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Taking stock:
Data and evidence on gender equality in digital access, skills and leadership

Preliminary findings of a review
by the **EQUALS Research Group**

Research

Access

Skills

Leadership

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Introduction

The inaugural report of the EQUALS Research Group lays the foundation for the EQUALS Partnership agenda by surveying the landscape of knowledge on gender equality as it relates to the three EQUALS action areas – Access, Skills and Leadership. It should serve as a planning resource to inform future activities of EQUALS partners and the broader community of policymakers, practitioners and researchers interested in solving gender inequality challenges in access to information and communication technologies (ICTs), development of basic and advanced ICT skills and participation in the ICT industry. This high-level summary shares preliminary findings. The final report will be available in 2019, with detailed versions of all chapters and case studies.

Key Findings

The state of gender digital equality

- **While gender gaps are observable in most aspects of ICT access, skills and leadership, the picture is complex.** There are large regional variations; some countries are close to parity or have even reversed the gender gap on some indicators, while others still have persistent gaps. Individual countries can have both large and small gaps depending on the indicator being measured. Interpreting the gaps requires careful and contextualized analysis.

- **Barriers to gender digital equality are generally related to one or more of the following: 1) availability of infrastructure, 2) financial constraints, 3) ICT ability and aptitude, 4) interest and perceived relevance of ICTs, 5) safety and security and 6) socio-cultural and institutional contexts**. Most of these barriers cut across issues of access, skills and leadership, although they may manifest in slightly different ways. While research has documented these barriers, the evidence from different sources is sometimes contradictory, even within the same country contexts.

- **There is no one conclusive strategy for eliminating gender digital inequalities**. Recommendations generally call either for targeting specific symptoms of gender digital inequality (such as affordability or recruiting practices), or for reshaping deeply ingrained social norms and practices (such as gender stereotypes) that are at the root of gender inequalities. As with the evidence on barriers, research results are sometimes contradictory or nuanced.

- **The dominant approaches to gender equality in ICT access, skills and leadership mostly frame issues in binary (male/female) terms, thereby masking the relevance of other pertinent identities**. Insufficient research has been done on the implications of ICTs for intersectional identities. Data collection should move from binary sex-disaggregation towards finer degrees of gender disaggregation in order to recognise multiple and interacting identities (such as sexuality, poverty, class, education, age, disability and occupation).

- **To ensure privacy and safety as well as full participation in the digital economy, women should have equal opportunities to develop adequate basic and advanced digital skills**. Cyberstalking, online harassment, image manipulation, privacy violations, geotracking and surveillance can compromise women's and girls' safety online and offline. In addition, some evidence suggests the digital transformation of labour may be widening gender wage gaps. These outcomes can be averted with the right types of training

combined with social and institutional change.

- **Developments in digital technologies open new pathways to gender diversity and inclusion; however, lack of attention to gender dynamics hampers the potential for true progress**. For example, evidence suggests that most women's work in the digital economy, particularly in the Global South, reinforces existing social divisions. Moreover, artificial Intelligence (AI) systems, designed largely by men, tend to ignore the negative gender implications of their designs. Research, government policy and design principles should include gender awareness and analysis, for example by building in data and privacy protections and avoiding gender stereotypes.

The state of data on gender digital equality

- There is limited internationally comparable sex-disaggregated official data and geographic coverage on most ICT indicators, especially for developing countries. Most of the official statistics and scholarly research are from North America and Europe. Furthermore, only a few countries have longitudinal data for comparison of trends over time.

- Official data on gender-related negative and unintended consequences of ICTs are not systematically collected. Both data collection and social change are important to ensure that greater gender inclusion online and in the ICT field does not lead to increased exposure to negative experiences, such as cyber violence, sexual harassment, and gender discrimination.

- Despite the existence of commendable research and data collection efforts, measuring gender digital equality is plagued by definitional and methodological challenges. These include a lack of internationally agreed definitions and methodologies for collecting data; the sheer range of possible dimensions for measuring gender digital equality; the moving target of technological developments; and low research capacity of both government agencies and academic institutions in most countries. In addition, the existing body of scholarly and corporate research is often limited to narrow national or topical contexts, and has sometimes produced contradictory findings, thus limiting the ability to generalize beyond the research context. In addition to carrying out targeted systematic reviews and meta-analyses to make sense of existing research, more data collection and original quantitative and qualitative research are needed to conceptualise gender digital equality, identify gender gaps with greater specificity and geographic coverage, understand the contexts in which they occur, and determine what works and why in different socio-cultural contexts.

Definitions

Gender: To accommodate diverse researchers and data, this report does not subscribe to any particular definition of gender. The content therefore incorporates multiple notions of gender.

Gender gap: Unless otherwise indicated, gender gaps are calculated using the absolute approach (percent female minus percent male) rather than relative approaches (such as (percent men minus percent female) divided by percent men). A negative gap means more men than women, while a positive gap means more women than men.

ICTs: For the purposes of this report, ICTs are defined as computers, mobile phones and the internet. They do not include older technologies such as television and radio.

ICT access: This refers to people's access to and ownership of computers, mobile phones and the internet. It also covers the ability to use these technologies in meaningful ways – possession of the requisite basic digital skills, as well as the types of content and services provided.

ICT skills: ICT skills refer to the more advanced technical skills (such as

software development) that are required to enable people become creators, innovators and leaders in the ICT field.

ICT leadership: This refers to 1) employment in ICT and related fields, and in particular at leadership levels and 2) participation as entrepreneurs in the ICT industry.

While our primary interest is in ICTs, this topic intersects with other issues, in particular the science, technology, engineering and mathematics (STEM) field in general. Scholars argue that in many respects the state of gender digital equality can be traced back to trends in the socialisation of STEM as a male-dominated field (for example, Quirós et al., 2018; Steinke, 2017). Furthermore, significant definitional issues complicate the analytical focus for this type of research. The continually evolving nature of technology and the existence of different categorisation schemes give rise to questions about what falls within the scope of ICTs and what constitutes an ICT or ICT-related occupation. The nature of available information also affects analysis – much of the existing research and data (particularly for skills and leadership) relate to STEM, technology or engineering broadly. Throughout this report, we use a variety of terms including “STEM”, "science and technology”, “technology”, "digital technologies", “ICT” and "computing" depending on the subject matter of the available data.

Report outline

The report has two parts. The first reviews research and data on the three core action areas of the EQUALS Partnership – ICT Access, Skills and Leadership. It covers trends as represented in official statistics, academic and grey literature, and it assesses the availability of relevant sex-disaggregated data.

It begins with a discussion of selected dimensions of access to ICTs, defined broadly as basic access (access to computers, mobile phones, and the internet) and meaningful access (focusing on basic digital literacy and access to financial services- the few areas for which official statistics are available). This is followed by a discussion of gender equality in advanced ICT skills from early to tertiary education as well as through non-traditional pathways. The third chapter examines gender equality in ICT leadership from the perspective of employment within the industry and academia, attainment of leadership positions, entrepreneurship participation, and inclusion in relevant policymaking. The fourth chapter deals with the dark side of the digital age – risks and dangers associated with digital technologies, as well as negative outcomes and responses to advances in gender equality. The fifth chapter summarises observed obstacles and associated recommendations to improve gender equality in access, skills and leadership. The final chapter of Part 1 assesses the availability of relevant sex-disaggregated data.

The second part of the report comprises independently authored chapters from members of the EQUALS Research Group. It brings together theoretical perspectives and research data on themes to broaden our understanding of pathways to gender equality in the digital age and outline potential agendas for the Partnership. These themes fall into three broad categories: People, Digital Skills and Pathways.

The first category focuses on People – specific populations of interest in technology – diverse sexual minorities (*Gender variance and the gender digital divide*), people in low and middle-income countries (*Understanding the gender gap in the Global South*), children and youth (*Technologies and youth*), women with disabilities (*Accessibility, intersectionality and universal design*), and women farmers (*ICT for food security*).

The second category highlights the importance of addressing gender gaps in Digital Skills through educational and training institutions (*The role of educational institutions*) and discusses the implications of these gender gaps in the labour market (*The gender wage gap* and *Skills development: Perspectives of young women*). *A gender perspective on security and privacy* discusses the skills that are needed to deal with these challenges in the digital age.

The third theme, Pathways, places the gender digital equality agenda within broader frameworks related to the pitfalls

of over-enthusiasm about the equalising potential of technology (*Investigating technological determinism*), arguments for more inclusive technology-driven social innovation (*Technology and wealth creation*) and the potential of artificial intelligence for eliminating gender inequality (*Hello, Siri*).

1. Gender Equality in ICT Access

Many believe that there is no longer a gender gap in ICT access, given the high levels of mobile phone adoption even in less developed regions. However, equality in ICT access involves more than mere availability and use of mobile phones (Case study 1). To what extent do women have equal access not only to mobile phones but also to other types of devices, control over those devices and the ability to use the technology in beneficial ways? This chapter assesses data on a variety of indicators related to computer, mobile phone and internet access to identify the extent to which gender divides exist or have been closed.

Basic access

A critical element of bringing women online and enabling them to use the internet and its various applications is ensuring that they have unfettered access to devices such as computers. There is a gender gap in computer usage in most countries, ranging from-17% (Turkey) to +4% (Saudi Arabia). **Irrespective of whether overall computer use levels are high or low, a gender gap persists**, although in some cases the direction is reversed in that there is a higher proportion of female than male computer users (Table 1). For example, in both Europe and Asia, overall levels of use for women are above 50% and in some countries (such as Ireland, Finland, Lithuania) the usage level is slightly higher for women than for men. In Africa and the Americas, the few countries with data show that overall, less than 50% of women use computers but a similar trend pertains of gender gaps ranging from-9% to +3%. In some countries (such as Saudi Arabia, Cuba and Panama) the data indicate that computer usage is higher among women than among men.

Regionally, gender gaps in mobile phone ownership range from-9% to 0% in Africa; -3% to 0% in the Americas;-21% to 0% in Asia; and-4% to 0% in Europe. At the country level, the largest gap is-21% (Saudi Arabia) while the smallest is +2% (Brazil). **Mobile phone use gaps are mostly smaller than those for ownership**, and also show wide regional and country variations (where data are available) – from-5% to +2% in Africa; -4% to +2% in the Americas;-12% to 0% in Asia; and-2% to +2% in Europe (Figure 1).

In a majority of reporting countries around the world, higher proportions of men than women use the internet. Gender gaps range from-16% (Turkey) to +6% (Jamaica). In Asia, 23 out of 26 reporting countries have a higher proportion of men than women using the internet. The same trend is seen in Europe where 29 of the 39 reporting countries have a higher proportion of men than women using the internet. In Africa,

only one country (Morocco) has over 50% of the female population using the internet, but the same country also has the largest internet use gender gap in the region (-9%; Figure 2). For the **mobile internet**, official national statistics are not publicly available, but GSMA's demand-side survey calculates regional gaps ranging from 4% (Americas, Europe & Central Asia, East Asia & Pacific) to 70% in South Asia (GSMA calculations measure the relative gap – (male users minus female users) divided by male users).

Case Study 1. GSMA Connected Women Initiative: Bridging the mobile gender gap

Mariana Lopez (GSMA)

Context

GSMA Connected Women research has estimated that women in low and middle-income countries are, on average, 10% less likely to own a mobile phone than men, which translates into 184 million fewer women owning mobile phones. Even when women own a mobile phone, they report using phones less frequently and intensively than men, especially for transformative services such as mobile internet, further widening the divide. Women are on average 26% less likely to use mobile internet than men.

Project description

GSMA Connected Women aims to reduce the gender gap in mobile internet and mobile money services and unlock significant commercial and socio-economic opportunities. Through the Connected Women Commitment initiative, mobile operators are making formal commitments, with targets, to reduce the gender gap in their mobile money or mobile internet customer base by 2020. As of May 2018, 36 operators have made 51 commitments to reduce the gender gap in their mobile money and/or mobile internet customer base across Africa, Asia and Latin America, driving an effort to accelerate digital and financial inclusion for women.

Case Study 1. GSMA Connected Women Initiative: Bridging the mobile gender gap (continued)

Activities undertaken by operators participating in this initiative include, for example, increasing the number of female agents, improving the data top-up process to be safer and more appealing to women, improving digital literacy among women through educational programmes and interactive content, and developing and marketing use cases which appeal to women.

Project status and outcomes

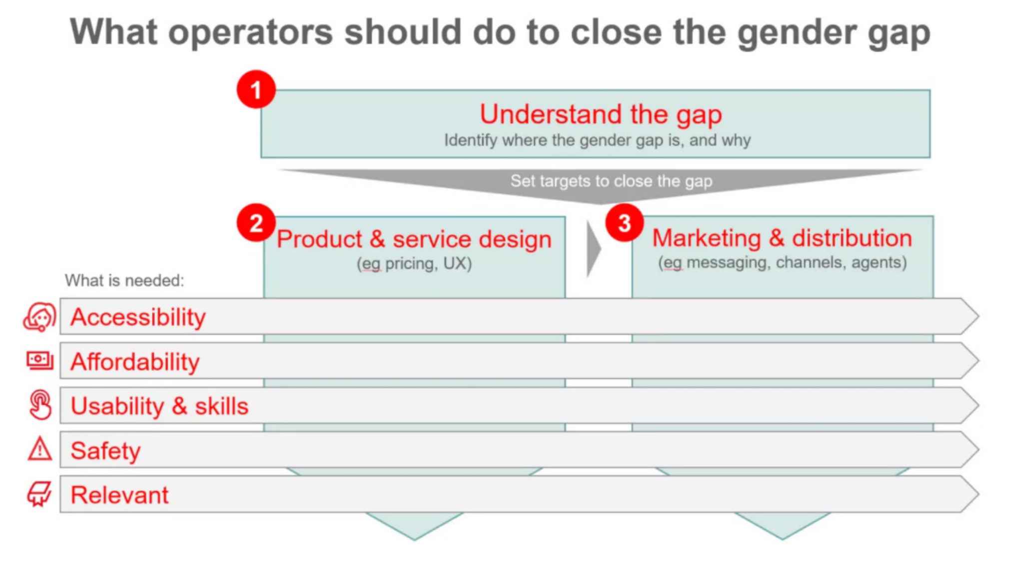
To date, the mobile operators that have committed to the Connected Women Initiative have reached over 10 million new women with mobile money or mobile internet services. This figure reflects new female customers acquired by mobile operator partners since they have committed to closing the gender gap in their customer base.

Challenges

The root causes of the mobile gender gap are driven by a complex set of social, economic and cultural barriers and targeted intervention is urgently needed from a wide range of different stakeholders to overcome the barriers women face to mobile ownership and use.

Key Lessons

Based on their experience working with operators and researching women across Africa and Asia over a number of years, GSMA Connected Women has developed a framework to help mobile operators take action on this important issue.



Meaningful access

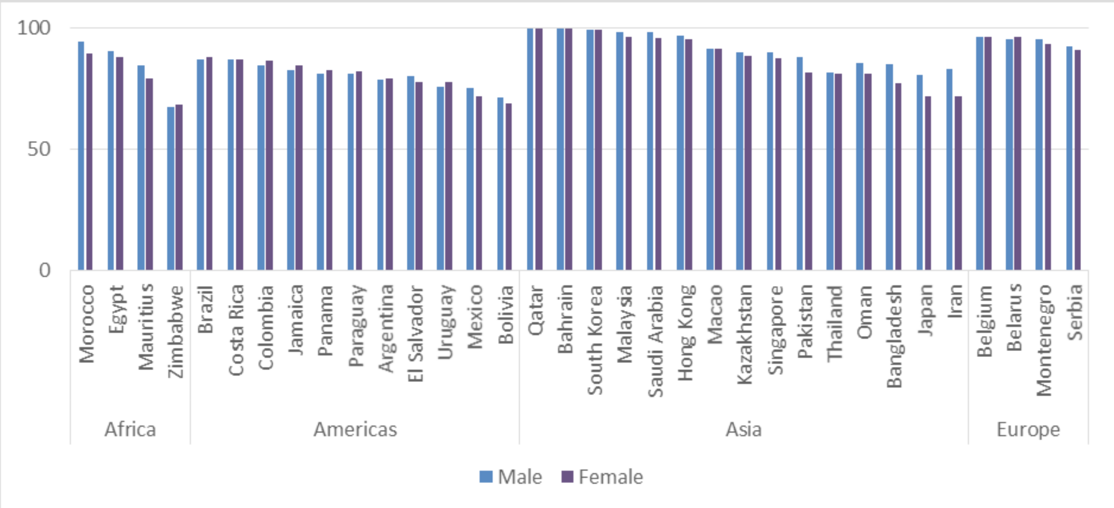
Studies on gender digital divides mainly examine gender inequalities in basic access or more specifically, access to the internet and use of mobile phones. But once online, there are also noticeable differences in usage patterns between men and women. There is growing recognition that basic access to ICTs is not a sufficient condition to eliminate inequalities. For both mobile phone and internet use, **gender divides widen as technologies get more sophisticated and expensive and enable more transformational uses and impacts** (Deen-Swarray et al., 2012; Highet, 2017; GSMA, 2018). Meaningful use

Table 1. Difference in computer use

Region	Number of reporting countries	Percentage of largest gap	Percentage of smallest gap
Asia	25	-17	4
Europe	34	-9	1
Africa	6	-9	-1
Americas	13	-5	3

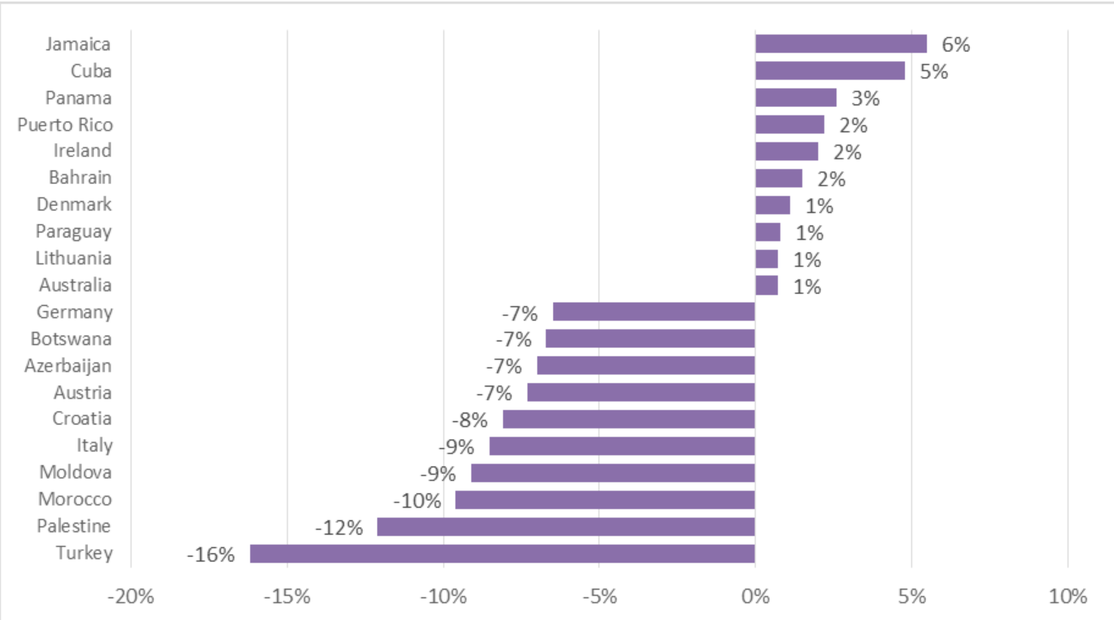
Source: ITU WTI Database 2017
Note: Positive value means more women than men.

Figure 1. Mobile phone use



Source: ITU WTI Database 2017

Figure 2. Difference in internet use (top 10 and bottom 10 countries)



Source: ITU WTI Database 2017
Note: Positive value means more women than men.

Case Study 2. SheTrades – Empowering Women Entrepreneurs with Digital Skills

Poonam Watine, (International Trade Centre)

Context

In line with the EQUALS Global Partnership, the SheTrades Initiative responds to global issues surrounding women and trade, including gender digital inequality. Through a project with the Indian Ocean Rim Association, SheTrades focused on women owned and/or led enterprises operating mostly in information technology and information technology-enabled services sectors in Indonesia and Kenya.

Project description

The project was funded by the Australian Department of Foreign Affairs with the goal to galvanise the economic empowerment of women by increasing the participation of export-ready women owned and/or led enterprises in international trade and investment. The project was launched in January 2016 and ended in June 2018. The project established networks with the private sector, women's business associations and relevant trade and investment support institutions to scale up interventions and foster inclusive trade in the region. One key outcome of the project was to increase the competitiveness of women entrepreneurs through capacity building activities, for which specific trainings were geared towards digital marketing, social media and e-commerce.

Project status and outcomes

While it is too soon to describe long-term economic, social and environmental impact produced by the project, some immediate outcomes include directly supporting over 250 women owned and/or led enterprises in the two beneficiary countries (213 SMEs in Indonesia and 165 in Kenya). Moreover, over 47 women owned and/or led SMEs under the project locked sales and commitment with various companies in 42 countries, valuing around $2.3 million.

Key Challenge

Identifying the financial impact of the project remained a key challenge. Therefore, a database was developed to help track transacted sales between beneficiaries and buyers.

Key Lessons:

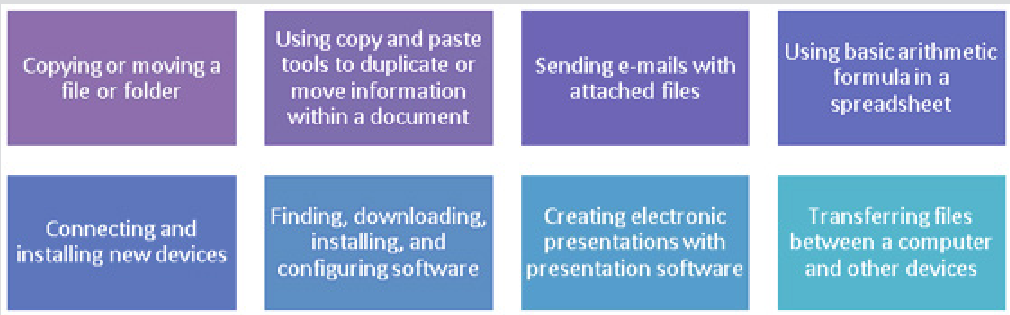
- Collaborative partnerships with the private sector can result in potential sales with buyers for beneficiaries.
- Online trainings and webinars helped to minimise the cost for capacity-building activities.
- Focusing on three countries and the services sector allowed a tighter and stronger focus.

encompasses numerous aspects such as basic ICT or digital skills, access to and use of digital financial, health or education services, or ability to produce and disseminate online content (see Case study 2: SheTrades, for an example of promoting meaningful ICT use for entrepreneurial activity). However, lack of sex-disaggregated data inhibits examination of most of these dimensions. Therefore, this analysis focuses on two areas where relatively higher amounts of official statistics exist – basic digital skills tracked by ITU (Box 1) and access to digital financial services tracked by the World Bank.

In **two-thirds (35) of the reporting countries, women are less skilled than men in all eight areas of basic digital skills**. On the other hand, in about one-quarter (14) of reporting countries, women are more skilled than men in one or two skills and in four countries women are more skilled in three or more. The differences range from-25% to +6% and exist regardless of whether overall skill levels are high or low. Except for *finding, installing, and configuring software*, there are primarily single-digit gender gaps in most countries.

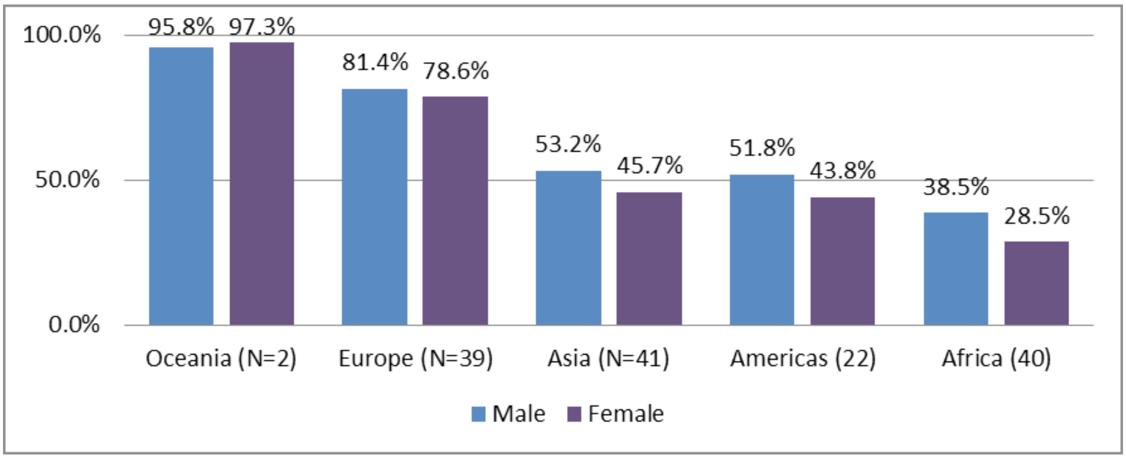
In general, access to and use of digital financial services by women is highest in North America, Europe and Asia (up to 100% of women). **Differences in access to and use of digital financial services are wide and variable, with some instances where financial inclusion is higher for women** (Figures 3 and 4). The gaps range from-22% (Bangladesh) to +6% (Taiwan) for use of the internet or mobile phone to access a bank account, -17% (Slovenia) to +9% (Taiwan) for using the internet to make a payment,-32% (Saudi

Box 1. ITU Digital Skills Indicators, 2017



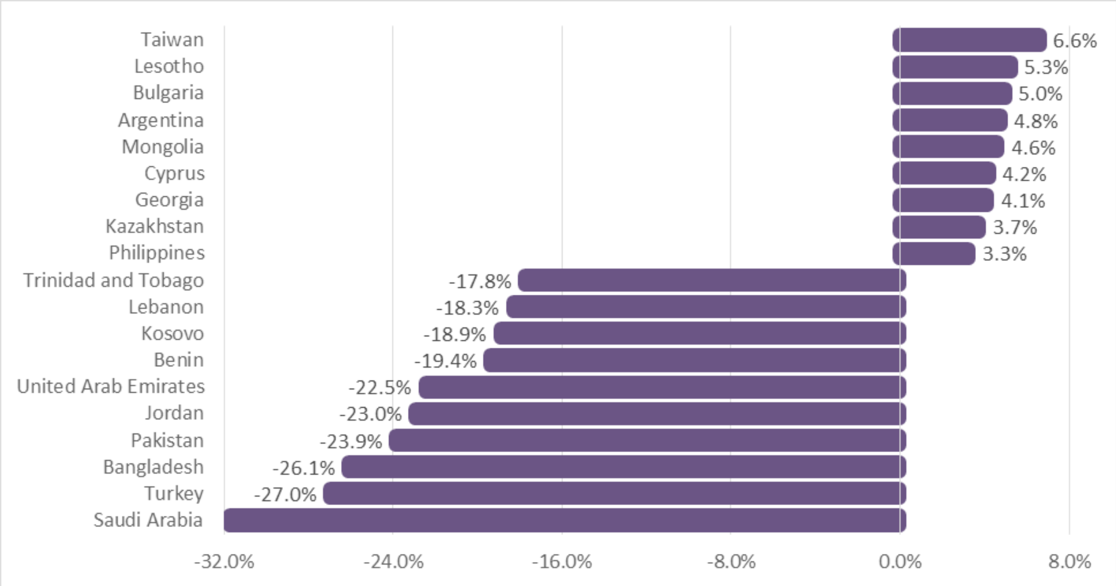
Note: ITU's Digital Skills Indicators also includes "writing a computer program using a specialised programming language" which is discussed in the section on advanced skills.

Figure 3. Made or received digital payments in the past year, by region



Source: World Bank Global Findex Database 2017

Figure 4. Difference in making or receiving digital payments in the past year (top 10 and bottom 10 countries)



Source: World Bank Global Findex Database 2017

Arabia) to +7% (Taiwan) for making or receiving digital payments and-14% (Uganda) to +6.5% (Lesotho) for using mobile money services.

Conclusion

The size of the gender gaps in mobile access and use is more significant because it represents a far larger population than the gap in computer-based internet. It also reflects a major change in data collection – the first sex-disaggregated ICT statistics that emerged before the mobile era were based on computer and computer-based internet access. Most of these now pale in comparison to the numbers of mobile-based users. As technologies get more sophisticated, measures of access need to keep pace in order to pre-empt gender digital divides. Equal ability to meaningfully use ICTs in multiple spheres of life is also a critical component of gender digital equality.

2. Gender Equality in ICT Skills

Having observed a tendency for women to have lower basic digital skills than men, this chapter asks how this tendency extends to advanced skills as well. To what extent do girls and women have equal opportunities to develop advanced technical skills for personal expression, employability and/or to become technology innovators and creators? Are there gender differences in motivation and aptitude for learning the types of subject matter needed for expertise in ICT fields?

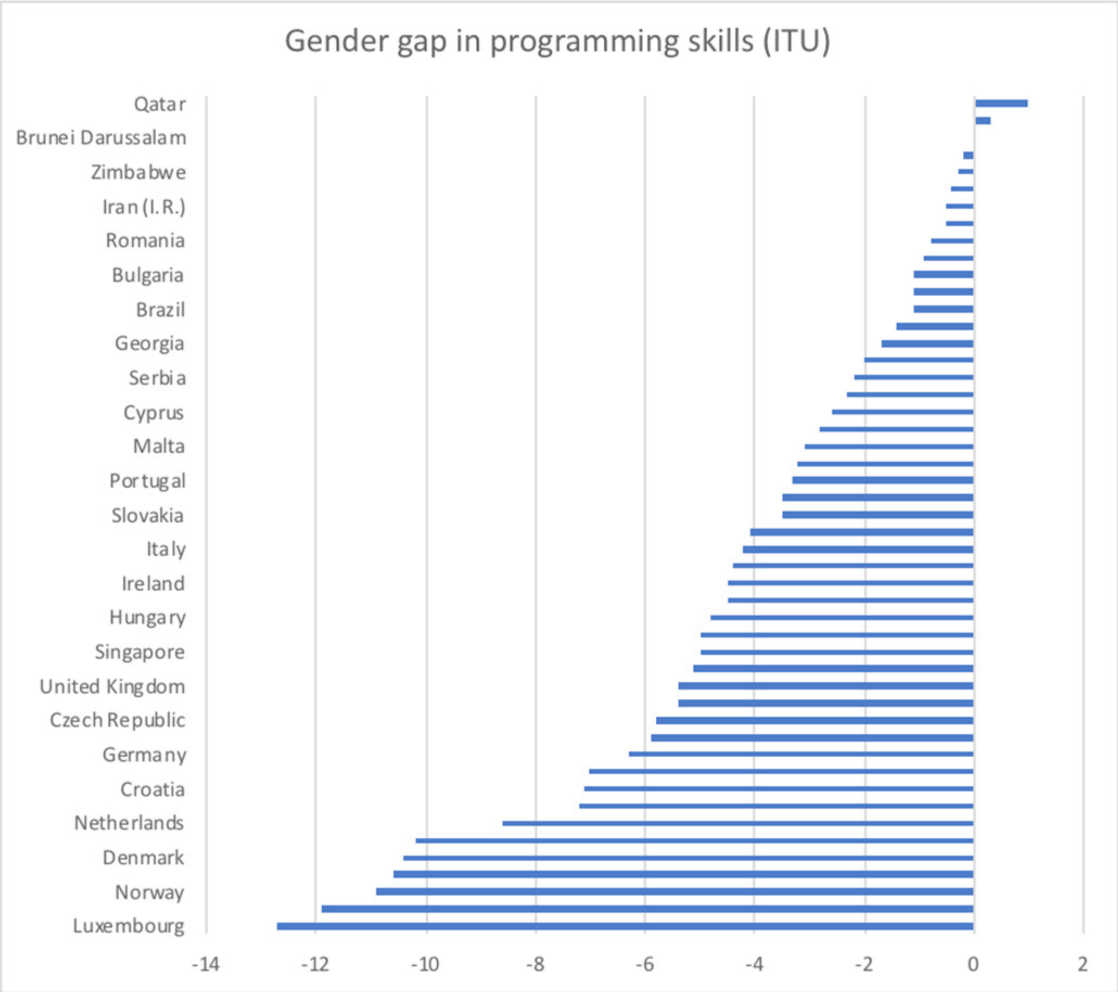
Advanced skills

As is the case with basic digital skills, **men are overall more likely than women to have advanced digital skills**. For instance, ITU 2017 data from 49 countries shows that, **the proportion of men who can write a computer program is twice that of women** (7.8% versus 3.5%; Figure 5). In almost all countries with relevant data, women lag behind men in having programming skills; the gap ranges from-13% (Luxemburg) to +1% (Qatar).

However, the intersection of gender and age can produce contrasting trends. For instance, Eurostat data shows that young females (16-24 years) in the European Union (EU-28) region are more likely to have above-basic skills (54% compared to 51% for males in the same age group), while adult and elder females are least likely to have above-basic skills (Figure 6).

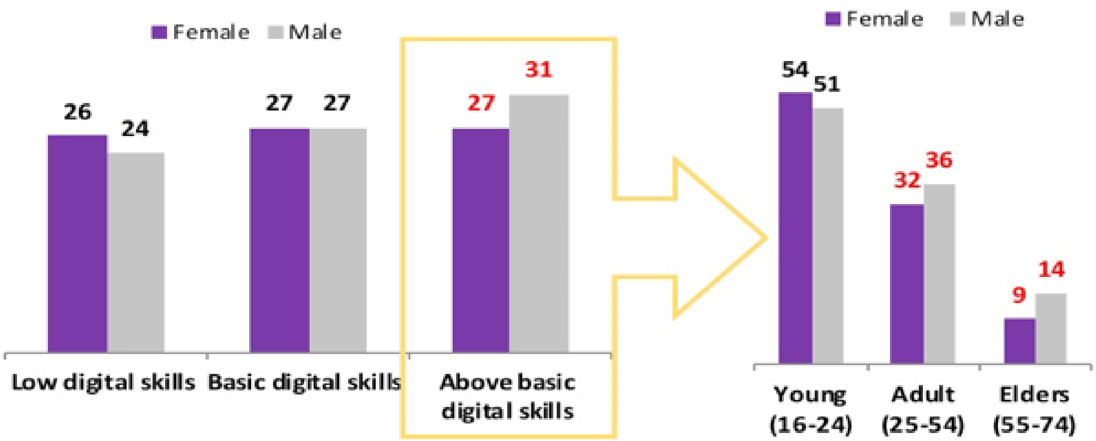
When it comes to ICT skills in the workplace, men in Organisation for Economic Co-operation and Development (OECD) countries are more likely to have a higher level of ICT-based problem-solving skills according to the Survey of Adult Skills.

Figure 5. Difference in computer programming skills



Source: ITU WTI Database 2017

Figure 6. Gender difference in low, basic and above-basic digital skills



Source: Eurostat 2017
Note: Excludes those with no digital skills and those who had not used the internet in the last 3 months.

STEM education

Pre-college STEM exposure

As math and sciences are part of the core national curriculum in most countries, exposure to STEM subjects is similar between boys and girls at the primary and lower-secondary level. **The participation gap becomes noticeable when students start to make choices for subject specialisation at higher-secondary level**. The size of this participation gap is unknown as very few countries have published this type of data. Based on data for only nine countries in the Trends in International Mathematics and Science Study (TIMSS) advanced test, female participation in advanced math and physics classes ranges from 25% (Portugal) to 60% (Slovenia). Data on Technical and Vocational Education and Training (TVET) graduates in OECD countries show low proportions of women (11%) graduating in engineering, manufacturing and construction specialisations, whereas over 65% of social science, business and law graduates were women (OECD, 2017).

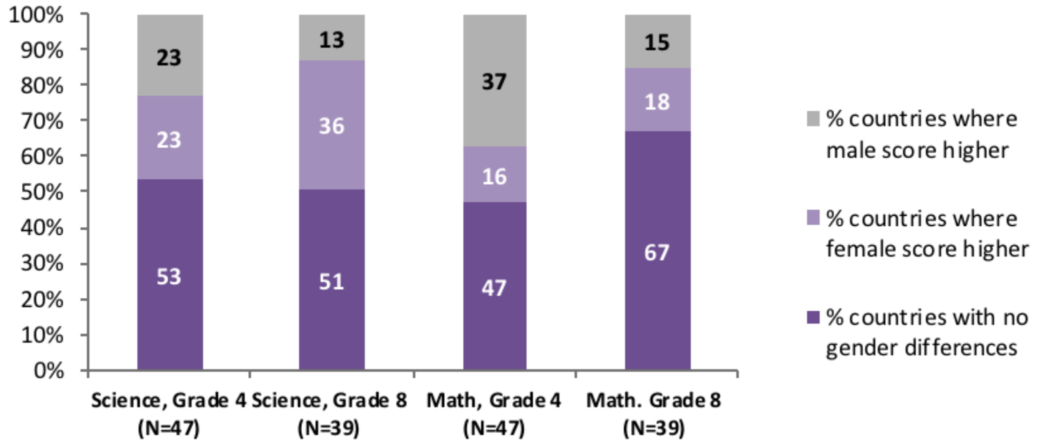
Pre-college STEM performance

In terms of performance, both Programme for International Student Assessment (PISA) and TIMSS data indicate that in most participating countries**, there is marginal or no gender gap in STEM performance**. PISA 2015 data for 72 countries shows that girls slightly underperformed boys in math and science (by 8 and 4 points respectively), while TIMSS 2015 data for 57 countries, shows that in over 85% of these countries there was either no gender difference or girls outperformed boys in Grade 8 math and science (Figure 7). Country-level data also reveal interesting patterns often hidden in the global average figures; for example, girls in Western Asia perform better than boys in math, while several European countries show a more conventional gender gap with boys scoring higher than girls (Figure 8).

Attitudes towards STEM

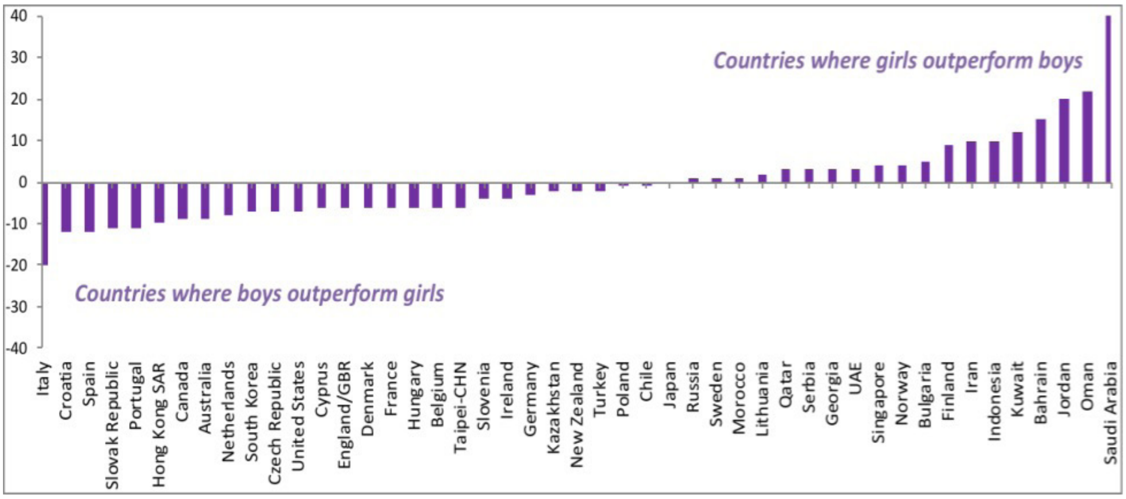
There is **some evidence of gender gaps in self-concept, self-efficacy, interest and aspirational levels related to STEM subjects, at least in Europe and OECD countries**. For example, even though there is only a 5% difference between boys' and girls' perception that they get good grades in math, when it comes to feelings of self-efficacy, **girls are much more likely to feel that they do not have strong skills in math (between 11% and 16% difference from boys)**. Furthermore, in OECD countries, girls are less likely than boys to aspire towards computing careers – **less than 1% of girls are contemplating an ICT-related career, compared to 5% of boys**.

Figure 7. Gender differences in Science and Math Scores (2015)



Source: Based on analyses of TIMSS, 2015 data by UNESCO (2017, pp. 26, 31)

Figure 8. Gender difference in Grade 4 Math scores (2015)



Source: TIMSS, 2015

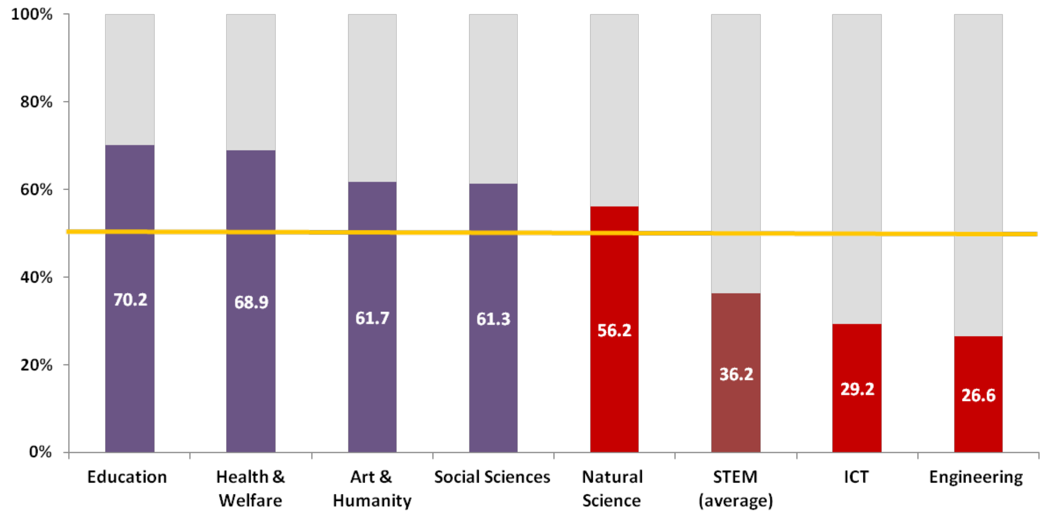
College STEM education

Three major trends can be identified. First, despite considerable progress in women's participation in higher education, **the proportion of women STEM graduates has been steadily low (around 35%) across world regions**. Second, considerable gender segregation exists within STEM fields as women tend to choose to study natural sciences over computer science and engineering. **Women constitute 56% of natural science program enrolments but only 29% of ICT studies and 27% of engineering studies** (Figure 9). Lastly, contrary to expectations of a positive correlation between gender equality (as measured by the Global Gender Gap Index) and women in STEM, scholars (Stoet & Geary, 2018; Thakkar, Sambasivan, Kulkarni, Kalenahalli Sudarshan, & Toyama, 2018) have noted that **countries with higher levels of gender equality (generally higher-income countries) seem to have lower proportions of women in STEM education and ICT-related majors**. The disparity can be quite wide as seen in Algeria with a gender equality index of 0.64 (lower gender equality) and female STEM graduates at 56%, versus Finland with gender equality index of 0.85 (higher gender equality) and female STEM graduates at 27% (Stoet & Geary, 2018). Figure 10 shows the top and bottom 20 countries in female ICT majors. Reasons for this paradox have not been explored in detail, but some scholars hypothesise that it is driven more by scarcity of economic opportunity than by progressive gender attitudes (Thakkar et al., 2018). On the other hand, this could point to a gap in the indicators used to develop global gender gap indices – most of these indices do not include STEM or ICT-related measures (Huyer & Hafkin, 2008).

Alternative pathways

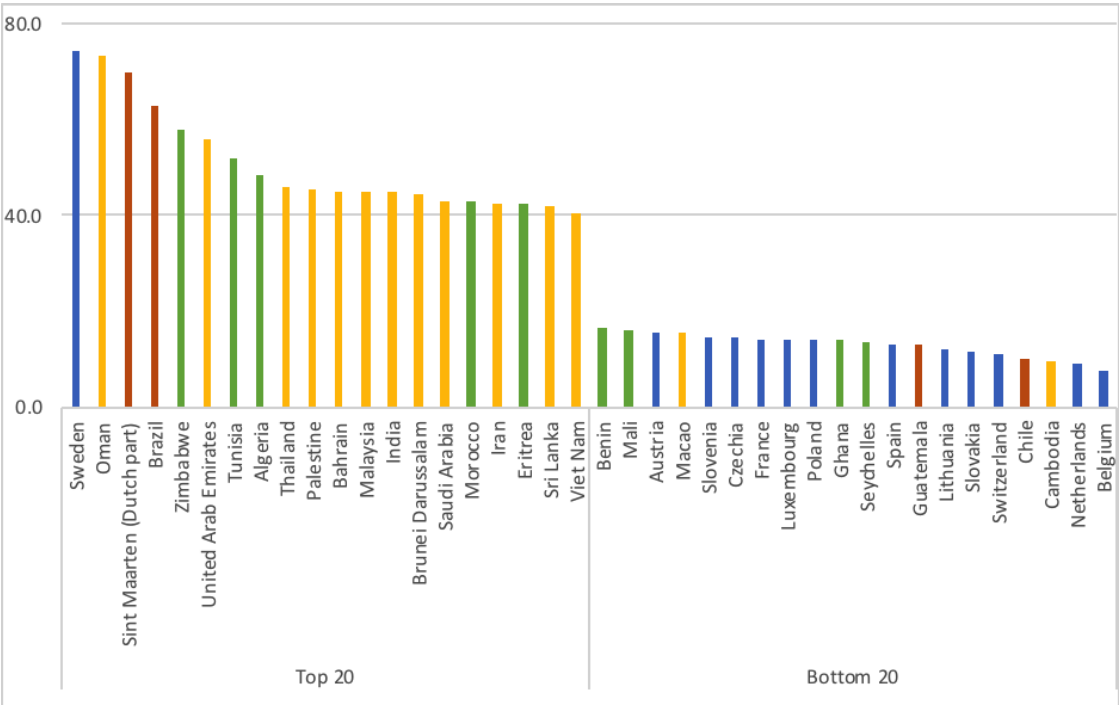
New approaches to developing advanced digital skills are gaining attention for their potential to reach populations underserved by college programs (Brown & Adler, 2008; Liyanagunawardena, 2013; ITU, 2016). Some of these, such as computational thinking curricula at primary school level, MOOCs and coding bootcamps offer learning structures that are somewhat similar to long-standing online and offline education approaches. Others such as hacker and maker spaces offer informal learning environments, some of which are specifically targeted at women and girls. However, **there is limited data and evidence on the efficacy of these pathways for closing gender gaps** in acquiring advanced digital skills. In fact, some research suggests that these pathways are equally dominated by men and present some of the same challenges women face in traditional pathways (Ho et al., 2014; Lewis, 2015; Moilanen, 2012; Toupin, 2014).

Figure 9. Proportion of female enrolments by field of study, global



Source: UNESCO Institute for Statistics (UIS), 2016
Note: STEM data represents the number of graduates, not enrolment

Figure 10. Percentage of female students in ICT majors, 2016 (top 20 and bottom 20 countries)



Source: UIS, 2016

Conclusion

Equal access to education in itself is insufficient to attain gender digital equality. Girls start out equally in math and science studies but tend to fall out at higher secondary levels. Those girls who do study math and science perform at levels near or equal to those of boys. However, girls tend to evaluate their performance differently, and are less likely to gain self-confidence from it. Women are nearly everywhere less advantaged than men in advanced digital skills, particularly in those that lead to high-level ICT employment. It is interesting that the societies that rank highest in gender equality indexes do not necessarily have the highest levels of girls and women in ICT studies.

3. Gender Equality in ICT Leadership

To what extent are women gaining employment in ICT and related industries, and what is their representation at senior management levels? Are women engaged in digital entrepreneurship, and how does their access to business capital compare to that of their male counterparts? Starting from the premise that women are capable of leadership in ICT fields and that there is often a reasonable pool of female talent for technology jobs, this chapter draws on existing research and data to explore the state of women's participation in ICT industry leadership around the world.

Employment

At the global level, over **40% of high-skill occupations are filled by women, but it appears these jobs are mostly not in the ICT industry**. This is demonstrated in low levels of women employed in telecommunications and other ICT-related industries, where the median proportion is less than 35% (Table 2). However, there is wide regional and country variation. For example, women exceed men employed in the Latvian telecommunication industry (60%) but comprise only 23% of the industry in Austria. Similarly, in Africa, the proportion of women ranges from 11% (Mali) to 55% (Uganda), while in Asia it ranges from 5% (Pakistan) to 50% (Mongolia).

Occupational segregation by gender appears to be particularly stark in sectors related to ICTs. **Women make up very small proportions of ICT professionals and electrical and electronic trades workers** (Figure 11) – median levels are below 34% for most regions. Again, country variations abound. For instance, women comprise 45% of ICT professionals and 60% of electrical and electronic trades workers in Peru. Furthermore, within the ICT industry, some sectors may be attracting high proportions of women – for example, in the United States women's participation in the Computer Systems Design sector is only 27%, but almost 40% in Internet Publishing and Web Search Portals. The **software developer community appears particularly devoid of women** (Case Study 3).

In the research and academia sphere, the data suggests that women's representation is equally low, but the ability to draw solid conclusions suffers from limited data availability. Based on UIS data, while **women's share of Engineering and Technology researchers stands at under 30%** for most of the 25 countries with 2015 data, a few are close to achieving equal participation (Malaysia, the Philippines, Kazakhstan and Mongolia). On the other hand, OECD (2017) research finds that the proportion of women ICT specialists consistently lags behind the proportion of men in all OECD communities. **Women's representation as STEM and business school faculty also appears to be low**. In the United States, National Science Foundation data for 2013 shows that women make up an equal proportion of graduates employed in science and engineering-related occupations in universities, but constitute only 34% of science and engineering occupations, and just 17% of computer and information scientists.

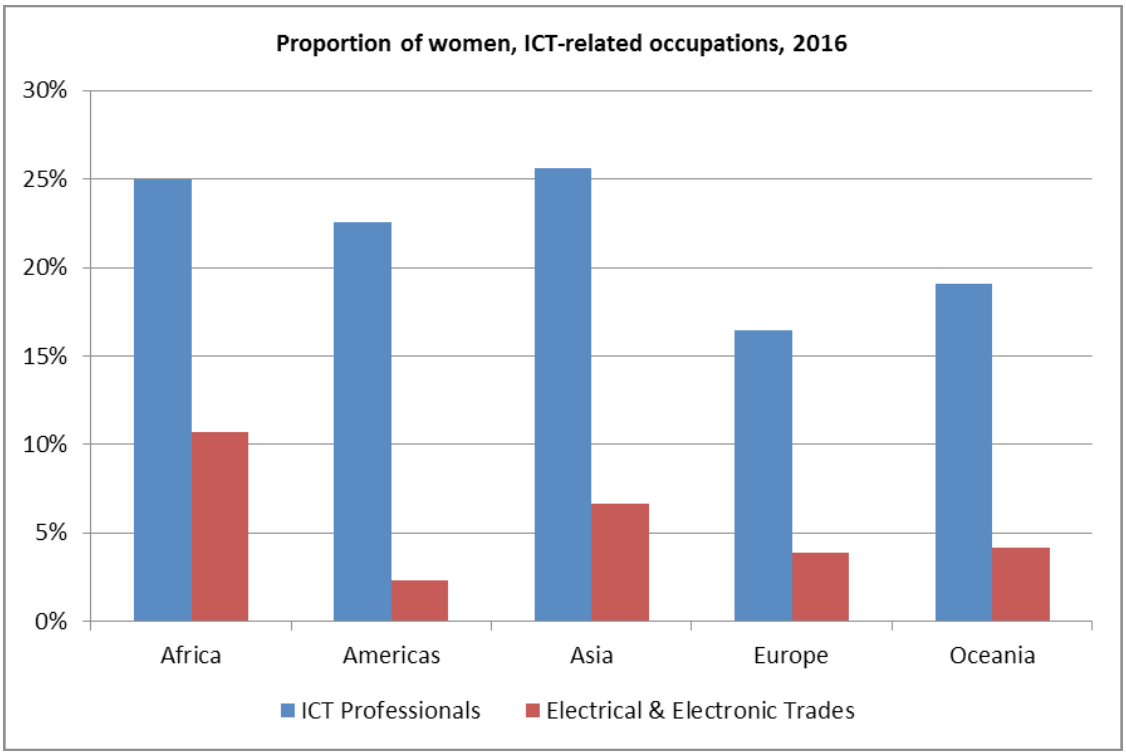
Official statistics on **retention** rates are not collected at the global level, but evidence

Table 2. Proportion of women in the telecommunication industry

			Range (last known year)		
Region	2016	Median	Lowest percentage	Highest percentage	Number of countries
Africa	17.9	33	11 (Mali)	55 (Uganda)	13
Americas	33.2	33	21 (Guatemala)	51 (Ecuador)	11
Asia	35.3	34	5 (Pakistan)	50 (Mongolia)	18
Europe	30.5	32	17 (Bosnia/ Herzegovina)	60 (Latvia)	36
Oceania	27.6	28	28 (Australia)	29 (New Zealand)	2

Source: ILOSTAT labour market indicators

Figure 11. Proportion of women employed in ICT-related occupations, 2016



Source: ILOSTAT labour market indicators
Note: Thin data for most geographic regions.

from North America and Europe indicates that **women leave science and engineering jobs at higher rates than men** (Ashcraft, McLain, & Eger, 2016; Gumpertz, Durodoye, Griffith, & Wilson, 2017; Hunt, 2010). Their reasons for doing so are contested – some researchers attribute it to family life demands, while others believe the true culprit is workplace discrimination such as unequal pay, low access to advancement opportunities, dominant male culture and unwelcoming environments.

In terms of **advancement**, at all levels of leadership (lower management, upper management, executive boards) and across diverse types of institutions (industry and academic), available evidence indicates that men outnumber women. ILO data on women in managerial positions (irrespective of industry type) shows proportions range from 3% to 52%, with regional median values between 22% (Asia) and 37% (Americas and Oceania). Similar trends prevail for women in other types of leadership such as chief executives, senior officials and legislators. Within the ICT industry as well as in academia, data is sparse, but indications are that **women tend to be in junior and support rather than managerial roles**. Where women have made inroads into management, they **are often in staff positions, rather than the line positions which constitute the main pathway to executive roles** (Molina, Lin & Wood, 2015; United States Government Accountability Office, 2017; World Economic Forum, 2017). These trends appear to be repeating in the new industries developing around artificial intelligence (Case study 4).

Some **data are difficult to interpret due in part to varying definitions and the diversity of industry sectors**. For instance, Chanavat & Ramsden, 2013 concluded that telecommunication service company boards are less diverse than those of technology companies (15% versus 20% women); and according to Deloitte (2017), globally, board membership in the technology, media and telecom sector is less gender diverse than other sectors. On the other hand, Quirós et al. (2018) found that in Europe, compared to other sectors, the telecommunication service sector had the highest percentage of women on boards – 27%.

Case Study 3. Women in online software developer communities

Michael Madaio & Araba Sey (UNU-CS)

Online developer communities boast millions of users – over 29 million on GitHub (2018) and over one million on Stack Overflow (2018a). Participation in these communities is becoming one of the primary ways software developers improve their skills, develop collaborative projects and find new job opportunities (David & Shapiro, 2008; Ford et al., 2016; Vasilescu et al., 2015). However, our analyses of open survey data (made available by GitHub, Stack Overflow, and HackerRank in 2017), indicate that women may not be reaping the full benefits.

Who participates in online developer communities?

While women are estimated to comprise nearly 20% of the software development workforce (Wang et al., 2018), in the Stack Overflow survey of approximately 100,000 software developers, only 4% identified as female. In GitHub's survey of 5,500 users, only 2% identified as female. HackerRank had 16% of 25,000 respondents identifying as female.

Among users of Stack Overflow and HackerRank, men were nearly 15% more likely to be senior developers, nearly twice as likely to be in manager positions, and nearly four times as likely to be in executive roles. Male respondents on HackerRank were also nearly 15% more likely than women to be in hiring positions. On the other hand, women on Stack Overflow were nearly twice as likely as men to have technical roles like “data scientist” and “development operations engineers”. These were listed as the top two best-paying jobs in 2018 by the GlassDoor job salary aggregator (2018).

Do women and men participate differently?

On Stack Overflow, women were less likely than men to have a registered account, and more likely to view questions and answers on the site without responding or posting questions themselves. For GitHub, women were less likely than men to contribute code and “follow” other developers' repositories. These publicly visible acts of participation are the very types of “signaling incentives” that are a benefit of online developer communities for jobseekers (Lakhani and Von Hippel, 2003; Vasilescu, 2014).

Entrepreneurship

Although the gender gap in entrepreneurship has narrowed since 2014, **women are less likely than men to start enterprises in the ICT sector** (Kelley et al., 2017). Women constitute only 6% of IT entrepreneurs in the United States (Gompers & Wang, 2017), while in Europe females comprise 23% of entrepreneurs in the ICT industry (Quirós et al., 2018). For other parts of the world, official and research data on this topic is lacking.

OECD data indicates that **women generally have less access than men to training on how to start a business**. The tendency is the same in the six non-OECD countries included in the dataset. Similarly, **there is a gender gap in access to financial services** that could facilitate access to business capital. World Bank data on account ownership, savings activity and borrowing activity shows gaps ranging from 2% to 11% in favour of men. In a few countries (in Oceania) the gap is reversed with women being more active financial service users.

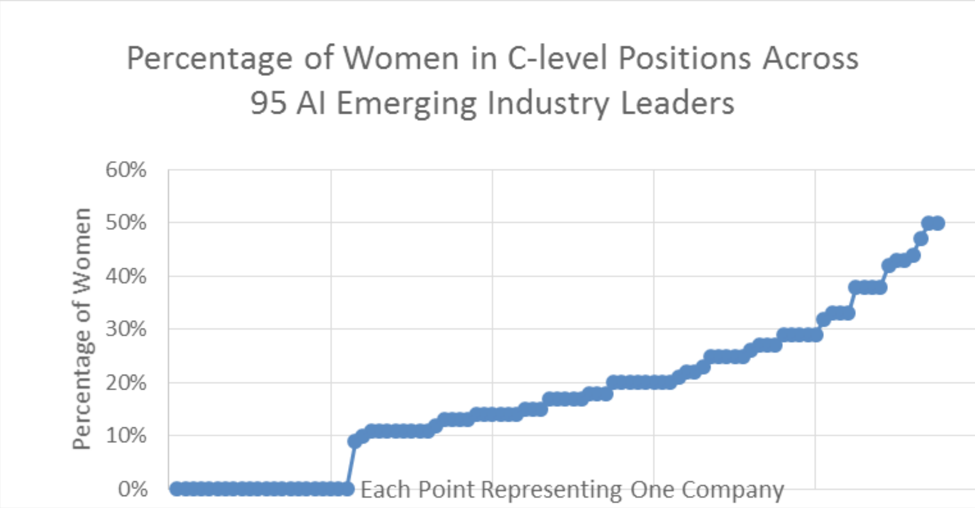
Case Study 4. Where are the Women? Gender disparities in AI research and development

Michael L. Best (Georgia Tech) and Dhaval Modi (UNU-CS)

The artificial intelligence (AI) community has a diversity problem. Microsoft researcher Margaret Mitchell has called AI a “sea of dudes” (Boddington, 2017). New York University (NYU) professor and Microsoft researcher Kate Crawford (2018) asserts that AI has a “white guy problem” and articulates why this matters: "Like all technologies before it, artificial intelligence will reflect the values of its creators. So inclusivity matters — from who designs it to who sits on the company boards and which ethical perspectives are included. Otherwise, we risk constructing machine intelligence that mirrors a narrow and privileged vision of society, with its old, familiar biases and stereotypes."

The low level of female presence among AI researchers, developers and thought leaders might best epitomise this diversity challenge. Hannah Wallach, another Microsoft based AI researcher, has guessed that the entire field of machine learning is only 13.5% female (Weissman, 2016). Wallach’s estimate is depressingly low and underlines an enormous diversity challenge across the field. To better amass evidence on this gender disparity, we have accumulated data on women’s participation in leadership among top AI companies, as well as scholarly presence among the top United States-based university computer science faculty.

Our new study finds that women represent a paltry 18% of C-level leaders among top AI startups across much of the globe and just 22% of faculty in top United States-based university AI programs. Of the 95 companies, only two have an equal number of women to men in their C-level positions and none are majority female. Three in five have less than 20% women in their leadership team and one in five have no females at all. As stated above, females overall made up 18% of these AI leaders. Out of 18 top programs in the United States, the percentage of female AI faculty ranged from a low of 8% (University of Pennsylvania) to a high of 43% (Harvard).



The distribution of venture capital investment provides a view on the experience of women trying to start ventures in the ICT industry, since a majority of venture capital goes into the ICT and related sectors (Ernst & Young, 2015). Here the evidence is that first, **there are very few female venture capitalists**, and second, **women-run companies receive a dismal proportion of venture capital**. Although investment in businesses with female partners has increased, it remains low. In the United States, 15% of companies receiving venture capital funding between 2011 and 2013 had a woman on the executive team, up from less than 5% in 1999, and these companies received more funding than in previous years (Ernst & Young, 2015; NVCA, 2016). However, only 2.7% of the companies had a woman CEO, and those companies received only 3% of total VC investments Likewise, in Europe, wholly women-owned startups received less than 5% of all VC deals in 2016 (Quirós et al., 2018).

Policymaking

The dearth of female perspectives in the development of the technology industry could potentially be addressed by including more women in senior policymaking positions not only in technology organisations but also in political institutions. At the level of national governance, gender diversity is already low globally – all regions have less than 30% female representation. To examine this topic further, we compiled public information on the gender of heads of two types of ICT-related government agencies; ICT ministries and telecommunication regulators. The results show that **worldwide, only 27 countries have a woman in charge of the ICT ministry** (Table 3) **– nearly 87 percent of ICT ministers are men**. Similarly, **only 26 countries have a woman heading the telecommunication regulator**.

Table 3. Proportion of women heads of policymaking agencies

Region	ICT Ministry	Telecom Regulator
Americas	23%	16%
Africa	17%	9%
Europe	15%	13%
Oceania	7%	13%
Asia	2%	6%
TOTAL	**13%**	**13%**

Source: UNU-CS desk research.

Conclusion

While more women are holding highly skilled jobs, few of them are in ICT fields. However, there is wide variation in this by country. Within ICT and STEM occupations, women are nearly absent from software development, engineering and technology research and university teaching. There is a high rate of women leaving science and technology jobs due to the lack of work-life balance frequently found in male dominated fields as well as obstacles to achieving their career goals. Few women are found at all levels of technology leadership; instead, they tend to be found in subordinate roles with little chance for advancement. Women are also less likely to become ICT entrepreneurs and have very little access to venture capital. Most seriously, they have a very low rate of representation in science and technology policy making.

4. The Dark Side

Promoting gender digital equality does not stop at women having the capabilities to access, meaningfully use and create ICTs. Neither does it end with the opening of doors to enable women to participate on an equal footing with men as workers, employers or decision-makers in the digital economy. For all its advantages, the digital age comes with general (Unwin, 2017) and gender-related risks and pitfalls, some of which are an extension of already existing dangers, while others are a direct response to women's increasing connectivity and visibility in male-dominated spaces. **Greater female inclusion in the EQUALS Partnership action areas can become associated with increased exposure to undesirable experiences unless that inclusion is accompanied by corresponding changes**

in the social and institutional cultures that enable or tolerate negative behaviour.

Areas of concern include cyber violence against women and girls (cyber VAWG); sexual harassment in public, educational and employment settings; education and work-related discrimination; and work and life balance. Other potentially relevant issues such as internet addiction, risky online behaviours like sexting, or human exploitation are not covered in this report.

Cyber violence

Data from the United Nations Statistics Division (UNSD), shows that between 1% (Singapore) and 51% (Bangladesh) of women in reporting countries have experienced some form of physical or sexual violence. As access to mobile phones and the internet become widespread, it is important to ensure that the violence women and girls experience offline are not replicated and amplified online. The Broadband Commission Report on Cyber VAWG estimates that **about 73% of women have already been exposed to or have experienced some form of cyber violence**. In the EU, it is estimated that one in ten women have already experienced a form of cyber violence by the age of 15 (EIGE, 2017). Surveys in the United States, Germany, Australia and Pakistan among others indicate that **women are the target of most online abuse**. Global data are harder to come by with no single international repository of data on cyber VAWG. While data on the incidence of cyber violence against women are lacking, UNCTAD's Global Cyberlaw Tracker shows that several countries are passing laws that could be applied to cyber violence. As of May 2018, 140 countries (72% of the 194-member states) have enacted legislation related to cybercrime and 112 countries (58% of countries worldwide) have enacted laws related to data privacy and protection. Europe leads with almost 100% of its countries enacting legislation on cybercrime and data protection, followed by Asia, the Americas, Africa and Oceania.

Sexual harassment

In recent years, several gender-related scandals in the technology industry have dominated the news headlines, pointing to a culture of gender-based discrimination and harassment that discourages women from pursuing technology careers or makes professional life challenging for those that stay. Although sexual harassment is often discussed in the context of workplace, other areas such as public education and the public sphere are increasingly becoming recognised as sites of harassment (National Academies of Sciences, Engineering, and Medicine, 2018; World Bank Group, 2018).

Increased access to ICTs unfortunately means increased potential to experience sexual harassment in the form of online violence online, but also in offline spaces such as cybercafés. Likewise, increased access to educational and professional opportunities in male-dominated STEM and related areas also increases the possibility of encountering insensitive or hostile masculine environments. These environments simultaneously act as barriers to entry and retention for some women and physical and psychological burdens to those who choose to brave an often-hostile environment. For example, **one in ten female tech job leavers in the United States reported having experienced unwanted sexual attention in their last job** (Scott, Kapor Klein, & Onovakpuri, 2017). This is by no means a problem for women only, as one in twelve men also reported unwanted sexual attention.

In terms of regulatory protections, **although most countries (154) have some legislation against sexual harassment, existing regulations are primarily workplace-related**. As of 2018, **65% (123 countries) of reporting countries have no sexual harassment legislation for schools and 83% (157 countries) have no legislation covering public spaces**.

Discrimination

Gender-based discrimination in occupational settings may be overt but can also take subtle forms and tends to affect women more than

men. Types of gender-based discrimination include unfairness in hiring, firing and promotions, unequal pay, unequal access to professional advancement opportunities, and unconscious biases. Quirós et al. (2018, p.10) report that women in the European digital workforce experienced gender discrimination more so than men. Between 23% and 45% of women science, engineering and technology workers in China, United States, Brazil and India said they felt stalled in their careers; and between 20% and 32% said they were likely to quit their jobs within a year (Hewlett & Sherbin, 2014). Over 50% of female cybersecurity professionals reported having experienced discrimination in the workforce (Frost & Sullivan, 2017).

Unequal pay for the same work is one of the more enduring forms of gender-based discrimination in the workplace. Data scarcity limits our ability to accurately capture the state of the gap, both generally and in the ICT industry. In Europe, available data for all professions shows pay gaps in favour of male workers ranging from 6.6% to 38%. The Americas show a similar trend of mostly higher wages for men (2% to 25% more) and in Asia, male workers also tend to earn more than female workers (from 2% to 33% more). **Evidence on gender pay gaps within the technology industry is contextual and sometimes contradictory**. Glassdoor's analysis of salaries (Zarya, 2016), controlling for variables such as age, education, experience, occupation, industry, location, company and job title found that **even when workers were almost identical in every way except gender, the gender pay gap for technology workers (28.3%) was much higher than the gender pay gap for all workers** (5.9%). However, to the contrary, the United States Department of Commerce (Noonan, 2017) reported that there was **a smaller gender pay gap in STEM occupations than in non-STEM occupations**.

In terms of the policy environment, **most countries have some legislation in place addressing employment-based gender discrimination**, including: constitutional non-discrimination provisions specifying gender; and prohibition of discrimination in promotions, demotions, training opportunities and pay. Europe has the strongest record of legislation protecting against discrimination in all areas, although only a few countries in Europe mention gender in their constitution's non-discrimination clause. In all regions except Oceania, more than half (51% or above) of countries have legislated against each type of discrimination.

Work and life balance

A masculine-oriented work model pits work-devotion against family-devotion, and the associated tension can lead to overload among women in technology professions (Blair-Loy & Cech, 2017; Bright Horizons, 2017; Weisgram & Diekman, 2015). Labour force data indicates that **women generally work fewer paid hours than men and spend a much larger proportion of their time than men on unpaid domestic and care work**. The evidence on how much this impacts their participation in the ICT labour force is unclear. Sassler, Glass, Levitte, & Michelmore (2017) conclude that it "is difficult to account for the factors associated with these employment disparities" (p.19). However, according to Erosa, Fuster, Kambourov, & Rogerson (2017) an "asymmetry in household production" leads to women self-selecting out of occupations (such as the technology sector) that reward long hours (p.4), with a 10% reduction in women's discretionary time due to their nonmarket activities, causing a 14% reduction in their labour market participation. Some scholars assert that **having children is the most important factor preventing women from pursuing careers in science and engineering** (Xie, 2006), while others have argued that **women's primary reason for leaving technology jobs is not family-related but rather due to obstacles to achieving company and career goals** (Ashcraft et al., 2016; Hunt, 2010; Meiksins, Beddoes, Masters, Micah, & Shah, 2016). This of course does not address potential quality of life compromises made by women who persevere in combining family life with the rigors of ICT careers.

If family care plays a role in shaping women's career decisions, then the extent to which organisations make it possible for women to combine motherhood with work can be a crucial factor affecting the

size of the female work force. Data show that in theory, **most countries have legal provisions to support working mothers**. European countries have the most generous policies related to paid parental leave and breastfeeding at work, while countries in Oceania have the least generous allowances.

Conclusion

With violence against women widespread globally, access to ICTs increases the exposure of girls and women to cyber violence. The response to this must come from overall culture change in attitudes towards sexual harassment and all forms of sexually based violence. Similarly, as more women venture into STEM and related training and occupations, they risk exposure to sexual harassment and various forms of discrimination associated with the field. A dominant masculine-oriented work ethic also presents challenges for people interested in ICT careers but seeking greater work and life balance.

5. Barriers and Recommendations for Gender Equality in ICT Access, Skills and Leadership

Barriers

The barriers and disadvantages that inhibit women's equality in ICT access, skills and leadership are diverse, multifaceted and often embedded in longstanding social structures that generally privilege men over women. Overall, barriers can be grouped into six broad categories (Table 4).

Access

Barriers to ICT adoption and meaningful use include: i) availability of the technology, especially in rural settings where more women may be concentrated; ii) affordability due to low income or economic conditions; (iii) educational background, aptitude and skills to use ICTs; (iv) women's perception of the usefulness of ICTs in their daily lives and the availability of content that is relevant and accessible; (v) safety issues such as cyber violence; and (iv) the cultural contexts and norms that limit women's access to and use of ICTs (for example through restriction of women's movements outside the home).

Skills

Perhaps more so than with ICT access, the gender gap in advanced digital skills is created by ambiguous intersections of multiple barriers at the individual, family, school and society levels (SWE 2016). Despite several years of research, scholars have not reached a consensus on how and why this occurs. Identified barriers to gender equality in advanced digital skills include four challenges: i) inaccurate self-perception, which leads females to underestimate their own ability to develop high-level digital skills or succeed in STEM studies, ii) information barriers, limiting women and girls' ability to make informed decisions about their education and training options; iii) gender stereotyping of STEM as a male domain, that pushes away many talented young women; iv) lack of role

Table 4. Barriers to gender digital equality

	Access	Skills	Leadership
Availability of infrastructure	√		
Financial constraints	√		√
Ability and aptitude (perceived and real)	√	√	√
Interest and perceived relevance	√	√	√
Safety and security	√	√	√
Socio-cultural and institutional contexts	√	√	√

models to inspire and attract girls and young women to STEM careers; v) institutional barriers within schools and colleges which fail to provide gender-sensitive curricula to embrace the needs of girls and young women.

Leadership

While numerous reasons have been proffered for the low presence of women in ICT-related industries and occupations, few are backed by strong empirical evidence, especially across different national contexts. The barriers women face can be challenging to observe or capture, considering the complex personal, social, cultural and organisational factors that encircle and intertwine the issue. Barriers may be either supply- or demand-driven. Supply side factors deal with the interest and willingness of women to participate in the ICT industry. Demand side factors address the openness of the ICT industry to female participation. While some scholars attribute gender inequalities primarily to supply factors, others argue that demand factors play a stronger role. The truth is probably somewhere in between. As Xie (2006, p.167) observed: "women's severe underrepresentation in science and engineering is an extremely complex social phenomenon that defies any attempt at simplistic explanations." Summarising Xie (2006), competing supply-related rationales for gender gaps include the i) "critical filter hypothesis" (girls are handicapped because they are not good at mathematics); ii) "pipeline problem" (women drop out of science training or careers), iii) "productivity puzzle" (female scientists are less professionally productive than men); and iv) "family life hypothesis" (women prioritise family life over careers in science). Demand-side rationales include i) perceived lack of aptitude, ii) biased recruiting and financing practices; iii) gender-based discrimination; iv) unwelcoming professional environments; v) social norms and pressures regarding female roles (see Case study 5 on gender stereotyping of AI), and vi) unsupportive policy and regulatory regimes.

Recommendations

Resolving gender digital inequalities requires addressing the different barriers that affect women's engagement with ICTs, development of digital skills and career opportunities in the ICT industry. Table 5 summarises recommendations identified in the literature, as they relate to the barriers discussed in the previous section. The complexity and diversity of possible solutions grows as the topic moves from access to skills to leadership-related gender inequalities.

Access

Strategies to increase gender equality in basic and meaningful ICT access generally propose addressing accessibility and affordability barriers, providing relevant content, improving safety and security on and offline through public education as well as technical and legal means, mainstreaming gender perspectives into policies and budgets, and sharing good practices (Broadband Commission, 2015b, 2017b). Investing in women's education and basic digital skills capacity-building are also frequently proposed (Web Foundation, 2015).

Skills

The main proposals for closing gender gaps in advanced digital skills and STEM education range from making training more accessible for women and underrepresented groups (Huyer, 2001; Microsoft, 2017; UNESCO, 2017) to addressing gender stereotyping of STEM education and building girls' self-efficacy and confidence in STEM (Accenture, 2017; OECD, 2015; Ro & Knight, 2016). Approaches include mainstreaming gender equality into STEM education policy and promoting collaboration between multiple stakeholders (schools, teachers, private sector and government) to deliver consistent messages about gender equality.

Leadership

Most proposed remedies target one or several of the following: combating gender stereotypes

Case Study 5. Ok Google: Is AI gendered?

Araba Sey & Lisandra Fesalbon (UNU-CS)

As artificial intelligence (AI) products such as Siri, Alexa and Cortana become prominent fixtures in daily life, debates rage about their potential and dangers. Due to its perceived neutrality, there are high expectations that AI will engender diversity, social inclusion, fairness and equality. However, evidence is already emerging that even AI is prone to reproducing social biases and stereotypes (Gustavsson & Czarniawska, 2004; Gustavsson, 2005). This case study examines whether AI products are given overtly gendered identities and whether these identities reinforce occupational gender stereotypes.

To determine gender identity, we classified the names, voices and appearances of 129 AI products, based on information on product websites as well as product advertisements and demos. Overall, virtual personal assistants had primarily female identities, followed by neutral identities (Table 1).

Table 1: Gender identities of virtual personal assistants

	Female	Male	Neutral	Both	Unsure	Total
Name	40 (41%)	23 (23%)	27 (28%)	0	8 (8%)	98 (100%)
Voice	48 (68%)	9 (13%)	0	9 (13%)	4 (6%)	70 (71%)
Appearance	21 (50%)	8 (19%)	12 (29%)	1 (2%)	0	42 (43%)

Text-to-speech products, on the other hand, were overwhelmingly neutral on the surface (Table 2). However, most (84%) offered the option to choose gendered names and their respective voices within the software.

Table 2: Gender identities of text-to-speech software and applications

	Female	Neutral Name	Both	None	Total
Name	1 (3%)	30 (97%)	0	0	31(100%)
Voice	5 (16%)	0	26 (84%)	0	31 (100%)
Appearance	0	0	0	31 (100%)	31 (100%)

These findings suggest an inclination for AI products to have gendered identities that to some degree replicate occupation stereotypes, especially regarding "pink-collar" jobs. Most virtual personal assistants are designed to carry out basic clerical tasks such as answering e-mails, reading or sending messages and planning calendar agendas. The fact that the sample of virtual personal assistants was primarily female-gendered is consistent with the tendency for these types of frontline services to be associated with female workers in the offline world (Gustavsson, 2005; LaFrance, 2016; Piper, 2016; Zdenek, 2007). However, the strong presence of products with neutral identities is an encouraging sign that some developers are proactively limiting overt gender stereotypes from their products.

Recommendations

Future research should expand the scope of analysis to include AI products of varying types, life-stages, sectors, geographic origins and languages. Demand-side analyses would shed light on consumer preferences as well. To mitigate widely-held gender stereotypes, AI product developers could give their products neutral identities, or at the very least, incorporate multiple options, allowing consumers to decide.

Table 5. Recommendations for addressing barriers to gender equality in ICT access, skills and leadership

Barriers	Recommendations
Availability of infrastructure	• Expand infrastructure to unserved and underserved communities • Support original research and the collection, tracking, analysis and sharing of sex-disaggregated data
Financial constraints	• Improve affordability • Remove gender-based barriers to acquiring business capital • Support original research and the collection, tracking, analysis and sharing of sex-disaggregated data
Ability and aptitude (perceived and real; endogenous and exogenous)	• Invest in digital literacy capacity-building • Address gender stereotyping of STEM • Invest in entrepreneurship capacity-building • Support original research and the collection, tracking, analysis and sharing of sex-disaggregated data
Interest and perceived relevance	• Provide relevant content and services • Increase awareness and demonstrate potential and relevance of ICTs and ICT careers • Address gender stereotyping of STEM • Support original research and the collection, tracking, analysis and sharing of sex-disaggregated data
Safety and security	• Develop social, technical and regulatory measures to eliminate safety and security threats in public, educational and workplace settings • Support original research and the collection, tracking, analysis and sharing of sex-disaggregated data
Socio-cultural and institutional contexts	• Combat stereotypes, biases and discriminatory norms at individual, institutional and societal levels (for example increase media awareness and sensitisation, establish and enforce legislation, promote gender sensitive learning approaches and environments, spotlight role models, foster work and life balance, diversity policies & programs, gender lens investing) • Collaborate with stakeholders (for example consult and involve both women and men, share good practices and lessons) • Support original research and the collection, tracking, analysis and sharing of sex-disaggregated data

and biases at individual, institutional and societal levels; establishing programs and supportive structures to encourage female participation and advancement in ICT occupations; legislating diversity obligations; and diverting resources to institutions that are more gender diverse. Proposed actions cover a wide range of possibilities: equipping young girls with the skills and information to make informed choices about working in STEM; promoting alternative pathways to STEM careers; changing the image of computing and engineering in the media; and addressing the unevenness of historical transformations in gender roles, by promoting male participation in female-dominated occupations (AAUW, 2017; Ashcraft, McLain, & Eger, 2016; Banchefsky & Park, 2018; F. D. Blau, Brummund, & Liu, 2013; Corbett & Hill, 2015; Erosa, Fuster, Kambourov, & Rogerson, 2017; ILO, 2017a; Miller David I., Nolla Kyle M., Eagly Alice H., & Uttal David H., 2018; Molina, Lin, & Wood, 2015).

While some proposed remedies target specific manifestations or symptoms of gender digital inequality (for example affordability or recruiting practices), others

Case Study 6. Gender Digital Inequality from the Life Course Perspective

Moon Choi (KAIST Graduate School of Science and Technology Policy)

Everything has its roots. Nothing comes out of thin air. The current state of gender digital inequality is the outcome of accumulated oppressions that women, who used to be girls, have faced throughout the course of their lives. For the last decade, research and discourse on gender digital inequality has advanced slowly but steadily; still, it lacks theoretical perspectives which could provide insight into the mechanisms of gender digital inequality as well as critical intervention points to reduce it. The concept of "life course" — one of the primary theoretical frameworks in the field of gerontology and human development — can be applied to enhance understanding gender digital inequality.

Individuals belong to a particular cohort, based on their birth years, in historical context and time (Elder, 1998). The life course perspective emphasises the structural influences of cohort, history, culture, and location in relation to individuals' life experiences and pathways while attempting to bridge sociological and psychological constructs (Hooyman & Kiyak, 2011; Settersten, 2006). Early life experiences and decisions, often constructed by society, affect future life experiences; and advantages and disadvantages in early life tend to be accumulated over the life course and maximised in old age (Dannefer, 2003). The gender digital divide needs to be understood from this life course perspective, considering that women's decisions on education and career arise from early life experiences and social constructs by cohort. The decision not to take mathematics — largely due to gender socialisation (Nosek, Banaji, & Greenwald, 2002) — would become a constraint on moving into careers in science and engineering afterward (Moen, 2016). Also, after starting a family, women often become the primary caregiver for children and other family members. Those caregiving responsibilities may conflict with full-time employment, especially in positions requiring more time and effort.

The life course perspective would suggest that enacting seemingly simple solutions such as increasing access to the internet and digital devices among girls and women cannot work effectively without fundamental changes in prevalent gender norms and culture. In order to reduce the gender digital divide effectively, current and future cohorts of both girls and boys should not learn gender, and also both women and men need to unlearn gender, especially around the potential to succeed in math, science, and other technical subjects. Older women also suffer social exclusion related to digital literacy in that accumulated disadvantages tend to be maximised in old age.

call for reshaping of deeply ingrained social norms and practices that are at the root of gender inequality (Case study 6).

Conclusion

Factors that contribute to gender digital inequalities usually fall into one of the following six categories: infrastructure availability, financial constraints, ability and aptitude, interest and perceived relevance, safety and security, and socio-cultural and institutional constraints. There is growing acknowledgment that **these barriers can only be eliminated through concerted efforts involving multiple stakeholders, including academia, policy makers, the private sector, non-government organisations and civil society**. Proposed solutions include those that target symptoms of gender equality, and others that target underlying socio-cultural environments. Scholars also increasingly **caution against one-size-fits-**

all solutions, considering the contextual nature of gender digital divides and the need to identify root causes before trying to apply solutions. Due to the sometimes-contradictory evidence for different solutions, data collection and monitoring are essential components to determine if solutions are effective and why. Furthermore, i**t is important to act in an inclusive manner so as not to alienate the male population, overlook other disadvantaged populations or exacerbate backlash**.

6. The State of Sex-Disaggregated Data on ICT Access, Skills and Leadership

There is a severe lack of official sex-disaggregated and gender data on most ICT-related topics, and yet such data are essential for gender research to make it possible to capture and analyse societal differences between men and women (UNECE, 2010, p.1). Considering the centrality of ICTs in modern society, sex-disaggregated data are critical for meaningful dialogue and policymaking on gender equality. Furthermore, an absence of longitudinal data inhibits insights into trends. Contributors to the dearth of data include lack of national capacity to collect the relevant data as well as the diversity of potential indicators, definitions and data collection methodologies that constrain international comparability.

Over the years, advances have been made in promoting collection of sex-disaggregated data on basic ICT access, with the UN including three ICT access measures in its Minimum Set of Gender Indicators (UNSD, 2017). The Minimum Set of Gender Indicators categorise the prescribed indicators into three tiers based on three criteria – conceptual clarity, established methodology and regularity of data collection (Figure 12). In this section we assess the ICT access, skills and leadership indicators covered in this report against those criteria.

Based on the UN data availability tiers and our searches for academic studies, we conclude that **most of the information relevant to gender digital equality falls into Tier 2 or 3** (Table 6). Notably, even some of the indicators classified by the UN as Tier 1 might be better classified as Tier 2 since (as shown in Tables 7 to 9), few countries are reporting those data. Research knowledge is mostly fair or poor, as much of the existing scholarly work takes the form of narrowly-scoped research concentrated in a few North American and European countries.

Access

Based on the ITU World Telecommunication and ICT Indicators database, **most countries currently do not collect or share sex-**

Figure 12. **UN Minimum Set of Gender Indicators tier definitions**

Source: UN Statistics Division

Table 6. **State of data and knowledge on gender digital inequality**

	Access	Skills	Leadership	Dark side	Barriers & Recommendations
Official statistics	Tier 1/2	Tier 2/3	Tier 3	Tier 3	Tier 3
Research knowledge	Good/Fair	Fair/Poor	Fair/Poor	Fair/Poor	Fair/Poor

disaggregated data on ICT access and basic digital skills. The proportion of countries with data on basic access ranges from 17% for mobile phone use, to 46% for internet access. The highest number of countries reporting any of the eight digital literacy-related skills is 50 (26% of countries worldwide), and the lowest number is 17 countries. Only nine countries worldwide have data for all the eight basic skills that ITU monitors. European countries have the best data availability and African countries the least.

Data on financial inclusion, on the other hand, are more readily available – the World Bank's Global Findex contains data on between 142 and 144 countries for most indicators (except for use of mobile money services where data collection was focused on developing countries). **Data are not yet systematically collected on cyber VAWG** as codifying and translating the various notions into measurable indicators remains a major challenge. Table 7 summarises the state of ICT access data availability.

Skills

Beyond basic digital literacy, **there is also a lack of internationally comparable data to comprehensively measure advanced digital skills**. ITU's indicator on the proportion of a population that can write a computer program has data for only 49 countries. OECD's Survey on Adult Skills includes a test-based measure of ICT skills for problem-solving, but the data is limited to 36 mostly European OECD countries. In general, high-level digital skills are estimated via a proxy of qualification obtained from formal educational or training in ICT or STEM specialisations. The main source for this data is the UNESCO Institute of Statistics (UIS). As is the case with data on ICT access, Europe has the most data coverage, followed by Asia; while data from Africa are sparse. Table 8 summarises the state of ICT skills data availability.

Leadership

Data from the primary source of global occupational data (International Labor Organization, ILO) include some breakdowns by gender, sector and occupation. However, **the quantities, classifications and types of data available obscure insights into the levels of gender participation in the ICT industry specifically**. The data also only capture stationary metrics; so, a gap remains in our knowledge of trends in *retention* of female ICT workers. Some major countries such as the United States and Canada are generally not covered in the ILO databases. The World Bank, OECD and Inter-Parliamentary Union are alternative sources for some of the relevant data; however, there are several issues on which there are simply no official internationally comparable statistics. Again, Europe has the most robust data for most official indicators. Table 9 summarises the state of data availability on issues related to women in ICT leadership.

Clearly much work is needed, both conceptually and practically, to fill gaping data holes. Scholarly research (both quantitative and qualitative) is mostly focused on countries in North America and parts of Europe. Data on African countries is particularly lacking (Case study 7). Three case studies illustrate attempts to improve data from different angles – leveraging big data to supplement existing data sources (Case study 8), using citation databases to track female academic productivity (Case study 9) and collaborating with educational and government stakeholders to collect primary data (Case study 10).

Conclusion

There is a serious lack of official statistics on most topics related to gender equality in ICT access, skills and leadership, especially in the developing world. Coverage is best for ICT access, but even here there are large gaps. A majority of the indicators identified so far are conceptually unclear, lack an established methodology, or are not regularly collected by countries. Big data may offer some possibilities to fill knowledge gaps. There is also limited rigorous qualitative and quantitative research on a wide range of issues and contexts.

Table 7. Status of conceptualisation and collection of sex-disaggregated data on ICT access

	Tier 1	Tier 2	Tier 3	Number of reporting countries	Note
Used a mobile phone or the internet to access an account	√			144 (74%)	UN classification
Used the internet to pay bills or buy something online		√		144 (74%)	Indicator produced from demand-side surveys by World Bank (not by country governments) but consistently collected on the last two rounds of FINDEX (2014/ 2017)
Made or received digital payments in the past year		√		144 (74%)	Indicator produced from demand-side surveys by World Bank (not by country governments) but consistently collected on the last two rounds of FINDEX (2014/ 2017)
Individuals using the internet	√			90 (46%)	UN classification
Proportion of women subjected to physical and or sexual violence by a current or former intimate partner		√		89 (46%)	UN classification
Individuals using a computer	√			78 (40%)	UN classification
Used a mobile money service in the past year		√		77 (39%)	UN classification
Literacy: Copying or moving a file or folder		√		49 (25%)	UN classification
Literacy: Transferring files between a computer and other devices		√		50 (26%)	UN classification
Proportion of women subjected to sexual violence by persons other than an intimate partner, since aged 15		√		50 (26%)	UN classification
Literacy: Creating electronic presentations with presentation software		√		49 (25%)	UN classification
Literacy: Writing a computer program using a specialised programming language		√		49 (25%)	UN classification
Literacy: Using basic arithmetic formula in a spreadsheet		√		43 (22%)	UN classification
Literacy: Finding, downloading, installing and configuring software		√		42 (22%)	UN classification
Individuals owning a mobile phone	√			40 (21%)	UN classification
Literacy: Using copy and paste tools to duplicate or move information within a document		√		35 (18%)	UN classification
Individuals using a mobile phone	√			34 (17%)	UN classification

Table 7. Status of conceptualisation and collection of sex-disaggregated data on ICT access (continued)

	Tier 1	Tier 2	Tier 3	Number of reporting countries	Note
Literacy: Connecting and installing new devices		√		20 (10%)	UN classification
Literacy: Sending e-mails with attached files		√		17 (9%)	UN classification

Table 8. Status of conceptualisation and collection of sex-disaggregated data on ICT skills

	Tier 1	Tier 2	Tier 3	Number of reporting countries	Note
Primary education enrolment, Female	√			167 (86%)	Defined by UNSD
Secondary education enrolment, Female	√			149 (76%)	Defined by UNSD
TVET education enrolment, Female	√			125 (64%)	Similar to others defined by UNSD
Tertiary education enrolment, Female	√			123 (63%)	Defined by UNSD
Female graduates from STEM programmes in tertiary education	√			97 (50%)	Defined by UNSD
Female graduates from ICT programmes in tertiary education	√			96 (49%)	Defined by UNSD
Student performance in STEM (PISA 2015)			√	72 (37%)	Limited to participating countries (less than 50%)
Student self-concept in STEM (PISA 2012)			√	65 (33%)	Not regularly collected
Student performance in Math and Science by gender (TIMSS 2015)			√	57 (29%)	Limited to participating countries, Collected every four years
ITU ICT skills on programming		√		49 (25%)	Defined by UNSD
Adults with vocational education (OECD)			√	44 (22%)	OECD countries
OECD Survey on Adult Skills (ICT-based problem-solving)			√	36 (18%)	Only OECD countries
EU comprehensive digital skills indicators			√	28 (14%)	Only EU countries

Part 1

Table 9. Status of conceptualisation and collection of sex-disaggregated data on ICT leadership

	Tier 1	Tier 2	Tier 3	Number of reporting countries	Note
Proportion of seats held by women in national parliaments, 2018	√			193 (99%)	UN classification, 2018
Paid leave available for mothers of infants, 2013	√			193 (99%)	UN classification, 2017
Maximum wage replacement rate of paid leave for mothers of infants	√			193 (99%)	UN classification, 2017
Mothers of infants guaranteed breastfeeding breaks at work or paid breastfeeding options	√			193 (99%)	Author's assessment; similar to others classified by UN
Non-discrimination clause mentions gender		√		193 (99%)	UN classification, 2018
Gender non-discrimination policies for employment (promotion or demotion, vocational training, equal pay)		√		193 (99%)	UN classification, 2018
Legislation prohibiting sexual harassment in employment		√		189 (97%)	UN classification, 2018
Proportion of females by occupation skill level, 2017	√			188 (97%)	Author's assessment; similar to others classified by UN
Bank or mobile account ownership	√			144 (74%)	UN classification, 2018
Saved at financial institution	√			144 (74%)	Author's assessment; similar to others classified by UN
Borrowed from financial institution	√			144 (74%)	Author's assessment; similar to others classified by UN
Firms with female participation in ownership			√	119 (61%)	UN classification, 2017
Proportion of women in managerial positions, 2016	√			82 (42%)	UN classification, 2018
Mean hours of work		√		66 (34%)	Author's assessment; similar to others classified by UN
Proportion of females, telecommuni-cation industry, 2016		√		60 (31%)	Author's assessment; similar to others classified by UN
Proportion of female senior & middle managers, 2016	√			59 (30%)	UN classification, 2018
Proportion of female ICT professionals, 2016		√		53 (27%)	Author's assessment; similar to others classified by UN
Proportion of female chief executives, senior officials & legislators, 2016		√		52 (27%)	Author's assessment; similar to others classified by UN
Proportion of time spent on unpaid domestic and care work		√		52 (27%)	UN classification, 2018
Proportion of female electrical and electronic trades workers, 2016		√		51 (26%)	Author's assessment; similar to others classified by UN
Proportion of female engineering & technology researchers, 2015	√			25 (13%)	UN classification, 2018
Average hourly earnings: managers, professionals, technicians & associate professionals		√		17 (9%)	UN classification, 2018

Table 9. Status of conceptualisation and collection of sex-disaggregated data on ICT leadership (continued)

	Tier 1	Tier 2	Tier 3	Number of reporting countries	Note
Access to business training			√	38 (20%)	Author's assessment, OECD data only
Proportion of female STEM faculty			√	N/A	Author's assessment; no global repository
Proportion of female business school faculty			√	N/A	Author's assessment; no global repository
Proportion of female software developers			√	N/A	Author's assessment; no global repository
Proportion of males and females leaving ICT industry			√	N/A	Author's assessment; no global repository
Experience workplace discrimination or harassment			√	N/A	Author's assessment; no global repository
Proportion of female managers, telecom companies			√	N/A	Author's assessment; no global repository
Proportion of female members and heads – Academies of Science			√	N/A	Author's assessment; no global repository
Proportion of females, ICT company boards			√	N/A	Author's assessment; no global repository
Access to venture capital			√	N/A	Author's assessment; no global repository
Proportion female heads of ICT regulatory agencies			√	N/A	Author's assessment; no global repository

Case Study 7. ICT, Gender and Data in Africa

Gloria Muhoro (Gender, Women and Civil Society Department, African Development Bank)

Despite the potential of ICTs to catalyse women's empowerment, the scarcity of gender data on this topic makes it difficult to fully justify the consideration and inclusion of gender issues in ICT policies, strategies and initiatives, particularly in developing countries. While this may be a global problem, it is more pronounced in Africa where we know very little about the situation of women and ICTs; from mobile phone and internet access and use, to ICT employment, decision making, entrepreneurship, ICT skills and ICT policies.

Many African National Statistical Offices do not collect national ICT statistics with consistency and regularity, and rarely is the data disaggregated by sex. The telecommunication companies or the national regulators provide most data on ICTs in these countries, and it is hardly sex-disaggregated.

Case Study 7. ICT, Gender and Data in Africa (continued)

Development partners, private sector and non-governmental institutions also provide some data, though limited in geographic coverage. In Rwanda, for instance, the Ministry of Information Technology & Communications produces annual ICT sector profiles which lack data on women's and girls' access and use of technology. This points to the need for gender sensitisation training beyond the national statistics offices to all institutions that provide and manage national data. Development partners and multilateral partnerships can assist in this area. Civil society, particularly gender equality advocates also have a role to play in pressuring policy makers and national statistical offices to produce and publish accurate, relevant and accessible sex-disaggregated data.

Most of the available data today is connectivity-based. It hardly touches on other indicators such as content, education, entrepreneurship, employment, decision-making, skills and policy. In Kenya for instance, the Kenya National Bureau of Statistics publish key indicators measuring gender equality in ICT access, but there is insufficient data in other areas, such as ICT employment, entrepreneurship, policy, leadership and education. To paint the full picture on ICTs, new and comprehensive indicators are needed.

A first step would be collecting all available national ICT data in the context of citizen-generated data, despite its insufficiency or heterogeneity, and using it to enhance ongoing policy discussions. This would have the effect of a) pointing out the need for better sex-disaggregated data and indicators on ICTs and b) initiating dialogue between Civil Society Organisations and National Statistical Offices on the same. In the medium-term, the inclusion of questions on the differential access and use of ICTs by sex can be incorporated as a module into already existing national data collection mechanisms such as census or labour force surveys.

Case Study 8. Measuring Gender Digital Inequality with Web Data

Ridhi Kashyap (University of Oxford) and Ingmar Weber (Qatar Computing Research Institute)

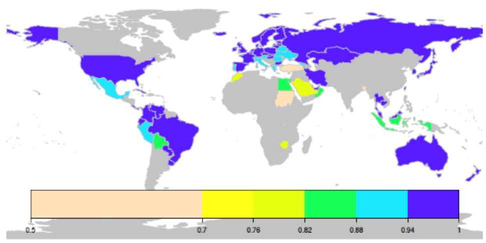
Tracking progress on gender digital inequalities is challenging due to limited gender-disaggregated data, especially in less developed country contexts. With support from the Data2X initiative of the United Nations Foundation, we have been exploring how data obtained from social media advertising application programming interfaces (APIs) can be used to generate real-time measures of gender digital inequality.

In a recently published study, we leveraged Facebook's advertisement audience estimates available from the platform's marketing API to generate measures of gender gaps in internet and mobile phone access in a global perspective (Fatehkia, Kashyap, & Weber, 2018). The publicly accessible Facebook advertising audience estimates are provided to potential advertisers to help them identify target audiences for their ads, but we have found that these data can also be valuably repurposed for social research.

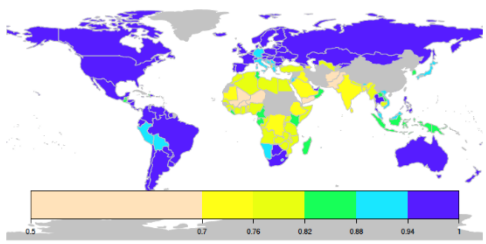
Case Study 8. Measuring Gender Digital Inequality with Web Data (continued)

We used the Facebook data to generate a "Facebook Gender Gap Index", an indicator of the number of female to male Facebook users in a given country. While the Facebook Gender Gap Index reflects gender gaps in Facebook use and not internet access per se, we found it to be highly correlated with official statistics on internet (from the ITU) and mobile phone gender gaps (from the GSMA). Using these Facebook indicators we sought to predict internet and mobile gender gaps from official statistics, and compared the performance of the models using online Facebook indicators with two other types of models: 1) those using offline variables linked to a country's development (for example GDP per capita) and to the gender digital divide (for example gender gaps in literacy) and 2) those for which we used a combination of online Facebook variables with offline ones. For internet gender gaps, we found that models using Facebook data did better than those using offline indicators alone. As shown in Figure 1 panel (b), using Facebook data, we were able to significantly expand geographical coverage of internet and mobile gender gap indicators compared to available statistics in the ITU database (Figure 13 panel (a)), with the biggest gains for less developed countries. Higher values in the figure show greater levels of gender equality, with 1 indicating complete parity.

Figure 13: The internet gender gap index (proportion of the female population with internet access divided by male population with internet access)



(a) Internet gender gap index computed using ITU ground truth data



(b) Internet gender gap index predicted from our Online Model using the Facebook 18+ user gender gap index

Case Study 9. Gender in the Global Research Landscape Gender Disambiguation Methodology

Sarah Huggett (Elsevier)

Critical issues related to gender disparity and bias must be examined by sound studies drawing upon high-quality global data sources and analytical expertise. As an information analytics company, Elsevier is fortunate to have access to both. Our 2017 report, *Gender in the Global Research Landscape,* employs bibliometric analyses and methodologies that enable gender disambiguation of authors within the Scopus® abstract and citation database.

As a proxy for researchers, we use authors whose published articles, reviews and conference proceedings have been indexed in Scopus, Elsevier's indexing and abstracting database covering 70 million documents and over 22,500 journals. Scopus uses a sophisticated author-matching algorithm to precisely identify documents published by the same author. To analyse the gender of researchers and authors, we first identify the gender of the authors in Scopus. This is done by combining Scopus data with data sources providing information on first names and gender per country, which allow us to assign a gender to author profiles with a first name.

We use three data sources to assign genders to the corpus of author profiles. Our first source, Genderise.io, uses data from social media platforms to provide lists of first names, and the number of people with this first name that are women or men. A second data source, NamSor™ Applied Onomastics, uses sociolinguistic characteristics to mine Big Data sources with its name recognition software and assigns a probability that the bearer of a given name is a man or a woman. We use a third source for gender disambiguation of names from Japan: a set of the most common masculine and feminine names from Wikipedia.

The use of Genderise.io and NamSor tends to work well for authors from Western countries and for Latin or Anglophone names. However, these methodologies are not sufficient for robustly determining the gender of names of authors of African, Arabic or Asian descent. Gender disambiguation based on author's first name and country of origin presents challenges, especially for names originally written in other alphabets or languages using different character sets. For these, transliteration into the Roman alphabet often provides an incomplete proxy of the actual name. The issue is particularly prominent for tonal languages such as Chinese, as the tone is lost in the transliteration. As linguists and data scientists continue to improve name gender disambiguation, the combined potentials of artificial intelligence, machine learning, and natural language processing technologies may provide a way forward.

Case Study 10. Tracking data on female programmers in Argentina

Romina Colman, Cecilia Vazquez, Carolina Hadad, Mariana Varela, Yanina Paparella, Melina Masnatta (Chicas en Tecnologia)

Introduction

Chicas en Tecnología has been developing programmes to bridge the gender digital divide by fostering knowledge and enthusiasm of young women in science, engineering and technology. As part of this effort, we are creating a database to gather information on the professional profile of the population to inform public policymaking. Building such a resource requires collaboration with a range of stakeholders who either have relevant data or can facilitate access to it.

Methodology

We collected information on new enrolments, re-enrolments and graduations between 2010 and 2015 in 73 programming courses at 84 public and private universities and institutes. The database will be open and publicly accessible at www.mujeresprogramadoras.com.ar

Main findings:

- Although women outnumber men in new enrolments in all the country's universities and for all reference years, female enrolments in programming courses of study never exceeded 17%. Between 2010 and 2014, five men enrolled for every one woman. In 2015, the ratio increased to six to one.
- The programs with the strongest presence of women were Associate Technical Degree in Web Programming (39%) and Associate Technical Degree in IT (35%). The program with the lowest female presence was Associate Technical Degree in Video-Game Development (6%).
- The greatest number of females graduated in Information Systems Engineering (1,027 or 23%), followed by University Associate Degree of Systems Analyst (362 or 8%) and IT Engineering (321 or 7%).
- In 13 out of 78 organisations, men held more than 90% of technical positions and four of them did not have any women in this kind of job. Only 13 institutions had women represented in at least 50% of technical positions.

Challenges:

- Some institutions lacked specific guidelines for public requests.
- Sex-disaggregated data for some years and institutions were not available.

Case Study 10. Tracking data on female programmers in Argentina (continued)

- Different program naming conventions.
- Documents in a non-reusable format, for example pdf files.

Recommendations:

- Compare female enrolments in programming courses to those in other fields.
- Take advantage of the availability of sex-disaggregated data on Masters and PhD degrees in Argentina to conduct comparisons with undergraduate enrolments.
- Conduct research to find out if any governmental statistics system has gender-disaggregated data on faculty of associate and undergraduate programs.

PART 2

This part deals thematically with three key elements in achieving goals of the EQUALS partnership: People, Skills and Pathways.

People

The emphasis on people first is to underline the importance of viewing technology in its social context. Technology does not exist in a vacuum but is embedded in society. Technology not only has social impact but functions in social contexts and is shaped by social factors. The People section looks at how technology impacts society through inclusion or exclusion of people in various groups – on the basis of gender, in all its varieties, age, disability, and geographical location. The papers in this section look at gender variance in relation to technology, the differences in the gender gap between North and South, the participation and utilization of technology by female children, youth and women with disabilities, and the potential for women's empowerment in rural areas through the utilization of ICTs.

Skills

The skills that are needed for full participation in technology are wide and varied. To secure their privacy and security in modern society, women need at least basic digital and security skills. At a higher level, women need to be involved in designing systems and tools for privacy and security that incorporate their situation and needs. Papers in this section look at whether educational institutions are doing the job in closing STEAM education gaps, on whether differential skill levels and cognitive abilities are responsible for the gender wage gap in technology and whether all jobs in the technology industry enhance technology skills and provide advancement possibilities for women, as evidenced by the case of call center employment.

Pathways

EQUALS is dedicated to achieving global gender equality in the processes and benefits of technology, in particular information and communication technologies and STEM. What are the ways to achieve this result? What courses of action are needed to be taken? The pathways outlined in this chapter examine some of the paths that have been outlined to gender equality in technology, whether the promises of the paths have been fulfilled and what must be done to achieve it. The authors examine the empowerment of women in the technology work force, the participation of women in knowledge and technology transfer, and the prognosis for gender equality in the rapidly expanding field of Artificial Intelligence.

People

Gender variance and the gender digital divide

Tina Beyene (California State University) and Remy Frost (University of New Hampshire)

Gender is a broad and fluid social construct that is not limited to the conventional male and female dichotomy that commonly informs the gender analysis of gender and ICT. Despite two decades of lesbian, gay, bisexual, transgender, queer and intersex (LGBTQI) scholarship that has shown how gender and sexuality are lived along a wide spectrum that show great variation across regions, age groups, times, spiritual traditions and cultural practices, the framing of gender and ICT overwhelmingly focuses on women understood in binary terms. Hence, data on access, inclusion, and innovation of gender and sexual minorities in the ICT sector is scant. Despite the lack of accurate data, gender and sexual minorities innovatively employ computer language coding, gaming, social media and mobile apps as empowerment tools, using them to raise awareness about discrimination and violence and to build social and political communities. But the spread of ICTs also raises concerns of safety for gender and sexual minorities who face harassment and violence via technology-based surveillance tactics. Because of the extreme discrimination, violence and surveillance gender and sexual minorities face, they have unique set of needs for ensuring their success in employment including in the ICT sector; these include healthcare, equitable work spaces, safety, visibility and mentorship. This chapter provides a review of the link between gender and sexual minorities and ICTs, examining the opportunities for access and use and assessing the pitfalls involved. It also makes suggestion for further research and programming to promote gender and sexual equality in ICT.

Key findings

- The review finds that policy and research on gender and ICT focuses mostly on women understood as a binary concept of males and females. Such framing excludes transgender people and often imagines an alignment between gender identity and sexual preference. Consequently, most approaches to women and ICT do not capture the relationships of gender and sexual minorities to ICTs.

- The review also finds that ICTs can make a significant impact in "protection against violence and discrimination based on sexual orientation and gender identity," as enshrined in the 2016 United Nations Human Rights Council resolution. The spread of the internet and social media permit gender and sexual minorities to authentically express their gender without the stress of medically and or socially transitioning or pressures of "coming out".

Smart phones and mobile apps facilitate fast, affordable and culturally relevant dissemination of crucial services such as eHealth interventions to gender and sexual minorities who are disproportionately affected by illnesses such as HIV/AIDS and mental illness.

- Recent moves by the largest social media platforms allowing users to customise their gender has not only made social media more accessible to gender and sexual minorities but is also helping educate millions of users on the broader gender spectrum beyond male and female. However, social media platforms still sell to advertisers, user information that is coded along binary gender categories.

- Technology-driven surveillance and cyberbullying of gender and sexual minorities is increasing. Doxing; phishing; metadata mining; legal requests for information from host sites or internet service providers on the private lives of gender and sexual minorities; the use of social media platforms as "honeypots" to lure gender and sexual minorities by posing as romantic and social suitors and then exposing their private information and more are now common occurrences. These tactics lead to workplace discriminations, physical attack, blackmail, arrest, detention, torture, sexual assault and murder of gender and sexual minorities worldwide.

Recommendations for practitioners and policy makers

- To end violence and discrimination based on sexual orientation and gender identity, ICT-related UN agencies and their partners should visibly express support for existing legal instruments as enshrined in the 2016 United Nations Human Rights Council resolution and the Yogyakarta Principles. This can include high-profile campaigns tailored for the ICT sector, such as the UN Free and Equal online campaign for LGBTQI rights, which reached 2.3 billion social media feeds.

- To ensure that the gender concepts in ICT do not unwittingly mischaracterise peoples' self-understanding of gender and/or reinforce discrimination, include gender and sexual minorities in the shaping of gender equality frameworks at all levels.

- Select or develop ICT services such as e-health interventions in consultation with gender and sexual minority community organisations.

- To end technology-driven security threats, raise awareness of the threats and build the capacity of gender and sexual minority communities, ICT sector employers, healthcare providers, education institutions, and human rights activists, among others. This could include integrating digital security practices into the contexts of specific communities at risk; supporting groups doing this work; and lobbying social media providers whose technologies are used to perpetuate crimes.

- To decrease workplace discrimination, provide training to ICT sector workers about the complexity of gender concepts.

Recommendations for researchers

- To undertake any research that gives insight into the complex relationship of gender and ICT, encourage national and international statistical offices to collect gender-disaggregated data that reflect evolving and fluid concepts of gender and sexuality. To minimise harmful interpretations and to develop culturally accurate data, include members of gender and sexual minority communities at all levels of data collection.

- Assess the rate of access, use and benefits of ICTs such as internet and mobile apps by underserved gender and sexual minorities and account for those who also belong to other under-represented groups.

Understanding the gender gap in the Global South

Alison Gillwald (Research ICT Africa), Helani Galpaya (LIRNEasia), Aileen Aguero (DIRSI)

Central to the call for digital equality are claims that the internet has the potential to be a driver of accelerated progress towards the achievement of the Sustainable Development Goals (SDGs) contained in the UN's 2030 Agenda for Sustainable Development. It is important to understand how these benefits are distributed between men and women and why there appears to be significant unevenness in the adoption at a global and national level. Yet our ability to assess where we stand currently in relation to access and use of the internet and the progress we are making to achieving SDG targets related to information and communication technologies (ICTs) is constrained by the dearth of reliable data. This is particularly so in pre-paid mobile markets where supply-side data can neither tell us the number of unique subscribers, nor can it be disaggregated demographically. This research aims to address the data challenges involved in understanding gendered digital inequality through quantitative and qualitative analysis of not only ICT access and use in 17 countries across the Global South, but also the barriers to coming online and the limitations on optimal use. The nationally representative After Access 2017 household and individual survey was conducted using national census as its sample frame. Households were sampled using simple random sampling and the head of the household interviewed to obtain household indicators. An individual, 15 years or older, was then randomly selected from each household and interviewed on their mobile access and usage. The findings of the ICT access and use survey undertaken by DIRSI, LIRNEasia and RIA across 17 countries in the Global South during 2017 highlight the significant demand-side challenges to achieving SDG ICT goals including affordability of devices and services, low education and associated income levels, digital literacy, and limited availability of local and relevant content. Through the modelling of the data it identifies the factors behind digital inequality often masked by aggregated descriptive indicators, revealing the real point of policy intervention to address gender inequality.

Key findings

The extent of mobile phone ownership and the gender gap broadly aligns with GNI per capita. The five Latin American countries surveyed (Argentina, Colombia, Peru, Paraguay and Guatemala), together with South Africa, are the richest among the countries surveyed and they show the lowest gender gap. In contrast, the poorer countries from Africa show high gender disparity in mobile ownership, but particularly in internet use. These however, are lower than some of the higher income countries of Asia in which we see some of the greatest disparities in income. The GNI per capita in India and Bangladesh is more similar to that of Ghana and Kenya, but both countries, together with Tanzania, which is also among the poorest countries in the world, have much lower gender disparities than in the Asian countries surveyed. There are some countries that buck the trend. Although overall mobile penetration is lower in Colombia than its Latin American counterparts, it has gender parity in mobile ownership. South Africa, which has similar average GNI per capita to the Latin American countries surveyed, despite having one of the highest income disparities in the world, has more women who own mobile phones than men. Of all the countries surveyed India, Pakistan and Bangladesh have the highest mobile phone ownership gender gap. Together with Rwanda and Nigeria (which has by far the largest population in Africa, similar to that of Bangladesh) they also have among the highest gender gap in internet use, though Rwanda has a fraction of the population and land mass of these large countries.

The regional studies examine different aspects of the research to provide insights into the diverse findings. The section on Africa highlights some of the intersectional aspects of exclusion by looking at gender in relation to rural and urban location, education, and income and then seeks to move beyond the descriptive indicators to identify the underlying factors contributing to gender digital inequality by modelling the data. It finds education and associated low income to

be the main determinant(s) of access to the internet. (Women are generally less educated, less employed and have lower incomes.)

The section on Asia highlights the danger of thinking of “women” as a homogenous group and attempting to address barriers to their connectivity in a uniform way. It shows that even the most basic disaggregation of women into rich versus poor introduces new classes of marginalisation and draws attention to the importance of intersectionality. In the section on Latin America, the main factors affecting the gender gap are investigated through an estimation of the effect of observable characteristics like age, occupation and household characteristics. The effects of non-observed factors enabling the identification of country-specific policy interventions to diverse problems facing countries in the region are also investigated.

Recommendations for practitioners and policymakers

Digital inequality is an issue of poverty. As women are concentrated among the most marginalised in society, initiatives that make internet use more affordable and accessible are likely to contribute to reducing the gender gap in internet access. While affordability remains the primary barrier to digital inclusion from a policy perspective, it is clear that demand-side interventions are as critical to digital inclusion as supply-side measures. These will also have to extend far beyond the communications sector if we are to redress disparities between men and women’s access to the internet. With education and income the primary determinants of gender inequality in relation to access and use, far greater intersectoral state co-ordination will be required beyond the telecom sector. As we move beyond consumptive measures of digital equality to production, inequality in education will become an even more significant factor in explaining gender inequity unless access to all levels of education and employment in most developing countries is transformed.

Recommendations for researchers

The dominant research on ICT and gender is binary in its conceptualisation, with gender relations reduced to those of women and men. Finding ways of developing indicators for others than can be safely gathered — especially where they are marginalised and even victimised on the grounds of their sexuality — presents a challenge that the UN as a rights-based body needs to address with the support of research communities. Within the narrow confines of gender as currently defined there is still a dearth of rigorous quantitative research on the digital inequality between men and women that delves beyond descriptive statistics and models the data available in order to understand factors of exclusion and better inform policymakers. Further, many gender research questions cannot be answered by quantitative analysis and require qualitative and hybrid research approaches. Deeply entrenched factors such as social and cultural norms and practices are best explored through qualitative research and theory. Effectively redressing digital inequality will require transforming the structural inequalities that perpetuate economic and social exclusion and that are mirrored, and sometimes amplified, in the digital world. Political economy research that examines relations of power and interests in relation to gender can provide insights into the nature of digital inequality and how it might be structurally addressed.

Technologies and Youth: Key dimensions for investigating gender differences

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This chapter underscores the importance of understanding the use of the internet through a gender perspective and acknowledging gender-specific discourses on the uses of information and communication technologies (ICTs), as well as their implications in terms of opportunities and risks for the young population. The growing use of digital technologies by youth has highlighted the importance of understanding how such transformations affect their lives. Furthermore, such uses potentially provide a multitude of opportunities - ICTs have also been considered by many as a means of supporting children’s

rights, of which those pertaining to gender equality are important. However, such internet use also replicates and creates new inequalities affecting young people — many which are not adequately portrayed in quantitative research — and affect both the unequal uptake of opportunities by girls and boys provided through such use, as well as the nature and the degree of various risks they face online. In this context, how can we portray the inequalities related to the access to and use of ICTs by the young population and how do these differ for girls and boys? How can we identify gender differences in terms of opportunities and risks online? This information is crucial to inform policymaking that aims at bridging the gender digital divide, considering uses and impacts of technology through a gender perspective. In this context, taking gender as a fundamental cross-cutting dimension for understanding the social implications of digital technologies in the lives of the young population, the Regional Centre for Studies on the Development of the Information Society (Cetic.br), a department of the Brazilian Network Information Centre (NIC.br), developed a qualitative research framework aiming at investigating practices of access, use and activities of young people online which escape quantitative approaches. The qualitative study was implemented in the urban setting of São Paulo, Brazil, by Cetic.br in 2016. Focus groups were conducted with internet users aged 11-17, as well as mothers and fathers and also teachers in order obtain more insights into gender specific issues on the use of ICTs by the young population. Additionally, in-depth interviews were conducted with young people who were selected according to their self-identified gender identity and or sexual orientation. Specifically in this chapter we present preliminary results on the intersection of two important dimensions: online privacy and violence, aiming at addressing the emerging challenges of how the population aged 11-17 manage their information online with their different networks and the role of gender in this complex process.

Key findings

- Girls and boys manage their privacy settings according to their intended audiences, and digital skills prove to be particularly relevant for this.

- Both boys and girls aged 11-17 believe that parents are more restrictive and controlling of girls' use of the internet. Many attribute this to gendered norms of what is appropriate or acceptable for girls. This is noteworthy as limited access to ICT may influence how children use and uptake opportunities.

- Girls have more concerns about their personal information online being more exposed to risky situations and are also more likely to suffer negative consequences from this than boys.

- The non-consensual disclosure of nude photos appears to be a common practice and this affects youths' lives. This practice is gender-based: girls' photos are disclosed by boys, without consent, and overall the consequences of such actions are perceived as extremely problematic for girls, with consequences ranging from changing schools to depression and suicide attempts.

- Both girls and boys don't know how to proceed or to whom they would turn for help in situations of non-consensual disclosure of nude photos.

Recommendations for practitioners and policymakers

- Include all stakeholders when addressing the ICT and gender debate: the young population themselves, parents, educators, media, private sector and researchers.

- Mainstream gender in evidence-based policymaking on ICT and youth, considering emerging issues such as privacy and online violence.

- Disseminate information among the population on online privacy and online violence, with special attention not to reproduce victim-blaming discourses or limiting girls' opportunities related to internet use.

- Promote specific actions with a gender perspective for dealing with online violence, such as helplines, integration of this topic in school discussions, and so forth.

Recommendations for researchers

- Conduct more research on uses of ICTs by the young population through a gender perspective, in order to produce more timely data that address knowledge gaps and inform policymakers.
- Involve the young population in the research process: from design to dissemination of results.
- Address specific data gaps and emerging themes on the use of ICTs by youth (for example online privacy and violence), including broader age ranges (such as young girls) and broader geographical scopes (global south, rural areas).
- Conduct researches with mixed-methods approach, producing quantitative and qualitative data.

Accessibility, intersectionality and universal design: How overlapping forms of discrimination limit access to tech for women with disabilities

Anthony Giannoumis (Oslo Metropolitan University)

This chapter focuses on the relationship between the gender digital divide and other forms of social disadvantage and discrimination. The United Nations (UN) Convention on the Rights of Persons with Disabilities (CRPD) recognises the relationship between gender and disability stating "women and girls with disabilities are subject to multiple discrimination", and States Parties have an obligation to, among other things, ensure access to information and communications technologies (ICTs), including the internet, to women with disabilities, on an equal basis with others. Borrowing from feminist legal scholarship, disability rights scholars have adopted the term intersectionality to describe the overlapping forms of discrimination and systematic injustice that affect women with disabilities. Since the 1990s, researchers in human-computer interaction, legal scholars, and industry practitioners have promoted ICT accessibility in an attempt to remove the barriers that persons with disabilities experience using ICTs. Similarly, the UN has argued that under the CRPD, States Parties have an obligation to design technology that is usable for persons with disabilities. The UN is also a proponent of universal design, which refers to the design of ICT "to be usable by everyone to the greatest extent possible without the need for adaptation or specialised design". This chapter explores universal design as a mechanism for promoting access to and the accessibility of ICTs for women with disabilities and the overlapping forms of discrimination that women with disabilities experience accessing and using ICTs.

Key findings

- Universal design provides a useful basis for promoting both access to and the accessibility of ICTs for women with disabilities and provides a useful framework for understanding the overlapping forms of discrimination that women with disabilities experience accessing and using ICTs.
- Research has yet to fully theorise and operationalise universal design in a way that allows scholars and advocates to integrate an intersectional perspective in the design and development of ICTs.
- Scholars have yet to investigate substantively the experiences of persons belonging to multiple socially marginalised groups accessing and using ICTs.
- While ICT developers have made significant strides towards the automatic detection of hate speech online the implementation and technical implications for persons with intersectional identities have yet to be explored.
- Research on ICT accessibility has not yet fully examined the socioeconomic and

sociopolitical mechanisms that persons with disabilities and in particular women with disabilities in the Global South experience accessing ICTs. This has the effect that accessibility becomes accessible for a small fraction of people with disabilities.

- Research in universal design has yet to provide a useful theoretical framework or model that captures the experiences of persons with intersectional identities, such as women with disabilities.

Recommendations for practitioners and policy makers

- National and international law and policy requires systematic reform to incorporate an intersectional understanding of accessibility in technical guidelines, accessibility regulations and antidiscrimination laws.

- Governments must legally acknowledge the experiences of persons with intersectional identities who are subject to multiple forms of discrimination.

- Laws, policies and standards must include requirements for ensuring the universal design of ICTs while at the same time recognising human diversity and the overlapping forms of discrimination and inaccessibility that exist at the intersection of different forms of social disadvantage.

Recommendations for researchers

- Future research could usefully collect data on the experiences of women with disabilities, and focus on ICT barriers that are created at the intersection of different discriminating structures such as racism, transphobia, sexism, homophobia and xenophobia.

- Future research could usefully investigate the interdisciplinary application of knowledge, such as theories, models, and methods, commonly utilised in other fields to inform further research and development within the field of Universal Design of ICT.

- Research could usefully examine the experiences of women with disabilities across the gender diversity spectrum accessing and using ICTs, and research could additionally adopt an intersectional perspective to examining highly salient topics in the ICT industry such as online privacy, child online protection and cybersecurity.

- Future research could usefully employ culturally responsive computing (CRC) to enrich computing education by focusing on an individual user's cultural and social contexts. This includes presenting content in a rich and culturally-embedded way, rather than attempting to "sanitise" it, and framing technology use in innovative ways that invite more active participation, rather than excluding users who don't separate themselves from their multiple identities.

ICT for food security in a changing climate: A path to women's empowerment

Sophia Huyer (Women in Global Science and Technology & CGIAR Climate Change, Agriculture and Food Security Programme)

Women play a critical role in food security in the developing world, but their agricultural activities are often characterised by gaps in information and resource access, with deficiencies in several areas: land, labour, credit, information, extension and technology. Coping with the increased stresses on food security brought about by a changing climate requires the active contributions of women; their equal participation in decision making; equal access to agricultural resources and services; institutions that address their concerns; and technologies and information that are useful to them. ICT and information services have the potential to promote gender equality and empowerment of rural women if they contribute to needs and priorities of women and men in rural areas and increase their resilience to cope with climate change. However, information is not reaching women farmers adequately. ICTs are not providing them with the information, services and knowledge they need and want. Sufficient

evidence and experience exists, however, to base new agricultural information strategies for food security that at the same time support women and promote gender equality. This chapter provides a review of women's access to and use of climate and agriculture information and provides examples of successful strategies for reaching women, with suggestions for further research and programming to promote gender equality with climate information.

Key findings

- The review finds that ICT can play an important role in facilitating support to women in the critical areas defined by FAO for supporting women's activities in food security: livelihood support, reducing women's workloads, ensuring protection from gender-based violence, and equitable access to resources and services. It can do this in particular through access to markets, easing work burdens through increased efficiency and information, increasing agricultural production, facilitating access to resources and services, and supporting women's participation in decision making at household and community levels. Through these avenues it can also encourage women's empowerment and gender equality.

- Analysis of experience to date indicates that successful approaches to reach women with agriculture and climate information seem most often to consist of "mixed" approaches. These take into account low resource access and gender norms that inhibit women from interacting with formal and organised information channels and networks and that restrict their access to certain technologies. Mixed modes or channels of communication will overcome the barriers faced by women at various points in the information dissemination process and also provide the opportunity to take advantage of already existing communications networks and channels. For example, informing traditional social networks with information from mobile phones, or transmitting information received on mobiles through village structures and networks have been shown to produce a significant increase in the quality and speed of information delivery. Intermediary organisations such as farmer associations and women's organisations have also been found to be important avenues for women's information access.

Recommendations for practitioners and policy makers

- Consult with women and women's organisations in the development of ICT-enabled agricultural information to ascertain their information needs and priorities.

- Separately assess climate information needs of women and men farmers, with further disaggregation by male and female-headed households, age, and socioeconomic status where these may shape roles, constraints and hence information needs.

- Assess gender barriers in accessing ICT and information.

- Select or develop ICT services and channels in consultation with women's and community organisations.

- Consider providing a range of useful information services tailored to women's expressed interests including nutrition, health, weather, livelihood and other information, in order to increase the value of these services to women.

- Promote the participation of women and girls in STEM-related subjects, workforce and decision making at all levels.

- Work with the private sector to recognise the potential of women as a market for agricultural technologies, including ICT.

Recommendations for researchers

- Assess the value of climate information services to women in terms of rate of access, use and perceived benefits from use (Huyer et al., 2017).

- Undertake research and assess impacts relating to the key factors and strategies promoting women's empowerment in the use of climate information, for both content and communication and information channels.

Digital Skills

The role of educational institutions in closing STEAM education gaps

Mmaki Jantjies (University of the Western Cape, Department of Information Systems)

Higher educational institutions have a critical role to play in reducing the global gender gap within the science, technology, engineering and mathematics (STEM) fields. Considered the driving force behind the production of human resources to contribute to the knowledge economy, such institutions provide a fertile ground for interventions that can improve the participation of women in STEM. Their two-fold role of both being able to provide skills in STEM as well as produce research in the STEM field, places these organisations as key contributors to the future STEM workforce. This chapter provides a qualitative literature review of challenges that may affect the participation of women in STEM areas, as well as interventions which have sought to increase female participation in higher educational institutions. The chapter also looks at the widespread call by STEM organisations for institutions to consider the importance of arts as a component in developing well-rounded STEM (or STEAM) graduates prepared for the needs of the 21st century workforce. In this chapter, we identify various factors which research attributes to the challenges faced by higher education in increasing the participation of women in STEAM. We present a literature review of studies that evaluate lack of representation in STEAM fields and the role that policy frameworks and practices have played in growing diverse STEAM student populations in educational institutions and, subsequently, as contributors to the economy.

Key findings

- The lack of female role models in STEAM has been cited as a major factor in the low uptake of STEAM programs and courses by young girls in elementary as well as higher educational institutions.

- The lack of a diverse academic and research STEAM workforce in educational institutions, particularly in management roles, leads to perceptions of STEAM as a male-dominated domain. Academic institutions thus often battle to both attract and retain women as students as well as employees in STEAM.

- Educational institutions have sought ways to improve the participation of women in STEAM fields, employing policy frameworks to support an increase in female STEAM participation such as student funding incentives, gender sensitive institutional admission criteria, and gender-sensitive curriculum designs, all of which have a role in increasing the representation of skilled women in STEAM.

Recommendations for practitioners and policy makers

- Invest in early childhood math and science education to support the early development of young girls in math and science subject areas.

- Ensure equal representation of men and women in the educational materials (such as textbooks) used in early childhood STEAM education.

- Direct funding to encourage more equal gender ratios in higher education by, for instance, providing scholarships for more female STEAM researchers and faculty; providing funding support for early-career female STEAM faculty for teaching relief; and funding mentorship programs for female STEAM faculty.

- Increase public-private partnership to fund STEAM programmes and community partnerships between local primary and secondary schools and higher

learning institutions to improve STEAM participation.

Recommendations for researchers

- Conduct research to identify high-impact opportunities for higher education to improve the representation of women in STEAM.

- Conduct longitudinal studies on the efficacy of initiatives to support STEAM uptake, from primary level through high school and further education into the STEAM workforce.

- Conduct research on the network effects of mentorship and the presence of female role models in STEAM education and research labs on female STEAM students' persistence through the STEAM educational pipeline.

- Conduct research on the efficacy of openly accessible educational opportunities for fostering women's persistence in STEAM, including, but not limited to, targeted Massive Open Online Courses (MOOCs), open educational resources, and zero-rated open platforms.

The gender wage gap in the digital era: The role of skills

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As the digital revolution unfolds and continues to change the nature and content of jobs, the demand for skills also changes. This chapter addresses the question of whether women are equipped with the skills needed to navigate the digital economy. It exploits individual level data from 31 countries worldwide to analyse and compare the returns to skills for men and women in terms of wages, and how these returns differ between digital intensive and less digital intensive industries. If labour markets value differently the different skills that workers are endowed with and reward to a higher extent the skills needed in the digital era, differences in returns should allow identifying which skills are in relatively higher demand and the extent to which returns differ in digital intensive industries, as compared to less-digital intensive ones. Results show that the digital transformation may be contributing to widening the gender wage gap, as digitally intensive sectors display greater gender wage disparities than less digitally intensive sectors, even after accounting for a number of features of the workers and of their job places.

Key findings

- Workers' skills, both cognitive and non-cognitive, are found to explain part of—but not all— the gender wage gap in 31 countries.

- Men are on average found to be better endowed than women with the task-based skills that are most demanded in digitally intensive industries, namely managing and communication, self-organisation and advanced numeracy skills. They also appear to obtain higher returns for those very skills in digitally intensive sectors, but not in less digitally intensive ones.

- Women are generally found to be better endowed with information and communication technology (ICT) task-based skills and to be rewarded relatively more for them, in both digitally intensive and less digitally intensive sectors.

Recommendations for practitioners and policy makers

- Policies aimed to reduce the gender wage gap should foster women's participation in education and continuous learning, especially in foundational skills, ICT and advanced numeracy (STEM) skills. To this end, it would be important to raise awareness through information campaigns, to encourage female pupils to enrol in STEM studies, and to target gender biases and social norms hindering women's enrolment in STEM and ICT studies. Companies and the non-profit sector have a role to play, by providing examples of best practices and by contributing to changes in societal norms.

- Enhancing women's participation in the labour market would allow them to further develop their self-organisation and management and communication skills, which are often learnt or developed on the job. Governments should step up efforts to bring women to work and to let them grow in their careers. This includes social policies such as improving childcare provision, offering paid leave for fathers and more generally addressing gender discrimination, also in the workplace.

- Digital technologies can facilitate women's participation in education and the labour market by offering new work (for example e-commerce and platforms) and learning opportunities (such as online courses), and by relaxing time and location constraints. This may require further investments in digital infrastructures, especially in remote areas, and the design of financial schemes aimed to decrease the direct and opportunity costs of accessing such technologies, especially for low-income individuals. Also, it is important to ensure that digitally enabled jobs are also quality jobs, to avoid the condition that women's greater participation in labour markets comes at a cost of low job quality and poor social protection.

Recommendations for researchers

- Further research could address the importance of bundles of skills for individuals and for their participation in labour markets. It would be especially important to identify which bundles of cognitive and non-cognitive skills are needed in the digital era and link this to education and VET systems, to try and identify best practices in education and training aimed at endowing workers, and women and girls in particular, with the skills needed to thrive in the digital transformation, and to narrow the gender wage gap.

- Furthermore, the chapter has mentioned, but not provided evidence of, the possible transformative impact of the digital transformation on social norms, notably — but not exclusively — about gender. It would be important to understand how to exploit the potential offered by digital technologies to eradicate gender biases and discrimination, also in labour markets.

Skills development: Perspectives of young women who work in the call centre industry in South Africa

Sisa Ngabaza (University of the Western Cape, Women's and Gender Studies)

As part of neo-liberal free market strategies and unemployment reduction in global contexts, the call centre industry continues to grow as a major business outsourcing project. National and international organisations are increasingly using call centres which are enhanced by different information communication technology (ICT) platforms, in their marketing as well as outsourcing of services particularly to developing countries. The South African government plays into this neo-liberal business strategy by outsourcing project through prioritising call centres for investments and job creation for its young people. A 2017 quarterly labour force survey (QLFS), released by Statistics South Africa in the last quarter of the year, shows national unemployment rates of 26.7%, with a high youth unemployment rate of 29.7% among 15-24-year olds. Such high youth unemployment rates make call centres ideal in South Africa. Empirical findings from this sector show that 75% of the employees in South African call centres are young women who have just finished school, or college students. It is therefore necessary to consider such an exploration of skills development in the call centre industry to be an exploration of skills development for young women who are the majority of workers. The argument of this chapter is developed from qualitative focus group discussions and individual interviews conducted with young women who work as agents in call centres in Cape Town and Johannesburg in South Africa. Four focus group discussions of six to eight participants, and twenty semi-structured individual interviews were conducted, with 19-34-year-old women who worked as agents in different call centres. All interview participants were recruited

through convenience and snowball sampling. Focus groups and interview data was analysed through a qualitative thematic analysis.

Key findings

Agents were taken through different skills for job competency and these included:

- Training for key competencies varied from organisation to organisation, with some taking a few days, others weeks.
- The training took different forms which included brief teaching sessions followed by tests, memorising scripts to master what questions they had to use on the shop floor, basic keyboard skills, which included word processing and speed typing, communication skills where they learnt how to pronounce words, phone etiquette and voice demeanour.

Informal training: "*We learn on the floor*"

- Some participants indicated that key readiness for tasks was obtained through hands-on experience, on the shop floor, with minimal or prior training.
- This included informal side by side coaching, "buddying up", where they had to understudy their fellow workers.
- Agents were also put under pressure to test their level of resistance.

Skills training and career development

- Much emphasis was put on the development of "people skills"; they found call centres extremely good in developing people skills more than any technical or digital skills no matter what technological systems were adopted in training, but cautioned against call centres' capability to promote skills development.
- Skills adopted in call centres only qualified one to work in call centres.
- Few leadership positions were available, and there was a lack of personal growth.

Looking at the skills offered in such digitalised contexts, the chapter argues that although the industry finds great support from the government as a source of employment for young people, it is not adding much value to labour skills appropriate for progression prospects, and this is a threat to gender equality. Most of the skills acquired are soft skills or people skills which largely promote personal growth and not career growth for those who work in this sector. The chapter is critical of such skilling processes, which solidify young women's lack of progression in the labour market.

Recommendations

- Call centres can avoid being a threat to gender equality, through harnessing emerging technologies in their training processes to fully equip young women for better job progression prospects in South Africa.
- Call centres should support career advancement for women by investing in formal technical skills training rather than relying on informal processes to cut down on training costs.
- More scholarship is needed to advocate against organisational recruitment processes that use digital technologies in ways that tacitly promote gendered feminine skills, perpetuating gender inequalities.

A gender perspective of security and privacy in the digital age

Ashley Fraser and Elizabeth A. Quaglia
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This chapter explores the fundamental notions of digital security and privacy from a gender perspective. In a world that is increasingly relying on digital technologies, developing a knowledge and understanding of how to protect oneself when online is of paramount importance. Unfortunately, studies show that

as much as digital technologies represent an incredible opportunity for growth and change, they also offer a much larger platform from which abuse can occur. Recently, the Association for Progressive Communication has pointed out that cyberstalking, online harassment, image manipulation and privacy violations have compromised women's and girls' safety online and offline in many countries. This disturbing behaviour has branched out to geo-tracking and surveillance in certain extreme cases. Equipping women with the adequate digital knowledge and skills to ensure a more secure and private online experience could prove to be an effective way to limit this kind of abuse. Here, we would like to take this argument one step further, and advocate women's involvement in rethinking security research and solution design in terms of gender. We believe in fact that security technology (including cryptography) is not gender neutral. Indeed, it has been proposed and designed by a very specific and non-diverse community, and this has inevitably affected its development. From trust assumptions and security models, to the technical language of security, involving terms such as attacks and adversaries, advances in security research appear to be very male driven and dominated. However, there is a growing awareness that security solutions cannot be based on a unique viewpoint but need to be designed in and for a context, and need to take in consideration much more diverse design principles. This chapter advocates the need to provide women with basic digital security and privacy skills, which can be argued is part of a wider need to reduce the gender gap in digital literacy. Furthermore, we raise the issue of gendered security technologies, and consider women's greater involvement in the design of security (and, in particular, cryptographic) solutions as key to the successful integration of digital technologies in our lives.

Key findings

- Technology can be used as a wider platform from which abuse towards women can occur.
- In the field of Information Security women are largely underrepresented.
- Security technology is gendered. More diverse design principles need to be developed.

Recommendations for practitioners and policy makers

- Women need to be aware of and develop more cybersecurity skills. This can be addressed by raising awareness through skills-building training but also getting women more involved the area of Information Security.
- Several measures are being put in place to mitigate the underrepresentation of women in Information Security, and these should be pursued further. Examples are unconscious bias and discrimination awareness trainings, as well as a fairer recognition of women's achievements in security technologies.
- More diverse design principles can be achieved by creating a more diverse community of security designers and practitioners.

Recommendations for researchers

- Further studies are required to better understand why women are underrepresented in Information Security. Such insight would inform educators and employers on how to better attract and retain women in the field.
- Further research is needed to understand to what extent current security models and designs are gendered.

Pathways

Investigating empowering narratives around women, work and technology

Nagla Rizk, Nancy Salem and Stefanie Felsberger (Access to Knowledge for Development Center, American University in Cairo)

Despite many efforts, women's participation in STEM fields and representation in the tech workforce in many places remains quantitatively low and qualitatively difficult with prejudice in education and work. Women's work in technology related fields has been specifically historically and structurally devalued. With a focus on women's work in information and communications technology (ICT), this chapter reviews feminist literature on women and technology which discusses the shortfalls of the current narrative of the empowering potential of technology. The chapter explores two areas of research: first, we look into literature on women's work in ICT, especially focused on intersectional and global literature, and attempt to widen the scope of whose experiences are included in the narrative; second, we explore an area of literature that reframes data production as labour and analyse how feminist literature has influenced the arguments. Finally, the chapter provides some recommendations for how to include this type of literature in future research agendas on women in ICT and STEM.

Key findings

This chapter has identified the need for more diverse literature on women and work in ICT and STEM. We argue that this literature should incorporate a more global analysis that takes into account women's experiences of work in these sectors. An intersectional approach to research and programs allows for a more nuanced understanding of how women's experiences are shaped and shape in STEM fields.

Recommendations for practitioners and policy makers

- Commission case studies on experiences from the Global South should be undertaken for a better understanding of how women's work in ICT is playing out.
- Diversify sources of expertise when it comes to technologies and women. Consider the use of consultants from an array of disciplines when designing gender and ICT programs, working towards an intersectional approach.
- A first principle of engagement should be to do no harm. This means that policy makers and practitioners need to establish proper guidelines to determine who will come to harm from the suggestions they will put into action.

Recommendations for researchers

Through our exploration of these research areas, we sought to point out gaps in the literature. In the next section we provide recommendations on how to make the current research agenda more inclusive.

- Further research is needed that documents the experiences of women working with ICTs; especially studies that pay close attention to intersectional approaches accounting for class, race and age.
- More case studies documenting experiences from the Global South should be undertaken for a better understanding of how women's work in ICT is playing out.

Research on online data producing activities should be guided by principles of intersectional approaches and seek to understand which groups are more at risk and which groups have the means to speak up for their rights or participate in market-based approaches.

A gender perspective on technology and wealth creation

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More than 40 percent of the world's population now has access to the internet, with new users coming online every day, while today the poorest households are more likely to have access to mobile phones than to toilets or clean water. In spite of these advances in technology, many are left behind from the wealth creation spurred by new technologies in the innovation economy. A new wave of innovation is arriving which will bring huge opportunities for the global economy. The next innovation wave could be a unique opportunity for women to reap the advantages of wealth creation from the innovation economy — to leverage women's potential for technical innovation and to create new female ecosystems between science, start-ups and industry. Or, as with the gender digital divide more broadly, this new wave of innovation could leave female inventors behind. "Technology transfer" is the process by which innovations are developed and commercialised, and is typically measured using intellectual property rights, patents, and copyrights. Supporting girls' digital literacy through the entire spectrum of science, technology, engineering and mathematics (STEM) education through participation in research and development (R&D) and technology transfer is a long-term investment that could potentially result in an exponential increase of wealth creation for women. With few exceptions, there is very little prior work that examines the causes and consequences for patent shortage among women. This chapter attempts to fill this gap by examining how social innovation and support from NGOs and global development organisations can work to make tech-transfer more gender inclusive. To face this challenge, the world needs to be as ambitious in supporting gender equity in technology transfer as it should be in STEM education and workforce development.

Key findings

- Despite claims to the contrary, the so-called pipeline problem — or shortage of women in STEM degrees and fields — plays only a tiny part in technology transfer, as women with such degrees are barely more likely to patent than women who lack them.
- The most significant determinant in the gender gap in technology transfer is women's underrepresentation in patent-intensive fields (especially electrical and mechanical engineering), and in patent-intensive jobs (especially development and design).
- There is a widespread absence of gender-disaggregated data for technology transfer (such as patents, copyrights and so forth) worsened by the lack of a global organisation to track trends in gender balance in tech transfer.
- Virtually all indicators related to gender balance in the World Intellectual Property Organization Patent Cooperation Treaty (PCT) or patent system as a whole show some degree of progress in recent decades, but assuming current progression rates, we will not see gender balance in patenting until 2070.

Recommendations for practitioners and policy makers

- Recruit more female talent into R&D projects, and support women with entrepreneurial coaching, training, internships and managerial opportunities to help create a new generation of female innovators who can help firms become more productive and innovative.
- Develop inclusive cultures in organisations to foster diverse talent at all levels.
- Leverage public-private partnerships to provide funding and thought leadership to boost inclusiveness across sectors by encouraging participation of female scientists and innovators in R&D and patent development.
- Start-ups and small and medium enterprises (SMEs) can sponsor social innovation projects with business models

that encourage female leadership and innovation.

- Create a Global Female Innovation Council (GFIC) to identify best practices in technology transfer and broaden female participation in breakthrough innovations and patent development. The GFIC could set up in each UN member country a sub-office to liaise with all UN projects for digital female education, training and incubation support.

Recommendations for researchers

- Develop a concerted effort in collaboration with national governments, research institutions, and global organisations to collect gender-disaggregated data for technology transfer, establishing "data observatories" to collect such data and identify trends.

- Develop a set of standards for the collection of high-quality, consistent gender-disaggregated data, including (but not limited to) data collection methods, data sources, levels of granularity, consistency of time intervals, and types of data.

- Universities should focus on equal and gender-unbiased education and research to attract and retain female students, as well as to encourage girl's career development in STEM fields.

- Universities should also support top-class female innovators to disclose their ideas, particularly if they are radically different from existing products, services or business models that are highly risky and have the potential to scale up internationally.

Hello Siri, how does the patriarchy influence you? Understanding artificial intelligence and gender inequality

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As artificial intelligence (AI) systems become more widespread there has been an associated increase in attempts to understand the social, economic and political implications of these technologies. One significant gap in this work is a critical analysis of AI in terms of gender. This chapter addresses this gap by examining the gendered implications of AI with an emphasis on countries in the Global South (generally low- and middle-income countries in Latin America and the Caribbean, Africa and Asia). We identify the ways in which AI shapes gender relationships and vice versa from various disciplinary fields, by using examples of AI applications globally and from countries in the Global South. In some cases, examples do not yet exist and our arguments focus on preventing the potentially negative impacts of biased AI applications. There is an opportunity to ensure that at a minimum AI does not exacerbate existing gender inequalities. We therefore propose steps that industry, civil society and policy-makers can take to achieve this.

Key findings

- As emerging technologies such as AI co-evolve with gender inequalities we argue that AI will simply reflect existing patterns of bias and discrimination against women, unless intentionally directed to do otherwise.

- Unfortunately, for many people, technology has no clear link to gender – there is a misconception that technologies such as AI are gender neutral. In fact, far from being neutral, AI based applications are gendered from their creation – by the inherent bias of their creators or the bias in the data which they rely on. In addition, while the form and impacts of AI will be gendered, so will the discourse around it.

- A few observers have suggested that if some forms of decision-making are flawed because of, for example, bias and discrimination against women in the field, then perhaps AI systems can also help correct those flaws. However, the use of technologies can help certain women (particularly those who are well off)

transform their individual situation but not social systems of inequity.

- AI can actually exacerbate existing gender inequalities- the lack of women in the field of AI is perhaps one of the main sources of AI's contribution to inequality. One of the consequences of the exclusion of women is various forms of bias discrimination.
    - One source of discrimination is technical – based on the structural constraints of a system. For example, training data used for machine learning may under-represent women and lead to skewed results. This points to the challenges that people in the Global South (particularly women) face, wherein data collection via mobile devices and or the internet will over-represent diversity among men (who are more likely to use these technologies).
    - A second source of discrimination is the economic environment in which the AI application is meant to operate, where there are no explicit rules that treat men and women differently. These include advertising business models that reward the targeting of men more than women, and ride-sharing algorithms that although seemingly gender-neutral pay men more than women.
    - A third source of discrimination is what we term social norms and language. For example, AI systems typically replicate the way their designers view language (for instance from a male perspective) in how they interact with humans or by learning them through the analysis of written texts.
- AI can also directly impact women by infringing on their rights and liberties.
    - For example, increasingly accessible machine learning tools are being used to create very realistic but computer generated pornographic media, using images of women without their consent.
    - The use of AI can also undermine women's privacy, by the drive and demand to acquire more and more data (for training machine learning models) often without the (informed) consent of women. Such data can also be used to target women's groups or even individual women.

Recommendations for practitioners and policy-makers

- Policy formulation in AI should be linked to the reality that no technology, including AI, is gender neutral. To ensure that the impacts of AI on both women and men are critically assessed, developing gender-responsive AI policy is important. A comprehensive gender-responsive AI policy (as with any technology policy) will mean that everyone understands and is aware of how gender-based inequalities manifest and are maintained in society. This can start with conversations about the roles of men and women in society and the kinds of inequalities women face, particularly through indirect and systemic forms of discrimination. The government can lead by example and initiate these discussions in the public sector.
- Support multi-stakeholder partnerships to achieve gender parity in AI. Partnerships between industry, academia and the government can promote networking and mentoring support for women and girls in the field. Governments must coordinate with industry groups and others to generate accurate and timely data on the participation of women in the field. Governments should also work with industry and other partners to fund women-owned firms working on AI, and to incentivise other firms to have more diverse staff at all levels.
- Ensure that the research agenda and design process going forward particularly for "AI for development" is driven by actors in the Global South. They should also lead in identifying and implementing their own solutions to local challenges, such as gender equality. The AI developer in their design process can start by asking

themselves how their solution maintains gender inequality or makes it worse. The aim is for the developer to actively employ a “discrimination-conscious by-design” approach. We suggest that members of the AI scientific community in a given country (or building upon research networks in the Global South and elsewhere) collaborate on developing such an approach.

- Address direct potential harm from AI. This includes data and privacy protection, which can be critical for women’s safety online and offline and online. Having clear terms of service and privacy policies for AI applications will help – and will require adequate data protection laws, which are currently lacking in many countries in the Global South. In addition, much of the personal data in question (for these countries) will come from mobile internet users. Thus, governments through telecommunication and consumer protection regulators should work with mobile network operators to promote transparency in data collection and ensure they adhere to data protection rules where available. Another way of reducing potential harm is improving the quality of data used to train machine learning models, and – where possible – using open data as well as reporting on how the training data was created, and methods of aggregation and classification used.

- Improve grievance redress mechanisms for AI. The typical route for recourse in situations of harm is via the courts. The findings raised in this chapter highlight several possible scenarios where a woman may want to bring legal action against a party because of gender based discrimination. However, the challenge in seeking remedies against AI based discrimination is that most legal systems require evidence of intent to discriminate in order to rule against the discriminating party. Yet, as we note in this chapter, many of the results of AI based discrimination are unintentional. Thus, governments will have to recognise the limitations of their legal systems in providing recourse for these types of discrimination and develop alternatives for women and others affected by these situations. For example, governments could make audits mandatory for consequential decision-making algorithms.

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