

The Most Relevant Factors in the Gender Gap in European Countries

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Abstract: Gender equality is essential for the sustainable development of all countries. It brings economic growth, improved education and health for the entire population, poverty reduction, and social and political stability as democracy is strengthened and more peaceful communities are generated. However, its study is complex and includes various dimensions. This research aims to analyze the most relevant factors of the gender gap in European countries. The methodological strategy is based on machine learning techniques applied to the Gender Equality Index, which includes the EU27 countries and was developed by EIGE. These machine-learning techniques are methods computers use to learn from data and make predictions without being explicitly programmed. This index has 31 relevant indicators that are grouped into 14 subdimensions, which are, in turn, divided into six dimensions. The relevant dimensions in the study of gender equality are I. work (5 indicators), II. Money (4 indicators), III. Knowledge (3 indicators), IV. Time (4 indicators), V. power (8 indicators), and VI. Health (7 indicators). The results show a women's gap. Three of the most relevant dimensions from this research inhibit gender equity: I. Power in its three economic, political, and social dimensions; II. Knowledge in its two dimensions of attainment, participation, and segregation, and III. Time in its dimension of social activities. Women's most significant factors for the gender gap are power, knowledge, and time.

Keywords: Women; Gender Gaps; Gender Equity; Machine Learning; Knowledge; Power; Time; Gender Index; Sustainable Development Goals.

1. Introduction

Equality between women and men is a fundamental value of the European Union and an essential aspect of social rights. The EU is committed to promoting gender equality and has made significant progress. In the early 20th century, few countries allowed women to vote, own property, or work outside the home. Today, women can freely work, run businesses, and hold political office, making important life choices for themselves. This equality marks a significant advancement, yet substantial social and economic equality gaps between women and men remain. Progress has slowed or even regressed in areas like average earnings, management representation, the gender pay gap, and political representation, highlighting the urgent need for action to achieve gender equality (European Commission, 2023).

The study, analysis, and debate on gender equality and the policies to make it a reality have revolved around the approach called gender mainstreaming with the approval by the United Nations of the Beijing Declaration and Platform for Action in 1995, as a result of the Fourth World Conference on Women (Navarro, 2021), however, gender equality is not yet practical or accurate in the European Union.

Gender mainstreaming is the reorganization, improvement, development, and evaluation of policy-making processes so that the gender equality perspective is incorporated into all policies at all levels and stages" (Council of Europe, 1998; Lombardo, 2003; Navarro, 2021).

The problem of gender equity has been analyzed from different spheres of human behavior, highlighting the emphasis on organizational theories and public policy studies. However, despite the conceptual improvement and qualitative renewal of gender mainstreaming for equality policies, its capacity to change a profoundly unequal reality has shown its limits in practice. According to Navarro (2021), the distance between political discourse and real progress in terms of gender equality is marked not only by the practical difficulties in implementing the policies and actions designed but also by the very validity that defines and drives them.

Several international gender equality indices exist, including the United Nations Development Programmer (UNDP) Gender Inequality Index, the World Economic Forum Gender Gap Index, and the European Union Gender

Equality Index (EIGE-Index). Comparing them indicates a certain unanimity on a methodological and conceptual level; however, the EIGE was chosen for this research because it provides a better explanation of its indicators.

The Index produced by the EU Institute for Gender Equality (EIGE) measures gender gaps over time. It shows that progress has been made in the last decade, but progress has been slow, and there are still significant differences between countries. While most countries score relatively well on health and education, the same cannot yet be said for employment, access to economic and financial resources, or leadership, where the most progress has been made, but the gender gap remains the most comprehensive (European Commission, 2024).

For 2023, according to EIGE, the EU's gender equality score stands at 70.2 (out of 100 points), the most significant increase (+1.6 points) since the Index began to be compiled. Improvements were mainly recorded in the area of time, which covers indicators relating to the distribution of time between economic, care, and social activities. However, it should be noted that this gender gap was reduced not because men increased their contribution to unpaid domestic and care work but because women were able, on average, to reduce theirs, including through other means, such as the use of new technologies (European Commission., 2024).

Therefore, the European Commission (2020), in its strategy for gender equality, highlights the commitment of the Beijing Declaration and Platform for Action and the universal action plan to advance equality between women and men—to shape a better world for both women and men. That is under the Sustainable Development Goal on gender equality (SDG 5) and the status of gender equality as a priority across all SDGs¹², which it implemented four strategies: No violence or stereotypes, Focus on a gender-equal economy, Equality in leadership positions in all areas of society, and integration of the gender and intersectional perspectives in the policies of all EU countries.

In addition to the above, focusing on and being sensitive to stereotypes is essential. Stereotypes about how men and women think and behave are widely shared in different countries. However, empirical studies show that gender stereotypes affect how people pay attention to, interpret, and remember information about themselves and others. These stereotypes influence culture by widening the gender equality gap (Ellemers, 2018).

Gender statistics are vital for identifying inequalities between women and men and shaping global gender policies. The European Institute for Gender Equality, which developed the Index in 2013 and has enhanced it annually, conducts this analysis. The Index addresses women's well-being and quality of life, including socialization and health.

Derived from the previous problem, the questions that guide the research are: What are the dimensions with the highest impact on reducing the gender gap in European countries? What are the critical factors to reduce the gender gap in European countries? To uncover relationships between variables, the last question is, what are the best correlations between the various aspects of The European Institute for Gender Equality (EIGE) to reduce the gender gap in European countries?

2. Theoretical Framework

According to UNICEF (2017), gender equality is the equal appreciation by society of the similarities and differences between men and women and their roles. It implies that women's and men's rights, responsibilities, and opportunities do not depend on whether they are born male or female. Gender equality is a human rights issue and is considered a precondition for, and an indicator of, people-centered sustainability. It is about the fair and equitable treatment of both sexes that requires considering the different needs of men and women, cultural barriers, and (past) discrimination of the specific group (UNICEF, 2017).

Despite recent progress, women are still at a disadvantage due to different factors: on one hand, the more significant commitment to domestic chores, that has detrimental effects on the participation of women in labor markets, as found by Samtleben & Müller (2022) in a German based study. Related to this is the time dedicated to unpaid care work, that when valuated represents around 23% of the GDP in France (Ferrant & Thim, 2019). A second factor is the limited access to well-paid jobs, as it was found by Bamieh & Ziegler (2023), who confirmed that young women in Austria are less often hired for better-paying jobs. Thirdly, gender stereotypes (Manzi, *et al.*, 2024), and, in extreme cases, being denied the right to live, which has consequences for people's well-being and economic development.

Although tools, especially composite indicators, have been developed since the 1990s to assess countries' performance regarding gender equality, a historical perspective is lacking.

The discussion of gender inequality has gained importance over the last few years, with an impetus given by the 2030 agenda and the Sustainable Development Goals (SDG), including gender equality as SDG number five. However, it is not a new issue; previous studies have addressed this topic from different perspectives, such as inequalities in higher education (Jacobs, 1996), gender inequalities derived from religious preference, regional factors, and civil freedom (Dollar & Gatti, 1999), labor force participation and pay gap (England, 2005), gender differences in financial literacy (Potrich et al., 2017), or the impact of gender in well-being (Somarriba & Zarzosa, 2019) and on life expectancy (Pinho-Gomes et al, 2022), to name a few.

In addition to the recognition of gender gaps in different dimensions, several indices have been developed aiming to capture and represent the differences between men and women in various aspects of life and from international, national, and regional perspectives. Some of the first proposals were the Gender-related Development Index (GDI) and the Gender Empowerment Measure (GEM), introduced in 1995 by the United Nations Development Programme (UNDP). Still, although they received high recognition, some critics arose regarding methodological weaknesses and focused only on education, income, and health, disregarding areas such as employment (Schmid & Elliot, 2023; Bericat, 2012). The following indices incorporated more dimensions: political, legal, health, civil liberties, and physical integrity (Bericat, 2012).

All these indices have in common the purpose of measuring the gaps existing in different dimensions between men and women, and once the key factors are determined and evaluated, determine the steps needed to reduce those gaps. The difference among these indices relies on the areas or dimensions included. In the present study, the Gender Equality Index was selected as the reference that best describes the difference between men and women.

2.1 The Gender

The European Institute for Gender Equality (EIGE) has been tracking progress on gender equality since 2013, when the first edition of the Gender Equality Index was published. The background to EIGE stems from a Study to construct the basic structure of a European gender equality index, conducted by Janneke Plantenga, Colette Fagan, Friederike Maier, and Chantal Remery (2010) at the request of EIGE (European Institute for Gender Equality, 2012).

Gender equality manifests itself in different aspects of political, economic, social, or family realities. Structuring the Gender Equality Index into dimensions and sub-dimensions helps to understand in more detail what is happening in each aspect of reality. As Bericat (2012) stated, this index aims to “measure the availability of basic resources related to social status in these spaces, incorporating into its structure three basic dimensions: work, education, and power. The EIGE is specifically designed to measure to what extent and under what conditions women are incorporated into work outside the home, formal education, and positions of power” (Bericat, 2012, p.4).

In the 2023 report of the Index results, progress has been found on the time spent in care activities, the segregation and quality of work, the participation in decision-making in an economic sphere, and attainment and participation in education. However, inequalities persist in monetary terms, time spent in social activities, health status, and access to healthcare (EIGE, 2024). A brief comparison of the six dimensions that comprise the index and research literature is presented next.

2.1.1 Health

The variables analyzed in this dimension include self-perceived health, the life expectancy in years, the expected number of healthy life years, the percentage of people who do not smoke or are involved in harmful drinking, the percentage of people doing physical activities, the population without unmet needs for medical examination, and the population without unmet needs for dental examination.

The self-perceived health is evaluated as the percentage of people assessing their own health as “very good” or “good”, and the EIGE reported that the result of this indicator was 67% of women and 72% of men. The indicator of access-to-health-services remains as the variable with the highest score in this group, above 97.3 on a 100 basis.

In this regard, Alarcón-García et al. (2024) found differences in subjective well-being between men and women because women’s well-being is more related to access to nurseries for children up to 3 years old and to centers for people with disabilities. In contrast, Pinho-Gomes et al. (2022) confirmed that gender equality is correlated with narrowing the gender gap.

2.1.2 Money

The 2023 Gender Equality Index highlights Money as the second best-ranked dimension, focusing on financial resources, poverty risk, and income distribution. Despite progress, a gender gap persists in gross monthly earnings, with women's earnings constituting nearly 70% of equivalently qualified men's salaries, particularly among the highly educated and those aged 50-64 (EIGE, 2024). A study by Amate-Fortes et al. (2020) indicates that gender inequality is a significant factor behind income inequality in Europe and that government social welfare spending can help reduce this gap. It suggests that European governments should implement measures to equalize incomes between men and women.

2.1.3 Work

The sub-dimensions related to Work are the percentage of the population considered full-time workers, the duration of working life (years), the percentage of the population employed in Education, Human Health, and Social Work, the percentage of persons who can easily take an hour or two off, and the Career Prospects Index that evaluates job quality. In the 2023 Index results, this dimension ranked number 3, but it is mentioned that there are still sectors where women occupy jobs with lower remuneration and fewer options for upskilling.

The gender gap in the labor force remains an important area of improvement. Juhásová et al. (2023) mentioned that an analysis of the evolution of GDP per capita in 21 countries of the European Union showed that the female employment rate is the most statistically significant variable on GDP. Moreover, new challenges are foreseen when implementing technology, such as robotization. In this regard, Aksoy et al. (2020) suggest that a ten percent increase in the use of robots can lead to a 1.8 percent increase in the gender pay gap, mainly because men benefit from their medium- and high-skills occupations. Additionally, there is a critical gender gap in STEM areas in the labor market.

2.1.4 Time

The time dimension evaluates the percentage of people involved in caring activities for children, grandchildren, or older adults, the percentage of the population engaged in cooking and housework, the percentage of people doing sports, cultural or leisure activities, and the percentage of working people that participate in charitable activities. This dimension ranked number 4 in the 2023 Gender Equality Index. This low score is derived from the gender inequalities in social activities and the persistent gender gap in the time devoted to house chores.

Time analysis related to gender inequality and the time devoted to paid and unpaid work are also addressed. A study elaborated by Campaña et al. (2022) found significant cross-national differences by age across European countries in the time destined to unpaid work by gender in all age groups. They consider social norms and institutional conditions among the factors determining individuals' paid and unpaid work hours.

2.1.5 Knowledge

The knowledge dimension evaluates the percentage of tertiary education graduates, the percentage of the population participating in formal or non-formal education, and the percentage of the population studying in the fields of Education, Welfare and Health, Humanities, and Art. This dimension was the second lowest value in the 2023 EIGE Index. Inequality is due to segregation by studies, that is, to the more significant presence of women in studies related to education, health, well-being, and the humanities and their corresponding absence in science, technology, engineering, and mathematics studies.

The EIGE report on the 2023 index mentions that women tend to be more engaged than men in life-long education and training. According to Iñiguez-Berrozpe *et al.* (2020), after analyzing more than five thousand European women, participation in nonformal education activities provided them with more cultural participation, greater social confidence, and better health and employability. However, participation in both formal and non-formal education decreases with age. Verdugo-Castro et al. (2022) argue that although segregation does not occur in all countries, gender segregation in tertiary studies is a widespread trend among European countries. STEM fields are a clear example of this, where 63% of the students of Mathematics in the UK were men in 2018, and 70.41% in France (Verdugo-Castro et al., 2022).

The EIGE report on the Gender Equality Index remarks on the disadvantages women can face in accessing emerging labor opportunities from the green transition—environmentally friendly—which is expected to increase the demand for STEM-educated individuals. There is still an underrepresentation of women in these fields.

2.1.6 Power

The last place in the Gender Equality Index 2023 was for the Power dimension, where the share of female ministers, members of parliament, members of regional assemblies, members of boards in large companies, members of the central bank, members of the highest decision-making of research funding organizations, members in publicly owned broadcasting companies, and members of the highest decision-making body of the national Olympic sports organizations are evaluated.

Even though there has been essential progress from 2010 to the present, this remains the lowest score, “with uneven progress towards equality in decision-making across the EU Member States” (EIGE, 2024, p.13). A more excellent representation of women in social and political life may improve health, as Reeves et al. (2022) mentioned, because women are more likely to push forward dispositions and preferences different than those proposed by men. This study confirmed that countries with higher female political representation have achieved lower infant mortality and better life expectancy.

3. Methodology

This analysis uses the Gender Equality Index database from the European Institute for Gender Equality (EIGE, 2024), first published in 2013. It includes 31 indicators to assess gender equality and monitor progress across EU27 countries. The index is based on six key dimensions: I. Work, II. Money, III. Knowledge, IV. Time, V. Power, and VI. Health and it also addresses inequalities related to violence against women (Table 1). Scores range from 0 to 100, with 0 indicating no gender equality and 100 representing full gender equality. Machine learning techniques are used for data analysis.

Table 1: EIGE dimensions

Domain	Sub-domain	N	Indicator and reference population
Work	Participation	1	Full-time equivalent employment rate (% , 15+ population)
		2	Duration of working life (years, 15+ population)
	Segregation and quality of work	3	Employed people in Education, Human Health, and Social Work activities (% , 15+ employed)
		4	Ability to take an hour or two off during working hours to take care of personal or family matters (% , 15+ workers)
		5	Career Prospects Index (points, 0-100)
Money	Financial resources	6	Mean monthly earnings (PPS, working population)
		7	Mean equivalised net income (PPS, 16+ population)
	Economic situation	8	Not-at-risk-of-poverty, ≥60% of median income (% , 16+ population)
		9	S20/S80 income quintile share (16+ population)
Knowledge	Attainment and participation	10	Graduates of tertiary education (% , 15+ population)
		11	People participating in formal or non-formal education and training (% , 15+ population)
	Segregation	12	Tertiary students in the fields of Education, Health and Welfare, Humanities and Art (tertiary students) (% , 15+ population)
Time	Care activities	13	People caring for and educating their children or grandchildren, elderly or people with disabilities, every day (% , 18+ population)
		14	People doing cooking and/or housework, every day (% , 18+ population)
	Social activities	15	Workers doing sporting, cultural or leisure activities outside of their home, at least daily or several times a week (% , 15+ workers)
		16	Workers involved in voluntary or charitable activities, at least once a month (% , 15+ workers)
Power	Political	17	Share of ministers (% W, M)
		18	Share of members of parliament (% W, M)
		19	Share of members of regional assemblies (% W, M)
	Economic	20	Share of members of boards in largest quoted companies, supervisory board or board of directors (% W, M)

Domain	Sub-domain	N	Indicator and reference population
	Social	21	Share of board members of central bank (% W, M)
		22	Share of board members of research funding organisations (% W, M)
		23	Share of board members in publicly owned broadcasting organisations (% W, M)
		24	Share of members of highest decision-making body of the national Olympic sport organizations (% W, M)
Health	Status	25	Self-perceived health, good or very good (% , 16+ population)
		26	Life expectancy in absolute value at birth (years)
		27	Healthy life years in absolute value at birth (years)
	Behaviour	28	People who don't smoke and are not involved in harmful drinking (% , 16+ population)
		29	People doing physical activities and/or consuming fruits and vegetables (% , 16+ population)
	Access	30	Population without unmet needs for medical examination (% , 16+ population)
		31	People without unmet needs for dental examination (% , 16+ population)

Source: EIGE (2024)

The countries of the EU27 analysis are Germany, Austria, Belgium, Bulgaria, Czech Republic, Cyprus, Croatia, Denmark, Slovakia, Slovenia, and Spain. Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, and Sweden.

The analyzed dataset consists of 29 variables and 97 instances obtained from the EIGE indicators and countries reported. During the preprocessing stage, we ensured data integrity and removed any EIGE variables related to men, as our focus is specifically on women. We selected the Gender Equality Index as the target variable and ranked the features according to their correlation with it, utilizing the ReliefF scoring method. It aims to select the most relevant variables for the classification, with the EIGE as the target variable.

ReliefF is an enhancement of the original Relief algorithm, which evaluates a feature's ability to differentiate between classes in similar data instances. It assigns a feature score to each attribute, allowing for the ranking and selection of the top-performing features for feature selection tasks. ReliefF can detect conditional dependencies among attributes and offers a cohesive perspective on attribute estimation in regression and classification contexts. Moreover, the quality estimates produced by ReliefF are intuitively interpretable. The original Relief algorithm, as described by Kira and Rendell in 1992, estimates the quality of attributes based on how effectively their values distinguish between instances.

The next step was to measure the Pearson correlations among features, where Pearson's correlation coefficient is the covariance of the two variables divided by the product of their standard deviations (Ghaffarpour & Hansson,2021).

Then, the clustering ML technique was applied to group the countries according to their similarities. We used the k-means clustering algorithm to the dataset and generated a new version that includes the cluster labels as a meta-attribute. Additionally, the widget displays the silhouette scores for the clustering results across different values of k. In this context, a higher silhouette score indicates more effective clustering.

The last analysis applied was time series, a type of visualization of time series data in which the data points are arranged in a grid to show the tendency of the Gender Index over time. This analysis has reviewed available information on the EIGE from 2013 to 2023.

4. Results, Discussion, and Conclusions

The EIGE measures gender equality in each country and breaks it down into different dimensions. With a score of 88 points, health was the most equal dimension between men and women in the European Union. In contrast, power, knowledge, and time management were considered the most unequal dimensions.

Spearman's correlation assesses the strength and direction of the association between two ranked variables. It measures the monotonicity of the relationship between them. Spearman's correlation evaluates monotonic relationships. This means it can capture relationships where variables move in the same direction but not necessarily at a constant rate; the Spearman correlation coefficient ranges from -1 to 1. A value of 1 indicates a perfect positive monotonic relationship, -1 indicates a perfect negative monotonic relationship, and 0 indicates

no monotonic relationship. Binary correlations between the variables in the dataset under study are listed in Table 1.

Table 2: Spearman's correlation between variables

Feature 1	Feature 2	Correlation
Income distribution S20/80 W	Not at-risk-of-poverty (%) W	0.881
Share of members of parliament (%) W	Share of ministers (%) W	0.865
Share of members of parliament (%) W	Share of members of regional assemblies (%) W	0.839
Employed people in education, human health, and social work activities (%) W	People doing physical activities and consuming fruits and vegetables (%) W	0.815
Share of members of boards in largest quoted companies, supervisory board or board of directors (%) W	Share of members of parliament (%) W	0.814
People doing physical activities and consuming fruits and vegetables (%) W	People participating in formal or non-formal education (%) W	0.813
Career Prospects Index (points, 0–100) W	People who do not smoke and are not involved in harmful drinking (%) W	-0.561
People caring for and educating their children or grandchildren, elderly, or people with disabilities every day (%) W	People participating in formal or non-formal education (%) W	-0.609
Duration of working life (years) W	People caring for and educating their children or grandchildren, elderly, or people with disabilities every day (%) W	-0.611
Employed people in education, human health, and social work activities (%) W	People caring for and educating their children or grandchildren, elderly, or people with disabilities every day (%) W	-0.633

In this way, Figs. 1 and 2 show the most positively correlated variables, with a Spearman coefficient close to 1 (0.881). This correlation could express the importance of women's participation in decision-making and power groups in countries.

A notable negative correlation exists between "People employed in education, health, and social work" and "those who care for and educate children, the elderly, or people with disabilities daily," with a Spearman's coefficient near -1 (-0.633)(Fig. 3).

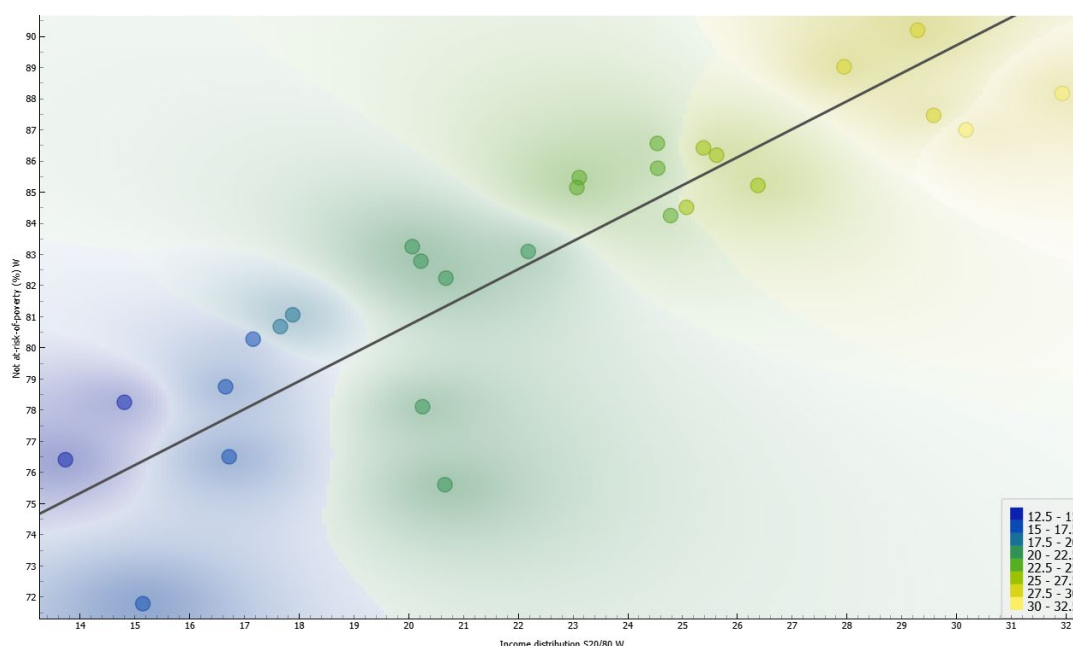


Figure 1: Spearman positive correlation between Income distribution vs Not at-risk-of-poverty (Women).

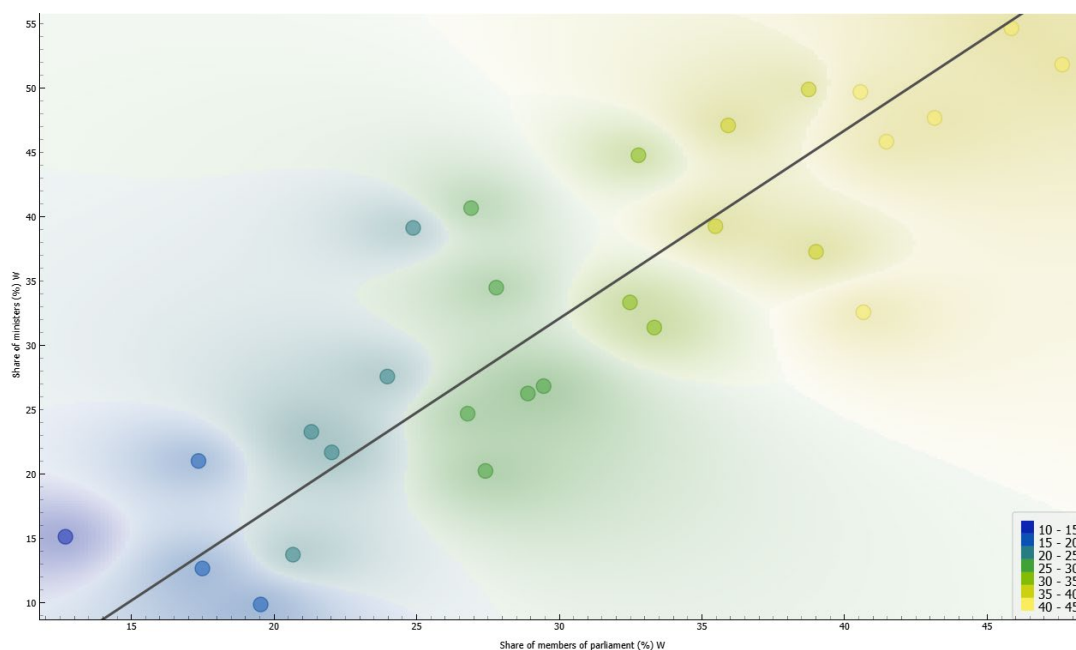


Figure 2: Spearman positive correlation for Share of members of parliament (women) vs Share of members of ministers (women).

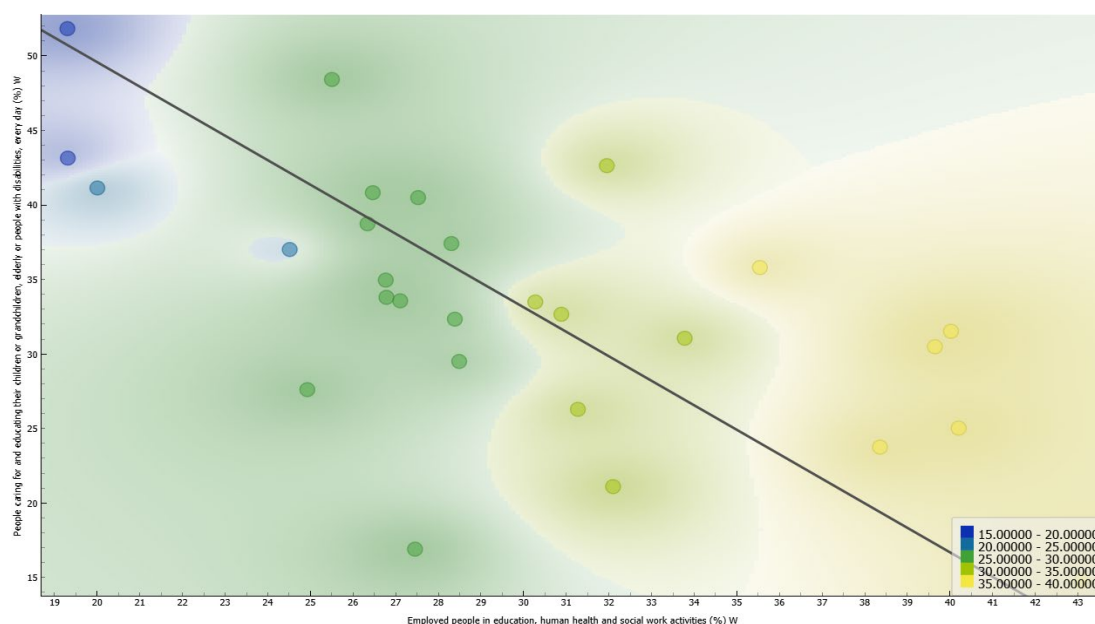


Figure 3: Spearman negative correlation for "People employed in education, human health, and social work activities" and "People who care for and educate their children or grandchildren, elderly people or people with disabilities every day."

Once the most relevant correlations were obtained, clustering techniques were applied to group countries according to their characteristics. Three clusters were found, indicating the shared attributes between countries in 2023. The similarities constructed three European countries' blocks, where Cluster 1(C1) is comprised of Bulgaria, Czechia, Estonia, Greece, Croatia, Latvia, Lithuania, Hungary, Poland, Portugal, Romania, and Slovakia; Cluster 2(C2) is comprised of European Union, Belgium, Denmark, Germany, Ireland, Spain, France, Italy, Cyprus, Malta, Netherlands, Austria, Slovenia, Finland, and Sweden; the Cluster 3 (C3) has just Luxemburg. C2 is the most favored group, constructed by the wealthiest countries in the analyzed set.

To give a perspective over the years, a Time series, considering data for 2013 to 2023, obtained the following trends for some selected variables considering their change over time (Fig 4 and 5). The variables that changed notably are Employed people in education, human health, and social work activities, Mean Equalized net

income, Share of members of boards in largest quoted companies, supervisory board or board of directors, Healthy life years at birth, and Carrier Prospects Index.

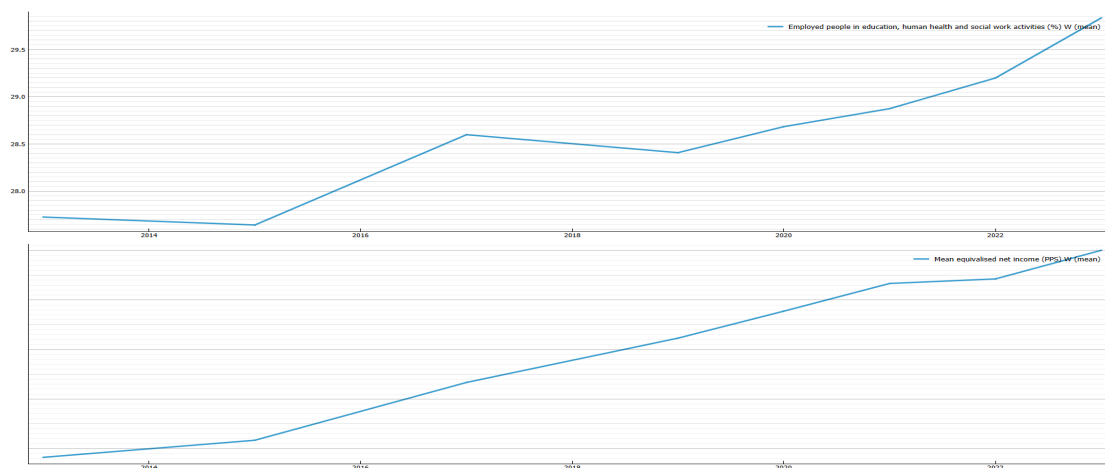


Figure 4: Tendency of the variables Employed people in education, human health, and social work activities, Mean equivalized net income from 2013 to 2023

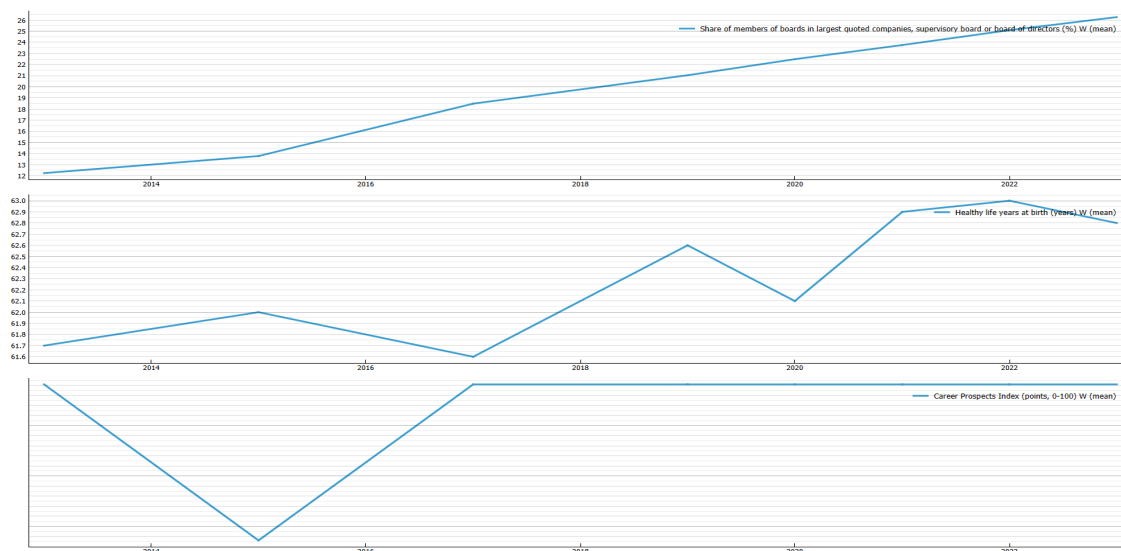


Figure 5: Tendency of the variables supervisory board or board of directors, Healthy life years at birth, and Carrier Prospects Index.

5. Conclusions

The Index measured by the European Institute for Gender Equality (EIGE) has experienced steady growth since 2013, with a notable acceleration in 2023. This progress is promising, but it is crucial to implement policies for gender equality soon. Equal opportunities for both sexes lead to improved economic growth and social well-being. Gender equality benefits everyone and is vital for societal advancement. Promoting equitable income distribution is essential to reduce poverty. Research suggests that European countries should increase the number of women in ministerial positions, particularly in education, healthcare, and social work. Additionally, encouraging women's socialization through physical activity and good nutrition is essential.

The analysis revealed strong correlations between women's participation in high-ranking positions—such as ministers, members of parliament, and company boards—and the opportunities within the power dimension of the Gender Equality Index (EIGE). Increasing women's representation in these roles can promote equality in power and benefit other social areas through policies that women typically support. Progress has been made in some countries, but there are still areas of regression, especially regarding unpaid work. Domestic workers often

face violence due to entrenched stereotypes. To address these issues, policymakers must create programs that raise awareness and work towards reducing the gender gap.

A deeper analysis of gender gaps in European countries reveals two distinct regions: Western and Eastern Europe. This division raises concerns about gender equality disparities that need further examination.

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