

Women and STEM skills for innovation and technological entrepreneurship

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Abstract: The role of women in innovation and technological entrepreneurship is fundamental in all countries. However, there are two key factors that decision-makers and public policymakers must consider; the first factor is related to the presence of women in the university and professional fields in STEM (Science, Technology, Engineering, and Mathematics) and the skills that derive from it. The second relevant factor is stereotypes. Female entrepreneurship Professional Field, Pension, equal pay for equal work, marriage rights, and region/country. Gender and generate more innovation and jobs. This research aims to analyze the STEM competencies and entrepreneurship carried out by women and highlight the most relevant factors to reduce the gap. The methodological strategy is based on the use of machine learning techniques for which three databases were used: two from the World Bank Women, Business and the Law, another on business and law from the World Bank, and another on education from UNESCO, with emphasis on STEM competencies. The results show that women's most significant focus on STEM careers is in the health sciences, and the one that offers the lowest degree is engineering. It is also evident that the critical factors for the incursion of women as entrepreneurs in technological sectors are professional field, pension, equal pay for equal work, marriage rights, and region/country, and in these, some stereotypes are present.

Keywords: women, STEM skills, gender gaps, innovation, technology, entrepreneurship, machine learning, stereotypes

1. Introduction

As today's world becomes increasingly digital, technology plays an increasingly important role in innovation and economic development. Today, countries' economic and social prosperity depends on the state of science and technology (Hammond, 2020). In addition to the above, the pandemic caused by COVID-19 has highlighted the need to increase skills in science, technology, engineering, and mathematics (STEM).

In this context, the participation of both men and women in STEM activities is essential. However, women and girls remain underrepresented in STEM studies, careers, and professional fields, although there is wide variation between countries and STEM fields. Beyond the wage gap that this underrepresentation entails, there is also a gender gap in this area, which is reflected in an inefficient allocation of labor and talent and a lost opportunity for the countries' economies (Sánchez, 2021).

According to Bello (2020), the factors of inequality between men and women in STEM fields are complex and diverse, and the magnitude of their impact changes in different contexts.

In addition to the above, today, in the knowledge-based economy, entrepreneurship is considered one of the critical skills needed in all countries. However, a significant challenge is that there must be a common understanding of entrepreneurship as a competence (AKRLappe et al., 2021 and CEPAL, 2023), especially in technological entrepreneurship.

Another relevant point is that according to the International Telecommunication Union (2023), for girls and women to thrive in science, technology, engineering, and mathematics (STEM) careers, they must acquire skills to become users and creators of ICT worldwide. . digital (Shukla et al., (2021). Therefore, encourage and inspire the pursuit of STEM education and engage the entire community and stakeholders to promote collaboration through all possible means (International Telecommunication Union, 2023).

To achieve this, women and girls need digital empowerment from an early age, allowing them access to technologies and opportunities and a place at the digital decision-making table on equal terms with men. These actions are crucial to addressing gender imbalances in science, technology, engineering, and mathematics (STEM) and promoting digital gender equality at a global level (Omar et al., 2017; ECLAC, 2023).

It is currently recognized that gender equality is fundamental in all countries since it contributes to all people's development, health, and social and environmental well-being. Therefore, innovation with a gender perspective (Schiebinger et al., 2020) and with an equity focus in the production of scientific knowledge (Heikkinen et al., 2020), especially in STEM, will contribute to improving sustainability results and in turn, it will make research more responsive to societal needs and promote the development of new ideas, patents and technologies (Schiebinger et al., 2020).

Analyzing women's entrepreneurship and measuring the gender gap is essential to understand better how women entrepreneurs contribute to the economy and society. However, the lack of comprehensive gender-disaggregated data on business creation and ownership presents an obstacle to the analysis of female entrepreneurship. That is due to the lack of standardized and internationally comparable data that includes sufficient data and factors to analyze and diagnose gender gaps related to entrepreneurship.

Therefore, greater participation by women in the STEM sector would benefit them and increase the competitiveness of industries, sectors, and countries by incorporating a greater diversity of perspectives for the development of innovation.

Currently, there are various indicators and measurements to evaluate the role of women in the various economies of the world and laws to reduce and eliminate the gender gap in STEM skills and entrepreneurship. However, a single indicator or measurement of gender equality does not exist. It is capable of capturing the multiple problems that women and girls face at the same time (UNDP, 2023).

For this reason, this research aims to combine different databases to analyze and elucidate the most crucial gender gaps for technological entrepreneurship so that decision-makers have a broader focus and take the necessary actions. Derived from the previous problem, the questions that guide the research are What are the STEM careers most studied by women worldwide? What are the most relevant critical factors to reduce the gender gap for technological entrepreneurship? What are the key factors for the entry of women as entrepreneurs in technological sectors?

This work is structured in three sections. The first section deals with the theoretical framework, specifically the conceptualization and importance of disciplines related to science and technology, known as STEM (Science, Technology, Engineering, and Mathematics), as well as the various types of gaps that exist between women and men the races that stand out the most. The second section presents the analysis with machine learning techniques. Finally, the third section presents the results, discussion, and conclusions.

2. Theoretical framework

Women present a historic and worrying gap in the disciplines related to science and technology known as STEM (Science, Technology, Engineering, Mathematics), except in the case of health professions (García-Holgado, 2022).

According to the World Economic Forum (2021), no country has achieved full gender parity. The global gender gap score in 2021 is 67.7%, meaning the remaining gap to close is 32.3% (World Economic Forum (2021)).

Access to education for women allows them to escape poverty and increase their chances of entering the labor market. In addition, it contributes to reducing the gender gap and countries' growth, development, and innovation. However, their presence in STEM fields is challenging, as they sometimes face unfavorable academic environments (Hernández, 2021).

2.1 Conceptualization and importance of STEM competencies and education

For Aguilera et al. (2021), Akerson, 2018 and Breiner et al. (2012), STEM education is an educational approach that integrates knowledge and skills from several disciplines involved in the acronym and which is oriented towards problem-solving and contextualized in situations with different levels of reality and authenticity.

For Grass and Alí et al. (2023), STEM education is the process that promotes integrated and interdisciplinary learning of Science, Technology, Engineering, and Mathematics as pillars for sustainable development and social well-being.

Therefore, STEM skills are fundamental for developing people and countries in an increasingly complex, interconnected, and changing world. Countries where people develop vital skills, learn throughout their lives, and use them fully and effectively at work and in society are more productive and innovative and enjoy higher confidence levels, better health outcomes, and higher quality of life.

The future of work is changing; existing jobs are changing, and new ones are emerging that require knowledge and skills in science, technology, engineering, and mathematics (STEM) (Alam and Sánchez; UNICEF, 2020). However, according to Alam (2020), 125 million primary and secondary school-aged girls in the developing world are out of school.

The exclusion of girls from education begins early and increases throughout their lives. While most upper secondary-aged adolescent girls begin primary education, less than half reach the upper secondary level, where STEM skills can be further consolidated (Alam, 2020), even though they have the same or more children's chances of achieving minimum proficiency in mathematics and science.

The under-representation of women in science fields, particularly in the academic area is a problem present in different countries, as shown in the study developed by Papadakis *et al.* (2018), who evaluated data of alumni of the Computer Science Department of the University of Crete from 1985 to 2017, finding that the disproportion in the number of male students admitted to this department compared to female students, as well as the number of postgraduate male students compared to female students is not only visible for the entire analyzed period, but also increasing over the last years.

Parents play a vital role in children's growth, so their expectations always affect children's academic performance (Boonk *et al.*, 2018) and participation in scientific activities (Boon, 2012). Parents of young students often play a vital role in STEM education (Hill & Craft, 2003; Park & Holloway, 2016), and their beliefs are crucial in establishing positive attitudes toward science in students (Chen & Lin, 2019; Crano & Prislín, 2006).

In several studies, parents who actively participate in children's STEM extracurricular activities (e.g., visiting museums, playing math games, helping with homework, and introducing particular STEM careers) would significantly increase motivation and performance in school their children's STEM learning (Archer *et al.*, 2019; Wang, 2012). The younger the children are, the more influential the effect of their parents' involvement and guidance is (LeFevre *et al.*, 2009; Froiland *et al.*, 2012). Most of the time, parents' positive expectations could have an even more significant effect on children than their behaviors (An *et al.*, 2019)

According to Sobieraj and Krämer (2019), Mavriplis *et al.* (2010), Smeding (2012), and Wang and Degol (2013), there are various factors why women avoid the path to STEM-related areas, including weaker math skills, implicit gender stereotypes, or structural deficits in school education.

Key factors perpetuating gender gaps in STEM:

- Gender stereotypes: STEM fields are often considered masculine, and both parents and teachers frequently underestimate girls' math skills as early as preschool.
- Male-dominated cultures: Because fewer women study and work in STEM, the field tends to perpetuate inflexible, exclusionary, and male-dominated cultures.
- • Lack of role models: There are few role models to inspire the interest of girls and women in these fields.
- Math anxiety: Teachers frequently transmit math anxiety to girls, assuming that girls must work harder to reach the same level as boys (Sobieraj & Krämer, 2019; Mavriplis *et al.*, (2010); Smeding, (2010));2; Wang & Degol, 2013).

According to Bem (1993) and Master *et al.* (2017), gender stereotypes can affect perception and behavior. Stereotypes about scientists can also influence the behavior of women and men. For example, when deciding whether to pursue science, technology, engineering, and mathematics, Master and Meltzoff (2016) argue that these stereotypes can act as barriers that prevent girls from studying STEM subjects. According to Papadakis (2018), even books and School textbooks have been a source of gender stereotypes in computer science education in Greece, creating a male-dominated perception in this field.

Sobieraj and Krämer (2019) argue that there are several apparent differences between men and women in terms of perceived competence and motivation to study. Socialization of such beliefs could motivate men to choose a STEM degree program and give them the confidence to experiment with competition after graduation. On the other hand, STEM students partly lack the perception of competence. In line with previous research on stereotypes, this may also have been induced by stereotypical beliefs about women and STEM, where women assume that their effort, skills, and abilities might be worth less compared to STEM students because STEM is a male domain (Hand *et al.*, 2017).

2.2 Women and the gaps in science, technology, engineering and mathematics (STEM) and technological entrepreneurship

The imbalance in the presence of men and women in STEM areas is palpable, and in entrepreneurship, there are more success stories from men than from women. That situation is evident in a term that Kovaleva et al. (2023) mention that is used to describe the "start-up culture" in Silicon Valley, which is "tech bros."

Although entrepreneurship constitutes a critical path to foster economic activity in different regions, the intention of becoming an entrepreneur among women is still less than the intention of men, and this is particularly relevant in STEM fields (Armuña et al., 2020).

Factors derived from deficiencies in education can become obstacles for women to pursue an entrepreneurial career. As shown by the evidence from a study based on the Global Entrepreneurship Monitor for 19 European countries and the USA, there is higher entrepreneurial activity in high-tech sectors in countries where there is greater equality in science education (Dilli & Westerhuis, 2018).

A study by Kovaleva et al. (2023) revealed that factors such as discrimination, social acceptance, and lack of a female role model in tech-related sectors are relevant in reducing women's intentions to start their own companies. It is worth mentioning that, in the same study, other elements like financial risks or high responsibilities are found to be non-gender related, affecting both male and female entrepreneurship.

The concept of entrepreneurship competencies plays an essential role in an individual's final decision to start a new business. These competencies are defined by Armuña et al. (2020) as "the set of skills and knowledge that a person achieves through education or experience" (p. 71), and the self-perception of these capabilities is essential. This study found three areas where female potential STEM entrepreneurs feel less competent: the ability to recognize potential value in an idea, financial knowledge, and digital know-how.

These studies provide valuable insights into the problem of identifying relevant aspects influencing new female ventures and elements that impact the gender gap, obtaining this information from interviews. However, there is still an opportunity to define these aspects using machine learning methods.

On the other hand, the balance of power in business has long been a male domain. While great strides have been made in the quality of life and its technical sophistication, the other side is discouraging. There are surprising extremes of wealth and poverty, regulatory burdens, and a growing culture of litigation, environmental abuse, and more. With their ability to listen, consensual management style, and sensitivity to the bigger picture, women will do a lot to help us achieve a better balance in business and life in general (Brocca et al., 2018).

3. Methodology

This research is quantitative. The methodological strategy is based on machine learning techniques, where three World Bank databases were used, one referring to the fields of women's professional education and another to businesses owned by women.

1. Women Entrepreneurs Finance Initiative (We-Fi).
2. Women graduates by field of study.
3. Women's Law

Two experiments were done; in the first, databases I and II were joined across the State and year fields to find the existing correlations between professional fields of studies and women-owned businesses; in the second one, the merge database was united with the Women's Law data; Machine Learning techniques for unsupervised learning were applied, where three clusters were generated that grouped the countries according to their characteristics.

4. Results and discussion

In the first phase of the work, the most relevant variables for classification expressed through the RRelief metric have been searched. This means that these are the most influential variables to reach the optimal result on the target variable based on the ReliefF metric. ReliefF is part of an algorithm's family that measures the ability of an attribute to distinguish between classes on analogous data instances (Robnik et al., 2003).

Table 1. Most relevant variable

Variable	Relevance (ReliefF)
Professional Field	0.518
Is the mandatory retirement age for men and women the same?	0.27
Is the age at which men and women can retire with full pension benefits the same?	0.248
Does the law mandate equal remuneration for work of equal value?	0.236
Length of paid paternity leave	0.231
Does a woman have the same rights to remarry as a man?	0.215
Region	0.192
Pension	0.188

The first experiment shows that women who study health careers have higher values (database of female graduates) with similar participation in e-participation (Figure 1). E-participation is generally used as a category, counting a variety of areas such as e-consultation, e-legislation, e-petition, and e-deliberation, as well as the use of information and communication technologies to enable the participation of citizens in democratic processes.

Previous studies confirm this finding in exploratory studies about the influence of education on electronic participation; one of them is Pérez-Morote et al. (2022), who have identified a negative impact of gender and education, among others, on electronic participation.

The measurement index used in the database of female graduates by area of study (value) increases for women who study careers in Health, Natural Sciences, and Services and is lower for Engineering and Sciences. It talks about the presence of women in these areas where the parameter e-participation vs study area indicates that this value is higher in those who studied careers corresponding to health and well-being (Figure 2). The United Nations supports this finding in the Women in Health Journal (2022), stating that women contribute to the disruptive digital transformation in health and demonstrate their ability to be solution-oriented based on the activity of several women in various places around the world.

In the second experiment, where the databases Women Entrepreneurs Finance Initiative (We-Fi) and Women graduates by field of study were joined, it was found that the relationship between the value parameter and the number of women who own a business is influenced by the area of professional studies that they choose (Figure 3).

Additionally, the database resulting from the union has been processed using clustering. This unsupervised learning technique has allowed countries to be grouped according to their characteristics. In this work, three clusters have been generated, where Cluster number 2 includes the countries with the most significant number of women business owners. Additionally, it has been found in this study that the most important number of women located in cluster number two have studied careers in the Health and welfare area (Figure 4).

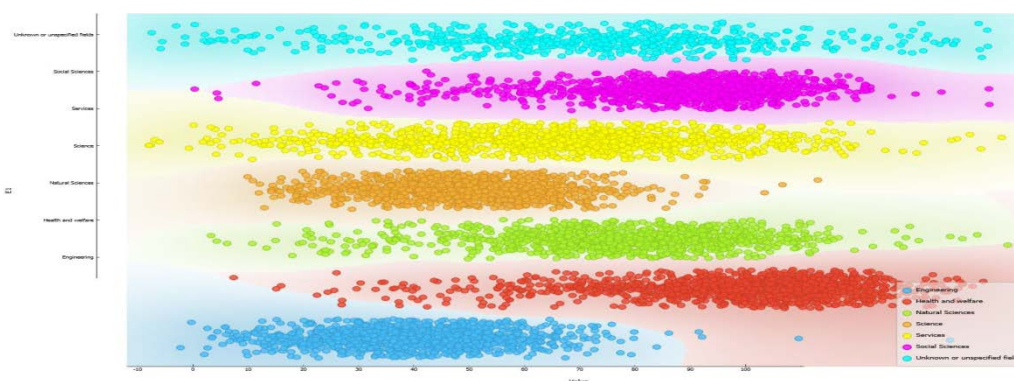


Figure 1. Value vs. women’s professional studies area

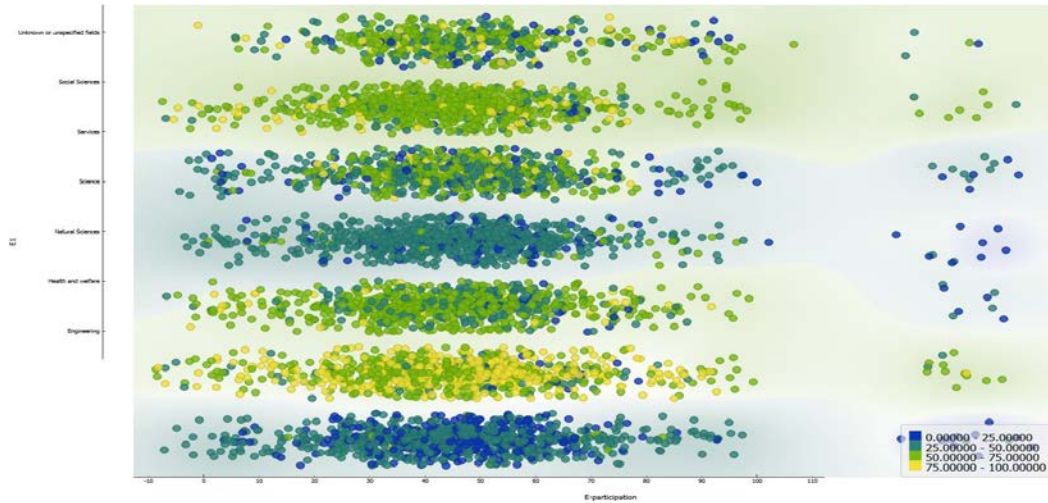


Figure 2. E-participation vs. women's professional studies area

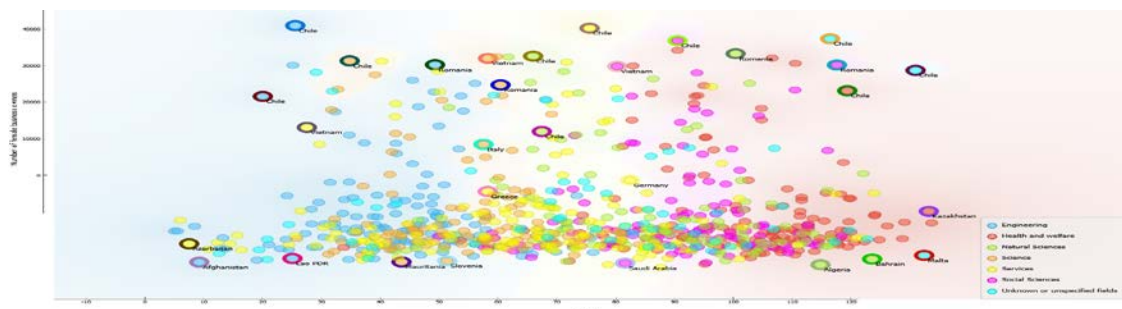


Figure 3. Number of female business owners vs. value parameter colored by professional studies area

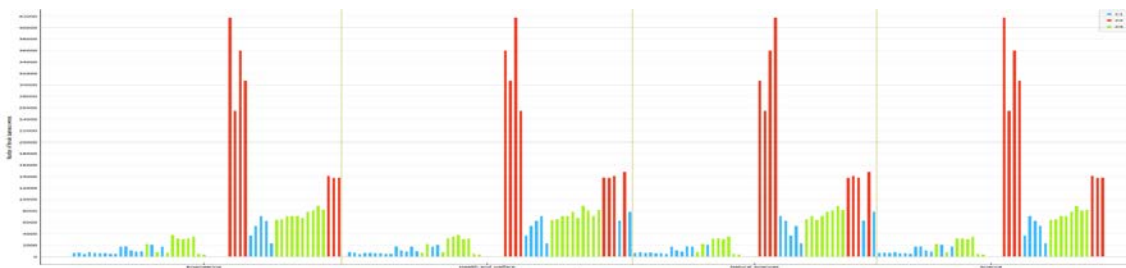


Figure 4 Relationship between the area of professional studies and the number of women business owners grouped by clusters.

Finally, when doing a review by cluster, it is observed that the best-valued cluster (cluster 2) economies belong to countries such as Chile, the United Arab Emirates, Italy, the Korea Republic, Germany, and Romania, among others. These are more prosperous economies than clusters one and three (Figure 5).

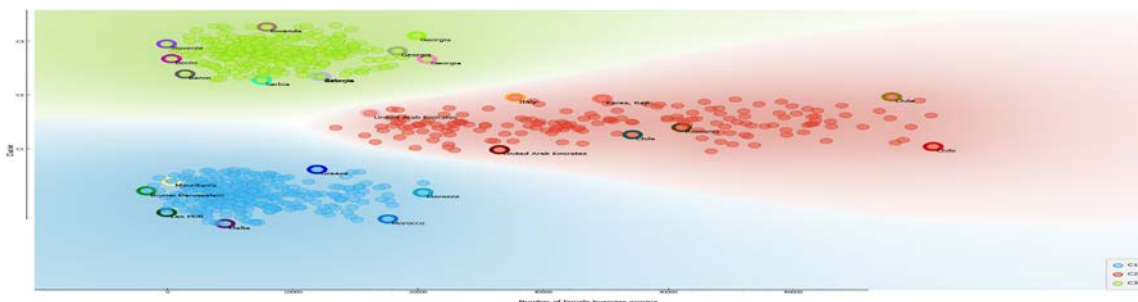


Figure 5 Clustering by country's similarities.

Considering the income group from de WBL Women’s Law, the high-income group increases their quantity where the women possess services business; the high-income group has fewer members once the women are in the other professional fields (Figure 6).

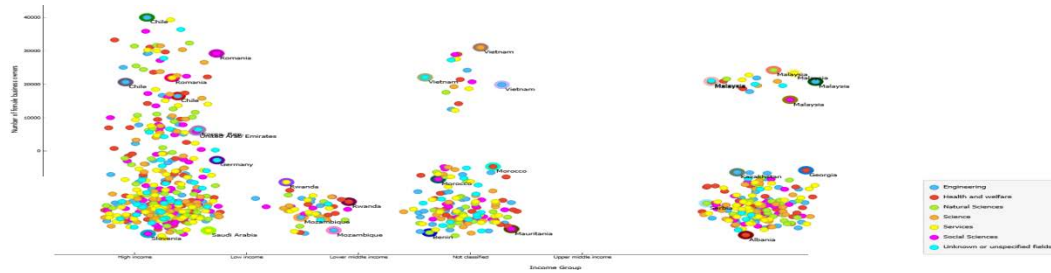


Figure 6. Income Group vs Number of Women Business Owners Grouped by Professional Field.

Through the union of the three databases studied, it is notable that the number of women business owners increases in countries where women select where to live the same way as men. It can also be noted that most businesses are dedicated to the service area (Figure 7). Related to these findings, the World Economic Forum (Koch-Mehrin & Weh, 2023) reported increasing evidence showing the impact of women in law and when they hold public office. Countries with more female political leaders tend to pass more laws that eliminate inequality and score higher on the World Bank’s Women, Business and Law (WBL) Index, which measures legal equality of economic opportunity (Figure 7).

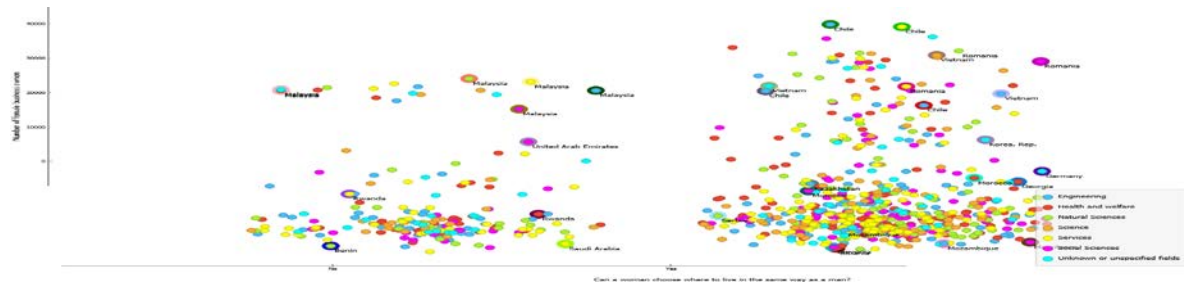


Figure 7. Relationships among the number of business properties of women, freedom to select how to live grouped by Professional Field.

According to the data analyzed, the number of women business owners has diminished over the years. This is shown through the negative trend lines from 2016 in almost all countries reported by WB (Figure 8).

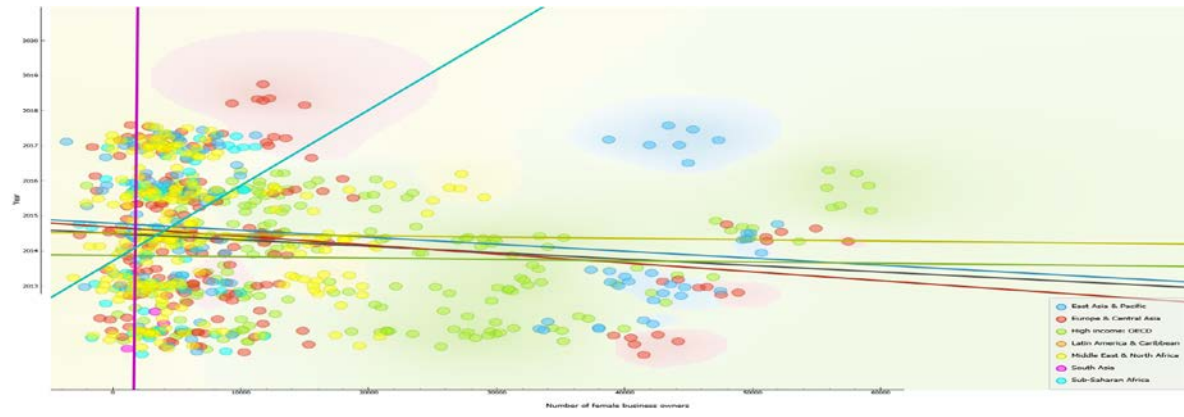


Figure 8. Negative trend in the number of women business owners

5. Conclusions

In order to analyze the elements of the STEM competencies and entrepreneurship carried out by women and highlight the most relevant factor to reduce the gender gap, three public datasets were joined: a) Women Entrepreneurs Finance Initiative (We-Fi), b) Women graduates by field of study, and c) Women’s Law. Their union allows the authors to obtain highlights about the actions to improve equality in STEM career participation.

To deal with the vast challenges of this century, among which climate change, digitalization, technological changes, the future of work, and to meet the sustainable development objectives, science is necessary, which is why the world does not. It can deprive the potential, intelligence, and creativity of thousands of women who are victims of inequalities or prejudices (Mondejar et al., 2021). According to the European Institute for Gender Equality (2024), gender inequalities have been documented by weakening women's contributions in the digital field, where there is a lower participation in digital education and under-representation of women in information and communication technologies roles.

The gender disparity in STEM is an opportunity for all countries to be more productive, innovative, and competitive and thus be able to face the dynamics of current markets. Therefore, it is necessary to eliminate the cultural and social barriers that inhibit women's entry into this sector. For this reason, it is necessary to expand and promote opportunities in technical areas that allow women to develop the required skills and give more visibility to the role models of female entrepreneurs in the technological field. Implementing these strategies, educational improvements, skill development, and training emphasizing technological knowledge should support Promoting STEM skills by all countries to promote the teaching of science, technology, engineering, and mathematics as support columns for sustainable development and social well-being, without forgetting that the person must always be at the center.

One of the actions proposed by the European Commission in the Digital Action Plan 2021-2027 (European Economic and Social Committee and the Committee of the Regions, 2020) is to boost women's participation in STEM and support the European Union STEM Coalition to develop new higher education curricula for engineering and information and communications technology based on the STEAM approach to be more attractive for women and growth their participation and career development in STEM subjects. Other countries could adopt this good practice to promote women's participation in the digital age.

The results of this work underpin that countries must continue promoting laws and regulations to generate more laws, regulations, and programs in more countries that encourage the reduction of the gender gap. However, there must also be specific strategies to eliminate stereotypes - since Sometimes they have a more significant impact - even on the law. The results in which clusters in some cases report the countries show similarities that are not obvious, as in the case of cluster 2, where the economies belong to countries such as Chile, the United Arab Emirates, Italy, the Korean Republic, Germany, and Romania, among others are grouped. These are more prosperous economies than clusters one and three. Countries belonging to different continents are grouped; however, they share characteristics that indicate that the actions to be taken to improve the inclusion of women can be similar. The special care could be focused on the clusters that grouped the less prosperous economies, where women have more disadvantages and inequality.

In future work, it is necessary to analyze whether the negative tendency in the number of women business owners has continued after forced.

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