Women in Latin American science: gender parity in the twenty-first century and prospects for a post-war Colombia

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ABSTRACT
The aim of this study was to evaluate the status of gender parity in science in Colombia throughout the twenty-first century. Data were decomposed by research area, researcher rank level and academic level. Gender disparity was also estimated for changes in average age, access to scholarships for postgraduate studies, and number of doctoral graduates. Using logistic function modeling, temporal projections into the future were performed in order to estimate how long could it take to reach gender parity. Medical and health science is the only field to have reached gender parity, while also showing a steady decrease in women’s representation across time. On the other hand, engineering, humanities and natural sciences had the lowest percentages of women’s representation. Women researchers showed a decreasing presence as they move upward to more senior levels, exemplifying the “leaky-pipeline phenomenon” common in science. Possible drivers of these results are analyzed, suggesting that a combination of lack of research funding, insufficient legal framework, pre-existing biases, and poor protection of women’s rights inhibits women’s participation in science. It is estimated that, without any action to change current trends, it could take between 10 (humanities) and 150 (engineering) years to reach gender parity across all research areas.

Mulheres na ciência latino-americana: paridade de gênero no século 21 e perspectivas de uma Colômbia do pós-guerra

RESUMO
O objetivo deste estudo foi avaliar o status da paridade de gênero na ciência na Colômbia ao longo do século XXI. Os dados foram decompostos por área de pesquisa, nível de classificação do pesquisador e nível de escolaridade. A disparidade de gênero também foi estimada para mudanças na idade média, acesso a bolsas de estudos de pós-graduação e número de doutorados. Usando a modelagem da função logística, foram realizadas projeções temporais no futuro a fim de estimar quanto tempo levaria para atingir a paridade de gênero. A ciência médica e da saúde é o único campo que atingiram a paridade de gênero, ao
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RESUMEN
El objetivo de este estudio fue evaluar el estado de paridad de género en la ciencia en Colombia en el siglo 21. Los datos fueron organizados con base en área de investigación, nivel del investigador, y nivel académico. La disparidad de género fue estimada con base en cambios en la edad promedio, acceso a becas para estudios de posgrado, y número de graduandos doctorales. Para estimar el tiempo podría tomar alcanzar la paridad de género, se utilizaron modelos de funciones logísticas para estimar proyecciones temporales a futuro de paridad de género. Las ciencias médicas y de la salud fue el único campo en haber alcanzado la paridad de género, siendo a su vez el único en mostrar una disminución en la representación de mujeres en el tiempo. Ingeniería, ciencias humanas y ciencias naturales tuvieron los porcentajes más bajos de representación de mujeres. La paridad de género mostró una tendencia a disminuir en niveles de investigador más altos, siguiendo un patrón general visto en la ciencia a nivel mundial. Posibles factores que influyan estos resultados son explorados, sugiriendo que una combinación de falta de financiación, marco legal insuficiente, sesgos preexistentes y una protección insuficiente de los derechos de las mujeres bloquean la participación de mujeres en ciencia. Se estima que, de continuar las tendencias en lo que va de este siglo, podría tomar entre 10 (humanidades) y 150 (ingeniería) años para alcanzar la paridad de género en todas las áreas de la ciencia.
Orozco and Franco-Orozco 2018), among others. As a consequence, there are now numerous ongoing debates in an effort to improve the working conditions on all of the different branches of R&D (Stirling 2007). Historically, science has been traditionally patriarchal, favoring the proliferation of a false assumption that men are innately more well-suited for R&D. In an effort to disprove this idea and encourage higher women’s representation in R&D, studies have focused on the prevalence of unconscious biases and unfavorable conditions for women in Science, Technology, Engineering, Mathematics and Medicine (STEMM) (Christie et al. 2017; van den Besselaar and Sandstrom 2017). The second half of the twentieth century represented a major shift in this paradigm when feminism and gender parity started being discussed within academic circles (Rossi 1965; Harding 1987). As a result, for the first time in history we have quantitative data to analyze the current state of the R&D workforce (Ceci, Williams, and Barnett 2009; Ovseiko et al. 2016), allowing us to make more informed decisions at an individual, institutional and governmental level. Although major improvements have been accomplished on gender parity in undergraduate education, where women are increasingly studying science-related degrees (Valentova et al. 2017; Franco-Orozco and Franco-Orozco 2018), women’s representation at postgraduate studies and research positions steadily decrease as they pursue research-intensive careers at more senior levels (Pell 1996). Moreover, this phenomenon has shown differential trends depending on the area, with engineering and physics consistently showing more dramatic gender disparities (Holman, Stuart-Fox, and Hauser 2018). Gender disparity in science has also been reported in a myriad of variables other than workforce representation, such as conference participation (both in terms of proportion of invited speakers and time allocated for presenting; Jones et al. 2014; Débarre, Rode, and Ugelvig 2018), editorial boards’ composition (Cho et al. 2014), sentiment towards science communicators (Amarasekara and Grant 2018), grant success rates (Ley and Hamilton 2008; Pohlhaus et al. 2011; van der Lee and Ellemers 2015), and papers’ authorship (specially for invited papers and lead authors; Holman, Stuart-Fox, and Hauser 2018); all of which exemplify the complexity of this issue. Sexual harassment has especially impacted the scientific community as reports have shown a hostile environment for women in research and academia across the globe (National Academies of Sciences, Engineering & Medicine 2018), with several instances where senior researchers were involved in longstanding cases of sexual misconduct (Wadman 2018).

According to the UNESCO Institute for Statistics (UIS), only a third of the global workforce in science are women (UIS 2018). Myanmar and Bolivia are the countries with the highest percentage of women in science (83% and 63%, respectively), whereas at a regional scale, Central Asia and Latin America and the Caribbean are world leaders in gender parity in science with 48% and 45% respectively (UIS 2018). Nevertheless, loss of gender parity at postgraduate and more senior levels seem to be also present in these countries and regions. By 2016, a report led by the Interacademy Partnership concluded that on average women represented only 12% of the members of 69 Academies of Science worldwide (The Interacademy Partnership 2015). Science academies in Latin America and the Caribbean had the highest women’s representation (17%) followed by North America (15%) and Central and Eastern Europe (13%). Women researchers have also been found to be less internationally mobile, less likely to participate in international research collaborations, and less likely to publish papers as first authors, especially on high impact journals (Elsevier 2017). Projections on authorship in scientific publishing suggest
that it could take more than 100 years to reach gender parity in areas such as statistics and physics (Holman, Stuart-Fox, and Hauser 2018). Widespread gender disparity in science is in conflict with findings indicating that research impact is not gender-related, and that women researchers represent a larger proportion of interdisciplinary research outputs (Elsevier 2017). Significant efforts to promote gender parity include the creation of fellowship programs such as the L’Oreal-UNESCO For Women in Science program established in 1998, and institutions like the Athena SWAN accreditation program established in 2005 by the British Equality Challenge Unit, and the Science in Australia Gender Equity (SAGE) established in 2015 as a partnership between the Australian Academy of Science and the Australian Academy of Technology and Engineering.

Despite all these efforts, a major impediment to the implementation of policies that promote gender parity is the lack of information on the extent and magnitude of gender disparity in science at local scales, especially in nations with low R&D expenditure. Only recently, researchers from countries with low R&D expenditure have started meaningful efforts to establish a baseline understanding of the prevalence of gender disparity (Valentova et al. 2017; Franco-Orozco and Franco-Orozco 2018), limiting our understanding of the historical trajectories of women’s participation in science.

Regardless of Latin America’s relatively good performance in global indexes of gender parity in science, Latin American women researchers still face many challenges when pursuing a career in science (Daza and Pérez-Bustos 2008; Valentova et al. 2017; Franco-Orozco and Franco-Orozco 2018). Efforts to study gender parity in science in Latin America have shown a pervasive problem deepened by Latino cultural stereotypes (Pérez-Sedeño and Gómez 2008; Bonder 2015; Bernal et al. 2019). Within the Latin American context, over the last couple of decades most of the scientific output was produced by five countries: Brazil, Mexico, Argentina, Chile and Colombia (Scimago 2018). According to the Scimago Country Rankings, of all the scientific publications authored by researchers in Latin America from 1996 to 2017, 88.37% was produced by these five countries (Scimago 2018). Despite these five countries representing the scientific powerhouse of Latin America, most of them suffer from lack of funding (Brazil being the only one with an R&D expenditure >1% of GDP) (World Bank 2018), gender disparity (Argentina being the only one that has achieved gender parity) (UIS 2018), and gender pay gap (Franco-Orozco and Franco-Orozco 2018). A recent study evaluating women’s participation in scientific publishing worldwide over the last decade found that none of these five countries has reached gender parity, estimating that women’s participation in Argentina and Colombia will decrease, moving away from gender parity (Holman, Stuart-Fox, and Hauser 2018). Colombia’s R&D expenditure has consistently stayed below 0.40% of the GDP (the lowest amongst these countries), with a steady reduction of expenditure in recent years. Science gender parity in Colombia remains elusive with women representing only 38% of researchers, and 14% of the active members of the Colombian Academy of Exact, Physical and Natural Sciences. Gender salary gap in postgraduate graduates in the last decade exceeded 30% in areas such as medical sciences and engineering (Franco-Orozco and Franco-Orozco 2018). Nevertheless, gender parity in education in Colombia has improved since 2000 both at undergraduate and graduate levels (Franco-Orozco and Franco-Orozco 2018). Between 2000 and 2014, representation of women graduates increased from 54.5%, 44.8% and 33.6% to 55%, 47.7% and 38.3% at undergraduate, masters and doctoral levels, respectively (Franco-Orozco and Franco-Orozco 2018).
The signing of a peace deal in 2016 to put an end to the armed conflict between the Colombian government and the Revolutionary Armed Forces of Colombia (FARC) could facilitate the reordering of national priorities (Ocampo-Peñuela and Winton 2017; Salazar et al. 2018), providing an opportunity to improve the working conditions of women in science (Daza and Pérez-Bustos 2008; Daza, Farias, and Ariza 2016; Baptiste et al. 2017). The internal civil war in Colombia, the longest armed conflict in the western hemisphere, left over 260,000 deaths and 7 million people displaced (Overseas Development Institute 2015; Oxfam International 2017; Unidad de Víctimas 2017). The severity of the conflict also added additional limitations to scientific efforts in Colombia (Augusto, Ole, and Chrystian 2017; Sierra et al. 2017; Canavire-Bacarreza, Diaz-Gutierrez, and Hanauer 2018). Vast regions of pristine native ecosystems remained inaccessible to researchers for 50 years, risking kidnapping and assassination (Baptiste et al. 2017). The combination of limited funding and bad working conditions also created a collateral brain drain, with Colombia having one of the lowest rates of doctoral graduates in Latin America (8 per million inhabitants) (UIS 2018), and a significant number of Colombian doctoral graduates residing overseas (El Tiempo 2017). Post-conflict efforts to strengthen scientific production in Colombia have shown decisive advances, such as the Colombia BIO program, a series of scientific expeditions inventorying unexplored ecosystems in Colombia, that have resulted in the description of over 100 species previously unknown to science (COLCIENCIAS 2016).

The combination of challenges and opportunities that science in Colombia is facing reinforces the need to have a detailed (Ocampo-Peñuela and Winton 2017), overarching perspective of the current status of gender parity in science, in order to diagnose recent trends and inform future efforts and policies that would focus on promoting the participation of women in R&D. The purpose of this study was to assess the demographics of the scientific workforce in Colombia in the last two decades. To do so, I dissected women’s participation in science by estimating gender parity across research fields, researcher rank level, and training level from 2000 to 2017. Furthermore, I estimated changes in age distribution across genders and incorporated estimates of gender parity in access to education scholarships and number of postgraduate graduates. Finally, I modeled the trajectory of women’s participation across time in order to provide a rough prediction of the year when gender parity will be achieved at different levels. Based on the local information available, and global patterns of gender parity in science, the expectation is to find greater women’s underrepresentation in engineering-related research fields, as well as a decrease in women’s representation at higher academic levels and more senior levels of research.

2. Material and methods

2.1. Data acquisition

Demographic data of the Colombian workforce in science were retrieved from the UNESCO Institute of Statistics (UIS 2018), the Network for Science and Technology Indicators – Ibero-American and Inter-American – (RICYT 2018), the Colombian Science and Technology Observatory (OCyT; Observatorio Colombiano de Ciencia y Tecnología) (OCyT 2018), and the Science in Numbers data repository (SN) by the Administrative Department of Science, Technology and Innovation (COLCIENCIAS) (COLCIENCIAS 2017).
SN aggregated individual data for 39,342 researchers from the SCIENTI online platform between 2013 and 2017. SCIENTI was developed by COLCENCIAS as an online registry of CVs of individual researchers and research groups in Colombia. Demographic data were sorted based on research area, academic level, researcher rank level, doctoral graduates and access to scholarship grants. The overall percentage of women in science (between 2000 and 2015) and by research field (2006 and 2015) was collected from the UIS. Gender parity was decomposed following the OECD classification of research areas: Agricultural sciences, engineering, humanities, medical and health sciences, natural sciences and social sciences. Data for age distribution, academic level and researcher rank level between 2013 and 2017 were retrieved from the SN by COLCIENCIAS. SCIENTI classifies academic level in five different groups: Undergraduate, diploma, masters, PhD and postdoctoral; whereas researcher rank level is classified into four groups: Junior, associate, senior and emeritus. Data on gender parity in doctoral graduates were assessed based on data retrieved from 2006 to 2015 from the OCyT and RICYT. Numbers of granted scholarships by gender from 2006 to 2015 presented in this study were collated by the OCyT from different sources and retrieved from its 2016 Science and Technology Indicators report. Considering the inconsistency in resolution and coverage of the data retrieved across all the different sources, and in order to avoid statistical artefacts raising from this variability, each demographic variable analyzed was retrieved from a single source.

2.2. Statistical analysis

For all statistical analyses, women representation (as a percentage of the totality of researchers) was used as an independent continuous variable. To evaluate the different dimensions of gender parity, women representation was decomposed based on research area, academic level and researcher rank level. A database was compiled based on all the different measures of women representation, also including data on women doctoral graduates and access to graduate scholarships (included as a supplement). R&D expenditure (as a percentage of GDP) was used as a dependent continuous variable. Time was included in our analyses as a discrete variable (year).

To test whether investment in R&D correlates with gender parity in science, a linear model was used, based on data of R&D expenditure gathered from the World Bank Open Data (World Bank 2018). To build a temporal perspective of women in science in Colombia, the representation of women in science was calculated annually for each variable, and represented graphically both as a percentage, and as number of researchers for a given year. In order to test whether access to education associates with the number of women researchers in science, linear regression modeling was used to quantify the correlation between the percentage of women researchers and the percentage of women doctoral graduates across time. Finally, to project how long it could take to reach gender parity, a logistic regression model of proportion of women in science across time was used (assuming a sigmoidal relation between gender ratio and time; see Holman, Stuart-Fox, and Hauser (2018)), predicting the year in which the percentage of women reaches 50%. Using a logistic model allows for a non-linear growth rate that plateaus at a maximum value of 1, indicating in this case the complete loss of one gender (Holman, Stuart-Fox, and Hauser 2018). 95% confidence intervals were calculated based on 1,000
bootstrap iterations. All analyses were performed in R version 3.3.2. Logistic modeling was performed with the glm function, and temporal projections of future proportion of women in science were performed using the predict function of the stats package.

3. Results

Overall, women’s representation in science has increased in Colombia across the twenty-first century. Over the last 15 years, women’s representation grew by 4.69%, going from 33.71% in 2000, to 38.40% by 2015 (Figure 1). Raw number of researchers showed the same tendencies across genders, with three periods of increase in the number of researchers (2000–2003, 2004–2011, and 2014–2015), and two periods were the number of researchers decreased (2003–2004, and 2011–2014).

Across research fields (Figure 2), averaging the 2005–2015 period, medical and health sciences showed the highest percentage of women researchers (the only research field that reached gender parity), followed by social and agricultural sciences (55.99%, 44.20%, and 35.91%, respectively). Contrasting, engineering showed the lowest average of women’s representation, followed by humanities and natural sciences (19.89%, 30.02%, and 30.21%, respectively). Temporal trends reveal that the humanities had the highest increase in women’s representation with an increase of 13.85% between 2005 and 2015 (Figure 2(C)). Natural sciences and engineering also showed an increase in women’s representation for the same time period (7.34% and 4.28%, respectively; Figure 2(B and E)). Agricultural and social sciences showed almost no change across time (0.22%), reflecting temporal unsteadiness in agricultural sciences where women’s participation grew initially, and decreased subsequently, and temporal invariability in social sciences, ranging between 43.01% and 46.16% (Figure 2(A and F)). Despite having reached gender parity, medical and health science is the only field showing a temporal decrease in women’s representation, losing 4.94% between 2005 and 2015 (Figure 2(D)).

![Figure 1](image.png)

**Figure 1.** Women (bottom line and bars) and men (top line and bars) participation in science in Colombia between 2000 and 2015, represented as number of researchers (lines) and percentage of total researchers (bars).
Between 2013 and 2017, ages 25–45 represented more than half of researchers across genders, with ages 35–40 being the most frequent (Figure 3). Average age of researchers in Colombia has decreased for both genders between 2013 and 2017, women having the lowest average (44.39 for women and 45.49 for men). Age of women and men researchers decreased by 2.23 years (46.05 in 2013 to 43.82 in 2017) and 2.19 years (47.16 in 2013 to 44.97 in 2017), respectively (Table 1). Lowest age recorded for SCIENTI-registered individuals was lower for men (15–20) than women (20–25). Similarly, the highest age recorded for SCIENTI-registered individuals was higher for men (90–95) than women (80–85).

Proportion of academic level of Colombian researchers in the SCIENTI platform showed similar patterns for both genders (Figure 4). Across time, researchers with doctoral degrees were the most abundant, representing more than half of researchers, followed by researchers with master’s degrees (20–40%), postdoctoral positions (5–12%), diplomas and undergraduate (both under 5%). Between 2013 and 2014, percentage of researchers of both genders with a doctoral degree dropped on average by 10%, whereas researchers with master’s degrees increased approximately by the same amount. Furthermore, the

Figure 2. Women (bottom lines and bars) and men (top lines and bars) participation in science in Colombia between 2000 and 2015, represented as number of researchers (lines) and percentage of total researchers (bars). Results are divided into six different research fields: Agricultural (A), engineering (B), humanities (C), medical (D), natural (E), and social (F).

Figure 3. Age distribution of women (left) and men (right) researchers represented as percentage of total researchers of each gender per year, between 2013 and 2017. Shades of colors represent age brackets of five years each (from 15 to 95 years of age), darker shades representing younger ages, and lighter shades older ages.
The proportion of researchers with doctoral degrees was higher for men than for women, and the proportion of researchers with master’s degrees was higher for women than for men. Researchers with postdoctoral-level training were higher for men than women.

Women were underrepresented across researcher rank levels and across time, with a marked widening of the gender gap at more senior research rank levels (Figure 5). Averaging the 2013–2017 period, women represented 37.72%, 35.05%, 25.96%, and 21.51% of junior, associate, senior and emeritus researchers, respectively. Women’s representation has increased across all rank levels in the time period analyzed, with the highest rates of increase in the junior (6.03%) and emeritus (2.49%) levels, followed by the senior (1.13%) and associate (0.98%) researcher rank levels. The only decrease in the number of researchers was evident for men junior researchers between 2013 and 2014 (Figure 5 (A)). Data for the emeritus rank level were lacking for 2013 and 2014 (Figure 5(D)).

Women’s representation in doctoral graduates in Colombia between 2006 and 2015 remained below parity across research areas (Figure 6). Medical sciences had the highest average percentage of women doctoral graduates (48.65%), next to social (43.20%), agricultural (36.79%), natural (35.98%), humanities (35.03%), and engineering sciences (25.71%). The highest increase in the proportion of women doctoral graduates

Table 1. Summary statistics of age composition of SCIENTI-registered Colombian researchers, between 2013 and 2017.

| Age  | 2013 | 2014 | 2015 | 2017 |
|------|------|------|------|------|
|      | Women | Men  | Women | Men  | Women | Men  | Women | Men  |
| Minimum | 20.34 | 22.32 | 23.83 | 23.02 | 21.84 | 24.02 | 20.65 | 16.92 |
| Average | 46.05 | 47.16 | 43.08 | 44.89 | 43.89 | 44.92 | 43.82 | 44.97 |
| Maximum | 82.18 | 88.5  | 82.68 | 84.08 | 83.68 | 92.83 | 81.91 | 89.7  |

Figure 4. Temporal changes in the proportion of women (solid lines) and men (dashed lines) researchers with different academic levels between 2013 and 2017.
**Figure 5.** Women (bottom lines and bars) and men (top lines and bars) representation across researcher rank levels in Colombia between 2000 and 2015, represented as number of researchers (lines) and percentage of total researchers (bars). Results are divided into six different research fields: Junior (A), associate (B), senior (C), and emeritus (D).

**Figure 6.** Women (bottom lines and bars) and men (top lines and bars) representation in doctoral graduates in Colombia between 2000 and 2015, represented as number of researchers (lines) and percentage of total researchers (bars). Results are divided into six different research fields: Agricultural (A), engineering (B), humanities (C), medical (D), natural (E), and social (F).
was found in the medical (27.77%, Figure 6(D)), agricultural (16.92%, Figure 6(A)), and social sciences (12.68%, Figure 6(F)). Contrarily, humanities (2.95%), engineering (3.29%), and natural sciences (6.86%) showed the lowest increase in the proportion of women doctoral graduates (Figure 6(B–C,E)).

Individual linear regressions showed no significant correlation between the increase in women doctoral graduates and the overall percentage of women researchers across research areas (Table 2). From 2006 to 2015, access to scholarships for postgraduate studies showed higher women’s representation for master’s degrees (49.10%, Figure 7(A)) than for doctoral degrees (40.46%, Figure 7(B)). However, women’s representation in scholarship holders for doctoral studies had the highest increase (4.06%), compared to master’s degrees (3.30%).

For the 2000–2015 period, a positive and statistically significant correlation was found between gender parity and the percentage of GDP invested in R&D ($p < 0.001$, \(r^2 = 0.769\)). Based on logistic function modeling, the projections of future women’s representation in science predict that gender parity in the science workforce in Colombia could take up to 50 years (Figure 8(A)). Decomposed based on research field, projections indicate that gender parity can take from three years (humanities) to more than 150 years (engineering). Medical sciences represent the only scenario where projections indicate a decrease in women’s representation. Years until gender parity in access to scholarships for postgraduate studies could range between two (social and agricultural) and 50 years (engineering), with the exceptional case of the humanities, where women’s representation is predicted to decrease (Figure 8(B)). Finally, temporal projections to gender parity across researcher rank levels suggested that the junior rank could be first to reach gender parity, followed by emeritus, associate and senior ranks, where estimated years to parity range from five to 90 years (Figure 8(C)). Raw data were available as a supplement.

### 4. Discussion

This article represents a comprehensive study of the status of gender parity in science in Colombia in the twenty-first century (Daza and Pérez-Bustos 2008; Daza, Farias, and Ariza 2016), providing a diagnosis of the recent trends of women’s representation across research fields, researcher ranks and academic level, with some estimates of future temporal projections for gender parity. The analyses performed in this study represent to the best of my knowledge the first quantitative study examining the official data gathered by COLCIENCIAS and made freely available through the SCIENTI platform starting from 2015 (COLCIENCIAS 2017). This study also builds on previous results that have helped

### Table 2. Results of linear regression modeling analysis of the interaction between women doctoral graduates and overall percentage of women in six different research areas.

| Research area                  | df | F    | R²   | P     |
|--------------------------------|----|------|------|-------|
| Agricultural science           | 8  | 0.924| −0.008| 0.364 |
| Medical and health science     | 8  | 0.922| −0.008| 0.365 |
| Natural science                | 8  | 0.79 | −0.023| 0.399 |
| Social science                 | 8  | 1.74 | 0.075 | 0.223 |
| Humanities                     | 8  | 0.002| −0.124| 0.957 |
| Engineering                    | 8  | 4.322| 0.269 | 0.071 |
elucidate the reality of gender pay gap (Franco-Orozco and Franco-Orozco 2018), and access to education and scholarships in Colombia (Daza, Farias, and Ariza 2016). Given the scarcity of similar studies examining gender parity in science for the Latin American
and the Caribbean region, the current study also helps to inform the regional context of women in science, associating it with other recent studies in Colombia and Brazil (Daza, Fariñas, and Ariza 2016; Valentova et al. 2017; Franco-Orozco and Franco-Orozco 2018).

Figure 8. Temporal projections with 95% confidence intervals of women representation in science between 2000 and 2200 based on logistic function modeling using a binomial distribution, as a proportion of total researchers. Projections are represented as temporal trajectories of women representation (left column), and as the amount of years to parity from 2018 (right column). Projections were made for the overall science workforce (A) and access to scholarships for graduate studies (B) for six different research fields, and overall science workforce across researcher rank levels (C).
The results presented here show widespread lack of gender parity as well as underrepresentation of women in science in Colombia across the twenty-first century, informing previous analyses that reported an extensive gender disparity in science-related work fields (Daza and Pérez-Bustos 2008; Daza, Farías, and Ariza 2016; Franco-Orozco and Franco-Orozco 2018). The results presented here are consistent with reports of an overall decrease in the number of researchers between 2011 and 2014, and with levels of gender disparity across research areas (Daza, Farías, and Ariza 2016). However, this study includes more recent data that show an increase in women representation, contrary to the decreasing tendency shown by 2013 (Daza, Farías, and Ariza 2016). Following similar trends found for other countries, the lowest level of women’s representation was found in engineering, an area heavily dominated by implicit gender stereotypes, followed by the humanities and natural sciences (Ceci, Williams, and Barnett 2009; Ceci and Williams 2011; Meyer, Cimpian, and Leslie 2015; Christie et al. 2017; Valentova et al. 2017; Franco-Orozco and Franco-Orozco 2018). Gender inequality in the humanities has been reported in salaries and tenure promotion in the US, showing a lack of correlation with productivity and pointing to unconscious gender bias as a possible influencing factor (Ginther and Hayes 2003). However, the study of gender inequality in the humanities remains scarce, highlighting the need for increased research efforts. Recently, gender disparity in the natural sciences has been increasingly studied, providing evidence of gender differences in the length and tone of recommendation letters (Dutt et al. 2016), participation at scientific events (Jones et al. 2014; Débarre, Rode, and Ugelvig 2018), and representation in editorial boards (Cho et al. 2014). In Colombia, previous studies have provided evidence of a gender pay gap in the areas aforementioned, both for undergraduate and postgraduate graduates (Franco-Orozco and Franco-Orozco 2018). Temporal trends in the gender gap in Colombia followed similar trends found in other countries (Ramakrishnan, Sambuco, and Jagsi 2014; van der Lee and Ellemers 2015; Christie et al. 2017; Valentova et al. 2017; van den Besselaar and Sandstrom 2017). The decrease in women’s representation in medical and health science contrasts with the fact that it was the only research area to have reached gender parity in Colombia. Despite a general level of gender parity across different countries (Ramakrishnan, Sambuco, and Jagsi 2014; van den Besselaar and Sandstrom 2017; Franco-Orozco and Franco-Orozco 2018), women’s underrepresentation in the medical and health science could still be found at more senior positions, illustrating the “leaky pipeline phenomenon” (Ramakrishnan, Sambuco, and Jagsi 2014). A decreasing representation of women in medical sciences, generally considered a gender equal field, highlights the need to implement initiatives that not only promote the participation of women in men-dominated research areas, but also to secure the retention of women as they move upward to more senior rank levels. It also suggests that once gender parity is reached, without efforts to sustain it, demographics can revert to gender disparity.

Since it is expected that the average age of researchers increases at higher researcher rank levels, the lower average age in women researchers could reflect the lower representation of women in the most senior research levels, signaling another potential impact of the “leaky pipeline phenomenon” (Pell 1996; Blickenstaff 2005). Moreover, a discussion around how the ranking criteria could be systematically excluding women from higher rank levels should be opened for study. However, lower age in women could also represent an opportunity to secure the retention of a younger population of women researchers, driving a future increase in the representation of women at more senior
levels as they move upward across research ranks. Furthermore, the underrepresentation of women as a proportion of scholarship awardees for doctoral studies and doctoral graduates indicate that the completion of doctoral studies might be a limiting factor influencing the loss of women beyond the junior researcher rank (Valentova et al. 2017; van den Besselaar and Sandstrom 2017; Franco-Orozco and Franco-Orozco 2018). Also, the lack of a significant correlation between women doctoral graduates and the percentage of women researchers indicates that retaining doctoral graduates is a key component to consider. Based on this, it can be hypothesized that improving the retention of women with doctoral degrees in a younger population of women researchers could have a cascading effect, encouraging the participation and promotion of women across ranks (Shen 2013). However, the effectiveness of the SCIENTI platform to capture a significant sample of the science workforce has not been tested, and the results aforementioned could also be indicative of a faulty registry system that should be tested and improved.

Based on data from the UIS, Colombia ranks 15th out of 20 Latin American countries with available data, sitting below the average of women’s participation in Latin America (45%), distant from countries like Bolivia (63%), Venezuela (62%) and Trinidad and Tobago (54%), countries with the highest percentage of women’s representation in science in the region (UIS 2018). Considering the state of political and civil unrest that has prevailed over the last decades, it could be argued that the long-lasting internal armed conflict could be one of the drivers influencing women’s participation in Colombian science (Daza and Pérez-Bustos 2008; Franco-Orozco and Franco-Orozco 2018). It is estimated that 3.5 million women were victims of the internal conflict (49.5% of the victims), and that between 2010 and 2015, more than 800,000 were victims of some kind of sexual violence (Pérez 2008; Oxfam International 2017). Moreover, data from 2000 from the United Nations Development Program estimated that between 60% and 70% of Colombian women have suffered some kind of violence. According to the 2018

| Table 3. Comparison of percentage of women participation in science between 20 countries with similar 2018 Global Peace Index. |
|-------|----------------|
| Country       | % women in science | Peace Index |
| Iraq           | 40              | 3.425       |
| Central African Republic | 42              | 3.236       |
| Russia         | 40              | 3.16        |
| Sudan          | 40              | 3.155       |
| Ukraine        | 45              | 3.113       |
| Pakistan       | 34              | 3.079       |
| Turkey         | 37              | 2.898       |
| Nigeria        | 23              | 2.873       |
| Colombia       | 38              | 2.729       |
| Mali           | 10              | 2.686       |
| Venezuela      | 63              | 2.642       |
| Egypt          | 44              | 2.632       |
| Palestine      | 23              | 2.621       |
| Mexico         | 33              | 2.583       |
| Ethiopia       | 13              | 2.524       |
| Philippines    | 50              | 2.512       |
| Chad           | 5               | 2.498       |
| Cameroon       | 22              | 2.484       |
| Iran           | 28              | 2.439       |
| Saudi Arabia   | 23              | 2.417       |
Global Peace Index report (ranking the intensity of the internal conflict of a country), Colombia ranks 145th of 163 countries studied (Institute for Economics and Peace 2018). Nonetheless, comparing the percentage of women in science in Colombia with other countries with similar intensity of internal conflict, Colombia ranks 9th in 20 countries (Table 3), five points above the average for these countries (32.65%). This could indicate that despite the differential impact that war has on women’s rights, internal conflict is not the only limiting factor leading to women’s underrepresentation in science, and so additional factors should also be considered.

R&D expenditure has been discussed as a potential driver of women’s underrepresentation in science (Ceci and Williams 2011; Christie et al. 2017; van den Besselaar and Sandstrom 2017). Despite an increase in the percentage of GDP invested in R&D between 2000 (0.13) and 2013 (0.27) (World Bank 2018), COLCIENCIAS has seen a steady decrease in its annual budget between 2013 (430,000 million COP) and 2018 (337,000 million COP) (COLCIENCIAS 2017). The present results did show a significant correlation between women’s representation and R&D expenditure between 2000 and 2015, suggesting that the decrease in the annual budget of COLCIENCIAS since 2013 could have played a part in the decrease in the percentage of women in science in Colombia between 2012 and 2015. R&D expenditure in Colombia is below the average for Latin America and the Caribbean (0.7%) and is the lowest of the five countries with the highest scientific output in the region (UIS 2018), which reinforces the need for an increase in R&D expenditure to tackle women’s underrepresentation in the future. Moreover, comparing the percentage of women in science in countries with similar R&D expenditure (0.21–0.36% of GDP), the percentage of women in science in Colombia is below average (39.69%, Table 4). This informs the results above and suggests that the internal conflict and lack of funding are not the only decisive factors that could explain gender disparity in science in Colombia.

The legal framework ruling the institutional procedures that promote gender parity in science is also a major mechanism for the enhancement of women’s representation (Pell 1996; Ceci, Williams, and Barnett 2009; Ceci and Williams 2011). Recently, Colombia has made major steps towards ensuring the protection of women’s rights, especially in the context of the internal armed conflict (Overseas Development Institute 2015). Law 581

| Country                  | % of women in science | R&D expenditure |
|--------------------------|-----------------------|-----------------|
| Uruguay                  | 50                    | 0.36            |
| Mozambique               | 29                    | 0.34            |
| Georgia                  | 52                    | 0.32            |
| Mali                     | 10                    | 0.31            |
| Colombia                 | 38                    | 0.29            |
| Eswatini                 | 41                    | 0.27            |
| Armenia                  | 52                    | 0.25            |
| Oman                     | 28                    | 0.25            |
| Pakistan                 | 34                    | 0.25            |
| Venezuela                | 63                    | 0.25            |
| Bosnia and Herzegovina   | 47                    | 0.22            |
| Bermuda                  | 32                    | 0.22            |
| Uzbekistan               | 40                    | 0.21            |
of 2000 established a minimum quota of 30% of women’s representation in government (Bustamante 2007). A revised quota law was established in 2011 (law 1475 of 2011), extending the implementation of the 30% quota to the formation and operation of political parties and political movements (Bustamante 2007). However, the measurable impact of the benefits derived from these laws is under debate (Batlle 2016). A battery of additional laws has been established over the last decade, protecting the principle of gender equality, access to land and justice in cases of sexual violence. Nevertheless, despite the advancement in the protection of gender parity and women’s rights, no legislation has been established governing the representation of women in science. As an attempt to promote, stimulate and highlight women’s participation in science and technology in Colombia, the Colombian Network of Scientific Women (Red Colombiana de Mujeres Científicas) was created in 2015 (RCMC 2015). Examples of legislation promoting gender parity in science can be drawn from countries such as Spain (Law 14 of 2011), the United States of America (the Promoting Women in Entrepreneurship Act and the INSPIRE Women Act), and the European Union (article 16 of the Regulation 1291 of 2013 ruling the Horizon2020 program). Current discussions of science legislation in Colombia have focused on a proposal for the creation of a Ministry of Science, Technology and Innovation, by changing Law 1286 of 2009 (El Espectador 2018a). This would elevate COLCIENCIAS from an administrative department under the National Planning Department to an independent ministry. Beyond the discussion around the status of the institution, COLCIENCIAS has currently been under public scrutiny mainly due to the instability in its leadership, evidenced by the 10 directors that have been named since 2010 (El Espectador 2018b).

Assessing and controlling unconscious biases is also crucial to diminish gender disparity in academia, as it addresses the cultural and psychological drivers of women’s underrepresentation (Ceci and Williams 2011; Christie et al. 2017). Extensive evidence currently available on the sources of unconscious bias that impacts the participation of women in science could be divided into two components: opposite gender exclusion and self-exclusion (Ceci and Williams 2011; Christie et al. 2017). Opposite gender exclusion could be described as the result of a tendency to favor people of the same gender, leading to the unintentional exclusion of the opposite gender (Murray et al. 2018). This phenomenon has been reported equally for women and men in science (Murray et al. 2018). However, given the heavily men-dominated demographics of the STEMM workplace, women’s underrepresentation in science could be partly due to an exacerbated opposite gender exclusion. Implementing double-blind peer review and increasing gender and international diversity in review committees have been proposed to enhance the representation of minorities both in scientific publishing and in more senior institutional positions (Murray et al. 2018). Self-exclusion in science, on the other hand, can be viewed as the tendency to restrict oneself’s gender from becoming involved in scientific activities, resulting from a variety of unconscious negative stereotypes (Moss-Racusin et al. 2012; Smeding 2012).

Recent research showed that negative gender stereotypes on intellectual prowess appear early during childhood, leading both boys and girls to consider men as more intelligent than women by age six (Bian, Leslie, and Cimpian 2017). This early predisposition does not reflect a natural tendency in any way, as recent findings have found higher average academic grades for girls than boys (O’Dea et al. 2018). The same study estimated gender parity in the top 10% of a STEMM-related class, and higher women’s representation.
in non-STEMM-related classes (O’Dea et al. 2018). Self-exclusion has also been reported in later stages of the academic career, in faculty members of different Science faculties at university level (Moss-Racusin et al. 2012). Both women and men faculty members showed a tendency to rate men students higher than women students, favoring higher salaries and mentoring for men applicants, leading to a lesser probability for women students to be hired (Moss-Racusin et al. 2012). Additionally, pre-existing bias was associated with less support for women students but did not associate with reactions to men students (Moss-Racusin et al. 2012). This suggests that unconscious bias is a major driver of women’s exclusion in science, both as a result of opposite gender exclusion and self-exclusion.

5. Conclusions

The results presented here evidenced generalized women’s underrepresentation in science across the twenty-first century in Colombia. Even though temporal trends show an increase in the percentage of women across all but one research area (i.e. medical and health science), greater efforts are needed to increase and maintain gender parity across research fields. Initiatives to retain women in Colombian science should be of special focus for the medical and health science. Given the lower percentage of women researchers in engineering, humanities and natural sciences, these should be areas of special focus for institutions in research and education. The lower average age of women researchers could represent an opportunity to address the “leaky-pipeline phenomenon,” ensuring that young women researchers are supported as they move upward to more senior research levels. These results suggest that improving access to scholarships for doctoral studies, and the retention of women doctoral graduates in research, could be major strategies to ensure the increase of women’s representation in science in the future. Nonetheless, equal efforts should be made to improve the career prospects and working environment of Colombian women scientists in the present. This study also highlights the importance of long-term monitoring of demographic trends in science, in order to inform individual, institutional, governmental and global initiatives focused on increasing gender parity in STEMM. Following the increasing understanding of discrimination in science (Hughes 2018; Pew Research Centre 2018), future studies and discussion should also expand to evaluate representation of racial, ethnic and sexual minorities to inform the prevalence of minority discrimination in Colombian science. More and more refined data would allow more robust modeling techniques to be implemented in the estimates of temporal projections for gender parity, improving our predictive power.

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**Supplementary material**

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**Disclosure statement**

No potential conflict of interest was reported by the author.

**Notes on contributor**

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