unjust. To be able to establish a precise diagnosis of the situation, however, and to recommend measures to eliminate gender differences, it was necessary to gather, analyse, harmonise, and publish gender disaggregated statistics .

As Palomba, quoted in European Commission (2000), points out, the transformation of data into genuine information needs a theoretical and conceptual model behind it to give it meaning, and the first step to do this is establishing the aim of the indicators. In the case of science and gender indicators it is necessary to determine whether the aim of the indicator is to identify a social problem, a matter of justice, or a human capital problem in an attempt to avoid wasting resources. While recognising that all three of these are legitimate concerns, the ETAN report gives priority to the last one[1].

Once we have established the diagnosis, the identification of what we want to measure with statistics, and the ultimate aim of scientific policy in this field (presumably the achieving of equality), we come to the design of the indicators. As a result of the recommendations of the ETAN report and of subsequent reports[2], a set of indicators has been drawn up to include among others: the proportion of men and women graduates in applied science engineering and technology; the employment rate in relation to the level of studies; the proportion of men and women graduates (International Standard Classification of Education –ISCED- 5 and 6)[3] by field of study; and the proportion of men and women academic staff, differentiated by levels in the hierarchy[4]. On this set of indicators two indices have in turn been constructed to measure the degree of horizontal and vertical segregation within each national science and technology system and to establish an international comparison. These are the dissimilarity index and the glass ceiling index. The more complex the indicators are, the greater is the set of assumptions upholding them, or in other words, the more complex is the theoretical and conceptual model that gives them meaning. Therefore, in accordance with the definition given to the indicator in question and to the specific objectives targeted with the political measures, different interpretations of the data are possible.

This article analyses both indices, that of dissimilarity and that of the glass ceiling, in order to examine to what extent they fulfil the objectives proposed, both from a national perspective, seeing how values evolve over time, and from an international comparison. Throughout the present study our starting premise is that the indicators are good tools that inform us of the state of the system. They allow us to make a diagnosis from which to then take suitable political measures. The effectiveness of these measures does not depend on the indicators however, it depends on being able to identify the causes underlying the phenomenon. If the causes have not been correctly identified, or the political measures put into place do not act on the causes, then the values of the indicators will not change. In any case, analysis of the impact of the policies implemented on the situation in question is not the aim of this paper. However, for the indicators to work they have to reflect the real situation as closely as possible. The criticisms posed in the paper refer largely to the set of suppositions underlying the indicators, since there seems to be some ambiguity as to the definitions of the indicators and what they should be measuring.

The results of our analyses show in the first place that both indicators are much more useful in a dynamic perspective than in a static one. Second, they establish that the dissimilarity index as an indicator of gender bias in the choice of a career makes more sense when it is applied to the level of graduates than to the level of researchers. Third, they establish that, in an international comparison, the glass ceiling index gives answers that are not always in keeping with specific interpretations of the data. Finally, we propose to take up again, as an indicator, the number of years needed in each country to achieve equality in each of the stages of an academic career. The formula combines the growth rate and the percentage of women in each group. This indicator is especially useful for international comparisons.

## METHODOLOGICAL CONSIDERATIONS

Although the aim of this study was to analyse the various science and gender indicators and not any national system in particular, it was necessary to choose a group of countries which provided different scenarios in order to see how the indicators operate in various contexts. The initial selection was Spain, Italy, Denmark, and Germany. The first two correspond to the “overtaking” scissor diagram model, the last two correspond to the “The impossible pursuit” model[5],both of which are discussed in more detail later.

Sweden was subsequently included as it had the highest value in the dissimilarity index and it was considered of interest to see how it performed compared with the rest of the indicators. For its part, Portugal was selected because its results, in an international comparison, were good and because it appeared to share certain characteristics with Spain and Italy.

In order to collect data it was necessary to resort to various sources. Initially we had the report of the European Commission, She Figures, for 2003, 2006, and 2009. However, the 2003 report gives data for both sexes for Category A only, which made a search for these data inevitable. Finally, we had a table providing figures for both sexes with the various categories on the website of the European Commission, although the source of the data is not given.

The data for Spain in the Commission's reports are erroneous (Torres, et. al. 2011) given that in Grade A, Spain had included heads of departments, whereas according to the guidelines of the Helsinki Group the category should include only full professors and emeritus professors. This means that none of the data in the report referring to an academic career appearing are valid in the case of Spain. Although the Spain's National Institute of Statistics (INE) detected the error and sent an errata, there are other anomalies in the data. In this case we are referring to Grade C, in which only LOU[6] lecturers appear and not the lecturers of the old LRU categories, which had not yet been transformed in 2007; in this manner thirty-five thousand people disappear from university statistics[7]. In order to collect data for Spain therefore, it was necessary to resort to the statistics tables of INE and add together the LOU and LRU categories.

This is not the only error detected in the reports of the Commission. Analysis of the historical series of the German data showed that the 16,800 people appearing in Grade C in the 2006 reports became 4,929 in the 2009 report. This anomaly can only be explained by an error in the data.[8] Swedish data also contains inconsistencies. The number of people in Grade B decreased from 19,137 to 11,372 between 2002 and 2004 and rose to 23,108 in 2007; again this anomaly is hard to explain unless a mistake has been made. Given that it has not been possible to obtain corrected data, the data of the historical series have been projected in a linear regression in order to obtain the estimated data for 2004 pertaining to this group. This is why some of the data in this article do not coincide with those of the reports of the European Commission.

Finally, the Eurostat database was used to calculate the dissimilarity index for graduates (ISCED 5). This database separates scientific fields according to the UNESCO directives, while the reports of the European Commission follow the Canberra Manual[9] of the OECD. The main differences between them as regards this point is that the Canberra Manual classifies the Education sector as part of the Social Sciences, whereas the UNESCO directives keep it in a separate category and eliminate the service sector.

**DISSIMILARITY INDEX**

The dissimilarity index is a measure of horizontal segregation. Horizontal segregation refers to gender bias in the choice of career between young men and women. Traditionally young men choose engineering and natural science while young women study humanities or education. This choice pattern is common to all European Union countries. It is influenced by social and cultural factors, and "includes stereotypes often found in children's books and school manuals; gendered attitudes of teachers, gendered advice and guidance on courses to be followed, different parental expectations regarding the future of girls and boys; and so forth" (European Commission, 2009, p. 39)[10]. The way to measure this segregation is to calculate the concentration of women in the different sectors or disciplines. According to the aforementioned report, the dissimilarity index "provides a theoretical measurement of the percentage of women and men in a Grade who would have to move to another occupation to ensure that the proportion of women was the same across all the possible occupations" (ibid, p. 48). The higher the value of the index the greater the dissimilarity, given that when multiplied by 100 it gives us the percentage of people who would have to move from one field to another to achieve an equal proportion in all fields.

The index is calculated by determining the percentage of women in each field in relation to the total percentage of women in the sector under study, and by determining the difference regarding the same calculation made for men. The absolute values of these differences are divided by two. There are two reasons for this division by two. First, when dividing by two, then the index takes values between 0 and 1 (as opposed to values between 0 and 2), where 0 is complete equality and 1 is complete unequal distribution. Second, by definition the index describes the proportion that has to move from one category to another and this proportion is half of the difference between the categories. For example if person A has 2 apples and person B has 4 then only half of the difference has to be moved to obtain an equal distribution. Working with absolute values means that all the differences are added together and values from one scientific field to another are not compensated for. For example, if we have three different fields (A, B, and C) with 1, 2, and 1 women and 2, 1, and 3 men respectively, the total proportion of women is 40%. It is therefore necessary to calculate

$$\frac{|1/4 - 2/6| + |2/4 - 1/6| + |1/4 - 3/6|}{2} = \frac{0.08+0.34+0.25}{2} = 0.33$$

This means that 33% of individuals would have to change fields so as to maintain 40% of women in each one of them.

When defining the index in its report, the European Commission affirmed that the value of the index is sensitive to the number of fields that are introduced into the calculation; the greater the number of fields the higher the value that the formula gives us (European Commission, 2006). This is not always the case; it depends on the specific fields that are grouped together in each case and on the distribution of men and women in each of them. If in the previous example the fields A and B are grouped together the value of the index falls to 0.25, but if A and C are added the value of the index stays at 0.33. The difference lies in the grouping together of fields with similar distributions. In one case the fields joined have similar distributions and the index is maintained, as in the previous example where women were in a minority in both fields. In the other case the fields joined had different distributions e.g. men dominated in one field and women in the other and therefore the differences are compensated and the index falls. This illustrates the sensitivity of the index to field selection.

The report of the European Commission (2009) gives the dissimilarity index for researchers in higher education in the various member states. The Canberra Manual groups the 21 main fields of study proposed by the UNESCO directives into six essential sections: natural sciences, engineering and technology, medical sciences, agricultural sciences, social sciences, and humanities. The average of the 27 European member states[11] is 0.14, i.e. 14% of researchers in higher education would have to move to another field of knowledge for the percentage of women to be equal in all fields.

| | 2006 D.I. | % Women researchers |
|---|---|---|
| Spain | 0.03 | 38.3% |
| Italy | 0.11 | 35.5% |
| Portugal | 0.12 | 46.9% |
| Denmark | 0.19 | 36.8% |
| Germany | 0.21 | 31.4% |
| Sweden | 0.31 | 41.1% |

*Table 1. Dissimilarity Index of Researchers in Higher Education and the actual percentage of women researchers. Source: European Commission 2009.*

As can be observed in Table 1, the Spanish data are surprisingly good as far as gender equality is concerned in the various fields of knowledge. Only 3% of researchers would have to change their field of knowledge for the percentage of women researchers in higher education to be 38% in all fields. Sweden is at the other extreme with the highest dissimilarity index, where the percentage of mobility would have to be 31% for the percentage of women researchers to be 41% in all fields of knowledge.

The meaning of the index should not be confused; if, for instance, a country has 1% of women in higher education and this 1% is the same in all branches of knowledge, the country will have a dissimilarity index of 0, even if the presence of women at university is only 1%. The good Spanish figure is based on the fact that the percentage of women varies between 35 and 40% for the six fields, with the presence of women in research in higher education being 38%, while Swedish figures, for example, vary from a minimum value of 23% to a maximum of 53. Does the Spanish dissimilarity index mean that there is no horizontal segregation? When we examine the number of women graduates (ISCED 5) and calculate the value of the index, the data are not so promising.

| | D.I. Higher Ed. Research 2006 | D.I. ISCED 5 2006 | % Women graduates |
|---|---|---|---|
| Spain | 0.03 | 0.35 | 58.6 |
| Italy | 0.11 | 0.20 | 59.3 |
| Portugal | 0.12 | 0.28 | 65 |
| Denmark | 0.19 | 0.26 | 58.2 |
| Germany | 0.21 | 0.31 | 57.5 |
| Sweden | 0.31 | 0.33 | 64.8 |

*Table 2. ISCED 5 Dissimilarity Index and percentage of women graduates. Source: Author's calculation using Eurostat data.*

In all cases the dissimilarity index rises for graduates in relation to researchers in higher education (first column). In the case of Spain the difference is of thirty-two percentage points and shows the highest value within the countries selected for the study. It is extremely useful to list these values with the percentage of women graduates in each field of study.

| | Humanities | Social Sciences | Natural Sciences | Engineering Technology | Agricultural Sciences | Medical Sciences | % of women grads |
|---|---|---|---|---|---|---|---|
| Italy | 74.6 | 63.7 | 53.8 | 29.5 | 43.7 | 65.4 | 59.3 |
| Spain | 62.8 | 69.8 | 35.1 | 26.3 | 45.5 | 79.7 | 58.6 |
| Portugal | 67.4 | 72.1 | 45.0 | 34.0 | 60.9 | 80.0 | 65 |
| Sweden | 61.8 | 71.0 | 44.3 | 30.8 | 65.2 | 85.2 | 64.8 |
| Denmark | 65.4 | 56.8 | 33.3 | 35.0 | 33.8 | 81.8 | 58.2 |
| Germany | 73.5 | 60.5 | 42.9 | 17.7 | 34.9 | 77.5 | 57.5 |

*Table 3. Percentage of women graduates by fields of knowledge and total percentages of graduates 2006. Source: Author's calculation using Eurostat data.*

Now let us compare the percentages of graduates in each field who are women with the percentage of women researchers in higher education. Only the case of Spain will be analysed. According to the European Commission 2009 report, Spain has the following percentages of women researchers in higher education: humanities 40%; social sciences 39%; natural sciences 39%; engineering and technology 35%; agricultural sciences 39%; and medical sciences 40%.At first sight it would appear that the data here and in table 3 are not related. In other words, it would seem reasonable to suppose that the proportion of women in the different fields at a graduate level is maintained, with slight fluctuations, in the field of research. The data reveal that this is not the case. One possible interpretation of these data is that while horizontal segregation persists in the choice of a career, it disappears at a research level. Choice at this level has to do with research motivation and is free from any gender bias as far as the selection of a field of knowledge is concerned.[12] However, this explanation fails to take certain aspects into account. In the first place, the indicators refer to the same population[13]. In this sense the choice of the field of knowledge predates the choice of following a research career or not. The question is, how can a population with high rates of concentration in a series of fields be distributed homogeneously after a period of time has passed?

Second there has been a significant loss of women from the level of women graduates to the level of women researchers (from 59% to 38%). At first the explanation seems simple; not all graduates work in research. This has to do with choice at the second level, that of research motivation. Surprisingly, while the number of women graduates in relation to women researchers falls by over 20%, that of men increases by the same proportion. It may be concluded from this that women are less highly motivated to do research than their male colleagues. This assertion is at best risky, if the obstacles faced by women to follow a career in research are taken into account. In this case these obstacles have to do with vertical segregation.

Third, if we consider distribution by knowledge areas, the percentages are surprising. In natural sciences, engineering, and technology the percentage of women researchers increases in relation to that of women graduates. It appears that in this case it is easier for women to embark on an academic career than to compete in the business world. However, the percentage falls by 40% for medical science women researchers; a probable hypothesis is that the practising of medicine is a more "friendly" field than that of research, or at least has fewer obstacles. There is equally a fall of 30% for social science women researchers, in which field professional practice or the possibility of working freelance may presumably provide more opportunities for women. Each of the proposed explanations, though tentative, can in principle explain the relationship between the data on women researchers and those on women graduates. Each of these explanations has in common that they refer to the obstacles women face in following a research career.

To recapitulate, it is possible to maintain that the two sets of data are unconnected, but this does not solve the problem of the homogenisation of the distribution when it starts from a heterogeneous whole. An alternative hypothesis is that on applying the index to researchers within the higher education sector the latter is contaminated by factors of vertical segregation. As mentioned earlier, the explanations proposed have to do with the difficulties of a research career. In other words, the low percentage in, for example, Spain, and to a lesser extent in Portugal and Italy, is the result of the number of women who leak through the academic pipeline before reaching research[14]. There is an initial loss at doctorate level, which continues with negotiating the sticky floor that hinders women's access to the top posts of a research career. This is the reason why the index has been calculated for graduates (ISCED 5) and not for people with PhDs (ISCED 6)[15]. To determine at which level the indicator should be applied, its aim must be established. In its most aseptic sense it measures the rates of concentration of a specific characteristic among different populations.[16]

However, it is not only the use of the index but also its objective that must be determined, together with the political objective that one wishes to meet. The question is: what does the index measure? Is it the degree of distribution of women researchers per study area or the degree of horizontal segregation, defining the latter as the gender bias in the choice of career between young men and women? If the second alternative is chosen the population to which it must be applied is at the level of graduates, where it can be observed whether there have been changes in the choice of careers by young men and young women. In order to do this, the best thing is to monitor the evolution of the data and the index. The oldest piece of data appearing on the Eurostat database corresponds to 1998. Table 4 shows the distribution of women graduates by fields for that year.

| | Humanities | Social Sciences | Natural Sciences | Engineering Technology | Agricultural Sciences | Medical Sciences | Total Women Graduates |
|---|---|---|---|---|---|---|---|
| Italy | 81.0 | 57.8 | 56.6 | 26.6 | 42.9 | 57.5 | 56.4 |
| Spain | 66.8 | 64.1 | 43.1 | 24.2 | 44.5 | 77.9 | 58.2 |
| Portugal | 71.6 | 70.2 | 55.8 | 31.8 | 57.5 | 77,8 | 65.0 |
| Sweden | 62.7 | 68.4 | 38.6 | 21.9 | 54.8 | 82.2 | 60.8 |
| Denmark | 70.6 | 50.9 | 32.1 | 30.0 | 42.9 | 83.7 | 57.9 |
| Germany | 67.0 | 52,3 | 31.4 | 14,1 | 26.2 | 73.4 | 49.2 |

*Table 4. Percentage of women graduates per field of knowledge 1998. Source: Author's calculation using Eurostat data.*

In general terms, compared with the distribution for 2006, the proportion of women graduates is increasing in all the countries selected for the study and is well over fifty per cent. In all cases the proportion of women in social sciences is increasing. Except in the case of Germany, the proportion of women in humanities is falling -in a field traditionally thought of as being for women- and with the exception of Denmark the number of women in medical sciences is increasing.

The dissimilarity index for 1998 is shown below. In Table 5 it is compared with the index corresponding to 2006. The results show that the index is increasing for Spain, Italy, and Portugal and is decreasing for Denmark, Germany, and Sweden. The reason for this increase in Spain, Portugal, and Italy and the decrease in Denmark, Germany, and Sweden is that in the latter countries substantial increases have occurred in natural sciences, while in the former the presence of women in these fields has dropped. The importance of analysing the values underlying the indices lies in that although Denmark, Germany, and Sweden have higher dissimilarity indices than those of southern European countries, it can be seen that horizontal segregation genuinely seems to be decreasing in the former countries.

In other words, young women are choosing disciplines that were previously selected only by their male colleagues (engineering and technology and natural sciences), and at least in the case of Sweden and Denmark, with increases ranging from 21% to 30% and from 30% to 35% (for engineering and technology). The case of Germany is a different one. Although its dissimilarity index had dropped by five points and the proportion of women in engineering and technology had increased, the initial situation in 1998 was by far the worst of the countries selected, with 14%

of women in engineering. As has been pointed out, moreover, Germany is the only country where the number of women in humanities is increasing instead of falling.

| | 1998 D.I. | 2006 D.I. |
|---|---|---|
| Spain | 0.25 | 0.35 |
| Italy | 0.19 | 0.20 |
| Portugal | 0.21 | 0.28 |
| Denmark | 0.35 | 0.26 |
| Germany | 0.36 | 0.31 |
| Sweden | 0.34 | 0.33 |

*Table 5. Dissimilarity index for graduates. Source: Author's calculation using Eurostat data.*

It has been pointed out that the interpretation of the indicator has also been said to depend to some extent on the political measures being taken. In this case the indicator operates as an index of the impact of these measures over time. Although horizontal segregation may occur at any level, its origin lies at the choice of career. Any political measure should then be orientated towards correcting it at that level. For example, the ETAN report recommended the following as pertinent political measures: gender equality as an important part of teacher training; publishing academic guides to science to support young women; an annual science day at universities to encourage young women to choose scientific careers; support for research into the history and culture of science, especially that which makes women scientists visible, and so on (p. 74). To determine to what extent the political measures undertaken by each country are effective, the index must be analysed at the career selection stage and not at later levels.

In international comparisons, the dissimilarity index must be used with caution. The various factors that influence the final value of the index may give rise to an erroneous interpretation of its value. It should be taken into account that each country has a different proportion of women that must be equalled in all fields; this figure is 58% for Spain while for Sweden it is 65%. The feminisation[17] of many areas, for example medicine and social sciences, means that the index is increasing. Finally, as was mentioned in the ETAN report, a strong assumption behind the use of this indicator is that it starts from the basis that the various areas should be equally divided and does not allow variations in the process of people adapting to their occupation. However, "it is a useful starting point for raising the issue of gender in the scientific community, which defines itself as gender-neutral". (European Commission, 2000, p. 76)

## PROGRESSION RATES AND FUTURE PROJECTIONS

In most European Union countries progress has been made regarding the presence of women in science and technology. The percentage of women in research institutes or in academic careers has increased in recent years, although this has not occurred equally in all categories. It is generally thought that once explicit discrimination measures have been eliminated, it is only a matter of time before men and women reach the same level. A graphic and extremely intuitive way of seeing why this cannot be so is to calculate in accordance with the observed progression rates the number of years which will have to pass for this to happen. The concept is not new, as already in the 2003 *Third European report on science and technology indicators* (OPOCE, 2003) the use of progression rates was proposed in this sense; unfortunately subsequent reports have not picked up this idea.

The calculations refer to academic careers followed at university. It is well known that the percentage of women in top academic posts is so low that this can only be explained by gender discrimination factors[18]. So as to unify the indicators and to be able to carry out international comparisons, the European Commission has proposed the grouping together of the academic categories of the various countries into four grades: A, B, C and D.

In order to calculate the progression rates in each of the grades we have used the reports of the European Commission, *She Figures*, for 2006 and 2009, in which statistics and indicators are given on gender equality in science, and a table drawn up by the European Commission for the years 1998/2002.Given that information is available for a four-year period at worst and for a seven-year period at best, a linear regression was decided upon instead of a compound growth rate, since the former gave a more precise value to the average growth rate throughout the historical series.

Table 6 shows the percentage of women in Grade A for each of the countries selected in the study, with the average growth rate and the number of years estimated in order to reach equality.

| | 1998 | 1999 | 2000 | 2001 | 2002 | 2004 | 2007 | Growth rate | Years |
|---|---|---|---|---|---|---|---|---|---|
| Germany | 6 | 6 | 7 | 8 | 8 | 9 | 12 | 0.65 | 59 |
| Denmark | | 8 | 8 | 9 | | 11 | 12 | 0.49 | 77 |
| Italy | 11 | 12 | 13 | 15 | | 16 | 19 | 0.81 | 39 |
| Portugal | | 19 | 20 | 20 | | 21 | | 0.38 | 77 |
| Sweden | 11 | 12 | 13 | 14 | 14 | 16 | 18 | 0.79 | 40 |
| Spain | | 15 | 15 | 16 | 13 | 13 | 14 | -0.13 | |

*Table 6. Percentage of women in Grade A, growth rate, and number of years estimated to achieve equality based on a linear regression. Source: Author's calculation.*

It is as important to observe the percentage of women in Grade A as the growth rate. For example, if we compare Portugal with Denmark, it can be seen that the former is almost twice the latter in its percentage of women in Grade A, taking into account that in 2004 Portugal had 21% of women in this grade while Denmark had 12% in 2007; however, both will take the same number of years to reach equality in Grade A, i.e. 77 years. The reason is a simple one; Denmark is growing at a much more rapid rate than Portugal. The best figure is that of Italy, which, with a sustained growth rate of 0.81% per year, will reach equality in 2046. What is happening in Spain? The problem is that Spain shows a negative growth rate. In 2001, 16% of professors were women, which is a figure that has not been repeated. If we extrapolate the historical series available, in Spain equality will never be achieved in the top posts of an academic career. If we are to be a little more optimistic we must consider the data from 2002, when there begins to be more or less sustained growth, and include the 2008 data. Although this trend is extremely unstable, it gives a result of 83 years for achieving equality in Grade A. If nothing is done about it, eight generations[19] of women researchers will begin their academic careers knowing that they will be subject to more or less active discrimination.

But the difficulties of women at university are not confined to the glass ceiling that prevents their ascending to the top posts of the hierarchy. The well known scissor diagrams tell us that these difficulties exist at all levels. An important stage, which is often not given sufficient attention, is moving from Grade D, postgraduate students, to Grade C, the first post of a person with a PhD. In the latest report of the European Commission (2009), the metaphor of a sticky floor was used to illustrate the difficulties women have in reaching top posts of their academic careers. Table 7 shows the same data for Grade C.

| | 1998 | 1999 | 2000 | 2001 | 2002 | 2004 | 2007 | Growth rate | Years |
|---|---|---|---|---|---|---|---|---|---|
| Germany | 21 | 22 | 22 | 23 | 24 | 26 | 25 | 0.54 | 44 |
| Denmark | | 34 | 34 | 37 | | 38 | 37 | 0.42 | 29 |
| Italy | 40 | 41 | 42 | 43 | | 44 | 45 | 0.56 | 8 |
| Portugal | | 41 | 41 | 41 | | 43 | | 0.55 | 9 |
| Sweden | 37 | 38 | 38 | 40 | 38 | 40 | 42 | 0.5 | 17 |
| Spain | | 35 | 35 | 36 | 36 | 36 | 38 | 0.37 | 33 |

*Table 7. Percentage of women in Grade C, growth rate, and number of years needed to reach equality. Author's calculation.*

The stickiest floor appears to be that of Germany, with only 25% of women in Grade C. Spain shows a figure of 38% but has a slower growth rate; although it has 13 points of advantage, it will take only 11 years less to reach equality in this grade. Much better prospects can be found in Italy, Portugal, and Sweden[20], where there are not only higher growth rates but better percentages in this grade.

Growth rates used in the manner proposed give a better analysis of the data than the growth rates or percentages on their own. Combining the proportion of women in each grade with the growth rate gives a unified result of the number of years needed to reach equality. This prevents us from considering the situation to be better in countries with a high growth rate but with an initial situation of a very low proportion of women, as was indicated in the case of Denmark for Grade A, or, on the contrary, countries with good starting points but very slow growth rates as was the case in Portugal. The estimated number of years provides us with a single value with which to combine data that may be inconsistent. Finally, translating these rates into the numbers of years needed to achieve equality gives a much better idea of the unsustainable situation for women researchers and of the need to introduce corrective measures.

The estimates are evidently not predictions; a great variety of factors may play their part in making the proposed estimates vary. Any active policy to eliminate discrimination will lead to a variation in the data. It is even possible that the trends mentioned currently vary as a result of the political measures introduced in recent years, given the period of time that has to pass before such measures change trends. The data only indicate what will happen if the system is allowed to continue its inertia; in the case of Spain it would seem that this is something we cannot afford to do.

## GLASS CEILING INDEX

The glass ceiling index measures the opportunities for women, compared with those of men, to achieve a post at the highest levels of the academic hierarchy. It is used as a vertical discrimination indicator and compares the proportion of women in Grade A with the total proportion of women in academia, i.e. grades A+B+C.[21] The formula divides the proportion of women in academia by the proportion of women in Grade A. An index of 1 would indicate that there are no differences in the promotion of men and women. The index can range from zero to infinity. At higher indices the glass preventing the advancement of women is thicker. An index of less than 1 would indicate that women are over-represented. Table 8 shows the glass ceiling index for the years 2000 and 2007 for the countries selected.

| | 2000 GCI | 2007 GCI[22] |
|---|---|---|
| Germany | 2.1 | 1.6 |
| Denmark | 2.6 | 2.2 |
| Italy | 2.2 | 1.8 |
| Portugal | 1.8 | 1.8 |
| Sweden | 2.9 | 2.3 |
| Spain | 2.2 | 2.4 |

*Table 8. Glass ceiling index. Author's calculation.*

The rate has dropped in all countries except in Spain, where it has increased, and in Portugal where it remains constant. It is surprising to find that judging by the data, Germany has the best figure of the countries selected. The proportion of women at the various levels of an academic career is calculated below, with the aim of comparing this with Table 8.

The countries in the best and worst position with respect to the glass ceiling are Germany and Spain, respectively. If we now analyse the percentages of women in 2007, in the various grades it can be seen that the percentage of women in Spain exceeds that of Germany for all grades, doubling it in Grade B and two percentage points ahead in Grade A. In the case of Sweden, which only exceeds Spain by 0.1 as to the glass ceiling, it can be seen that the percentages of women in the various grades are even better, with 18% in Grade A, 47% in Grade B, and 42% in Grade C. The problem with the index is that it places at a disadvantage those countries with a high number of women in Grades B and C. For example, for Spain to equal Germany in its glass ceiling index (1.6), the percentage of women in Grade C would need to be 16%, with everything else remaining the same.

| 2000 | | | | 2007 | | |
|---|---|---|---|---|---|---|
| | Grade A | Grade B | Grade C | Grade A | Grade B | Grade C |
| Germany | 7 | 14 | 22 | 12 | 18 | 25 |
| Denmark | 8 | 22 | 34 | 12 | 25 | 37 |
| Italy | 13 | 28 | 24 | 19 | 34 | 45 |
| Portugal | 20 | 33 | 41 | 21 | 34 | 43 |
| Sweden | 13 | 41 | 38 | 18 | 47 | 42 |
| Spain | 15 | 36 | 35 | 14 | 36 | 38 |

*Table 9. Percentage of women in the various grades of an academic career. Source: Author's calculation using European Commission 2009 data.*

An alternative formula for getting round this problem is what has been called the *progression glass ceiling index* (PGCI), which only takes into account moving from one grade to the grade above (Anderson and Connolly 2006); in other words, the proportion of women in a certain grade would be divided by the proportion of women in the grade immediately above it. If a grade is over-represented the index is smaller than 1. The following table shows the results for Grades A, B, and C in the various countries.

| | From B to A | From C to B | From D to C |
|---|---|---|---|
| Germany | 1.5 | 1.4 | 1.6 |
| Denmark | 2.1 | 1.5 | 1.2 |
| Italy[23] | 1.8 | 1.3 | |
| Portugal | 1.6 | 1.3 | 1.2 |
| Sweden | 2.6 | 0.9 | 1.2 |
| Spain | 2.5 | 1.1 | 1.3 |

*Table 10. Progression glass ceiling index, 2007. Source: Author's calculation using European Commission 2009 data.*

The first column shows no significant differences regarding the previous calculation (Table 8, year 2007). The differences range from 0.1 in the case of Germany, to 0.3 for Sweden. Germany's index falls with this formula whereas the Swedish index increases its value. The explanation is simple. Sweden has 47% of women in Grade B and only 18% in Grade A; it therefore appears that there is a barrier holding women back and preventing their promotion. In the case of Germany the difference between Grade B and Grade A is only 4 percentage points, which lowers the index. The only value below 1 in the whole table is that of Sweden with an index of 0.9 in the move from Grade C to Grade B. This implies that the women are over-represented, but this over-representation does not refer to the percentage of women in relation to their male colleagues in the same grade, but to the percentage of women in the preceding grade. Sweden is the only country that has a higher percentage of women in Grade B (47%) than in Grade C (42%). Measured in terms of opportunity, in this case women have had better opportunities than men in this grade. The index would give a result of 1.1 calculated for men in the passage from Grade C to Grade B. This scenario is not a momentary one; the index is 0.9 for all the years for which we have data (1998 to 2002) and also for the series of estimated data for 2004.

The progression glass ceiling index provides a more detailed picture of the career promotion difficulties, but in the top position the outcomes are very similar to the normal GCI; that is, the PGCI also places at a disadvantage those national systems with more women in category B. Another problem is that for an international comparison neither of the two indices take into account the absolute proportion of women in grade A. The question is whether promotion is easier in Germany than in Sweden or Spain. Let us now imagine a hypothetical country with 2% of women in Grade A, 3% in Grade B, and 5% in Grade C. The index gives a value of 2.2, which would place it above Spain and at the same level as Denmark. Is the degree of discrimination the same for a country whose percentages are 2, 3, 5 as for a country with 12, 25, 37? The essential point is: what question is the index trying to answer? According to its definition it measures the relative opportunities women have to reach the top level compared with men. This would imply that in our hypothetical country women have more opportunities than, for example, in Spain to reach that position. This seems to be counterintuitive.

The difficulties of achieving promotion do not have to do only with the top position, as there are intermediate positions that researchers must go through before they can reach that level. In 1998 Sweden had 38% of women in Grade B, in 2007 the percentage was 47%. In the same period Italy passed from 26% to 34%. These increases are important as more women are now in a position to be promoted, but this is precisely what the index does not take into account. Perhaps the index should be dynamic and take into account the number of women who have been promoted over a period of time. To return to Table 9, it can be seen that Germany showed an increase of 4 points in Grade B and 5 points in Grade A compared with the year 2000, Denmark 3 and 4, Italy 6 and 6, Portugal 1 and 1, and Sweden 6 and 5. It would appear that the increases in Grade B are becoming increases in Grade A at a proportion of almost one to one, although very slowly. Therefore, the index should not present such a high number of women in Grades B and C as a disadvantage when it is a clearly a necessary condition for eventual promotion to Grade A.

Another possibility is that the calculation of the glass ceiling index weights the total number of women in Grade A, and not only the differences between A and B and C.

In other words, the higher the percentages of women in Grade A, the lower the value of the index. This would avoid counterintuitive interpretations such as in the case of the hypothetical country that was mentioned, in which the figures were 2%, 3%, and 5% in each of the grades, respectively, having the same glass ceiling index as Denmark.

## FINAL CONSIDERATIONS

In the ruling of the European Council of 20 May 1999 the member States were invited to contribute to the common effort of improving the statistics on the participation of women in research. This invitation was reiterated in the ruling of 26 June 2001 and in the conclusions of the Council of 18 April 2005, and also in the European Parliament ruling of 3 February 2000. As a result of the ruling of 20 May 1999, the Commission established a group in November 1999 that consisted of civil servants and experts on gender matters from the 15 member States of the EU and the 15 countries associated with the V Framework Programme for research, technological development, and demonstration activities of the European Union (1998-2002). This body is specifically devoted to the subject of women and science. It is generally known as the “Helsinki Group on Women and Science”, as its first meeting was held in Helsinki during the Finnish presidency of the EU. At that time Eurostat was not gathering as much information as it is now, and therefore a large part of the information was compiled by a network of “Statistical Correspondents of the Helsinki Group” that had been established for drawing up European Union statistics. Taken as a whole, these actions give us a good idea of the importance of the indicators. At a time when gender discrimination is punishable by law, and when society at large and the scientific community in particular perceive themselves as gender-neutral, an accurate description of the real situation is needed more than ever. Indicators are a fundamental tool for raising awareness not only of decision-makers but also of the general public as to the state of the system. The achievements of the Helsinki Group, which is still in operation, have been considerable, but some of its results are tarnished by errors in the data. The fact that in six selected countries errors have been detected in the data in 50% of cases goes beyond normal statistical error. To attain an accurate diagnosis the data must be correct.

Despite their importance, indicators in themselves are not a solution to the problems detected. A solution can only be reached if the causes of the problems are detected and the political measures taken have an effect on these causes. All an indicator can do is determine whether there has been a variation in the data after a certain period of time has elapsed: whether there are more women in Grade A posts, whether more women choose science as a field of study, whether there are more women researchers in the business sectors of each country, and so on. There is no algorithm that can tell us how long these measures will take to have an effect; this will depend on each individual measure and with a package of measures it is also difficult to break down the individual effects of each separate measure, but in general it is possible to tell whether trends are changing by means of indicators. To do so we must be able to count on good indicators. In the case of the two indicators analysed, the glass ceiling index and the dissimilarity index, both show two important deficiencies that have to do with their definitions and with their underlying suppositions.

First of all, it is not clear what the definition of the indicator is, that is, what exactly it is measuring. The dissimilarity index is presented as an indicator of horizontal segregation, defined as a gender-biased choice of career, when girls choose areas such as humanities and social sciences and boys choose science and engineering. But what the mathematical design of the indicator is actually measuring is the distribution of men and women across the different areas. Although these two definitions may seem to be equivalent, they are not. If what it is measuring is horizontal segregation, the indicator should give more weight to the increases in the number of women in the areas of science and engineering (traditionally considered male domains) than, for example, a diverting of women from the humanities to the social sciences. As it stands, the index gives each situation the same weight. For its part, the glass ceiling index measures the opportunities women have to reach the top posts of the academic hierarchy compared with those of men. If this is taken in its strictest sense, it measures the difficulties in advancing from Grade B to Grade A. The question is whether this is the meaning that should be taken. An academic career consists of a multitude of intermediate steps that have to be taken in order to reach the top posts of the hierarchy. In this sense the difficulties in gaining access to Grade B and Grade C become important. As this situation evolves, in the absence of discrimination more women in Grades B and C would lead to more women in Grade A.

The second difference has to do with the set of suppositions underlying the indicators, which help to define their objective. For example, an indicator that measures the number of researchers in a given country as a proportion of its whole population starts from the supposition that the more researchers, the stronger the country’s science and technology system. The problem with the two indices examined here is that the underlying suppositions are not explicit. In regard to the dissimilarity index, and based on the different political measures recommended by the various European Commission reports in this respect, the supposition can be deduced that it is more important for girls to choose careers in science and engineering than in any other area; it is also possible to deduce that career choices take place at the undergraduate (first stage of tertiary education, or ISCED5) rather than at the research level. The indicator should therefore be applied at the earlier level. In this case there is the added difficulty that the index yields different measures depending on where it is applied.

As regards the glass ceiling index, it seems obvious to assume that the more women in the system as a whole, the less inequality, given that if there are no women in the lower professional grades there will be no women to promote to the highest grade. These are the reasons why the index should perhaps attach more importance to the total number of women in the system, and not make this a disadvantage, as is currently the case. It should be taken into account that the index is negatively sensitive to political initiatives designed to increase the number of women in Grades C and B. An international comparison becomes more difficult insofar as the measure is independent of the proportion of women in each grade. If on comparing various countries the question is whether it is easier to gain promotion in one country than in another, it would seem that the index is not giving an answer in accordance with the data. A proposal could be to introduce a weighting factor for each grade into the formula.

On the positive side, the usefulness of an indicator that provides us with information on the number of years needed to reach equality must be emphasized. Because of its simplicity, it seems to be one of the best indicators for influencing public perception of the scientific-technological system in terms of gender.

This study does not aim to rule out the indicators analysed but to point out their possible deficiencies and those factors that have not been taken into account. Whether we like it or not, nowadays every political measure taken is based on some kind of indicator, be it economic, social, educational or scientific. Future work should therefore aim to improve the indicators so that they can provide us with an accurate diagnosis of the real state of the system.

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## APPENDIX

**Academic hierarchies**. Four categories have been considered that harmonise the various academic structures of the different countries: Grade A which is equivalent to that of full professor, Grade B researchers working not at top level but with more seniority than a person who has just earned a doctorate, Grade C the first post obtained after finishing a doctorate, and finally Grade D, postgraduate students who have not obtained their doctorate and who work in posts where this is not required. The reports of the European Commission include an appendix that establishes the correspondence of these grades with the different categories of university teaching and research staff in each country.

**Canberra Manual**: The Canberra Manual pertains to the family of manuals devoted to measuring scientific-technological activity (the Frascati family). This manual is addressed in particular to human resources in the science and technology sector and starts from the supposition that "Highly skilled human resources are essential for the development and diffusion of knowledge and constitute the crucial link between technological progress and economic growth, social development and environmental well-being". (OECD, 1995, p. 3) In order to implement suitable political measures to foster the development of human resources devoted to science and technology it was necessary to compile the corresponding statistics. The human resources statistics in this manual can be broken down into the following main variables: levels of education (ISCED), fields of study, occupation (ISCO), HRST (Human Resources in Science and Technology) by workforce status, by sector of employment, by type of activity of the National Science Foundation. As regards fields of study, the Canberra Manual classified the 21 fields of the UNESCO, ISCED 97 manual into 7 groups: natural sciences, engineering and technology, medical sciences, agricultural sciences, social sciences, humanities and other fields. The main difference is that education is included in the social sciences and the service sector is not taken into account.

**ISCED 1997**: The International Standard Classification of Education was designed by UNESCO at the beginning of the 1970s in order to gather and present statistics on education at both the national and international levels. Over time its use led to a standardised set of indicators that was consolidated in 1997. The ISCED distinguishes between levels of education and fields of study. With regard to the former, it divides the educational system into 6 levels, ISCED 1-6, based on the concept of educational programmes as the set or sequence of activities organised to reach a predetermined objective. The levels that are of interest in this study are ISCED 5 and 6, which are defined as follows: ISCED 5, "first stage of tertiary education (not leading directly to an advanced research qualification)". This includes research programmes that do not lead to a doctorate degree. ISCED 6, "Second stage of tertiary education (leading to an advanced research qualification)" (UNESCO, 1997, p. 19). This level is orientated towards research leading to the presentation of a thesis or dissertation, and prepares its graduates for posts as university research or teaching staff. Study areas are broken down into 25 educational sectors which are in turn classified into 9 large groups: education, humanities and arts, social sciences, business education and law, science, engineering, industry and construction, agriculture, health and social services, services and unknown or unspecified sectors. The services sector, which is omitted from the Canberra Manual, includes the following: Personal services: hotels and restaurants, travel and tourism, sports and recreational activities, hairdressing, beauty treatment and other personal services, laundry and dry cleaning, cosmetic services, and home economics. Transport services: The training of seamen, marines, navigation, aeroplane crews, air traffic control, rail transport, road transport, and postal services. Protection of the environment: Conservation, vigilance and protection of the environment, control of air and water pollution, ergonomics, and security. Security services: Protecting persons and property: police and public order services, criminology, the prevention and extinguishing of fires, civil security; and military education.

**ISCED 2011**. At the UNESCO General Conference in October 2007, the national authorities expressed their desire to re-evaluate the ISCED in light of changes taking place in the education sector since the approval of ISCED 97. This revision has taken the form of a new document, ISCED 2011, currently pending approval by the UNESCO's 36th General Conference during 2011. The changes that are of interest to our study include the consideration of more detailed statistics as regards tertiary education. Thus, ISCED 97 levels 5 and 6 would be defined as follows: ISCED 5, 'short-cycle tertiary' education, refers to programmes often designed to provide participants with professional knowledge, skills and competencies. They prepare the students to enter the labour market. However, programmes may also provide a pathway to other tertiary education programmes. ISCED 6, 'bachelor or equivalent', programmes are often designed to provide participants with intermediate academic and/or professional knowledge, skills and competencies, leading to a first degree or equivalent qualification. They are traditionally offered by universities and equivalent tertiary educational institutions. ISCED 7, 'master or equivalent', are often designed to provide participants with advanced academic and/or professional knowledge, skills and competencies, leading to a second degree or equivalent qualification. Programmes at this level may have a substantial research component, but do not yet lead to the award of a doctoral qualification. ISCED 8 programmes, 'doctoral or equivalent', are designed primarily to lead to an advanced research qualification. (UNESCO, 2011, pp. 43-59). For comparative purposes, ISCED 97 Level 5 will become ISCED 2011 levels 5, 6 and 7, whereas the former level 6 will correspond to level 8 of ISCED 2011.

**Scissor Diagram**: a scissor diagram has the percentage of each gender on the vertical axis and the different levels of an academic career in ascending order on the horizontal axis. When the proportion of men and women are represented on the graph, the resulting diagram resembles a pair of scissors. As we move up the hierarchy the blades of the scissors gradually open up. The larger the gap between them, the greater the inequality. This is one of the most regularly observed statistical phenomena and is common to all EU member-States (EU-27)

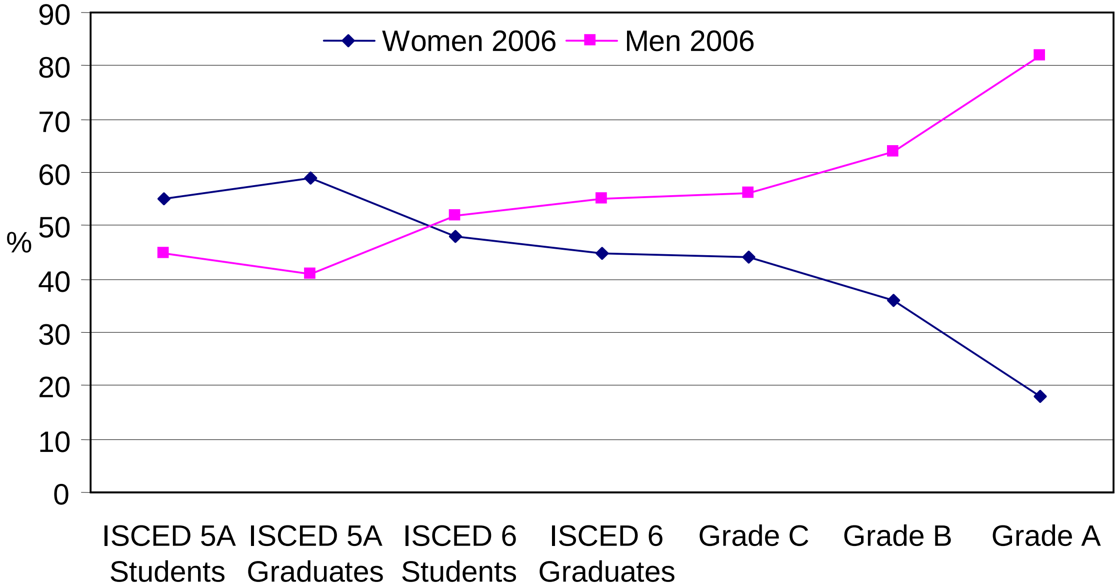


*Figure 1. Proportion of men and women in a typical academic career, EU-27. Source European Commission 2009.*

**Scissor Diagram model**: The scissor diagram allows us to characterise two different models of academic career: one in which women begin as the majority and are successively overtaken by their male counterparts, which is the "overtaking" scissor diagram model, and the "impossible pursuit" model, in which women begin their academic career in the minority with respect to men and the distance between them gradually increases as careers advance up the academic hierarchy. The difference between the two models lies mainly in whether the lines that represent the percentage of men and women at the different points of an academic career cross each other or not, and at what point they do so. The various scissor models are taken from the OPOCE, 2003, pp. 262-264.

**ENDNOTES**

[1] The reason is probably that each of the objectives is associated with different political measures and these measures determine the design of the indicators.
[2] Among others the following can be cited: European Commission 1999, 2004, 2006, 2009.
[3] See appendix ISCED 1997.
[4] See appendix Academic hierarchies.
[5] See appendix Scissor diagram.
[6] On 21 December 2001 the new Basic Law of Universities (*Ley Orgánica de Universidades*, LOU) came into effect in Spain to replace the Law of University Reform (*Ley de Reforma Universitaria*, LRU) of 1983. In the new law teaching categories were transformed.
[7] Both errors also occur in the 2006 report.
[8] The correspondent for the Helsinki Group in Germany has confirmed the error and provided the correct data. Many thanks to A. Löther for her kind collaboration.
[9] See Appendix Canberra Manual.
[10] Analysis of the causes underlying the phenomena analysed is beyond the scope of this study. Whenever a cause is noted we refer to those established by experts of the European Commission since they have served as a basis for their political recommendations.
[11] The European Commission's reports give different averages for subgroups of the European Union consisting of 15, 25 and 27 member states, respectively.
[12] M. A. Quintanilla suggested to me this possible interpretation of the data.
[13] Strictly speaking the data do not refer to the same population. Women researchers in 2006 are compared with women graduates in the same year, but the oldest data available (of 1998) show a similar distribution to that of 2006. See Table 4.
[14] This metaphor is considered inappropriate by some because it problematises women and does not encourage much reflection on the difficulties they face. While it is true that metaphors can entail a strong value judgement their use is so widespread in the field that they do serve to graphically describe a particular situation. See the European Commission 2000, p. 12
[15] One important problem in the use of ISCED 5 is that this level includes both the bachelor and master levels of the Bologna reform for higher education, whereas the academic hierarchy established by the EU refers only to masters degrees and excludes bachelors. The problem is that there are considerable differences among European countries as regards the proportion of masters and bachelors programmes in ISCED 5 and the proportion of women in each of them. Unfortunately the data gathered do not permit a more refined calculation of the move from bachelor to master. This issue is so important that a new classification has been developed in UNESCO, the ISCED 2011, which breaks down ISCED level 5 into three new categories that in future will enable us to take this step into account. See Appendix. I would like to thank an anonymous reviewer for calling my attention to this issue.

[16] For example, the index is used in anthropological biology to measure the concentration rate of genetic markers between population groups. I am grateful to Roberto Rodríguez for having given me this example.
[17] By feminisation we mean the increase in the number of women in the area with respect to the total. An area is said to be feminised when 75% of its occupants are women. See European Commission, 2009, p. 40.
[18] The ETAN report cites the following among the current forms of discrimination: "the language used in universities (e.g. bachelors and masters degrees) can imply students should be male. Privileging seniority (having been in the job for a long time) as a criterion of promotion is one example. The use of the 'old boys' network' as a source of recruitment for jobs discriminates. The 'long hours' culture benefits those men who do not carry the major burden of household responsibilities. Measuring productivity in terms of quantity rather than quality discriminates against women who take career breaks or are limited in the extra hours they can work by time-consuming domestic responsibilities". (European Commission 2000, p. 67)
[19] A generation is understood to be the number of years a class takes to replace another: four years of a degree, one year of a masters degree, and four years of a doctorate.
[20] Given that we have no Portuguese data for 2007, the progression rate has been calculated up to 2004. The number of years needed to reach equality would be 12; three years are discounted for the evening up of all the data to 2007.
[21] The index does not take Group D into account.
[22] Although the data for calculating the indices have been taken from the European Commission, 2009 report, the final value for Spain and Germany has been recalculated with the correct data; for this reason it does not coincide with the values of the European report that were 1.9 and 1.5 respectively.
[23] No Category D data exist for Italy in any of the reports.

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