

# Ecuadorian Scholarly Production in Computer Science. Analysis of Publication Patterns by Gender

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**Abstract.** Men and women compose the human capital and workforce needed for the economic and social development of a country. Despite this, in science, there is a gender participation gap, unfavorable for women. This statement is supported by a large body of literature that describes gender differences in scholarly productivity. But, mainly in the Computer Science field, there is little evidence about publishing patterns by gender in countries with a recent path in scholarly publishing. To meet the information gap of Ecuador, in this study, the authors focus on analyze publishing patterns by gender in Computer Science. Specifically, this paper examines (1) gender differences in research productivity and participation rates, and (2) publishing patterns regarding document type and impact. Findings show that despite the great difference in the number of female and male researchers that leading scientific production, both have common publishing patterns. Except, when a woman is the first author of a document, co-authors tend to distribute equitably by gender. Whereas when a man leads the research, the presence of women is reduced.

**Keywords:** Scholarly production · gender analysis · publishing patterns · Ecuador · Scopus

## 1 Introduction

Men and women compose the human capital and workforce needed for the economic and social development of a country. Likewise, in sciences, both female and male researchers are essential to creating and disseminating knowledge. Despite this, there is a gender participation gap unfavorable for women. More precisely, in STEM (Science, Technology, Engineering, and Mathematics) fields, women perform research activities in fewer numbers than men.

In scholarly production, an increase in female authors has been observed, from 12% in 1995 to 35% in 2005 [6]. But, there are differences with respect

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to the several disciplines in which women work, being 15% of participation in mathematics, physics and computer science. According to UNESCO Institute for Statistics (UIS), less than 30% of women in the world are researchers and numerous studies have shown that women in STEM fields publish less, their salaries are lower, and they do not have the same progress as their peers.

In Ecuador since the Constitution of 2008, equality has been promulgated for anyone who is in a situation of inequality. In the Magna Carta of 2008, access to education has been established as well as the fundamental rights of women living in Ecuador. Despite this, in 2014, 44.6% of full-time R&D personnel are women in Ecuador [14], which confirms that there is also a gender imbalance in terms of research.

There is a large body of literature describing gender differences in scholarly publishing productivity. Differences in productivity between men and women employed in the scientific world have always attracted interest from a wide range of observers [13,9]. Causes and effects [1,8] of gender imbalances in publishing have been studied widely in different contexts, in different countries, and in different scientific fields [12].

For example, [3] analyze whether two German programs (German Women Professorship Program and Pact for Research and Innovation) have allowed increasing the participation of women in leadership positions, as well as increasing their scientific publications. Also, authors of [4] analyze characteristics of women publications in the areas of physics and astronomy in India. Considering the same country, [5] presents an analysis of the publications made by Indian scientists in disciplines related to life science. The work of [6] presents an analysis of gender differences in the scientific career considering the information from 83 countries in 13 disciplines. Another work with a different approach in terms of analysis techniques is carried out by [2] who used network or graph theory to identify the importance of gender in patterns of scientific collaboration.

Furthermore, in [10], authors analyze the contribution of Iranian women to scientific production, emphasizing the characteristics of women's publications rather than a comparison with men. In the work of [7] they carried out an analysis of the factors that inhibit the research productivity of Iranian women, collecting the information with a questionnaire.

Most of these studies have focused on the analysis of different STEM carriers. Regarding the Computer Science (CS) field, [15] studied the participation of women as authors and editors in publications related to software engineering. This work includes information of authors from 61 different countries. So far, there are few works that analyze the contribution of female researchers from STEM careers in countries of South America with a recent path in scholarly publishing. Mainly in the CS field, there is little evidence about publication patterns by gender in countries with a recent path in scientific publishing. To meet the information gap, in this paper, authors try to provide evidence about publishing patterns from the Ecuadorian researchers. Specifically, this paper examines (1) gender differences in research productivity in Computer Science,

and (2) publishing patterns between women and men regarding document type and impact.

## 2 Methodology

In this section, the authors explain the two main stages that they have carried out to analyze Ecuadorian production in Computer Science by researchers' gender: data gathering and cleaning, and scope definition and data analysis.

### 2.1 Data gathering and cleaning

Production data of Ecuadorian researchers were collected from Scopus. This multidisciplinary database was chosen because it is the largest abstract and citation source of peer-reviewed literature. Scopus was launched by Elsevier in 2004 and indexes documents published in more than 22000 active sources. Scopus in addition to indexing abstracts and citations, allows authors and institutions to create profiles to facilitate the organization and searching for resources using different criteria.

To access Scopus information, people use search functionalities provided by the database through the user interface (UI). In addition to the UI, Scopus provides access from a set of Application Programming Interfaces (APIs), which offer the same functionality but in a machine-readable format. To obtain information about the publications of authors with affiliation from Ecuador we use the Scopus APIs. Different methods provide metadata about publications, authors, institutions, sources, and more.

To get data of Computer Science documents, published until 2018, in which at least one author with an Ecuadorian affiliation has participated, the following query was sent to the Scopus Search API.

```
AFFILCOUNTRY(Ecuador) AND SUBJAREA(COMP) AND PUBYEAR < 2019
```

The previous query was executed in early 2020 and, 3411 documents were retrieved, 6431 unique authors and 844 unique sources. From the list of authors, we used the Author Retrieval API to get relevant data of authors such as their metrics and alternate names. And, to get ranking information of sources, we download data from the Scimago Journal Rank (SJR) site. Using the identifiers of authors, documents and sources, the information finally was integrated.

To fill in the gender of the authors we made updates based on the most popular names in the database. Then, to update missing data, we used the Gender API which provides the gender probability according to the first name. For authors with an incomplete name, like initials, or with a probability under 70% of confidence, the gender was set with NA value. Finally, we found that 71.7% of the authors are men, 24.6% are women, and for 3.7% of the authors, their gender could not be determined. This result could be related with the difference of percentage of female and male graduation of tertiary ICT programs. According to data of the UNESCO Institute for Statistics, from 2014 to 2016,

the percentage of graduated were 2.4%, 3.3% y 2.9% for women and 6.5%, 7.4% y 6.7% for men.

## 2.2 Scope definition and data analysis

From collected information, we analyze some variables and defined the scope of this study based on the following criteria.

- Publication date. The first published document dates from 1986. From this year until 2006, the annual production was minimal, i.e. around five papers per year. From 2013, the production rise to more than 50 documents per year. Considering the low production of the first years, we focus on the analysis of documents indexed between 2009 and 2018. Applying the filter for the selected period, 3363 documents were obtained, 48 documents minus of those retrieved from the original query.
- Document type. Regarding the distribution of documents by type, three categories had few publications, Book (2), Errata (1), and Note (1). These types were discarded, therefore, we analyze 3359 documents.

Table 1 shows the number of documents per year and per type. From this figure, two relevant facts are inferred 1) in the last couple of years (2017-2018), 2166 documents were indexed, i.e. 64% of Ecuadorian production in CS; and 2) of each 5 documents indexed by Scopus, 4 are conferences, and 1 is an article. This last data stats that CS researchers prefer conference proceedings as the main source for publishing.

**Table 1.** Total of documents by year and type

Group of year	Total	Document type	Total
2019 & 2010	46	Review	18
2011 & 2012	68	Editorial	21
2013 & 2014	163	Chapter	37
2015 & 2016	920	Article	579
2017 & 2018	2.166	Conference Paper	2.704

From the data collected, two dimensions led the analysis. For each dimension, the following topics are studied:

1. Annual production and participation rates by gender:
  - Production of leading authors
  - Participation average rates
2. Publishing patterns by document type and impact:
  - Production of leading authors by document type
  - General distribution of leading authors
  - Annual production by quartile

- Annual production by quartile and H index

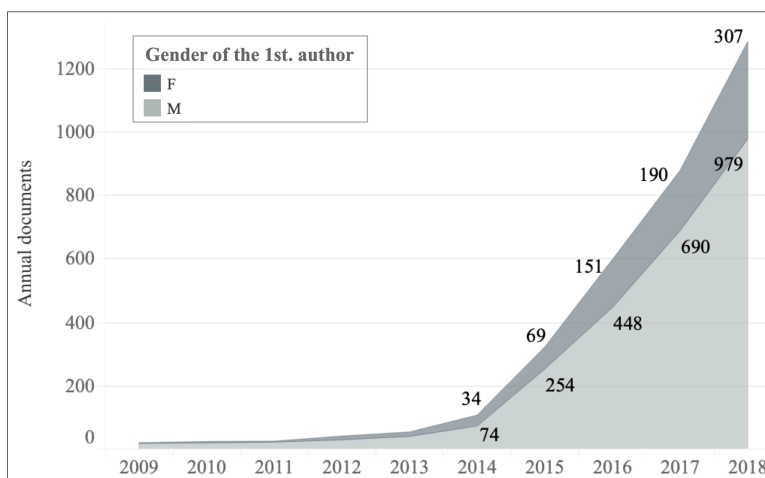
To analyze the first topic of each dimension, we assume that leading authors are those who have the first authorship. According to [11] the first author is who led the research or who contributed the most to the research on which the publication is based.

### 3 Results

In this section, we present the results for each analyzed topic. We use the Tableau tool to create visualizations.

#### 3.1 Annual production and participation rates by gender

**Production of leading authors:** Fig. 1 shows the annual evolution of the scholarly production in CS by gender.



**Fig. 1.** Papers by year and first author gender

The stacked area chart shows that both women and men have increased their production since 2014. But, the growth rate of publications led by male (M) authors is higher than those achieved by female (F) authors. In the last year analyzed (2018), of every 4 indexed documents, 3 have a man as the first author, and only 1 paper has a woman as the first author.

**Participation average rates:** Table 2 presents the annual average of authors per document, considering: 1) the total number of authors by gender, 2) the

total number of authors by gender when a woman is the first author, 3) the total number of authors by gender when a man is the first author. As we can see, when a woman is the first author, co-authors tends to distribute equitably by gender. Whereas when a man is the first author, the presence of women is reduced.

**Table 2.** Annual average of authors per document

Year	Annual average of authors								
	All papers			Female leading author			Male leading author		
	Total	F	M	Total	F	M	Total	F	M
2009	3,2	0,6	2,9	1,5	1,0	0,5	3,4	0,5	3,2
2010	3,2	0,6	3,0	3,4	1,8	1,8	3,2	0,4	3,3
2011	3,1	0,5	3,2	3,0	2,0	1,7	3,1	0,3	3,4
2012	3,5	0,9	2,8	3,5	1,8	2,1	3,6	0,6	3,1
2013	3,5	0,9	2,8	3,7	2,0	2,2	3,4	0,6	3,0
2014	3,9	1,1	3,2	3,8	1,9	2,2	4,0	0,6	3,6
2015	3,9	1,0	3,3	3,4	1,9	1,9	4,0	0,8	3,7
2016	4,2	1,0	3,5	3,9	2,0	2,2	4,3	0,7	3,9
2017	4,2	1,0	3,5	3,9	2,1	2,1	4,2	0,7	3,9
2018	4,2	1,1	3,4	4,0	2,0	2,4	4,2	0,8	3,8
<b>Average</b>	<b>3,7</b>	<b>0,9</b>	<b>3,2</b>	<b>3,4</b>	<b>1,9</b>	<b>1,9</b>	<b>3,7</b>	<b>0,6</b>	<b>3,5</b>

### 3.2 Publishing patterns by document type and impact

**Production of leading authors by document type:** Table 3 resumes the type of document published considering the gender of leading authors. Article, Conference paper and Editorial show similar percentages of participation for both genders. On the other hand, in Chapter and Review, the participation of women almost duplicate men. Furthermore, authors regardless of gender, have preference to send their works to a conference, out of every 10 documents, 8 are in this category.

**Table 3.** Document type by gender of leading author

Document type	Total (%)	Gender of leading author	
		F (%)	M (%)
Article	17,2	16,3	17,5
Chapter	1,1	1,7	0,9
Conference Paper	80,5	80,6	80,5
Editorial	0,6	0,5	0,7
Review	0,5	0,9	0,4

**General distribution of leading authors by quartile rank:** Table 4 shows the percentages of publication in articles and conference papers according the gender and the quartile of publication. The ranking of journals are divided into four quartiles: Q1, Q2, Q3 and Q4. Journals with the highest rank are in the Q1 that represents the top 25% of journals. Authors, regardless the gender, have similar preferences considering the quartile of the publications. 21% of authors prefer to publish in articles in quartile Q1. Most of the woman (26%) prefer to publish in conferences papers in quartile Q3 and 21% prefer quartile Q2. Most of the men (27%) prefer to publish in conferences papers in quartile Q2 and 21% prefer quartile Q3.

**Table 4.** Contributions by quartile

First author	Best Quartile	Document type		
		Article	Conference Paper	Total
F	Q1	21,72%	0,71%	22,42%
	Q2	12,02%	20,71%	32,73%
	Q3	13,43%	26,36%	39,80%
	Q4	4,24%	0,81%	5,05%
M	Q1	21,15%	0,89%	22,04%
	Q2	13,17%	26,93%	40,09%
	Q3	12,25%	21,26%	33,51%
	Q4	3,57%	0,78%	4,35%

**Annual production by quartile:** This topic was analyzed considering 565 articles and 479 conference papers because not all of them are published in sources with information from SJR.

Fig. 2 and Fig. 3 show articles and conferences paper published since 2009 to 2018 by quartiles, respectively.

Both women and men, have the same interest in publish articles in Q1, as we can see in Fig. 2, there is a constant increase of publication in this quartile. A possible difference between both genders is that women have published more articles Q3 in 2018. Considering conference papers, both genders show a similar pattern, the percentage of authors publishing in conference papers in Q3 have increased considerably in the last year.

**Annual production by quartile and h-index:** Fig. 4 and Fig. 5 show articles and conferences paper by quartiles and h-index, respectively. Considering the articles, most of the them have low h-index, but in conference papers most of the authors are looking for publishing in conferences of Q2 with high h-index.

Finally, after analyzing the six topics associated with the publication patterns of leading authors, we have been able to confirm that men and women share similar preferences when choosing the type of document, and the impact of

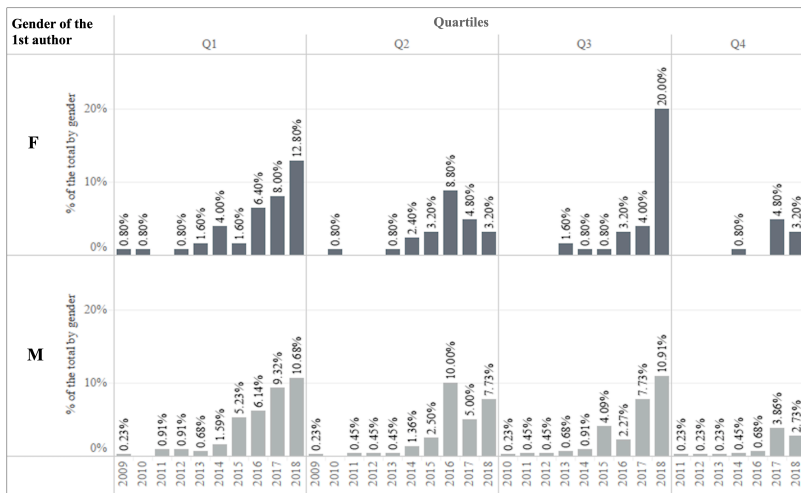


Fig. 2. Articles by year and quartile

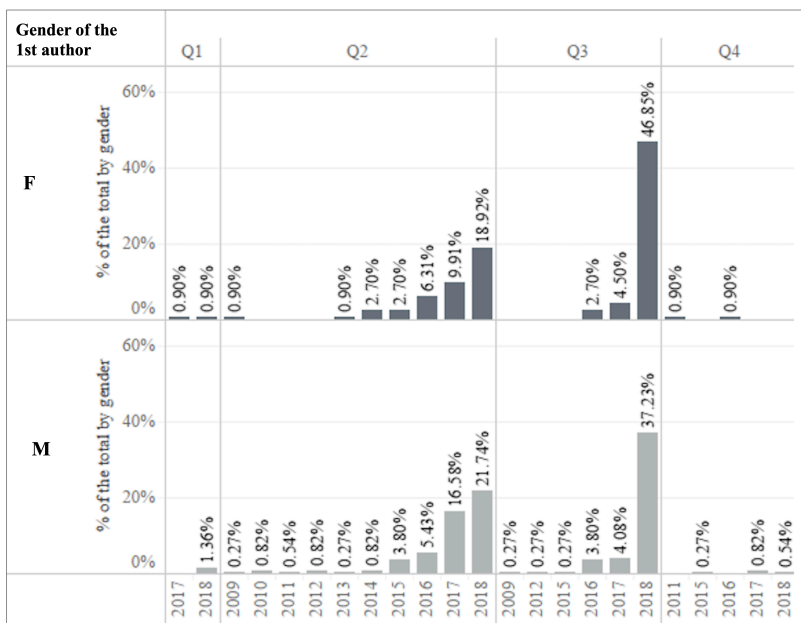


Fig. 3. Conference papers by year and quartile



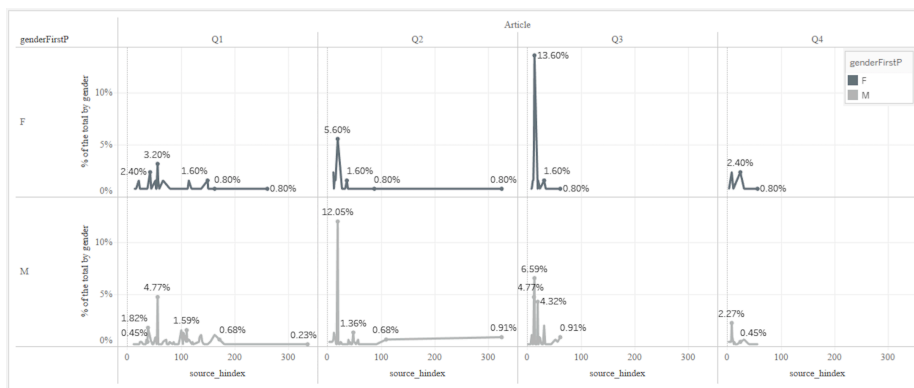


Fig. 4. Articles papers by quartiles and h-index

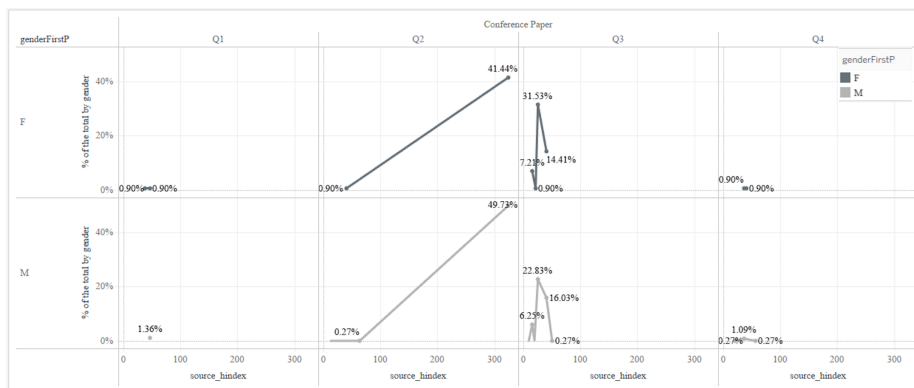


Fig. 5. Conference papers by quartile and h-index

the sources. However, there are two substantial differences 1) in the proportion of men and women who publish as the first author, and 2) in the proportion of co-authors by gender. Co-author groups in which a woman leads are more homogeneous than those groups led by men.

## 4 Conclusion

In recent years, the scholarly publishing of Ecuadorian authors began to position itself as a common practice among researchers. Computer Science production is one of the promising in the country. Currently, the CS field ranks the third place of the Ecuadorian scientific production indexed by Scopus.

In this study, we have found that there are differences in scientific production by gender. Although the publication rate grows every year, those leading by men are three times more than the leading by women. Of the 3359 documents indexed by Scopus, 76% of the first authors are men, 23% are women and 1% represent people with unidentified gender. This means that of four documents published, three have a man as the first author, and only one is led by a woman. Despite of this, women as first authors tend to work with equitable groups of co-authors of both genders.

Furthermore, in order to determine the effects of the low participation of women in scientific production in the area, we evaluated some publishing patterns considering two measures associated with the quality of the sources: quartiles and h-index. With regard to the quality of conference papers, both genders are inclined to quartiles Q2 and Q3. Also, since 2016, both genders have increased article publications in Q1. It is also evident that most articles and conference papers of both genders have a low h-index.

As a result, despite the great difference in number of female and male researchers that leading scientific production, both genders have the same behaviors, in the sense that in recent years they have sought to increase their publications. Therefore, if women had greater participation in the scientific production of the country, they could also improve their visibility and impact.

The findings found in this study encourage us to continue working on this topic. In fact, this study is part of a larger initiative that tries to analyze gender bias in Ecuadorian research. Currently, we are analyzing other indicators related to the impact of researchers and papers. Gathering evidence on how women publish in Computer Science can help government, and educational and research institutions establish mentoring, support, and promotion programs to improve women's participation.

## Acknowledgments

This work was partially supported by the scholarships provided by the Secretaría Nacional de Educación Superior, Ciencia y Tecnología of Ecuador (SENESCYT).

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