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The Gender Equality Paradox in STEM Fields: Evidence, Criticism, and Implications

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Abstract

The gender gap in the fields of STEM (science, technology, engineering, mathematics, and computer science) in richer and more egalitarian fields compared to poorer and less egalitarian countries is called "Gender Equality Paradox" (GEP). We provide an overview of the evidence for the GEP, and respond to criticism against the GEP. We explain the GEP by the higher identity costs of women in wealthier countries due to an increase in the gender stereotype gap and at the same time lower increase in life satisfaction. We discuss why the GEP in wealthy countries in the future might undermine empowerment of women by increasing the gender pay gap within partnerships.

Key words: Gender stereotypes; women in STEM; gender pay gap, career aspirations, preferences, identity costs, power imbalances.

Introduction

The lack of representation of women in STEM subjects (science, technology, engineering, mathematics, and computer science) is a worldwide phenomenon. Remarkably, within wealthy countries like Switzerland and Sweden which at the same time are characterized by high levels of formal gender equality, the proportion of female STEM graduates is lower than in countries like Algeria or Morocco. For example, female STEM graduates in Switzerland make up 22 percent, in Germany 28 percent, in Sweden 36 percent, while in Morocco there are 45 percent, and in Algeria 58 percent of female STEM graduates.[1] The gender gap in STEM fields in richer

[1] https://genderdata.worldbank.org/indicators/se-ter-grad-fe-zs/?fieldOfStudy=Science%2C%20Technology%2C%20Engineering%20and%20Mathematics%20%28STEM%29&view=bar

and more egalitarian fields compared to poorer and less egalitarian countries is called “Gender Equality Paradox” (GEP). It contradicts the common assumption that as countries become wealthier and more gender equal[2], the preferences between women and men become more equal.

In our paper, we first provide an overview of the evidence for the GEP. Second, we respond to criticism against the GEP. Third, we try to explain why the share of women in STEM is lower in richer than in poorer countries. Fourth, we discuss why the GEP might matter, in particular for wealthy countries. Section five concludes.[3]

Empirical Evidence for the Gender Equality Paradox

In recent years, the GEP has been the subject of extensive research. Stoet & Geary (2018) are among the most cited authors studying this phenomenon. They find a negative cross-country correlation between what they term the "propensity of women to graduate with STEM degrees" and formal gender equality. The authors call it the ”educational-gender-equality paradox”. They used the 2015 PISA database, an every-3-year international assessment of half a million 15-year-old students in mathematics, reading, and science in 37 mostly developed countries and 39 developing countries, and calculated each student´s highest subject, second highest and lowest performing subject. The results on achievements in science, mathematics, and reading show that girls perform better in reading than boys, but at the same time perform similarly or even better than boys in STEM fields across most countries. However, women obtain fewer college degrees in STEM disciplines than men. Paradoxically, the loss of females graduating in STEM fields is higher in gender-equal countries. The study suggests two explanations for this finding. The first explanation is rational decision-making concerning the relative strength of women and men: According to expectancy-value-theory (Eccles, 1983; Wang & Degol, 2013) to decide about their educational choices, students use their knowledge of what subjects they perform best and enjoy most. The second explanation concerns economic opportunities and risks: in wealthy environments with more gender equality girls and women can afford to engage in subjects according to their individual interests. In contrast, in poorer contexts, girls and women tend to choose high-paying STEM occupations because of economic reasons.

[2] There is a strong positive correlation between a country’s Gross Domestic Product and measures of formal gender equality, see Duflo (2012).
[3] This article is a revised and supplemented version of Hizli, Osterloh and Mösching 2022.

A more recent study by Stoet & Geary (2022) investigates sex differences in adolescents' career aspirations across 80 countries using the 2018 PISA database. The study shows that boys are more likely to aspire to things-orientated or STEM careers, while girls tend to aspire to people-oriented occupations, leading to stereotypical male and female careers. In countries with higher levels of women's empowerment, these sex differences are more pronounced. The authors interpret this result from different economic backgrounds: an increase in women's empowerment leads to a higher national wealth, allowing students to pursue careers based on their interests rather than on economic considerations. The authors refer to this interpretation as the "Counter Intuitive Gender Empowerment Model" (CICEM). This model leads them to scepticism about policy interventions to reduce stereotypical careers. If anything, information about STEM can be provided at an early age, though there is no guarantee that such interventions would be effective. The authors propose more effective interventions, such as encouraging girls to pursue careers that are neither things- nor people-oriented, for example, careers in management.

The study of Thelwall and Mas-Bleda (2020) extends the GEP to academic research publishing. The study unravels the gender disparities among researchers in STEM by comparing the first-author gender in 30 million articles from various academic fields across 31 countries. In countries where there is a higher proportion of female first-authored research, disparities in gender across different academic fields are larger. These gender disparities are analysed and categorized as subject-wide or nation-specific. The results show that the proportion of female first authors varies to a large extent between the countries as well as the fields. Greater diversity between fields in the proportion of female first-authored research is found in countries and fields with more female researchers, suggesting that in these countries there is more leeway for cultural and biological sex differences in preferences. In order to enlarge the percentage of female researchers in STEM the authors suggest increasing gender differentiation in a more gender-equal academic environment.

Vishkin (2022) considers the GEP in chess participation. He shows that today women in countries with lower gender equality tend to participate more frequently than in the past. The study suggests a generational shift, with younger players participating more in countries with less gender equality. Additionally, a curvilinear effect is found, indicating that gender differences in chess participation are most pronounced at both the highest and lowest ends of the gender-equality spectrum.

Napp and Breda (2022) analyse how gender stereotypes concerning brilliance, talent, competitiveness, and self-confidence vary across countries and across students with different abilities. The authors use the PISA 2018 database. They measure the strength of gender talent stereotypes among a group of students by the average difference in the attribution of failure to lack of talent, comparing equally able boys and girls within this group. The authors show that stereotypes linking talent and brilliance to men are more pronounced in more developed and gender-egalitarian countries. They also observe similar patterns for competitiveness, self-confidence, and willingness to pursue ICT-related occupations. Moreover, the stereotypes associating talent primarily with men are larger among higher-ability students. The more women are present in education, labour force and politics, the stronger is this gender talent stereotype. The authors explain their findings by deeply rooted essential gender norms. Those norms are strengthened in wealthy and egalitarian countries by more individualistic values that give more importance to self-realization and self-expression.

Falk and Hermle (2018) establish a positive cross-country correlation between six fundamental preferences and economic development and gender equality.[4] These values comprise altruism, trust, risk-taking, patience, positive and negative reciprocity. The authors find a strong correlation between GDP per capita and the gender equality index. Both – economic development and gender equality - are associated with higher gender differences in fundamental preferences. The study uses data from the Global Preference Survey across 76 countries. The survey was validated by incentivized choice experiments and controlled for potential confounding factors. The authors explain their findings with better material and social resources available in wealthy countries. These resources eliminate the gender-neutral goal of subsistence and create scope for gender-specific ambitions and desires for self-expression.

Objections to the Gender Equality Paradox

The findings on the gender equality paradox have met some objections. Richardson et al. (2020) challenge the robustness of the Gender Equality Paradox, showing that it is sensitive to

[4] Falk and Hermle (2018) do not relate explicitly to the gender equality paradox.

measurement methods. Stoet and Geary (2018) find a negative cross-country correlation between the "propensity of women to graduate with STEM degrees" and formal gender equality. However, Richardson et al. (2020) demonstrate that the correlation between gender equality, as identified by Stoet and Geary (2018), and women in STEM shows small effect sizes and becomes insignificant when alternative measures of gender equality and of women in STEM are considered. In addition to this methodological criticism, two points have to be taken into account.

First, STEM is a broad designation, including biology, mathematics, physics, or mechanical engineering. The share of women within these fields varies strongly: more than 60% of students in biology are female, while the share of women in electrical or mechanical engineering is less than 20% (Federkeil & Friedhoff, 2022). To address this issue, some papers have introduced more narrow definition of scientific fields of study: For instance, Ceci et al. (2014, 2023) have categorized these fields into LPS (life sciences, psychology, and social sciences) and GEMP (geosciences, engineering, economics, mathematics/computer science). LPS-fields tend to have a higher share of women and GEMP-fields a lower share of women. Osterloh et al. (2023) distinguish between female-dominated fields of study (more than 70% of women) and male-dominated fields of study (more than 70% of men). A more precise classifications might lead to a different size of the GEP.

Second, the correlation between the "propensity of women to graduate with STEM degrees" and wealth or formal gender equality is based on cross-country data. However, "propensity of women to graduate with STEM degrees" is an individual disposition. Due to the "population fallacy"[5] one cannot simply infer from conclusions about countries to which those individuals belong to individual characteristics. Consider a scenario in which countries with a high average GDP consist of very few extremely wealthy individuals and many poor individuals, e.g. South Africa.[6] Migration can also lead to a "population fallacy". A high percentage of people with a migration background from poorer countries in a wealthy country (e.g. Switzerland) may have a great impact on the GEP.

Third, the GEP suggests causality between wealth and gender equality and gender-specific values. For example, Falk and Hermle (2018) propose as an explanation for their findings the

[5] According to the population fallacy, making assumptions about individual characteristics solely based on group-level data can lead to incorrect conclusions.
[6] In such cases, it would be suitable to consider the median instead of the average GDP per capita.

“resource hypothesis”. This hypothesis predicts that the greater availability and gender-equal access to material and social resources as well as the lower exposure of women to male influence reduces economic pressures. It opens opportunities for gender-specific ambitions and desires and contributes to the expression of gender-differentiated preferences across countries. The underlying assumption of the resource hypothesis is inherently different characteristics of men and women. The resource hypothesis thus assumes that affluence *causes* gender-differentiated preferences. However, causality can only be inferred by panel data or laboratory experiments. To our knowledge such data do not exist.

Nevertheless, numerous research papers show a cross-county association between affluence of a society, gender equality, and gender gaps in STEM. We acknowledge the difficulties in measuring this gender gap and refrain from assuming causality due to the absence of panel data or experimental evidence on the GEP. Therefore, in the next chapters, we focus on possible explanations of the observed positive correlation between wealth and gender gaps in STEM and why this matters for gender policy.

Possible explanations for the Gender Equality Paradox

Undoubtedly, there is greater financial security associated with STEM degrees which is particularly important for poor countries with little social security (Stoet & Geary, 2020). However, this applies equally to men and women. Why then increases the difference between the proportion of male and female STEM students with rising wealth and formal equality?

We try to explain this fact in four steps. In the *first* step, we draw on the empirical study by Breda et al. (2020). The authors show that the stereotype "math is not for girls" is more widespread in rich, egalitarian countries compared to poor, non-egalitarian countries. That is, horizontal gender norms are stronger. At the same time, in egalitarian, rich countries, a general superiority of men is rejected, as expressed for example in the statement "a university degree is more important for men than for women", i.e., vertical gender norms are weaker. Consequently, horizontal and vertical gender norms are negatively correlated.

To explain this empirical fact, in a *second* step, we combine it with the study by Falk and Hermle (2018). The authors state that the gender difference increases for several fundamental preferences in rich, egalitarian countries. In our context, the difference in altruism is particularly important. Consistent with this finding, Eagly et al. (2020) show that in the US over the past 80 years, as wealth has increased, the stereotyping of women as "communal" or caring has increased, but that of men has not. Thus, as wealth increases, gender preferences differ not only between but also within countries. The growing gender gap in altruism is important because most STEM careers are seen as incompatible with altruistic goals (Diekman et al., 2010). We conclude that in wealthy countries there is an increasing difference in preferences for STEM subjects due to the increase in stereotyping women as communal. Violation of such stereotypes causes identity costs (Akerlof and Kranton, 2000, 2010). As a result, identity costs increase for women who choose STEM subjects in rich, egalitarian countries. For men, these identity costs do not change.

Third, we draw on the result of happiness research, according to which there is a decreasing marginal utility of wealth (Layard et al., 2018; Frey and Stutzer, 2002). Higher income in STEM professions increases life satisfaction less in rich countries than in poor countries. At the same time, the identity costs for women in choosing STEM subjects increase. This leads to a relatively lower share of female STEM graduates in these countries. However, why the stereotyping of women as communal or caring has increased in rich countries remains unexplained.

As a result, we find some possible explanations for the initially counterintuitive "Gender Equality Paradox". However, we find no explanation for the increase of communal preferences of women in wealthy countries. We do not know whether this is due to "gender essentialism" or due to a deep history of learned cultural prejudices. Alesina et al. (2013) and Jayachandran (2015) show traditional cultural imprints of values and norms are very stable. As long as there are no panel data or experimental findings, causality cannot be claimed.

Why does the Gender Equality Paradox matter?

On the one hand the GEP might not be problematic, since the literature on subjective well-being has demonstrated that on average life satisfaction of women in wealthy countries is as high as that of men, even though they earn less and expect lower pensions than men (Schröder 2020). On the other hand, GEP may lead to an increasing gender pay gap between men and women, and therefore, lead to a power imbalance in partnerships that contradict factual gender equality.

For example, in Switzerland, Austria, and Germany, men earn about 20 percent more per hour than women (Eurostat, n.d.). This wage gap is partly due to the fact that women are less occupied in well-paid STEM professions. In Germany, graduates in academic STEM subjects earn 17% more than those in non-STEM subjects (Anger et al., 2021). In general, STEM-related education is associated with higher earnings (Kirkeboen et al., 2016).

As soon as children arrive, gender wage gaps and power imbalances increase. In Germany the part-time rate of women increases from 38 to 68 percent (Lott et al., 2022), and in Austria from 37 to 65 percent.[7] The wage difference between STEM and non-STEM professions apparently plays a role: the lower-earning mother will restrict her working hours more than the well-paid father with a STEM degree. Moreover, the mother's career prospects decrease when returning to a full-time job (Zweimüller, 2021), as well as her retirement income and, her income security in case of a divorce.

In addition, more female STEM graduates would counteract the shortage of STEM professions and promote innovation. The higher the share of female STEM graduates, the higher the number of female innovations (Niggli & Rutzer, 2021; Rutzer & Weder 2021). Increasing the share of women in STEM would therefore be beneficial at both the individual and the macroeconomic level.

Conclusion

The "Gender Equality Paradox" (GEP) reveals that richer, gender-equal countries have a larger gender gap in STEM graduation compared to poorer, non-gender-equal countries. This poses challenges as women earn more and face a smaller wage gap within STEM fields. We propose a theoretical explanation of the GEP. In rich, gender-equal countries, the stereotype that math is not for women is prevalent, leading to higher identity costs for women pursuing STEM careers. Also, the value of the STEM income premium is lower for women in such countries due to the decreasing marginal utility of money. For women in poor, gender-unequal countries, the opposite holds.

Overall, our considerations lead to a negative prediction for women's and men's income inequality and power imbalances as wealth increases. A first step to test the assumptions of our theoretical explanation would need to develop a measurement of identity costs in order to

[7] https://www.statistik.at/statistiken/arbeitsmarkt/erwerbstaetigkeit/familie-und-erwerbstaetigkeit

compare these costs in rich and poor countries. This would include an operationalisation of the concept of identity costs, which is still outstanding.

Further research is needed to explore two crucial aspects. First, it is important to investigate the correlation between the wealth of a country and its democracy index. High democratic values which might influence the choice of individuals concerning STEM subjects. Second, we need to understand why the preferences of men and women in wealthy countries diverge. Is it biology, inertia of norms, gender marketing or something else? Further investigations of these factors will provide valuable insights into the complex interplay of societal and individual influences on preferences and career choices.

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