Between Education and Employment: Women's Trajectories in STEM Fields

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Changes and instability in the pathways that women follow in the fields of Science, Technology, Engineering and Mathematics (STEM) in terms of both education and employment have become a major issue of national and international debate. Despite a growing number of women at the university and post-university levels (doctorate research programs, PhDs) in STEM fields, there still appear to be old and new composite inequalities in female trajectories of study that continue in their professional careers. Through an analysis of various data sources regarding women’s participation in these fields of study and employment, the paper analyzes if and how phenomena of gender-based polarization in scientific fields are decreasing over time, if women’s professional and study paths are being reconfigured and, finally, whether there is a trend toward greater gender equity or if, conversely, expansion processes are accompanied by new polarizations between different STEM fields. Taking into account the differences between STEM disciplines, our empirical analysis reveals a differential expansion that maintains the persistence of inequalities based on both gender and social background.

Keywords: STEM; Educational Choices; Social Inequalities; Occupational Paths; Gender Inequalities.

1. Introduction

In recent years, national and international debate alike has come to focus on changes and instability in the pathways that women follow in the fields of Science, Technology, Engineering and Mathematics (STEM) in terms of both education and employment. Indeed, these fields and their internal pathways of development have acquired an increasingly central place in public debate (Magaudda and Neresini 2011; Neresini 2015; Pellegrini and Saracino 2016), being recognized as fundamentally significant in relation to progress in scientific production itself and becoming a strategic area of interest in indicating research and development policies at the international level (OECD 2015). Furthermore, the fact that STEM fields host growing numbers of women at the university and post-university levels (doctorate research programs, PhDs) has attracted particular attention. This development
not only indicates a change in educational choices, which have become more varied and differentiated by gender than in the past (European Commission 2015), it also marks a change in students’ aspirations and expectations as well as the image of science held by both male and female students and their families (Pellegrini and Saracino 2016). While on the one hand there has been undeniable growth in the number of women in these fields (Giancola and Fornari 2009), on the other hand it also appears that old and new composite inequalities continue to operate – for example, disparities between genders and social classes (Barone 2010) – in both academic trajectories and professional employment.

This paper seeks to problematize these trends and look inside the data in order to pursue previously unexplored lines of analysis. It aims to conduct a diachronic analysis of women’s participation in these disciplinary fields in terms of both academic pathways and professional employment. The underlying hypothesis is that these fields currently represent an extremely interesting testing ground for analyzing if and how the phenomena of gender-based polarization in scientific fields have been losing their grip over time, if women’s professional and study trajectories are being reconfigured and, finally, whether the different STEM fields present homogeneous tendencies or, conversely, expansion processes are accompanied by new forms of polarization in which the disciplines diverge.

Taking into account the differences between STEM disciplines, the paper thus seeks to show how pathways in the educational world interlock and then reverberate in professional trajectories, bearing in mind that such pathways (which likely produce their own internal cumulative effects) in the various levels of the educational and training system and employment market may be affected – albeit in diverse ways – by variables such as family background, school track in upper secondary education and academic performance.

2. Between Education and Employment: An Example of Differentiated Expansion

Many countries, not only those characterized by higher levels of economic development, have by now achieved a significant degree of feminization of the school and university system. In OECD countries in 2012, females overtook males in both secondary and tertiary education. In many national contexts, these greater female achievements have
also been followed by a differentiation in university choices in which an increasing number of women have chosen and obtained a degree in STEM discipline fields. For example, the OECD-PIAAC (Programme for the International Assessment of Adult Competencies) data for Italy (collected between the end of 2011 and the beginning of 2012 and arranged in a temporal perspective based on different age groups) show a growth in the overall number of graduates in the technical and scientific sectors. While both men and women have benefitted from a general increase in the number of STEM field degrees, the diversification of training choices seems to be more evident for the latter. In fact, women represent 23% of total graduates in the 25-34 age range, with a trend that clearly indicates that the new generations of women are establishing an increasing presence in these disciplinary fields, compared with older age groups. However, the same data also show that there is still a clear gap between women and men’s participation in courses in technical and scientific disciplines. Calculated as a ratio of total graduates by gender, men account for 43% in STEM disciplines while women account for 23%. This trend can be seen in all participating countries, with women over-represented in Teacher Training and Education Science and Health and Welfare courses while men are over-represented in Engineering, Manufacturing and Construction (OECD 2016).

While evolutionary psychology has often hypothesized an innate predisposition towards altruistic or cooperative activities that leads girls to favor educational paths in the humanistic and caring disciplines, a wide range of theories have been developed over the years to explain these differences in the area of educational choices. Economic disciplines have supplied explanations based on either rational choice – girls tend to choose educational paths that allow them access to more family-friendly positions, for instance (England 2005; Frehill 1997) – or performance (Jonnson 1999). In this case, girls tend to choose disciplines more closely related to the subjects in which they obtained better grades in high school (theory of comparative advantage), thereby reducing the risk of scholastic failure. This theory in particular has given rise to a rich vein of research aimed at analyzing the different performances of male and female students in scientific subjects, together with a series of alternative explanations, mostly sociological, which blame primarily social and cultural factors for hampering women’s progress. Indeed, sociological perspectives have emphasized the role of socialization processes, different value structures and, finally, systems of reinforcement and reward. In the first case, scholars argue that the family, as well as
schools and the media to a lesser degree, encourages boys and girls to develop divergent attitudes towards certain abilities, skills and behaviors which then affect educational choices (Sherman 1980). Girls are often encouraged to develop and appreciate activities that involve cooperation, aesthetics and relational and communicative skills, while boys are instead provided with a model based on independence, the importance of practical activities and formal reasoning. In this way boys and girls are driven to follow educational choices in line with the gender stereotypes embedded in society more broadly. In the second case, in contrast, researchers hold that the key factor in female educational choices lies in their intrinsic interest in a subject, or the social and cultural significance of a certain field of study as opposed to the economic value of male-dominated ones (Beutel and Marini 1995; Bobbitt-Zeher 2007; Johnson 2001).

Finally, other explanations seem to suggest that the system of social sanctions and rewards enacted by families, teachers and peer groups plays a fundamental role in pushing students to choose one pathway or another. In this case, excluding any alleged female inferiority in scientific subjects, scholars hypothesize that powerful conditioning, the «threat of a stereotype» (Nguyen and Ryan 2008), influences girls to such an extent that they are driven to give up on competing with their male peers in scientific subjects. The sum of these approaches has contributed extensively to identifying the factors that condition educational choices while leading to the definition of a series of policies aimed at encouraging girls to engage with scientific disciplines. At the same time, however, these theories have underestimated the importance of the differences between and within STEM disciplines. In fact, a significant portion of the research tends to treat STEM as a homogenous field, overlooking the fact that the various disciplines are not only both very different from one another and characterized by significant internal subdivisions, but have also undergone different processes of gender expansion. In fact, the different sources of data show that there is a kind of model of association between gender and academic sector that affects not only the opposition between humanist and scientific disciplines, but also the one between technical knowledge and relational knowledge, or knowledge linked to the dimension of care (Barone 2011; Barone 2010; Triventi 2010). These tendencies, which are consistent across different countries, not only involve greater male participation in mathematical-scientific sectors but also polarization within the STEM disciplines themselves. In terms of quantity, for example, there are many
fewer female students in Engineering courses than any other scientific faculty, while the most highly feminized departments are those, such as Biology or Mathematics, that offer a more easily-accessible range of professional opportunities, for instance in teaching. Meanwhile, little attention has been granted to the makeup of university courses. Even at the highest level of the Italian education system – that is, in the choice of post-degree specialization or PhD – it is quite possible that new polarizations or reconfigurations could direct men and women along non-linear trajectories.

In light of these considerations, it makes sense to look inside the STEM fields in order to analyze how the increase in women’s participation is distributed in the various disciplinary sectors and what factors condition not only the choice of study sector but also the construction of post-degree university courses and their occupational consequences. Given what we might define as a differential expansion of women’s participation in STEM disciplines, therefore, it becomes particularly interesting to analyze not only differentiation in female students’ choices in the various disciplinary fields but also how training pathways interlock; that is, how scientific curricula are constructed and, above all, what these produce in terms of different occupational outcomes.

Scholars frequently argue that the sector of study women choose at university contributes to determining their advantages or disadvantages in the employment market. In fact, the different academic disciplines offer different cognitive and competency-oriented resources that have a significant effect on occupational outcomes. If educational choices are essential for understanding occupational outcomes, however, it also seems that this area continues to present the greatest challenges. The STEM disciplines indeed are unique in entailing specific obstacles to accessing the workforce. The problem does not lie in difficulty of entry per se, as this is facilitated by the possession of highly sellable qualifications, but rather in the quality of available professional positions. While the Italian employment market in general continues to offer a higher number of less-qualified openings (Ballarino and Scherer 2013), it is specifically in terms of employment conditions (qualifications, type of contract, remuneration) that this expansion, albeit differential, seems to have failed to offer equal opportunities for men and women. Naturally this problem has been identified, widely discussed and documented in the literature, with respect to both difficulties in career progress and advancement as well as professional recognition. In relation to professional advancement, more recent studies tend to discard met-
aphors such as the glass ceiling and the sticky floor in favor of broader expressions such as Aker’s (2009) proposed inequality regimes or the labyrinth of leadership (Eagly and Carli 2007). This move is principally motivated by the fact that traditional metaphors not only assume the idea of an impenetrable barrier but also describe career paths as if they were an orderly upwards progression, abruptly obstructed by an invisible barrier only shortly before reaching the finishing line. In so doing they overlook the fact that career obstacles are found in all directions and along the entire expanse of the employment pathway, beginning with a jobseeker’s first entry into the market (Meyerson and Fletcher 2000).

Even regarding the issue of vertical segregation, however, while available research (Bilimoria et al. 2014; Blickenstaff 2005; Hewlett et al. 2008; Kleist 2015) has succeeded in highlighting the difficulties facing women (hostile work environments, extreme job pressure, too much travel, lack of advancement and low salaries), it is inclined to analyze the STEM professions as a group without any distinction. While it is true that vertical segregation is a transversal phenomenon, the studies carried out on specific professions also demonstrate the need to adopt a perspective that distinguishes among the professional fields. For example, research carried out on female engineers shows that the main factor in these professional fields is the ability to hold out over time (Buse et al. 2013; Fouad et al. 2016; Singh et al. 2014) and that career opportunities depend largely on a lack of family responsibilities (Ayre 2014). There are additional barriers to success in professions that are not only male-dominated but also represented in a way better suited to masculine attitudes. This difference in attitudes also gives rise to obstacles to career advancement in computer science (Schulte and Knobelsdorf 2007; Trauth et al. 2008). Studies focused on the medical professions reveal a rather different scenario. These professions have recently undergone a process of feminization entailing increasing numbers of women in professions that were previously dominated by male practitioners (Riska 2008). Despite this reversal, women continue to be poorly represented in positions of power. On one hand, research shows that national welfare systems play a crucial role in enabling women’s career opportunities, for example through policies that support an effective work-life balance (Crompton and Le Feuvre 2003). On the other hand, studies point out that the medical professions now enjoy a lower level of social recognition following these feminization processes (Gjerberg 2001; Riska 2001; Riska 2008). This second issue stems pri-
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marily from women’s relative invisibility or, at a minimum, the difficulty they face in obtaining professional recognition, the so-called Matilda effect (Rossiter 1993) that results in progressively less female participation in scientific careers. This phenomenon is often referenced using the metaphor of a leaky pipe, a large inflow on the intake end that gradually dwindles to a desultory few drops at the higher levels of technological and scientific careers. Many studies, in fact, seek to explain why women abandon scientific careers in both professional and academic fields by focusing on how individuals construct their professional identities and their relative levels of commitment (Etzkowitz et al. 2001; Kulis et al. 2002). From this point of view the Italian case displays additional specificities. University-level training is deeply differentiated, which generates a new «pink ghetto» in certain degree courses such as those in the social services, nursing sciences or health professions. This new trend toward segmentation accelerates de-skilling processes in these scientific fields, thereby making it even more difficult for women to gain recognition for these professional skills.

The overall picture that emerges from this series of considerations is destined to become more and more complex, therefore, as a direct result of the effects of women’s expanding presence in both education and the technical-scientific professions. Consequently, in an attempt to make sense of processes of differential expansion while keeping a careful analytical eye on differences between and within the STEM disciplines, we propose to use the data to verify whether the interconnection between training and professional pathways offers different opportunities to reflect on these phenomena. Naturally, the analysis will take into account the weight that variables of family background have in conditioning women’s trajectories. Indeed, it is useful especially for technical-scientific disciplines to engage with the hypothesis of the maximum maintained inequality (Raftery and Hout 1991) and verify if and to what extent educational expansion in these sectors advances only certain social classes, and to what extent the impact of these variables produces differential effects for men and women.

3. The Research: Sources and Methodology

In terms of empirical analysis, the research began by focusing on educational choices (the specific fields of study chosen by students). To this end, we granted particular weight to the question of how male/
female graduation rates (bachelor, masters and five or six-year ciclo unico degrees) are shifting with respect to the way they have been depicted in the literature, in both quantitative (as absolute values, as a percentage of the total and within individual disciplines) and qualitative terms (gender, social origin). The next step concerned PhD graduates in the STEM fields and explored the hypothesis that changes are taking place in gender balance even at the highest levels of the Italian educational system. At this point it was particularly interesting to determine if and how internal pathways in the educational sphere interlink (from three-year degree courses through master’s degree to the level of research doctorate). Finally, we investigated the most significant trends in students’ transitions into the world of employment, analyzing the professional trajectories of male and female graduates (and PhDs) in the technical-scientific fields. In order to investigate these aspects, we drew on two main sources of data. The first is the sample survey regarding graduates’ entry into the job market (Sample Survey of Professional Entry of Graduate Students) conducted by Italy’s National Statistics Institute (ISTAT). In this survey, a sample of graduates who had earned their degrees four years earlier was interviewed. The survey (carried out in 2011) allowed us to analyze the employment status of graduates at a distance of approximately four years after graduation (the graduation year in this case is 2007). In addition to employment status and characteristics of the professional position, the survey also collected information about the individuals’ previous educational careers and social origin (parents’ education levels and occupations).

As a second source we drew on the findings of a survey on PhD graduates’ accessing of professional careers (Survey of Professional Entry of PhD Graduates). This survey aimed to reconstruct individuals’ employment status and occupational conditions, providing relevant information about the educational pathways and family background of all those who completed a PhD program: unlike other surveys based on sampling, this survey of PhDs is a census that addresses two PhD cohorts. For the 2014 edition of the survey, the respondents were PhDs who had earned their degrees in 2008 and 2010. In addition to the 2014 edition, for this article we also used the previous census (PhDs who obtained their degrees in 2004 and 2006 and responded in 2010) for descriptive purposes.

Both these data sources present common variables (for example, variables related to parents’ education levels and employment, which were used to construct a summary measure of family background, or
variables related to the ISCO code used to indicate professional level), but also deeply divergent variables (for example, the variable relating to field of study). The two databases were therefore used separately, but in accordance with the same logic: to investigate how the gender variable affects educational choices (choice of field of study) and analyze the relationship between gender, social origin, educational development and academic achievement. In this sense, the data contribute to constructing a kind of mosaic that allowed us to map students’ educational trajectories and job placement. Both surveys enabled us to conduct an analysis of pre-entry conditions (e.g. family background factors) and provided the data necessary to trace professional entry pathways in terms of differential access to the job market, both in and between the STEM fields. The survey of PhD graduates, focused on the highest segment of the university educational career, also allowed us to identify PhD graduates’ areas of interest in a context of gender differentiation as well as their occupational pathways or additional training (or a combination of both).

4. Male and Female Graduates in STEM Disciplines: Gender Differences and Social Origin

As already mentioned, the general overview of the phenomenon provided by the OECD-PIAAC data clearly confirm that women are participating in the STEM disciplines in increasing numbers. While the numbers of women in tertiary education are rising in all disciplinary areas, this expansion is particularly relevant in STEM because it signals a change in girls’ perceptions and expectations. However, while the data do indicate a general expansion in these disciplinary fields, with a simultaneous increase in numbers of both men and women, they also suggest different trends for the two sexes. While men appear to concentrate their university choices on certain scientific fields and sectors, women appear to be more clearly involved in a process of diversification in which the distribution of female students among the various scientific sectors is becoming more uniform. Having identified this long-term temporal trend, the ISTAT sample survey micro data regarding graduate professional entry (2011) allows us to also examine more recent trends by focusing on a larger and more near-term level of disaggregation. Looking at the higher level of education achieved by graduates in the sample, most of the scientific disciplines seem to be affected by a
significant process of feminization. Women make up over 70% in the linguistic group and almost 60% in the legal and social-political group.

If we instead consider the STEM sector specifically (table 1), the only field that remains highly male-dominated is the engineering group, while the other disciplines are undergoing an ongoing process of feminization similar to that occurring in the humanities. The most feminized group is Medicine. Here, besides the opposition between technical knowledge and relational or care knowledge, these disciplines are affected by two trends: first, better female scholastic performance, which gives women an advantage in passing entrance tests, for instance, and second, significant growth in the so-called health professions in which women outnumber men. The feminization of the geo-biology group is conditioned by the above-mentioned opposition between technical and care disciplines. In contrast the chemistry group, in parallel with the scientific group although to a lesser degree, displays the tendency already identified in which women are distributed more widely throughout STEM disciplines, although the different speeds at which the various disciplinary fields open up to women suggests that this expansion remains uneven in the different disciplines.

Stemming from these considerations, in order to better evaluate this initial growth in the numbers of women in STEM fields, it is important to analyze the weight that variables of family background have in conditioning these pathways. To this end we used a binomial logis-
tic regression model in which the dependent variable was represented by «having graduated in a STEM area vs having graduated in other areas» and the independent variables were «gender», «age at enrollment», «previous academic performance», «academic track» followed in upper secondary education and, finally, «family background». Rather than using individual variables related to the graduates’ parents’ education levels and occupation type, we opted for a synthetic measure: the family background index. This index is the result of a linear combination of the levels of formal education (arranged into three categories) and employment (likewise organized into three categories) of the interviewees’ mother and father. Subjecting the four variables to a

For educational level, we used a variable with three ranked categories (University degree, Upper secondary education, Less than upper secondary) and for occupational level we used a variable with three ranked categories (beginning with ISCO classification, we collapsed ISCO 1 and 2 into High professional status, ISCO 3-5 into Middle professional status, and ISCO 6-9 onto Low professional status).

### Tab. 2. Probability to graduate in STEM area (binary logistic regression)

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
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<tbody>
<tr>
<td>**Gender (ref. Male)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>0.765</td>
<td>0.866</td>
</tr>
<tr>
<td><strong>Age at enrollment (ref. 22 or more)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within 21 years</td>
<td>1.061</td>
<td>1.016</td>
</tr>
<tr>
<td><strong>Family Background (ref. Low)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.451</td>
<td>1.216</td>
</tr>
<tr>
<td>Medium</td>
<td>0.961</td>
<td>0.883</td>
</tr>
<tr>
<td><strong>School performance (ref. less than 89)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High performance: 90-100</td>
<td>1.410</td>
<td>1.447</td>
</tr>
<tr>
<td><strong>School track (ref. Other Lyceum)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific lyceum</td>
<td>2.924</td>
<td>.000</td>
</tr>
<tr>
<td>Classical lyceum</td>
<td>1.661</td>
<td>.000</td>
</tr>
<tr>
<td>Technical/Professional</td>
<td>1.356</td>
<td>.000</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>1.225</td>
<td>0.730</td>
</tr>
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</table>

*Source:* Our elaboration of data from *Survey on Graduate Employment, 2011.*
Principal Components Analysis, we obtained a single component that synthesized 64.5 percent of the overall variance.

Taking «having graduated in a STEM area vs having graduated in other areas» as the dependent variable, we were able to observe that being a woman still represents a disadvantage in relation to the probability of graduating in the STEM fields. Instead, it is mainly students from higher social classes (higher tertile of the family background index) who are advantaged. In fact, net of other variables, having a high socio-economic background substantially influences an individual’s chance of earning a tertiary-level degree in a STEM area, but having high past performance (measured in terms of final grades at the end of high school) also significantly influences this probability.

Replicating the model and controlling for the effect of the student’s previous school track, we found that students graduating from high schools with a scientific focus are highly advantaged in terms of obtaining a STEM degree. This relationship, already documented in previous studies regarding educational choices in Italy, clearly shows that stu-
Students’ earlier choices (among different school tracks) have substantial inertial power in influencing their subsequent trajectories. Finally, the remarkably high numbers of women in the scientific high school track (as in all the lyceum tracks) could explain the reduction of relative disadvantage related to the variable of gender.

The data suggest that the overall growth of STEM sectors involves mainly the upper social classes, with a decidedly differential effect for men and women. As can be seen from figure 1, obtained by overlaying disciplines from the STEM group onto the space produced by the intersection between the family background index and the male/female ratio – that is, the level of feminization in the various disciplines – family variables undeniably have a significant effect. In fact, not only are the STEM areas all concentrated in the quadrant of high-level family background, the STEM sectors with increasing female participation (with the partial exception of the biology group) show girls belonging to that social group at an advantage. The medical group displays particularly interesting results. In fact, if we consider the health professions (characterized by an average of three years of study) separately, it is clear that this sector’s growth in both overall numbers and feminization, the most significant of any sector, does not correspond to a progressive inclusion of women from lower family backgrounds in professional medical degree courses (the ciclo unico degrees lasting five or six years).

5. Female and Male PhDs in STEM: Aspects of Stability and Difference

At the level of higher education, and thus the peak of the tertiary education system, the two surveys (2004-2006 PhDs and 2008-2010 PhDs) on the employment obtained by PhDs reveal a more static situation. First of all, it should be noted that the disciplinary fields are grouped differently in the ISTAT PhD dataset than they are in ISTAT graduate dataset. In the second case, a more detailed classification is provided (for both censuses), and for the purposes of this research this further specification proved useful in ascertaining more accurately male/female differentiation among the different STEM sub-fields.

As seen in table 3, in general many disciplines show a decrease in PhDs course enrollment numbers, and this has led to a drop in both male and female graduates. Consequently, the sectors in the period under

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2 Data processed by dataset: Doctorate survey 2004-2006 (collected 2009-2010); Doctorate survey 2008-2010 (collected 2014).
consideration that show a decrease in the number of women also show
a decrease in male students. The only two exceptions are the chemistry
and biology groups, which instead display a decrease in the numbers of
women and an increase in those of men.

However, if we further subdivide this data into scientific sectors and
analyze it considering the numbers of men and women within each dis-
ciplinary area (table 4), it suggests not entirely unexpected trends. As
clearly shown by table 4, there seems to have been a kind of exchange
between men and women, on the one hand, while on the other hand
there has been a growth in certain PhD courses; these are not the same
scientific disciplines that have seen a greater increase in female gradu-
ates, however. Regarding the first point, a kind of alternation is taking
place in which the same doctorate courses (Mathematics and Computer
Sciences, Chemistry, Earth Sciences and Biology) that display an in-
crease in male participation also show a decrease in female participation
while women’s numbers have grown in the same sectors where men’s numbers are dropping (Medicine, Industrial Engineering and

<table>
<thead>
<tr>
<th>Disciplinary group</th>
<th>2004-2006</th>
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<th>2008-2010</th>
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<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
<td>Total</td>
<td>Men</td>
<td>Women</td>
<td>Total</td>
</tr>
<tr>
<td>Mathematics and Computing</td>
<td>4.2</td>
<td>2.3</td>
<td>3.2</td>
<td>4.1</td>
<td>1.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Physics</td>
<td>6.6</td>
<td>2.9</td>
<td>4.7</td>
<td>6.4</td>
<td>2.8</td>
<td>4.5</td>
</tr>
<tr>
<td>Chemistry</td>
<td>4.8</td>
<td>5.8</td>
<td>5.3</td>
<td>5.2</td>
<td>5.7</td>
<td>5.5</td>
</tr>
<tr>
<td>Scientific</td>
<td>2.8</td>
<td>2.3</td>
<td>2.5</td>
<td>2.5</td>
<td>2.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Biology</td>
<td>6.3</td>
<td>13.8</td>
<td>10.1</td>
<td>6.9</td>
<td>12.2</td>
<td>9.7</td>
</tr>
<tr>
<td>Medical Sciences</td>
<td>10.9</td>
<td>17.5</td>
<td>14.3</td>
<td>12.1</td>
<td>19.4</td>
<td>15.9</td>
</tr>
<tr>
<td>Agriculture and Veterinary</td>
<td>6.2</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
<td>6.7</td>
<td>6.4</td>
</tr>
<tr>
<td>Engineering and Manufacturing</td>
<td>8.7</td>
<td>7.3</td>
<td>8.0</td>
<td>8.0</td>
<td>6.2</td>
<td>7.1</td>
</tr>
<tr>
<td>Industrial and Information Engineering</td>
<td>17.6</td>
<td>5.1</td>
<td>11.2</td>
<td>17.9</td>
<td>6.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Other disciplines</td>
<td>32.1</td>
<td>36.8</td>
<td>34.4</td>
<td>30.7</td>
<td>37.2</td>
<td>34.2</td>
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<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Source: Our elaboration of data from Survey on employment outcomes of PhDs, waves 2010 and 2014.
In relation to the second point, in contrast, (with the exception of the medical group) women’s numbers in PhD courses have increased in Physics, Industrial Engineering and Information Sciences, that is, the two STEM areas in which the female presence has expanded less significantly. For the moment these remain weak trends that do not eliminate gender polarization within the technical-scientific sectors; instead, this polarization persists at multiple levels, including the highest level of the education system.

Just as in the previous operation, in order to estimate the probability of obtaining a PhD in a STEM area we employed a binomial logistic regression model, using «gender», «age at graduation» (as a proxy variable of regularity in university studies), «previous academic performance» (graduation performance) and, finally, «family background» (constructed in same way indicated for the model in table 2) as independent variables. In this case as well, gender clearly produces a penalty effect (induced by the continuity between university disciplinary fields and those at the doctoral level, which reflects the same mechanism of segregation outlined above). It is also important to note that regularity in university studies («age at graduation 25-29» in table 5) and a brilliant university career (indirectly captured by the variable of high graduation performance) have a significant impact in increasing

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<tr>
<td>Mathematics and Computing</td>
<td>63.8</td>
<td>36.2</td>
<td>66.6</td>
<td>33.4</td>
</tr>
<tr>
<td>Physics</td>
<td>68.8</td>
<td>31.3</td>
<td>67.3</td>
<td>32.7</td>
</tr>
<tr>
<td>Chemistry</td>
<td>43.9</td>
<td>56.1</td>
<td>45.9</td>
<td>54.1</td>
</tr>
<tr>
<td>Natural Science</td>
<td>53.5</td>
<td>46.5</td>
<td>54.1</td>
<td>45.9</td>
</tr>
<tr>
<td>Biology</td>
<td>30.3</td>
<td>69.7</td>
<td>34.2</td>
<td>65.8</td>
</tr>
<tr>
<td>Medical Sciences</td>
<td>37.4</td>
<td>62.6</td>
<td>36.3</td>
<td>63.7</td>
</tr>
<tr>
<td>Engineering, Manufacturing, Architecture</td>
<td>53.2</td>
<td>46.8</td>
<td>54.4</td>
<td>45.6</td>
</tr>
<tr>
<td>Industrial and Information Engineering</td>
<td>76.6</td>
<td>23.4</td>
<td>73.3</td>
<td>26.7</td>
</tr>
</tbody>
</table>

Source: Our elaboration of data from *Survey on employment outcomes of PhDs*, 2014.
60  Luisa De Vita and Orazio Giancola

**Tab. 5. Probability of achieving a PhD in STEM area (binomial logistic regressions)**

<table>
<thead>
<tr>
<th></th>
<th>Exp(B)</th>
<th>p-val.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender (ref. Male)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>0.769</td>
<td>.000</td>
</tr>
<tr>
<td><strong>Age at graduation (ref. 24 or less)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age at graduation: 30 or more</td>
<td>1.096</td>
<td>.000</td>
</tr>
<tr>
<td>Age at graduation: 29-25</td>
<td>1.562</td>
<td>.000</td>
</tr>
<tr>
<td><strong>Family Background (ref. Low)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.827</td>
<td>.000</td>
</tr>
<tr>
<td>Medium</td>
<td>1.055</td>
<td>.014</td>
</tr>
<tr>
<td><strong>Graduation performance (ref. 107 or less)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graduation performance: High (108 or more)</td>
<td>1.594</td>
<td>.000</td>
</tr>
<tr>
<td>Constant</td>
<td>1.630</td>
<td>.000</td>
</tr>
</tbody>
</table>

*Source*: Our elaboration of data from *Survey on employment outcomes of PhDs*, 2014.

an individual’s chances of earning a PhD in STEM areas. The impact of these variables notwithstanding, family background continues to have an equally significant effect.

**6. Implications for the Employment of STEM Graduates and PhDs**

The same polarization can also be found on the employment front. As table 6 shows, women with a degree in one of the STEM disciplines are unemployed at higher rates than men, and this finding holds true for all the various disciplines with the single exception of the chemical-pharmaceutical sector, which employs higher numbers of women.

The most critical data, however, have to do with inactivity, an aspect that is highly gendered in STEM disciplines as well. As compared to men, the most inactive women are degree holders in the geo-biology sector which, as seen above, is the field in which female growth was most extensive. There are no differences between males and females in the engineering group and the ratio is reversed in the chemical-pharmaceutical group, but overall women are more inactive than men on average. This disparity also appears in relation to employment conditions.
Overall, however, the gap is not large and, while in architecture, biology and the scientific fields the difference between men and women stands at around 7-8 percentage points, the gap decreases sharply in engineering and medicine and there are actually more women employed when it comes to the chemical-pharmaceutical group (with a positive discrepancy of 2.4% in favor of women). Employment outcomes thus seem to suggest an opening for STEM graduates, especially in the professional spheres. The engineering group presents the most interesting data in relation to this point. Female engineers are the most employed in absolute terms, not only in STEM sectors but in all the other disciplinary sectors as well. This indicates a high degree of female penetration in one of the most traditionally male-dominated professions, which might have important consequences in terms of both granting women visibility in the profession and influencing girl’s educational choices in the future.

With the exclusion of the differences reported above, the analysis of employment status does, however, indicate that STEM disciplines are highly internally heterogeneous, with intense oscillation between one disciplinary group and the next. By conducting a simple bivariate comparison, we found that the condition of being employed is substantially similar between the macro STEM area and the rest of the disciplines (with a 0.5% difference). Using the first two ISCO codes as proxy for having a work that is high-quality and consistent with the individual’s

<table>
<thead>
<tr>
<th>Disciplinary group</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inactive</td>
<td>Unemployed</td>
</tr>
<tr>
<td>Natural Science</td>
<td>18.3</td>
<td>8.5</td>
</tr>
<tr>
<td>Pharmaceutical Chemistry</td>
<td>13.9</td>
<td>14.4</td>
</tr>
<tr>
<td>Geo-biology</td>
<td>19.5</td>
<td>20.3</td>
</tr>
<tr>
<td>Medical Sciences</td>
<td>27.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Engineering</td>
<td>10.5</td>
<td>8.1</td>
</tr>
<tr>
<td>Architecture</td>
<td>8.3</td>
<td>13.5</td>
</tr>
<tr>
<td>Agricultural Sciences</td>
<td>9.4</td>
<td>13.9</td>
</tr>
</tbody>
</table>

*Source:* Our elaboration of data from *Survey on Graduate Employment* 2011.
level of education, the data show that being a STEM graduate produces an advantage, especially in the quality of employment.

In our analysis of graduates’ employment, starting from the variable that summarizes the ISCO code in a single number, we adopted a re-code into three categories (see table 7). It was decided to unify the two highest levels in view of the very low incidence of graduates in ISCO 1 (legislators, senior officials and managers), which amounted to only 2.6% of the total. We proceeded by maintaining the technical professions (ISCO 3) separate and collapsing the professions that fell under the other ISCO codes (4-9) into a single variable.

The data in table 7 confirm that there are no sizeable differences in employment position, in the sense that both women and men who possess qualifications in these areas are located for the most part in skilled professions. While the (relative) male advantage holds constant in managerial levels, for the pharmaceutical-chemical group, the geo-biological group and architecture, women in managerial positions (intellectual, scientific and highly specialized professions) make up a higher percentage than men; male employees are instead more highly represented in the technical professions (this is considering percentage distributions among men and women, not absolute values, as these latter confirmed the existence of a gender differentiation but without al-
One interesting exception is the medical group, where the difference between women and men in managerial positions rises to 8 percentage points. This figure is certainly caused by the intense feminization of the so-called Health Professions, which typically leads to technical careers and, as noted earlier, is the result of intense gender differentiation in degree courses. As mentioned earlier, men are over-represented as employees in all the fields considered here. This gap is partially reduced, however, if we consider the value of the degree (therefore, it is reduced only for individuals inside the employment market), at least in terms of valorizing skills acquired during university study trajectories (captured indirectly by being positioned in the first two ISCO categories and, partially, the third category).

Looking at the two models derived from a binary logistic regression (table 8), regarding the probability of being employed in apical professional positions, the first model shows that women are clearly disadvantaged; it is also clear that socio-economic background has a powerful effect on the quality of the individual’s employment position (captured by the proxy categories obtained using the collected ISCO codes). Furthermore, in the transition from the first model to the second

<table>
<thead>
<tr>
<th>Gender (ref. Male)</th>
<th>Exp(B)</th>
<th>p-val.</th>
<th>Exp(B)</th>
<th>p-val.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>0.791</td>
<td>.000</td>
<td>0.805</td>
<td>.000</td>
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<tr>
<td>Age at graduation (ref. 24 or less)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age 25 or more</td>
<td>1.196</td>
<td>.000</td>
<td>1.198</td>
<td>.000</td>
</tr>
<tr>
<td>Family Background (ref. Low)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.406</td>
<td>.000</td>
<td>1.292</td>
<td>.000</td>
</tr>
<tr>
<td>Medium</td>
<td>1.135</td>
<td>.000</td>
<td>1.020</td>
<td>.008</td>
</tr>
<tr>
<td>Degree in STEM field (ref. Other field)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STEM</td>
<td></td>
<td>.000</td>
<td>1.342</td>
<td>.000</td>
</tr>
<tr>
<td>Constant</td>
<td>0.458</td>
<td>.000</td>
<td>0.380</td>
<td>.000</td>
</tr>
</tbody>
</table>

Source: Our elaboration of data from Survey on Graduate Employment, 2011.
one, when we include the control variable related to graduation in the STEM group (as a dummy variable «STEM vs non-STEM») the effect of the background is reduced (because it is absorbed by the graduation field) but, despite the persistence of gender inequality, the possession of a STEM degree produces a comparative advantage for both men and women. Of course, it must be kept in mind that, as noted above, women are disadvantaged in graduating in this field and even when they do manage to graduate in STEM areas they are slightly more vulnerable than men to the risk of unemployment.

Moving on to the employment consequences of PhD possession, on average women benefit more than men from research grants or scholarships (men 19.6%, women 23.4%). This is particularly evident in the medical area (with a gap of more than eight percentage points: men 14.9% and women 23%) and chemistry (with a gap of around five points: men 22.9% and women 28.4%). It is also worth underlining the five-point gap in favor of women in the area of industrial engineering and information sciences, where women make up only 26.7% of the total of those participating in doctorate courses. Our processing of the data from the 2014 Survey on employment outcomes of PhDs also clearly shows a trade-off between male and female graduates: women seem to combine scholarship and work less frequently than men (men 7.5% and women 4.3%).

We should also mention that approximately 8% of women PhDs in the STEM area are unemployed, compared to 5% for their male colleagues. Finally, some consideration should also be granted to the ratio of men and women among those who continue in their research field as opposed to those who take up active employment. The larger proportion of women in this area might be seen as a valorization of their qualifications or an effect of the male-orientated job market. In fact, the rate of employment is around 70% of the analyzed sample of PhDs for men, while the rate drops slightly under 64% in the case of women. However, in this case as well the data on the quality of employment outcomes are interesting (here, employment outcome is understood as the ISCO classification placement of those in active employment as opposed

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3 In the case of the PhD, a recoding in four levels was necessary since the ISCO 1 professions were significantly more consistent. The ISCO 2 professions have maintained a prevalence that would justify the use of both apical classes. Technical professions (ISCO 3) remained independent, while (as for graduates) professions that fell in the other ISCO codes (4-9) have been collapsed into one variable.
to those with research grants or funding). The data show that many women occupy higher management positions (36.7% of PhD-holding women, with a peak of over 41% in chemistry, physics and biology but a well-documented disadvantage in the fields of industrial and information engineering). This is a particularly relevant finding, firstly because it confirms the fundamental role that higher education plays for women in technical-scientific careers in reducing gender differences, and secondly because it begins to undermine the well-established metaphor of the glass ceiling for women in the technical-scientific sectors.

7. Conclusions

The mosaic of data produced via an analysis of the various sources and presented in the previous sections of this paper provides a composite yet at times contradictory picture in which static elements mix with some elements of change. It is undoubtedly true that not having longitudinal data on groups broad enough to represent not only sectors but also disciplinary sub-sectors serves to shift the analysis to a highly distal level (Giancola and Viteritti 2014) from which it is hard to make out micro changes. The STEM field is characterized by numerous and heterogeneous intersections, subject to hybridization and changes and hard to map using the sectors as a category of differentiation, since the sectors themselves are highly aggregated in most educational surveys such as the OECD-PIAAC (OECD 2016) and only partially disaggregated in the ISTAT data used in this research.

However necessary it is to qualify the kind of data available – and thus underline the need to supplement them using a mixed-methods approach – we can nonetheless offer some comments of an interpretative character. A first salient point is that the expansion of the university system (in terms of male and female graduates and enrolled students) does not necessarily appear to bring with it a reduction in gender disparity. As illustrated through our descriptive statistics, these disparities persist despite the general scenario involving more significant female participation in the STEM sectors of higher education. In addition, after a phase in which women’s participation increased, the trend indicated by these data would (the conditional is obligatory) seem to suggest a stabilizing trajectory. Nevertheless, within this framework it should be borne in mind that the sectors are highly heterogeneous. While on the one hand this heterogeneity might represent a resource, on the other
hand it could represent a mechanism of further differentiation (primarily between STEM and non-STEM fields, and to a lesser degree within the vast STEM world itself). Educational choices thus play an absolutely crucial role in students’ passage from the cycle of junior-senior high school education. However, given that this formative segment is undergoing a period of change (one need only think of the new Italian curriculum, which has involved fragmenting the traditional scientific high school track), crucial intersections take shape in the passage from lower secondary to upper secondary school and from there to university, intersections that determine students’ study trajectories and, later, graduates’ prospects for employment.

As our analysis has shown, the probability of graduating in a STEM field is positively influenced by having earned a high school diploma such as that of the scientific track that provides an advantage not only in relation to technical or professional schools, but also in relation to all the other lyceum specialization tracks. The choice to enroll and then graduate in a STEM discipline appears to be the result of a process of long-term planning that is additionally reinforced by the student’s performance in school. Besides the greater gender divergence that appears to polarize choices, this dynamic (which in this paper is only observed downstream of the process) is also conditioned by the additional role of differentiation played by socio-economic background. Although sectors such as medicine (excluding the health professions that entail the possession of a three-year degree or, at most, subsequent specialization) and the chemical-pharmaceutical sector, characterized by a high percentage of women, are also characterized by a fairly high-level family background (we are clearly talking about average values within the individual sectors, so the relationship should not be read in an entirely deterministic fashion). Moving to the higher level of the education system (at which points students have overcome social selection by gender and family background) of the various PhD fields, women make up a remarkable proportion of the medical and biology area while areas such as engineering and computer science continue to be largely male-dominated. The research doctorate clearly represents the high point of academic and university training, but the consolidation of the trends highlighted here shows that similarities and differences are crystalizing. The moment of transition to the job market (or, in the case of doctorates, the continuation of a path of study) therefore represents a key vantage point for observation.
For graduates, employment rates confirm the gender gap, with women continually registering a disadvantage in both employment and activity rates even considered net of oscillations in the different fields and with the exception of the chemistry group. The question of employment quality, in contrast, displays greater symmetry. Both female and male STEM graduates for the most part tend to find employment in qualified professions, with a relatively reduced variance between men and women.

Despite this higher equality in reaching senior positions, it should be emphasized that it is mainly women in possession of a PhD who are able to achieve these more impressive performance levels, which emphasizes that women have to obtain additional training in order to reach a position that men can attain with an undergraduate degree alone. Beyond this compensation effect PhDs exercise for women, the data indicate that there remains a gender gap even among PhDs. Among all those with a PhD in the STEM area, women have higher rates of unemployment. One can hypothesize that the lower numbers of women in the job market are linked to models, stereotypes and male-orientated practices of staff selection (or, in the case of computer sciences, almost male-dominated). This fact might explain the higher percentage of women with STEM PhDs who hold study grants or research funding (in almost every case, these are in academia or research bodies). It remains to be seen whether this reflects a vocation on the part of female scientists or stems from constraints imposed by the job market. The data outlined here plainly show that the only way to reduce the gender gap in educational choices and subsequent careers is by implementing complex policy interventions. It is clearly necessary to move beyond equalizing policies in the job market (such as the so-called quotas) to include orientation and guidance policies in schools (beginning at the earliest levels of education) as well as outside of schools (family orientation and guidance), a step which would affect many aspects of the collective consciousness, systems of support and expectations, and paths of study. At the same time, the issue of employment and gendered cultures in the workplace still needs to be addressed, and it remains to be seen what effect the 2007-2008 economic crisis and subsequent employment stagnation will have on students’ university choices.

Tertiary education has often been a vector of change in phases of economic expansion (Benadusi and Giancola 2015), being at the same time the cause and effect of macro-economic cycles. The challenge of cultural change – linked as much to maintaining male participation as
encouraging the growth of female participation in STEM fields – is thus interwoven with economic processes, productive structures and gender stereotypes. Only multi-sectorial policy interventions at various levels can provide a minimally adequate response. From the data we have presented and interpreted here, it is clear that the sphere of education (in the broadest sense of the term) functions as a privileged field of intervention and experimentation.

References


Agenzia Nazionale di Valutazione del Sistema Universitario e della Ricerca (ANVUR) (2014), Rapporto sullo stato del sistema universitario e della ricerca 2013, Roma, ANVUR.


Women’s Trajectories in STEM Fields

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