Measuring Women's Digital Inclusion. A poset-based approach to the Women in Digital Scoreboard

Abstract

Women's participation in digital society is integral to achieving Agenda 2030 and an essential component in the EU strategy for digital transition. This article applies a poset-based approach to the European Women in Digital (WiD) Scoreboard, to examine women's digital inclusion in European countries. The poset methodology allows us to identify the most significant indicators for each of the dimensions that compose the WiD, considering the whole EU-28 as well as different clusters of countries, and to construct a new ranking that avoids the shortcomings of the aggregative approaches and the pre-treatment of data. Our results show that two indicators, STEM graduates and the unadjusted pay gap, are the most relevant ones in attaining women's digital inclusion. Our research contributes to better understand the dynamics and the underlying causes of women's digital inclusion in the EU-28 countries, providing a clustering of EU countries into four performance groups depending on their women's digital inclusion and contributes to the design of more targeted and effective policies for integrating gender equality in the EU digital transition strategy.

Keywords

Digital Economy, women's digital inclusion, digital transition, gender digital divide, poset

1. Introduction

Recent decades have seen how digital technologies transform the world of work (JRC, 2019). Using digital technologies for professional purposes has become a prerequisite for successful integration of workers into the digitalised economy. The COVID-19 pandemic has accelerated the pace of digitalisation in our societies and economies. This digital transformation of the labour market creates both opportunities for and risks to gender equality.

Although gender differences in digital skills and use of digital devices are gradually levelling out in the EU, particularly among young people, still women are behind men in the use of various ICT technologies at work (EIGE, 2020). Studies show that gender inequalities continue to prevent women from reaching their full potential and hinder EU societies from taking full advantage of women's digital potential and current contributions (European Commission, 2018). A study from EIGE (2017) shows that closing gender gaps in STEM education would have a positive impact on employment, with total EU employment foreseen to rise from 850 thousand to 1.2 million jobs by 2050. Consequently, this would imply an increase in EU GDP per capita from 0.7% to 0.9% by 2030 and from 2.2% to 3% by 2050. The productive capacity and the competitiveness of the EU would clearly increase (Norlén, Papadimitriou & Dijkstra, 2019).

These findings confirm that gender inequalities continue to prevent women from reaching their full potential and hinder EU societies from taking full advantage of women's digital potential and current contributions (European Commission, 2018). Gender equality needs to be introduced as a primary objective in the EU strategy for digital transition, incorporating the measurement of advances in digitalization for women and men as an essential component of this strategy. The monitoring of the effectiveness of public policies governing digital transition (Bánhidi, Dobos & Nemeslaki, 2020) is even more important in the post-COVID-19 economic recovery, in which digital services are becoming a key driver of our economic growth, making the Digital Europe program an essential part of the recovery plan. At least 20% of Next Generation EU will fund investments in digital, which means, roughly, €150 billion.

However, statistical data on digital inclusion are scarce and usually not disaggregated by gender. The Women in Digital (WiD) Scoreboard, formulated in 2019, is one of the few and most recent mechanisms put in place by the European Commission to assess women's inclusion in digital jobs, careers and entrepreneurship. The WiD index, which is part of the Digital Economy and Society Index, brings together twelve relevant indicators to assess the performance of Member States in the areas of Internet use, Internet user skills as well as Specialist skills and employment. The index was constructed to obtain a general characterisation of the performance of individual Member States by observing their overall index score and the scores of the main index dimensions, to pinpoint the areas where performance could be improved and to assess progress over time (European Commission, 2020b). The WiD Scoreboard presents a ranking of countries using a simple arithmetic mean of the twelve normalised indicators.

Using the poset-based approach (poset, for short), in this study we construct a new ranking which fully exploits all information present in the dataset and reduces the need for subjective choices (Badinger & Reuter, 2015). Poset allows to obtain a ranking avoiding the use of aggregation methods (Fattore, 2016; Fattore & Arcagni, 2018; Ivaldi, Ciacci & Soliani., 2020) and without pre-treatment of data: the performance can be evaluated considering all indicators simultaneously (Carlsen & Brüggemann, 2017). Therefore, the poset methodology is useful to overcome the curse of dimensionality without using a parametric model or introducing some subjective criteria. We compare our ranking and the ranking proposed by the Women in Digital Scoreboard for 2020, identifying similarities and differences. By applying the poset-based approach, we can also identify the most significant indicators for each of the three dimensions that compose the WiD, considering both the whole EU-28 and four different macroregions. Our findings about the different significance of indicators depending on the region contribute to identifying areas where policy intervention continues to be needed and to the design of more targeted and effective policies for integrating gender equality in the EU digital transition strategy. Additionally, our analysis provides a clustering of EU countries into four performance groups depending on their level of women's digital inclusion. Although the poset methodology has been already applied to socio-economic issues (Annoni & Brüggemann, 2009; Carlsen & Brüggemann, 2016; Carlsen, 2017; Iglesias et al., 2017; Arcagni et al., 2019; Fattore & Arcagni, 2019), also related to gender discrimination (Di Bella et al., 2018; Di Brisco & Farina, 2018), it has not been applied previously to the analysis of the WiD.

This article is structured in five sections. Section two presents a literature review of women's digital inclusion within the European Union framework. The third section defines the data and methods, describing the Women in Digital (WiD) Scoreboard, its dimensions and the poset methodology. The fourth one presents the results of the application of the poset methodology to study the different dimensions of WiD in the whole EU-28 and in 4 macroregions in which we divide the EU. The last section presents the discussion of findings as well as the limitations of the study.

2. From the digital gender divide to women's digital inclusion

Research on the digital gender divide and women's digital inclusion can be segmented in three main phases. Early feminists and gender studies on the digital revolution were largely optimistic about the potential of digital technologies to empower people. Women were considered as a 'disadvantaged' group that just needed support to reach a level of ICT access like the average of the population. This first-order digital gender divide referred only to the lack of adoption or access to ICT.

However, the second wave of digital divide studies from a gender perspective detected that access to technology alone does not lead directly to more social opportunities and highlighted how digital skills acquisition and uses of the internet are also gender stratified (Castaño, Martín & Martínez, 2011; Helsper, 2010; van Deursen and van Dijk, 2019). The second-order digital divide represents the ICT usage and the proficiency of ICT usage. Technology is gendered, and digital technologies form part of the structure and performance of gender inequalities (Wajcman, 2010; Wyatt, 2008). Digitalisation holds the potential to reorganise gendered work relations since the patterns of the gender division of labour are shaped, negotiated, or affected by digitalisation (Kohlrausch & Weber, 2020). In fact, despite the measures implemented to enhance women's digital skills and to increase the participation of women in the ICT workforce, studies show that disparities on digital skills gaps by gender are still more marked at the highest levels of skills. Gender gaps in the EU are still larger in the higher and more specialized levels of skills, which are broadly considered as key factors for future digital inclusion and employment (OECD, 2018). Women are less engaged in digital technologies, information-seeking activities, content sharing or contributions to free/open collaborative platforms (Hargittai, 2010; Hargittai and Shaw, 2015; Helsper and Eynon, 2013).

Therefore, a third level of digital divide studies focuses on quantifying the impact of the unequal distribution of benefits of internet use (Quan-Haase, Martin & Schreurs, 2016; Meri-Tuulia, Antero & Suvi-Sadetta, 2017; Sáinz, Arroyo & Castaño, 2020; Scheerder, van Deursen & van

Dijk, 2017; van Deursen & Helsper, 2015). The third digital gender gap refers to this differentiated use of the most advanced ICT technologies and applications. The recently created EU Women in Digital Scoreboard confirms that there is still a substantial gender gap in specialist digital skills. According to the WiD Scoreboard, even in those Member States where gender mainstreaming is more advanced, 'stereotypes and preconceptions' continue to create obstacles for women and girls (European Commission, 2019) and gender differences have persisted fairly stable along these years (Martínez-Cantos, 2017). These findings are in line with other longitudinal studies from particular contexts, such as the Netherlands, where the gender differences regarding digital skills have remained consistent in recent years (van Deursen & van Dijk, 2015; van Deursen, van Dijk & ten Klooster, 2015).

The digital gender divide becomes even more pronounced when it comes to women as creators of technology. Women are still under-represented in information and communication technology (ICT) jobs, top management and academic careers. This pattern applies to almost all developed countries and is largely independent of the country's level of economic development (Sorgner et al., 2017). Though 57% of tertiary graduates in the EU are women, only 20% of tertiary graduates in ICT-related fields are women and the share of women in ICT jobs is 19% (EIGE, 2020; European Commission, 2021b). There is no progress, as these figures have been stable over the last few years, but the 2030 Digital Compass has set the target that the EU should have 20 million employed ICT specialists, with convergence between women and men, by 2030 (European Commission, 2021a).

Beyond ICT, a striking gender gap exists among scientists and engineers in the high-technology sectors likely to be mobilised in the design and development of new digital technologies. In 2019, across the EU, there were close to 32 million scientists and engineers employed in high-technology sectors, of whom only one fifth were women. And even when women do study STEM, they face a glass ceiling preventing them from holding senior positions. Software development is also a male-dominated club. The majority of software packages are still authored by men. Start-ups and venture capital investment point to socio-cultural gender bias in equity financing: 93% of innovative start-ups seeking venture capital investments have been founded by men, women-owned start-ups receive 23% less funding and are 30% less likely to have a positive exit (European Commission, 2019; OECD, 2018). In summary, STEM sectors do not seem to be able to incorporate, retain and promote women properly. Gender inequalities remain and generate equity and efficiency problems that hamper economic growth and welfare for all, but especially for women (Vergés et al., 2021).

Summing up, while a number of positive policy developments can be noted, major challenges remain if gender equality in the digital world of work is to be achieved. One of the main challenges is the development of gender-specific and gender-sensitive indicators and indices that provide insights into the depth and breadth of women's digital inclusion, since ICT-focused indices which include gender dimensions have a relatively short history (Brimacombe & Skuse, 2013) The EU digital strategy 'Shaping Europe's digital future' (European Commission, 2020a) and the EU gender equality strategy 2020–2025 are the last steps taken by the EU for the integration of a gender perspective in this area. These initiatives are placing an emerging emphasis on the collection of sex-disaggregated data and development of indicators. However, the Women in Digital Scoreboard is still the only measurement framework to monitor the progress of European countries towards women's digital inclusion. Therefore, in this study we critically analyse it using the poset methodology, construct a more refined ranking and examine the differences by macroregions and clusters of countries.

3. Materials and methods

The Women in Digital (WiD) Scoreboard is part of the Digital Economy and Society Index (DESI) and assesses in detail women's participation in the digital economy in the EU-28 countries. It is based on 12 indicators divided in three dimensions (European Commission, 2020c), namely internet use, internet user skills, and specialist skills and employment.

The first dimension (internet use) is composed of six indicators, listed as follows: *1.1 % of women who use the internet at least once a week*; *1.2 % of women who never used the internet*; *1.3 % of women who used the internet in the previous three months to use online banking*; *1.4 % of women who used internet in the previous three months for doing an online course*; *1.5 % of women who used internet in the previous three months for taking part in on-line consultations of voting to define civic or political issues*; *1.6 % of women internet users who, during the previous year, needed to send filled forms to the public administration*. The breakdown for the indicators of this dimension is all females aged 16-74, and the source of the data is the Community survey on ICT usage in households and any individuals, provided by Eurostat.

The second dimension (internet user skills) consists of three indicators, which are: *2.1 % of women with basic or above basic digital skills in information, communication, problem solving and software for content creation*; *2.2 % of women with above basic digital skills in information, communication, problem solving and software for content creation*; *2.3 % of women who have used advanced spreadsheet functions, created presentation or document integrating text, pictures and tables or charts, or written code in a programming language*. The breakdown and the source of the data are the same of the ones of the first dimension.

The third dimension (specialist skills and employment) contains the last three indicators of the index: *3.1 Women graduates in STEM per 1000 individuals ages 20-29*; *3.2 % of women aged 15-74 employed ICT specialist based on the ISCO-08 classification*; *3.3 Gender pay gap in unadjusted form, considering all employees working in firms with ten or more employees*. The source of the data of this dimension is Eurostat questionnaire on education statistics, the labour force survey, and the structure of earnings survey. Indicator 3.3 measures the difference between male's average gross hourly earnings and female's one as a percentage of male's average gross hourly earnings.

In the WiD index 2020, all the indicators are considered of equal importance, and the aggregation of the indicators into the three dimensions and into the overall index is constructed as the simple unweighted arithmetic average of the normalised scores. In this paper, we use the normalised scores available from the Women in Digital website. No missing data are detected. The data matrix considered in this study is composed of 28 countries and 12 indicators; hence, the total number of observations is 336.

In this study we apply the partial order theory –or poset-based approach–, a discipline associated with discrete mathematics, in which the objects of a data set, composed of multiple indicators, are compared and ordered to obtain a ranking (Brüggemann & Patil, 2011). According to the poset theory, one object could be considered better than another if and only if it has better performance in all indicators of a data set, or, alternatively, if it is better performing in just one indicator and it ties in all the others. Furthermore, all the ordered pairs of objects could be graphically represented in the so-called Hasse diagram.

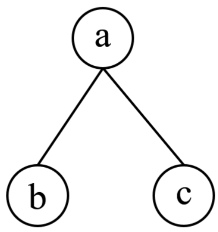
In the analysis presented in this work, the first step consists in the identification of the Hasse diagram, which represents the relations between the 28 countries according to their scores considering all 12 indicators together. To better understand poset's theory, consider the example in Table 1, identifying three countries (A, B, and C) and three indicators (q_1, q_2, and q_3).

Table 1 – Example: three countries (a, b, and c) and three indicators (q_1, q_2, and q_3)

Country	q_1	q_2	q_3
A	4	3	2
B	3	2	2
C	4	2	0

In the poset analysis it is crucial to compare all countries based on all indicators. Therefore, we could say that country A is better than both country B and country C since, even if it ties in q_3 with country B and in q_1 with country C, it shows a higher score on all other indicators. What is not possible to compare is country B with country C: country B shows a higher score in q_3 (2 > 0), but a lower score in q_1 (3 < 4); hence, country B is incomparable with country C. The relations among the comparable countries are country A > country B as well as country A > county C. At the same time, country B || country C (where || is the sign to represent incomparability). Figure 1 shows the Hasse diagram of our example.

Figure 1 – Example: Hasse diagram



The second step of the analysis includes the identification of the downset of any country as well as the incomparabilities in order to construct the ranking of the countries. The downset of country x consists of those countries y such that $y \leq x$; its cardinality is denoted as D(x). If $y < x$ for one or more indicators and $y > x$, then x and y are incomparable; the number of countries that are incomparable with a country x is denoted as I(x). In our example, we obtain the results as shown in Table 2.

Table 2 – Example: downsets and incomparabilities of the objects, in numbers.

Country	*D(x)*	*I(x)*
A	3	0
B	1	1
C	1	1

According to Table 2, the downset of country A is composed of three elements (country A itself, country B, and country C). To rank the countries, we apply the Local Partial Order Model (LPOM), where the "final score" of the countries is a function of D(x) and I(x). The formula to compute the "final score" of is as follows (Brüggemann & Patil, 2011):

$$\delta(x) = D(x)\ [(n+1)/(n+1-I(x))] \quad (1)$$

where *x* is the country of interest and *n* indicates the total number of countries, in our example, *n* = 3. For instance, the score of country A, applying the formula, is: 3 * (3 + 1) / (3 + 1 – 0) = 3 * 4 / 4 = 3. By contrast, the score of both countries B and C is: 1 * (3 + 1) / (3 + 1 – 1) = 1 * 4 / 3 = 1,33. Thus, we obtain the following ranking: first position for country A and second position for both countries B and C (tie). If we create a ranking by simply computing the unweighted arithmetic average, we will obtain a different ranking with country B better ranked than country C. In our analysis we will use the LPOM to create the ranking considering first the whole dataset, and then we will repeat the same process for each of the three dimensions of indicators.

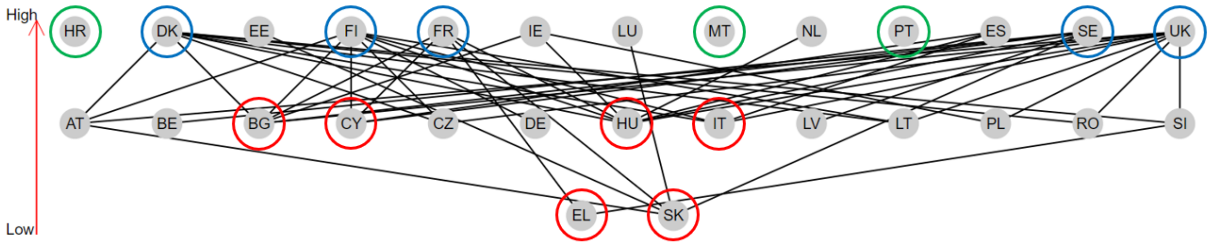
The third step of the analysis consists in the detection of the most significant indicators for each of the three dimensions through the "attribute-related sensitivity" analysis. The aim is to examine how an indicator influences the position of the countries in the Hasse diagram by removing one indicator from the data matrix (Brüggemann & Patil, 2011).

Our goal is to find the four out of six most important indicators of dimension 1, and the two out of three most relevant indicators of both dimension 2 and 3. We will conduct this analysis considering first the whole 28 countries and then just the countries of each of the four European macroregions (northern, western, eastern, and southern Europe) to examine in-depth regional variations. The last step of the analysis is the comparison between our results and the results of the Women in Digital Scoreboard for 2020, identifying similarities and differences among both rankings. The poset-based approach is applied using the online software called "PyHasse", available at https://posets.pyhasse.org/.

4. Results

In this section, we present the main results of the analysis, starting from the first step of the analysis, namely the Hasse Diagram of the 28 countries considering all the 12 indicators of the three dimensions (Figure 2).

Figure 2 – Hasse Diagram, 28 countries and 12 indicators



Source: Own elaboration based on WiD data.

The Hasse Diagram shows the connections between the countries analysed according to their data. The lines connecting two countries reveal that the country in the higher level is better than the country in the lower level, since it has higher scores in all the 12 indicators. On the one hand, the countries circled in blue (Denmark, Finland, France, Sweden, and United Kingdom) are in a higher-level respect to, at least, five countries; on the other hand, the countries circled in red (Bulgaria, Cyprus, Greece, Hungary, Italy, and Slovakia) are low-performing states in all indicators respect to, at least, five countries. The three countries circled in green (Croatia, Malta, and Portugal) are incomparable with all other countries; this means that they are very good performing in at least one indicator, as well as very low performing in other indicator(s).

From the Hasse Diagram it is now possible to move on to the second step of the analysis: to compute the downsets and the number of incomparabilities of each country, for calculating the final scores using the Local Partial Order Model (LPOM), and then constructing our own ranking, according to Figure 3.

Figure 3 – Ranking of the countries according to their scores obtained as a function of the downsets and the incomparabilities

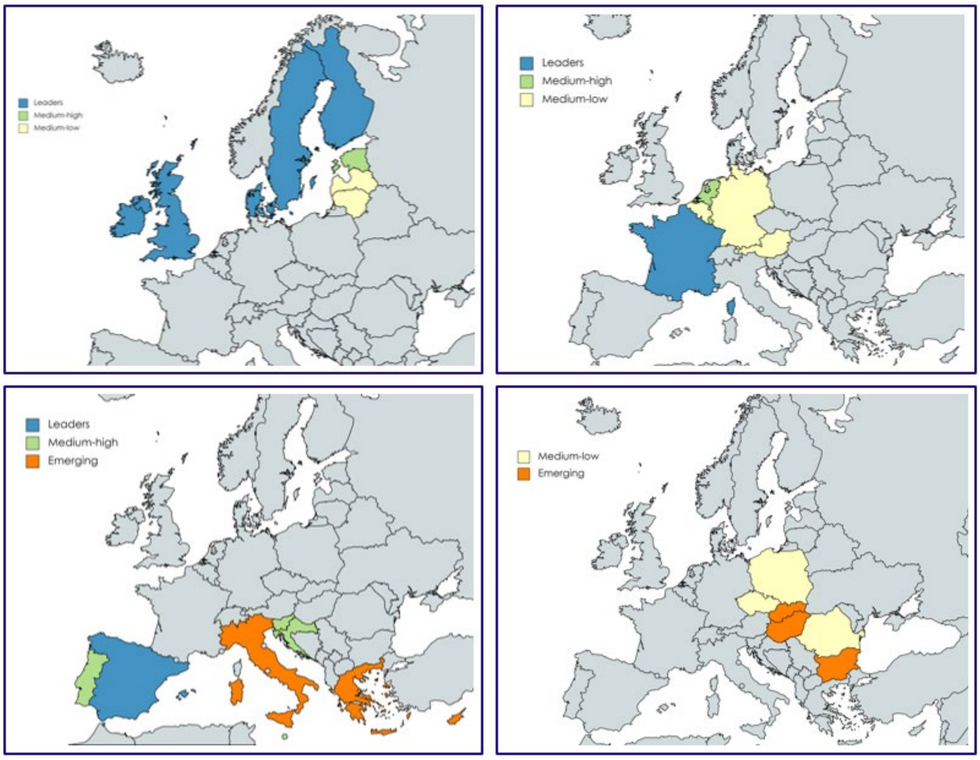
Rank	Country	downset	incomp	Score	Rank	Country	downset	incomp	Score
1	United-Kingdom	12	16	26.77	15	Austria	2	23	9.67
2	Denmark	11	17	26.58	15	Belgium	1	26	9.67
3	Finland	10	18	26.36	15	Germany	1	26	9.67
4	Sweden	7	21	25.38	15	Latvia	1	26	9.67
5	France	6	22	24.86	19	Poland	1	25	7.25
6	Ireland	4	24	23.20	19	Romania	1	25	7.25
6	Spain	4	24	23.20	21	Czechia	1	24	5.80
8	Estonia	2	26	19.33	21	Lithuania	1	24	5.80
8	Luxembourg	2	26	19.33	23	Cyprus	1	23	4.83
8	Netherlands	2	26	19.33	23	Greece	1	23	4.83
11	Croatia	1	27	14.50	23	Italy	1	23	4.83
11	Malta	1	27	14.50	26	Bulgaria	1	21	3.63
11	Portugal	1	27	14.50	27	Hungary	1	19	2.90
14	Slovenia	2	24	11.60	27	Slovakia	1	19	2.90

Source: Own elaboration based on WiD data.

The countries are grouped in four categories depending on their final score. Blue represents the "women digital participation leaders" (leaders, for short) with a final score higher than 20; green is the "medium-high women digital participation" group (medium-high, for short) with a final score between 10 and 20; in yellow the "medium-low women digital participation" group (medium-low, for short) is identified with a final score between 5 and 10; finally, red represents the "emerging women digital participation" group (emerging, for short) a final score lower than 5. All groups are composed of seven countries except the medium-low group (in yellow), which counts eight countries since Czechia and Lithuania have the same score.

To discuss this ranking, we should look at the downsets: 12 countries have greater results in all indicators with respect to at least one country (downset greater than 1). The largest downset is the United Kingdom's one: the UK has higher scores than 11 countries in all indicators. Hence, the UK leads the ranking thanks to its good performance in all indicators. By contrast, the countries with the downset equal to 1, are underperforming in at least one indicator respect to all other countries; 16 countries are in this situation, and their final score drops as the number of incomparabilities decreases, which means that the number of countries with better results in all the indicators of the dataset increase. According to our results, the last positions of the ranking are occupied by Hungary and Slovakia: they both present incomparabilities with 19 countries, which means that 8 different countries have higher scores in all indicators with respect to them. We show these results also in Figure 4 through political maps, one for each of the four macroregions.

Figure 4 – Results of the poset analysis considering all three WiD 2020 dimensions. Clockwise from top left: northern Europe, western Europe, eastern Europe, southern Europe.



Source: Own elaboration based on WiD data.

Figure 4 shows that the results significantly differ among the macroregions. Northern European countries are all in the leaders' group, except the Baltic countries (Estonia is in the middle-high group, Latvia and Lithuania are in the middle-low group). Western European countries range from the leaders' group (France) to the medium-low group (Austria, Belgium, and Germany). Southern European countries present Spain in the leaders' group, but at the same time Cyprus, Greece, and Italy are in the emerging group. Finally, eastern European countries belong only to the last two groups of the ranking: Czech Republic, Poland, and Romania are in the middle-low group, whereas Bulgaria, Hungary, and Slovakia are in the emerging group. Therefore, on the one side, northern and western European countries are at the forefront regarding women's participation in the digital economy (especially UK and Scandinavian countries). On the other side, some southern and eastern European countries present great shortcomings in this regard.

The third step of the analysis consists in the attribute-related sensitivity analysis. We identify the two out of three most significant indicators for each dimension. Since the first dimension is composed of six indicators, for this dimension we identify the four most important indicators.

The analysis is repeated five times: first considering all the countries together, and then considering one of the four macroregions at a time. The results are presented in Table 3. The indicators are listed following the enumeration presented in Section 3.

Table 3 – Most impacting indicators according to the attribute-related sensitivity analysis, both at EU-28 level, and at macro-regional level

Indicator	EU-28	Northern EU	Western EU	Southern EU	Eastern EU
1.1	X	X		X	X
1.2	X				X
1.3			X		X
1.4					
1.5	X	X	X	X	
1.6	X				X
2.1					
2.2	X	X	X	X	X
2.3	X			X	X
3.1	X	X	X	X	X
3.2			X	X	
3.3	X	X	X	X	X

Source: Own elaboration based on WiD data.

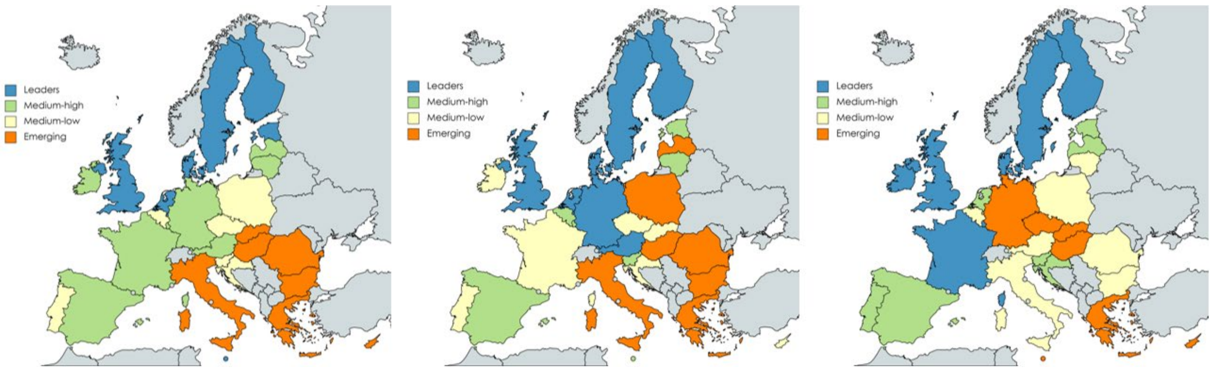
The indicators in bold in the first column are the most relevant ones for all the EU-28 countries. Regarding the analysis at a macro-regional level, it is important to underline the following considerations: first, notice that it was not possible to identify the two out of three indicators with the highest impact for all macroregions in all dimensions (for instance, the most important indicators considering northern European countries are just two out of six in dimension 1, and just one out of three in dimension 2); second, in some cases it was not possible to find more important indicators than others in a dimension (for instance, all three indicators of dimension

3 have the same impact in western and southern European countries) and for this reason all indicators of that dimension are considered as equivalent.

The attribute-related sensitivity analysis has then revealed 8 out of 12 most significant indicators for the EU-28. Specifically, three indicators about internet user skills, specialist skills and employment have the highest impact in all four macroregions, namely: *2.2 % of women with above basic digital skills in information, communication, problem solving and software for content creation*; *3.1 Women graduates in STEM per 1000 individuals ages 20-29*; *3.3 Gender pay gap in unadjusted form, considering all employees working in firms with ten or more employees*. Furthermore, two more indicators about internet use are the most relevant in three macroregions: *1.1 % of women who use the internet at least once a week*; *1.5 % of women who used internet in the previous three months for taking part in on-line consultations of voting to define civic or political issues*. Moreover, two indicators are significant in some macroregions even if they are not in the EU-28 analysis: indicator *1.3* in western and eastern Europe; and indicator *3.2* in western and southern Europe. Only two indicators are left out in all the analyses: *1.4 % of women who used internet in the previous three months for doing an online course*; *2.1 % of women with basic or above basic digital skills in information, communication, problem solving and software for content creation*.

Another interesting aspect of the analysis that deserves attention is the ranking obtained considering the three dimensions individually. The ranking is expressed in the form of the four performance categories discussed above. The results are showed in the maps of Figure 5.

Figure 5 - Results of the poset analysis considering the three WiD 2020 dimensions singularly. From left to right: dimension 1, dimension 2, and dimension 3.



Source: Own elaboration based on WiD data.

Looking at Figure 5 we can first consider that only a few countries are in the same performance category in all the dimensions. On the one hand, Denmark, Finland, Sweden, and the UK are the only four countries that are leaders in each of the three dimensions; on the other hand, Greece and Hungary are the only two countries in the bottom of the ranking in all the three dimensions. Our findings identify in which dimension some countries could improve the most. For instance, Austria, Germany, Lithuania and Luxembourg have good results in the first two dimensions, but they have strong weaknesses (especially Germany and Luxembourg) in the dimension related to specialist skills and employment. Another example is represented by France, Ireland, and Latvia, which are in the middle-high category in both dimensions one and three, but they could improve significantly in the dimension regarding internet user skills. Slovenia is the only country that has its strongest lacks in the first dimension (internet use).

The last step of the analysis concerns the comparison between the results and ranking proposed in the Women in Digital Scoreboard 2020 and our results obtained using the poset-based approach, by computing the Spearman correlation coefficient ρ, and the τ Kendall correlation, as in Alaimo et al. (2021a & 2021b). First of all, to test the validity of our ranking we calculate the Spearman correlation coefficient ρ, using the following formula:

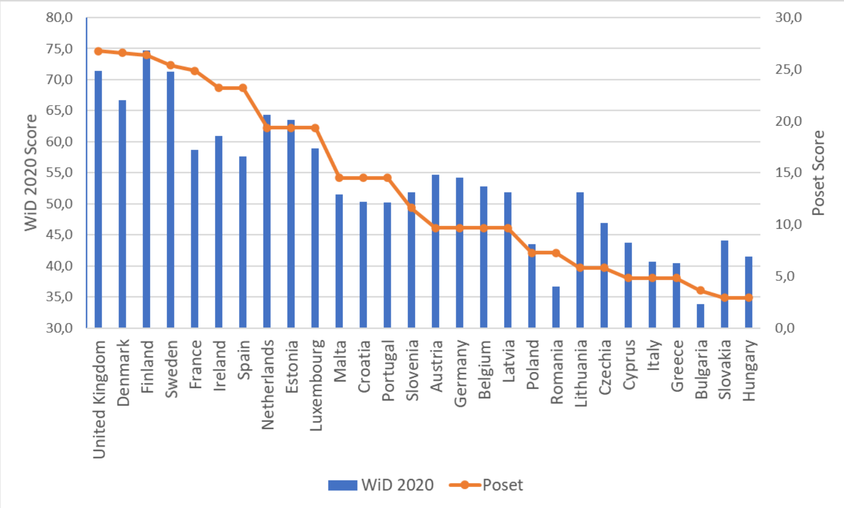
$$\rho = 1 - \frac{6 * \sum d_i^2}{n * (n^2 - 1)} \quad (2)$$

where d is the pairwise distance of the ranks of the different countries and n is the number of countries. The result (in a range between 0 and 1, where 0 is total discordance and 1 is total concordance) is 0.881 with a p value < 0.001. We also calculate the τ Kendall rank correlation, applying the following formula:

$$\tau = \frac{c - d}{c + d} \quad (3)$$

where c is the number of concordant pairs and d the number of discordant pairs. The result (in a range between -1 and 1, where -1 is total discordance and 1 is total concordance) is 0.687 with a p value < 0.001. The high values of the coefficients mean that the results obtained in the two ranking are similar, even if there are some differences, which we try to explain starting from Figure 6, which shows the scores of the 28 countries comparing our analysis and the score reported in the WiD Scoreboard 2020, and in Figure 7, which present the countries that change at least three positions in the ranking.

Figure 6 – Comparison between the scores of the 28 countries in the Women in Digital Scoreboard 2020 and in the poset-based approach analysis

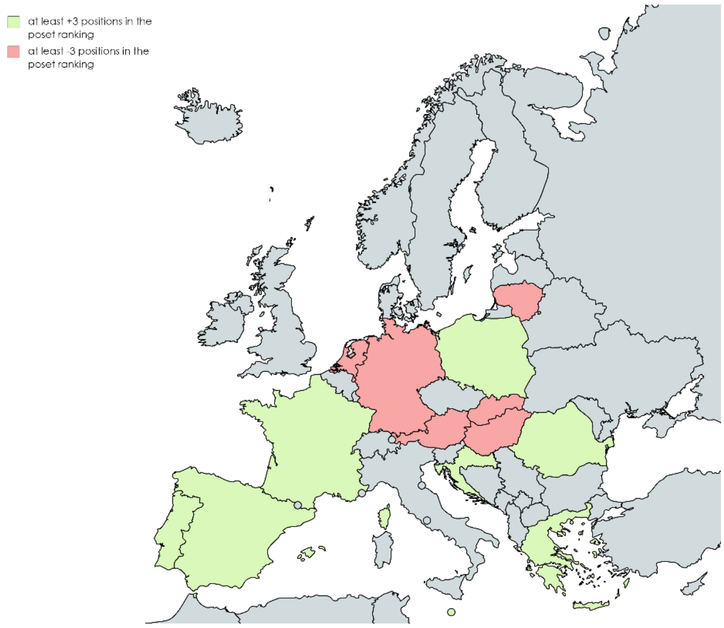


Source: Own elaboration based on WiD data.

Figure 6 shows that the ranking obtained with the poset-based approach is not the same as the one in the Women in Digital Scoreboard 2020. Countries like France, Spain or Ireland improve their ranking a lot with the poset methodology, while Lithuania, Slovakia or Hungary move down in the ranking. Therefore, our results show a quite distinct order of the ranking of countries.

Figure 7 represents in green the countries that improve their results of at least three positions in the poset-based analysis compared to their ranking in the Women in Digital Scoreboard: Portugal and Romania (8), Croatia (7), Malta (6), France, Poland, and Spain (4), and Greece (3). In red, the countries that fall off at least three positions in the ranking: Lithuania (-7), Slovakia (-6), Austria (-4), Germany, Hungary, and Netherlands (-3). The explanation of the differences between the two rankings lies in the performance of these countries in the most important indicators, particularly indicators *1.5*, *1.6*, *3.1*, and *3.3* (the last two even more substantially). Good performances in these indicators led to best ranking in the poset-based analysis as well as deficiencies in these indicators led to worse results in the ranking. To better understand this phenomenon, Figure 8 shows the average ranking of the aforementioned countries considering only indicators 3.1 and 3.3.

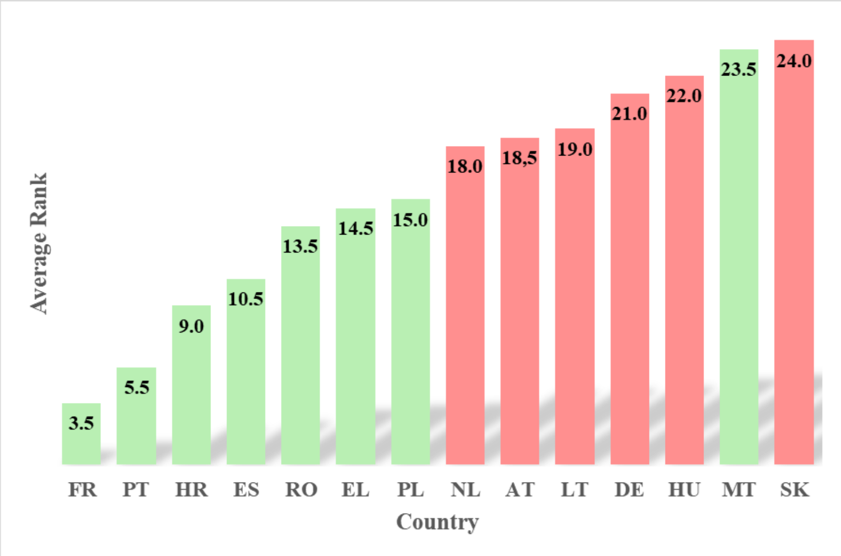
Figure 7 – Comparison between the poset-based approach analysis and the Women in Digital Scoreboard 2020 results



Source: Own elaboration based on WiD data.

According to Figure 8, we can identify two groups of countries considering the results in indicators *3.1* and *3.3*, except Malta, which climbs up the ranks even though its results in the relevant indicators of the third dimension are not good (25th in *3.1*, and 21st in *3.3*). However, as explained in the previous pages, Malta belongs to the small group of countries that cannot be compared with the rest, according to the poset-based approach theory, thanks overall to its very good results in indicator *1.5*, where Malta ranks 2nd. We can conclude that, in general, countries that have good results in the majority of indicators should improve their results in the most relevant indicators: *Women graduates in STEM per 1000 individuals ages 20-29* and *Gender pay gap in unadjusted form, considering all employees working in firms with ten or more employees*.

Figure 8 – Average ranking of the 13 countries underlined in Figure 7, according to indicators 3.1 and 3.3



Source: Own elaboration based on WiD data.

5. Discussion and conclusions

In this article we applied the poset theory to analyse women's digital inclusion in the EU-28 countries using the data from the 12 indicators of the Women in Digital Scoreboard 2020. The poset methodology allowed to construct a new ranking that avoids the shortcomings of the aggregative approaches. The analysis resulted also in a classification of countries, according to our new ranking, in four groups depending on their performance level. The leaders group is composed of the United Kingdom, Denmark, Finland, Sweden, France, Ireland, and Spain (leaders group); by contrast, the countries where women are most underrepresented are Slovakia, Hungary, Bulgaria, Italy, Greece, and Cyprus (emerging group).

According to the poset-based approach, the leaders group is composed of those countries who present better results in all indicators compared to at least other three different countries. United Kingdom is the country leading the ranking, since it has better scores in all indicators with respect to other eleven different countries; Ireland and Spain, the last two countries of the leaders group show better results in all indicators respect to three different countries. Similarly, the emerging group is composed of those countries underperforming in all indicators compared to at least four different countries (as in the case of Cyprus, Greece, and Italy) –eight in the case of Hungary and Slovakia, who are in the last positions of the ranking. Moreover, three countries

(Croatia, Malta, and Portugal) are incomparable with all the other countries; this means that they present very good results in some indicators and very low scores in other indicators.

We also analysed the data by macroregions, and the results seem to confirm the socio-economic pattern among European countries: northern countries are mostly in the leaders group, western countries are between the leaders and the middle group, southern countries are mostly between the middle and the emerging group, and eastern countries are mostly in the emerging group. Thus, countries in a macroregion usually belong to the same group, with very few exceptions: the former soviet Baltic states are the only countries in the North of Europe that are not in the leaders group, and Spain is the only southern European country represented in the leaders group.

Comparing our results with the ones proposed in the Women in Digital Scoreboard 2020 report, we found that half of the countries have equal or similar positions in the two rankings while the other half move up or down the ranking at least three positions. These differences depend mainly on the performance of countries in the most significant indicators revealed by the attribute-related sensitivity analysis that we have conducted, considering all countries first, and then the countries in each macroregion. Among the most relevant indicators two of them belong to the first dimension, internet use (*% of women who used internet in the previous three months for taking part in on-line consultations of voting to define civic or political issues*, and *% of internet users who, during the previous year, needed to send filled forms to the public administration*), and other two belong to the third dimension, specialist skills and employment (*Women graduates in STEM per 1,000 individuals ages 20-29*, and *Gender pay gap in unadjusted form, considering all employees working in firms with ten or more employees*). The last two indicators are even more important in the determination of the ranking. In fact, the countries who improved their ranking are those with good results in indicators *3.1* and *3.3* (except for Malta). The macroregional analysis performed results in different relevant indicators for each European region. For instance, our analysis suggests that only for western and southern European countries an important indicator is *% of women aged 15-74 employed ICT specialist based on the ISCO-08 classification*. Therefore, our research contributes to better understand the dynamics and the underlying causes of women's digital inclusion in the EU-28 countries. And the different significance of indicators in the EU and in the four macroregions helps to design more targeted and effective policies, showing the specific areas in which each country should focus to reduce the gender digital divide.

This study presents some limitations, both theoretical and methodological. Under the theoretical point of view, the set of indicators is not so exhaustive, and the data are collected just at country level. The methodological limitations are mainly related to the fact that, even in quite large dataset, the application of the poset-based approach can lead to a high number of incomparabilities, generated in some cases by small differences in the performance of some indicators.

For future research, it would be very interesting to collect regional data in order to replicate the analysis at a regional level and explore in detail the regional variances in the gender digital divide across Europe, as regional socioeconomic differences in some countries (such as Italy and Spain) are usually very high. Moreover, if more gendered data were available the set of indicators could be further enlarged, including for example many of the other indicators of the Digital Economic and Society Index (DESI), which is currently composed of 25 indicators. Finally, as data for more years is available, we will be able to expand the study to include a longitudinal analysis.

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