Awareness of Women's Inclusion in STEM: Twitter Data in Italy

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Abstract: This paper focuses on assessing public awareness of women in STEM disciplines. The underrepresentation of women in STEM has garnered recent attention, and this study is grounded in Social Cognitive Career Theory, which examines how individual, contextual, and experiential factors impact interests and goals in STEM. Individual factors, such as self-efficacy beliefs and outcome expectations, play a crucial role in shaping career choices. Contextual factors influence women's leadership roles, particularly in male-dominated environments, and may differ in female-majority settings. Additionally, social modelling, where individuals learn from observing others, contributes to self-efficacy. Our study focuses on contextual factors that influence awareness of women in STEM. We employ a panel-type econometric model spanning 2014-2022 and analyse 29,985 tweets to explore the influence of socioeconomic factors on public opinions in various Italian regions. Italy's significant regional disparities make it an ideal setting for this research, considering factors like human capital, industry, and government. The managerial implications underscore the importance of understanding public opinion to inform decisions that promote women's inclusion in STEM fields for policymakers and corporate management. This study's unique use of geolocated data on Twitter adds a novel dimension to the intersection of STEM and women.

Keywords: Twitter, STEM, Women, Awareness

1. Introduction

The abbreviation STEM stands for Science, Technology, Engineering, and Mathematics.

Beyond the overarching scarcity, women continue to face enduring underrepresentation in numerous quantitative fields, including but not limited to economics, engineering, and computer science (Owen, 2023).

Despite the fact that women make up 53% of STEM graduates on a global scale (Sirimanne, 2019), their representation dwindles to a mere 34% of STEM graduates within the European Union (EU) (European Commission, 2019), and just 40.6% in Italy as of 2020 (ALMALAUREA, 2022).

Reducing the gender gap in STEM education should be a priority for the European Union since it will boost economic growth. According to projections, these investments may raise GDP per capita by 0.7–0.9 percent by 2030 and by 2.2–3 percent by 2050, which would be a more significant growth (Serrano et al., 2023).

This gender gap in STEM enrolment has wide-ranging implications for the Italian labour market, where gender-based segregation in both vertical and horizontal career paths remains prevalent. Not only does this underrepresentation limit the pool of qualified STEM professionals, but it also perpetuates gender imbalances in the workforce, contributing to the enduring wage disparity (Sterling et al., 2020; Beede et al., 2011; Michelmore and Sharon, 2016).

At both corporate and public institutional levels, the scarcity of women STEM graduates significantly hinders their opportunities for career progression, thus perpetuating the absence of women in top-tier positions and leadership roles (Amon, 2017; Bilimoria et al., 2014). Consequently, it is imperative for governmental bodies to address this issue and champion gender equality in STEM education and professions, especially in light of the increasing demand for scientific and engineering skills. A highly skilled workforce, encompassing STEM expertise, is indispensable for the economic development of companies and the nation (Saucerman and Vasquez, 2014).

This study draws from the well-established Social Cognitive Career Theory (SCCT) in the STEM fields (Sevilla and Snodgrass Rangel, 2023). SCCT posits that individual, contextual, and experiential factors influence interests, goals, and goal-oriented behaviour, as documented in works by (Lent et al., 1994).

Within individual factors, self-efficacy beliefs pertain to individuals' personal convictions regarding their capacity to successfully accomplish specific tasks. These beliefs are closely linked to outcome expectations, which relate to the specific results anticipated from their actions (Lent et al., 1994; Bandura, 1977).

Moreover, individual and contextual factors, including gender, ethnicity, prior high school education, social support networks, and obstacles, contribute to shaping self-efficacy, perceptions of success, and career aspirations. This insight is consistent with Lent's research (Lent et al., 1994; Lent et al., 2002).

The relationship between social cognitive theory and the significance of role models is evident (Bandura, 2001), for instance, emphasized that witnessing a relatable role model succeed in a similar task significantly influences one's self-efficacy. Social modelling fulfils various roles in facilitating personal and societal transformation. These roles encompass instructive, motivational, social prompting, and social construction functions. In the instructive role, models convey information, ethical principles, cognitive abilities, and novel patterns of behaviour (Bandura, 1986; Bandura, 1977).

Graph 1 shows the theory behind the study specifically Social Cognitive Career Theory and the influence in promoting social roles.

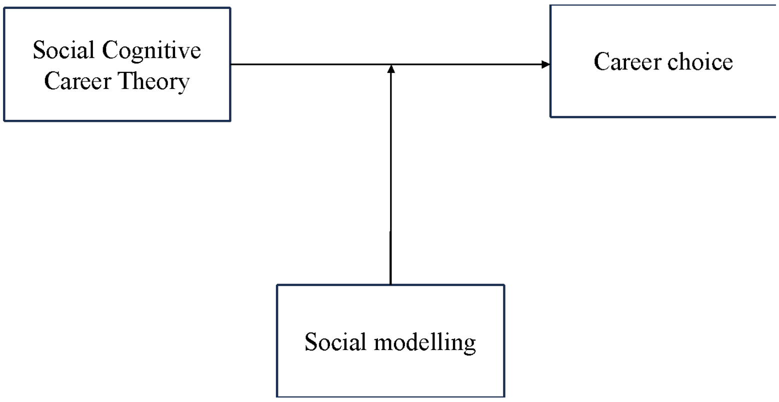

Figure 1: theory behind the study. Source: personal elaboration.

In recent times, Twitter has emerged as a valuable data source for capturing public sentiment through Social Opinion Mining (SOM). SOM involves the extraction of thoughts, emotions, and attitudes from user-generated online content by employing techniques such as sentiment analysis and topic modelling (Cortis and Davis, 2021). Virtual communities on social media platforms enable real-time, open exchanges of ideas and opinions, rendering them crucial data sources (Aladwani and Dwivedi, 2018; Kizgin et al., 2020; Mashayekhi et al., 2023).

Despite the widespread use of Social Opinion Mining (SOM), it's noteworthy that only a limited number of studies have ventured into this domain (e.g., Alkhammash, 2019; Stella, 2020; Floyd, 2021). Furthermore, most of these studies have primarily focused on the English language and have not considered the geolocation of tweets. This study stands out as the sole investigation of the Italian context, particularly at a regional level.

Specifically, our study aims to assess whether public awareness and discussions on the subject have witnessed changes over time.

This study aims to explore the impact of socioeconomic factors on raising awareness and promoting the emergence of social role models. We specifically concentrate on three socioeconomic dimensions that may affect awareness concerning women in STEM fields: human influence, corporate involvement, and institutional influence. Additionally, we take into account certain control variables.

2. Data

Twitter is a popular source for Social Opinion Mining (SOM) studies. Data is easily accessible through Twitter search APIs using criteria like keywords, locations, dates, and usernames (Cortis and Davis, 2021; Sharifi and Shokouhyar, 2021).

To gather data for this study, tweets in Italian from January 1, 2014, to December 31, 2022, were downloaded using Twitter's API and Twarc2, as recommended by (Uma Maheswari and Dhenakaran, 2023; Saha et al., 2019).

Keywords were selected based on the literature, combining "STEM" with terms related to women, common hashtags for women in STEM, and specific STEM fields like math, engineering, and chemistry (Alkhammash, 2019; Stella, 2020; Floyd, 2021).

The resulting keywords are:

- Word associated with STEM: Gendergap, women, woman, woman, women, researcher, girls, students, student, professor, professors, WomenInScience, WomenScienceDay, scientist, scientists, womenofscience, womeninscience, UnstoppableWomen, genderequality, womenscientists, womenofscience;

- Single word use: Womenatscitec, womenintech, womenintechnology, girlsintech, girlsintechnology, girlswhocode, womenwhocode, womancoder, girlcoder, femalecoder, womeninCS, womeninIS, womeninIT, WomenEngineers, WomenInAI, StemWomen, WomenInEngineering, engineeringgender, womenengineer, WomenInChemistry, WomeninMath, WomenInMaths, womeninmathematics, DonneinTech, donneinphysics.

We extracted 76,448 tweets with specific keywords and geolocated them using "author.location" data. A Python script provided latitude, longitude, and user locations. Due to incomplete author location information, a 29,985-tweet sample (39.22% of the initial dataset) was obtained.

In Table 1, analysing the time trend over the years, it can be observed that public awareness and interest have increased over time, from 668 tweets in 2014 to 8,746 tweets in 2022.

Table 1: Number of tweets over the years, source: personal processing.

	Tweet about STEM and women	Tweets about STEM and women geolocated	% of tweets geolocated on the total
2014	1,507	668	44.33%
2015	1,567	610	38.93%
2016	5,440	2,171	39.91%
2017	7,748	3,454	44.58%
2018	9,507	4,208	44.26%
2019	8,150	3,768	46.23%
2020	6,749	2,561	37.95%
2021	11,839	3,799	32.09%
2022	23,941	8,746	36.53%
Total	**76,448**	**29,985**	**39.22%**

Table 2 shows all the variables used in the study.

Table 2: Variables used in the study, source: personal elaboration.

Variables	Description	Source
Dependent		
Tweets	Number of tweets made in a certain region in a specific year	Twitter
Independent		
Risk of poverty	% of people at risk of poverty	Eurostat
Women doing research	% of women involved in research and development or are researchers	Eurostat
Women Patenting	Number of women who have patented	OECD REGPAT
Active women	Thousands of economically active women	Eurostat
Female education	% of women who have an educational attainment between 5-8 on the ISCED scale	Eurostat
SDG 10	Dummy equal to 1 if there is at least one company in the region that claims to support SDG 10 in a given year	Refinitiv
Board Diversity Policy	Number of companies that have a gender diversity policy on the board of directors	Refinitiv
Diversity & Opportunity Policy	Number of companies that have a policy to promote diversity and equal opportunities	Refinitiv

Variables	Description	Source
Female unemployment	Female unemployment rate	Eurostat
Men's Assembly	Male quota of members in Regional Assemblies	EIGE Gender Statistics DB
EQI	European Quality of Government Index	European Commission

2.1 Sources

The variables used in this study were derived from a diverse set of data sources. These sources encompass *EUROSTAT*, the *EIGE Gender Statistics DB*, the *European Commission*, *OECD REGPAT* and *Refinitiv*.

EUROSTAT, serving as the statistical arm of the European Union, is responsible for aggregating and processing data contributed by EU Member States. Information pertaining to various factors, such as the risk of poverty, the participation of women in research activities, the economically active women, women holding educational attainment levels between 5-8 on the ISCED scale, and unemployment women statistics.

EIGE Gender Statistics DB acts as a repository for gender-related data from across the European Union. It aims to provide statistical insights that can be use by European Commission's endeavours in advancing gender equality. Data from this source is the male representation in Regional Assemblies.

The *European Commission*, a prominent institution within the European Union, plays a central role in promoting the consistent implementation of the EQI (European Quality of Government Index), a crucial variable used to assess institutional quality on a European scale.

The *OECD REGPAT database*, curated by the OECD, aggregates data on patents registered with institutions like the European Patent Office (EPO) and the Patent Cooperation Treaty (PCT). This source facilitated the extraction of inventor names, allowing for the subsequent determination of their gender and the calculation of the total number of inventors.

Finally, *Refinitiv*, a globally recognized American-British data and infrastructure provider for financial markets, supplied information related to companies that profess their commitment to supporting Sustainable Development Goal 10 (SDG 10). Additionally, data on businesses with gender diversity policies at the board level and policies promoting diversity and equal opportunities at the corporate level were obtained from Refinitiv.

2.2 Variables

The economic situation of people living in a certain region (*Risk of poverty*) is measured by the percentage of the population at risk of poverty.

In order to measure the research commitment of women in a given region, the variables *Women doing research*, which represents the percentage of women researchers, *and Women Patenting*, i.e. the number of women inventors, were considered. To create this variable, all the patents made in Italy were extracted from REGPAT, the inventors (those who designed and created the patent in companies) were considered and using the *World Gender Name Dictionary database* they were classified into men and women. *A*ctive *women* measure the thousands of economically active women in a region. The variable *Female education* was used, which represents the percentage of women who have an educational level between 5-8 on the ISCED scale. Finally, *Female unemployment* represents the female unemployment rate.

To consider the influence of the industrial sector active in a region, a series of variables were considered to assess the attention of companies towards inclusion and diversity issues. *SDG* 10 is a dummy variable equal to 1 if there is at least one company in the region that claims to support SDG 10 in a given year. *Board Diversity Policy* measures the number of companies that have a gender diversity policy on the board of directors and finally *Diversity and Opportunity Policy* which represents the number of companies that have a company-wide diversity and opportunity policy.

The final aspect under scrutiny pertains to the governance of different Italian regions. The *EQI*, or European Quality of Governance Index, draws upon data sourced from regional governance surveys conducted within the European Union. These surveys initially commenced in 2010 and have been periodically repeated in 2013, 2017, and 2021. The EQI is constructed upon extensive feedback from citizens, encompassing their perspectives and encounters with public sector corruption. It also gauges the level of public trust in the equitable distribution and quality of public services*. Men's Assembly* is the variable that represents the male share of members in the Regional Assemblies and is an index of gender parity in top positions in regional public institutions.

3. Methodology

To explore the temporal evolution of public awareness ((Fu et al., 2020)), under the influence of economic and social conditions across diverse regions of Italy, we formulated a panel model. In this approach, the 21 Italian regions (with the Autonomous Provinces of Bolzano and Trento considered separately) were designated as the observational units spanning the years 2014 to 2022. The resulting dataset encompasses a total of 189 observations. Given the inherent characteristics of the dependent variable, specifically the count of tweets originating from each region, we employed a panel model using logistic regression with a Poisson-type distribution (Sun and Zhao, 2013).

The choice between a random-effects or fixed-effects model was deliberated through a Hausman test, leading to the selection of the fixed-effects model. The fixed-effects model allows for individual regional variations and incorporates intercepts to account for individual heterogeneity ((Campello et al., 2019)).

The subsequent section delineates the intricacies of the models:

Model 1: *Tweets = f(Risk of Poverty + Women doing research + Women patenting + Active women + Female education + Female unemployment + SDG 10 + Diversity policy on the board + Diversity and opportunities policy + EQI + Men's Assembly)*

Model 2: *Tweets = f(Risk of Poverty + Women doing research + Women patenting + Active women + Female education + Female unemployment + SDG 10 + Board Diversity Policy x Diversity and Opportunity Policy + EQI x Men's Assembly)*

4. Results

Table 3 presents the descriptive statistics of the variables used in the econometric model. The average of *tweets* is 158.65 but the standard deviation is high at 494.1 indicating that there is significant disparity in the regions. Other variables that have a high standard deviation are: *Women Patenting* and *Active women.*

Table 3: Descriptive statistics of the variables used, source: personal elaboration.

Variables	Mean/%	Std. Dev.	Min	Max
Tweets	158.65	494.1	0	5889
Risk of poverty	26.27	12.44	8.1	55.6
Women doing research	34.31	4.75	25.21	45.71
Women Patenting	75.21	135.24	0	747
Active women	516.31	482.67	26.8	2086.7
Female education	21.6	3.44	14.4	30.2
SDG 10	0.17	0.38	0	1
Board Diversity Policy	1.26	3.6	0	29
Diversity & Opportunity Policy	3.13	6.48	0	48
Female unemployment	12.13	5.76	2.8	26.2
Men's Assembly	80.93	9.02	60	100
EQI	-0.92	0.67	-2.23	0.72

Table 4 shows the results of *Poisson logistic regression* with fixed effects.

Table 4: Regression results, source: personal elaboration.

	Model 1	Model 2
Variables	Tweets	Tweets
Risk of poverty	0.043***	0.038***
	(0.004)	(0.004)
Women doing research	0.086***	0.032***
	(0.007)	(0.007)
Women Patenting	0.001***	0.001***
	(0.0001)	(0.0001)
Active women	-0.0003	0
	(0.001)	(0.001)
Female education	0.401***	0.411***
	(0.009)	(0.009)
SDG 10	-0.006	0.306***
	(0.029)	(0.039)
Board Diversity Policy	-0.096***	-0.193***
	(0.007)	(0.009)
Diversity & Opportunity Policy	0.05***	0.002
	(0.006)	(0.006)
Female unemployment	-0.233***	-0.199***
	(0.011)	(0.011)
Men's Assembly	-0.02***	-0.070***
	(0.002)	(0.004)
EQI	-0.104*	3.025***
	(0.052)	(0.285)
Board Diversity Policy x Diversity & Opportunity Policy		0.003***
		(0.0001)
Men's Assembly x EQI		-0.040***
		(0.003)

In model 1 *Risk of poverty*, *Women doing research* and *Women patenting* are statistically significant ($p<0.001$) with coefficients of 0.043, 0.086 and 0.001 respectively. *Active women* is not statistically significant and has a negative sign. *Female education* is statistically significant ($p<0.001$) and has a positive sign with a coefficient of 0.401. *SDG 10* is not statistically significant and has a negative sign. *Board Diversity Policy* is statistically significant ($p<0.001$) and has a negative sign with a coefficient of -0.096. *Diversity & Opportunity Policy* is statistically significant ($p<0.001$) and has a positive sign with a coefficient of 0.05. *Female unemployment* and the *Men's assembly* are statistically significant ($p<0.001$) and have a negative sign with a coefficient of -0.233 and -0.02 respectively. Finally, *EQI* is statistically significant ($p<0.05$) and has a negative sign with a coefficient of -0.104.

In model 2 *Risk of poverty*, *Women doing research* and *Women patenting* are statistically significant ($p<0.001$) with coefficients of 0.038, 0.032 and 0.001 respectively.

Risk of poverty sign is probably due to the fact that the more people are at risk of poverty, the better the population understands the need to integrate everyone into the world of work, even in specific sectors.

The presence of women actively engaging in research can likely be attributed to the fact that these individuals, possibly even publicly recognized in the media for their accomplishments, serve as inspiring role models for other women. Their experiences can contribute to the wider dissemination and increased awareness of topics related to women's participation in STEM fields. When women observe their counterparts achieving success and establishing careers in research, it can serve as a source of inspiration and motivation, encouraging them to consider pursuing careers in these fields as well.

The rise in the number of women involved in patenting and attaining success with innovative technologies and ideas can have a significant impact on raising awareness of women's capabilities in STEM subjects. These women serve as living examples that challenge gender stereotypes suggesting a lack of interest and aptitude in these areas. As mentioned previously, they act as positive role models for other women interested in pursuing STEM careers. Their visibility not only fuels their own passion but also instills a belief in their abilities. In doing so, they foster a network and community that actively supports and empowers other women in their STEM pursuits.

Active women is not statistically significant and has a negative sign. *Female education* is statistically significant (p<0.001) and has a positive sign with a coefficient of 0.401. This might be attributed to the accomplishments and prominence in academia. These women exemplify the abilities, expertise, and dedication that challenge gender stereotypes, inspiring others to pursue STEM careers. They serve as role models. A rise in female graduates or doctorates may signify a shift toward gender equality and STEM inclusion within institutions and culture.

SDG 10 is statistically significant (p<0.001) with a positive sign and a coefficient of 0.306. Companies declaring their commitment to SDG 10 send a powerful message to women in STEM. It signals the company's dedication to reducing disparities and fostering equal opportunities, potentially motivating women to pursue STEM careers, thereby boosting awareness and interest.

Board Diversity Policy is statistically significant (p<0.001) and has a negative sign with a coefficient of -0.193. *Diversity & Opportunity Policy* is not statistically significant and has a positive sign with a coefficient of 0.002. The relationship between *Board Diversity Policy* x *Diversity & Opportunity Policy* is statistically significant (p<0.001) and positive with a coefficient of 0.003.

Board Diversity Policy has a negative sign, and this indicates that taken individually this policy does not have a positive impact on awareness about women in STEM subjects. Although this policy alone may not suffice to raise awareness about women in STEM, when coupled with a comprehensive company-wide diversity and opportunity policy, it can create a synergistic environment that advances gender equality and inclusion. The board-level policy can drive increased female representation in leadership roles, fostering a workplace where women feel valued. Simultaneously, the diversity and opportunities policy may open new avenues for professional growth in STEM fields for women, facilitating their participation and progress. Together, these combined policies can have a positive impact by enhancing awareness of women in STEM and cultivating an inclusive and fair organizational culture.

Female unemployment is statistically significant (p<0.001) and has a negative sign with a coefficient of -0.199. This is likely because unemployment can lead to a decrease in job opportunities for women in STEM, creating a sense of discouragement and reducing women's motivation to pursue a career in that field.

Men's assembly is statistically significant (p<0.001) and has a negative sign with a coefficient of -0.070. *EQI* is statistically significant (p<0.001) and has a positive sign with a coefficient of 3.025, while finally the relationship between *Men's assembly* x *EQI* is statistically significant (p<0.001) and negative with a coefficient of -0.040.

In regions with strong institutions, they can facilitate gender equality in STEM through educational initiatives, awareness campaigns, and project funding. Conversely, when women are underrepresented in leadership roles, it can diminish attention to these issues, limiting opportunities and visibility for women in STEM. The combined effect of these variables can negatively impact women's awareness in STEM. Even with the positive influence of quality institutions, a greater male presence in top positions can mitigate it. Consequently, policies aimed at gender equality by institutions may face obstacles due to the imbalance in positions of power, potentially reducing their attention and effectiveness.

5. Conclusion

The issue of women in STEM fields has gained significant attention, impacting not only those who have chosen STEM careers but also influencing the aspirations of young women considering their educational and career paths. The study reveals that awareness on this topic has grown over time, influenced by external socio-economic factors. Understanding public opinion on this crucial matter is vital for supporting policymakers and corporate leaders in fostering women's inclusion in STEM.

Investing in initiatives to promote women's participation in research can enhance awareness in STEM subjects. Effective scientific communication is key. Presenting women's research in an accessible and understandable manner can raise awareness in society about the valuable contributions made by women in STEM. Having more female scientists in STEM fields introduces diversity to research areas, leading to discoveries that benefit communities. Additionally, they serve as positive role models, challenging gender biases and emphasizing the importance of female mentorship to encourage lasting female presence in STEM.

Companies striving to achieve these goals can promote various programs and initiatives such as professional development, mentorship, scholarships, and partnerships with academic institutions. Collaborations with external organizations can amplify the commitment to diversity and inclusion, fostering knowledge exchange and resource sharing. Such exchanges can raise awareness among women in STEM through knowledge dissemination events, awareness campaigns, and joint projects. Pursuing these sustainable development objectives can also serve as a marketing tool to showcase commitment and garner more attention and visibility on these important issues, ultimately driving social and cultural change. This dissemination can also inspire other companies to show interest in and advocate for these causes.

A limitation of the research is the potential omission of certain relevant keywords. Future developments could involve expanding the sample of analysed tweets to include English tweets from Italy and using bot detection algorithms to filter automated accounts' influence. Replicating the study at a European level could provide a broader understanding of the situation across various countries.

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