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Energy Poverty and Gender Equality in Education

An Econometric Analysis of Panel Data

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CONTENTS

INTRODUCTION

In today's interconnected world, the pursuit of sustainable development stands as a global imperative. Central to this endeavor are the United Nations Sustainable Development Goals (SDGs), a comprehensive framework made of 17 goals aiming at addressing a spectrum of social, economic and environmental challenges[1]. Within this framework, the intersection of energy poverty, gender equality and education emerges as a critical nexus influencing the trajectory of human development, in fact a study conducted in 2023 shows how certain SDGs are more frequently associated with synergies and trade-offs than others[2].

Chapter I focuses on energy poverty, examining its implications through the lens of SDG7 and indicators such as the Human Development Index (HDI) and the Inequality Adjusted Human Development Index (IAHDI). Moreover, it analyses 6 measures obtained from the World Development Indicators (WDI) based on two crucial factors associated to energy poverty: access to clean cooking fuels and technologies and electrification. In order to deeply understand the dynamics behind these indicators, the distinction between rural and urban areas will be made, obtaining six measures: (1) access to clean cooking fuels and technologies measured with the percentage of the population with access to clean fuels and technologies for cooking; (2) rural access to clean cooking fuels and technologies measured with the percentage of rural population with access to clean fuels and technologies for cooking; (3) urban access to clean cooking fuels and technologies measured with the percentage of urban population with access to clean fuels and technologies for cooking; (4) electrification measured with the percentage of population with access to electricity; (5) rural electrification measured with the percentage of rural population with access to electricity; (6) urban electrification measured with the percentage of urban population with access to electricity[3].

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[1] Anderson, C.C., Denich, M., Warchold, A. *et al.* (2022), "A systems model of SDG target influence on the 2030 Agenda for Sustainable Development". *Sustain Sci* 17, 1459–1472, 2022.
[2] Bennich, T., Persson, A., Beaussart, R., Allen, C., Malekpour, S. (2023), "Recurring patterns of SDG interlinkages and how they can advance the 2030 Agenda", One Earth, Volume 6, Issue 11, pp. 1465-1476, 2023.
[3] Acheampong, A.O., Opoku, E.E.O., Amankwaa, A., Dzator, J. (2024), "Energy poverty and gender equality in education: Unpacking the transmission channels, Technological Forecasting and Social Change", Volume 202, 2024.

Moving forward, Chapter II pivots towards the intertwined themes of gender equality and education, elucidating their significance within the SDG framework, respectively SDG5 and SDG4. Through exploration of SDGs, the Gender Inequality Index (GII) and the Gender Parity Index (GPI), this section focuses on the persistent challenges hindering progress towards inclusive and quality education, especially for marginalized communities. In particular, the analysis focuses on the weak party, more specifically on females, and on the possible causal channels through which access to energy could affect female education. In this sense, female literacy, female health, female employment play a central role in the potential transmission channels[4].

Chapter III embarks on an econometric analysis of panel data, offering methodological insights and empirical findings to highlight the complex interplay between energy poverty, gender disparities and educational outcomes.

Through rigorous examination, it seeks to explain the causes of the behavior of variables and their specific role depending on the country taken in consideration.

Moreover, some issues emerged in the study of the models will be analyzed, focusing on problems as poor data availability and reverse causality of variables.

The data are collected from the WDI and refer to developing countries which are known to be characterized both by higher disparity in gender equality in education and by energy poverty.

Finally, the conclusion draws upon the preceding discourse to encapsulate key insights and implications, reinforcing the imperative of collective action and inclusive policy frameworks in advancing the global agenda for sustainable development.

[4] Acheampong, A.O., Opoku, E.E.O., Amankwaa, A., Dzator, J. (2024), "Energy poverty and gender equality in education: Unpacking the transmission channels, Technological Forecasting and Social Change", Volume 202, 2024.

CHAPTER I: ENERGY POVERTY

Chapter I provides an overall illustration of energy poverty, a pressing issue that affects developing countries, focusing on its implications in three main areas: Africa, South Asia and Latin America and the Caribbean.

Indexes taken by the World Development Indicators (WDI) will be introduced and analyzed in all scenarios.

1.1 SDG7

According to the United Nations Department of Economic and Social Affairs, the 2030 Agenda for Sustainable Development includes a specific goal for energy: “ensure access to affordable, reliable, sustainable and modern energy for all” (SDG 7) [5].

Affordable, reliable, sustainable and modern energy services are fundamental for both well-being and economic functionality, in fact they are strictly connected to access to clean water, sanitation and healthcare, and, as a consequence, they permit the use of efficient lighting, heating, cooking, mechanical power, transportation and telecommunication services.

But what does “modern energy access” refer to?

The International Energy Agency (IEA)[6] highlights several common elements across different definitions developed through the years. These elements are based on two pillars: access to clean cooking fuels and technologies and electrification. Consequently, modern energy access should guarantee:

1. A basic level of electricity for households;
2. Safer and more sustainable cooking and heating fuels and stoves, that should minimize harmful effects on health and the environment;
3. Modern energy sources that facilitate economic activities in the productive field, such as mechanical power for agriculture, textile and other industries;
4. Modern energy for the public services field, in particular electricity for healthcare facilities, schools and street lighting.

These elements are integral to both economic and social development. Additionally, considerations related to the "quality of supply," such as technical availability, reliability, convenience, safety and affordability, are also crucial factors to ensure effective modern energy access[7].

Achieving these services requires an efficient energy system, which would reduce consumption and costs, decrease energy dependencies, and lessen environmental and climate impacts. The EU, for example, aims to increase its energy efficiency by at least 32.5% by 2030. Households account for 25% of total energy consumption, a share that

[5] https://sdgs.un.org/goals/goal7
[6] https://www.iea.org
[7] IEA (2020), “Defining energy access: 2020 methodology”, 2020.

has grown since 2016, driven by factors such as outdoor climate, building energy efficiency, and residents' economic behavior.

SDG7 underscores the importance of affordable energy for social equality and justice, aligning with Principle 20 of the European Pillar of Social Rights, which states energy access as an essential point to achieve. The access to affordable energy across the EU can be measured by the inability to afford adequate home heating, which can be seen as a key indicator. In this regard, progress has been made in the last 10 years. Although there was a slight increase in 2020, the percentage dropped again in 2021.

The issue represented by the inability to afford adequate home heating is influenced by income levels of the household: families which are below the poverty threshold are more likely to struggle heating costs.

While some Member States have achieved low rates of energy poverty, disparities persist across Europe, with colder regions generally faring better than warmer ones due to differences in building energy efficiency and income levels. Government interventions and financial support also play crucial roles in mitigating energy poverty and ensuring adequate home heating for all[8].

Examining a broader scope beyond the European Union, a significantly more intricate scenario appears.

In 2024 a new edition of “Tracking SDG7: The Energy Progress Report” has been published by the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), the United Nations Statistics Division (UNSD), the World Bank and the World Health Organization (WHO).

It sends a clear warning to the global community: current efforts are not enough to meet all the targets set by SDG 7 for energy by 2030. While there have been advances in specific areas of Goal 7 — such as the growth in the adoption of renewable energy — the world remains far from achieving "universal access to affordable, reliable, sustainable, and modern energy."

[8] Sustainable development in the European Union Monitoring report on progress towards the SDGs in an EU context, 2023 edition.

Two key targets at risk of not being achieved are universal electricity access and the use of clean cooking fuels. The number of people without electricity is still increasing, largely due to population growth, particularly in sub-Saharan Africa and Asia.

Moreover, over 2 billion people continue to use polluting fuels and technologies for cooking, with severe consequences for both health and the environment, resulting in 3.2 million premature deaths each year, mostly concentrated in Africa. Despite this, some areas of the SDG 7 agenda have seen more positive progress.

Renewable energy has experienced significant growth, and there have been improvements in energy efficiency, although these are still insufficient to fully achieve the SDG 7 targets.

On a positive note, the report from the International Energy Agency (IEA) also highlights new global commitments made by over 130 countries through the UAE Consensus. These commitments aim to triple renewable energy generation capacity and double energy efficiency rates, which would strengthen the SDG 7 objectives.

Immediate and decisive action is necessary to achieve these goals, particularly to address the substantial imbalance in clean energy investment, 80% of which is concentrated in only 25 countries worldwide. Under current policies, by 2030, 660 million people will still lack access to electricity, and around 1.8 billion will not have access to clean cooking technologies and fuels.

On July 15, the organizations behind the report presented the latest findings on the global energy situation to the international community, calling for greater financial, technological, and policy support to bridge the gaps in electricity and clean fuel access. This appeal aims to ensure all countries benefit from the accelerated deployment of renewable energy and enhanced energy efficiency[9].

More specifically, the Report underlines six indicators, which are resumed in Table 1, of global progress toward the SDG7 targets, providing a comparison between 2015 and the latest year.

[9] https://www.energiaitalia.news/policy/policy-mondo/iea-obiettivo-7-dellagenda-2030-lontano/34248/

Table 1. Global progress toward the SDG7 targets

INDICATOR	2015	LATEST YEAR	DELTA
people without access to electricity (expressed in million)	957,5	685	-272,5
people without access to clean cooking (expressed in billion)	2,7	2,1	-0,6
renewable energy share in total final energy consumption	16,70%	18,70%	0,02
energy intensity measured as a ratio of primary energy and GDP (expressed in MJ/USD)	4,9	4,6	-0,3
international financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems (expressed in USD billion)	12,3	15,4	3,1
installed renewable energy-generating capacity in developing and developed countries (expressed in watts per capita)	250	424	174

Source: International Energy Agency (IEA).

In 2022, for the first time in over a decade, the number of people without access to electricity increased, counterbalancing progresses achieved in the previous years. As a result, 685.2 million people lacked access to electricity in 2022, up from 675.1 million in 2021. It is important to underline the fact that these people who do not have access to electricity live in remote areas which are known to be difficult to reach.

These results were the consequence of terrible international issues that influenced the economic system. These global shocks are COVID-19, the Ukraine war, and regional issues such as climate change-induced droughts and floods in Sub-Saharan Africa.

Sub-Saharan Africa accounts for 83% of the global population without electricity, up from 50% in 2010. In 2022, 571.1 million people in Sub-Saharan Africa still lacked electricity, a

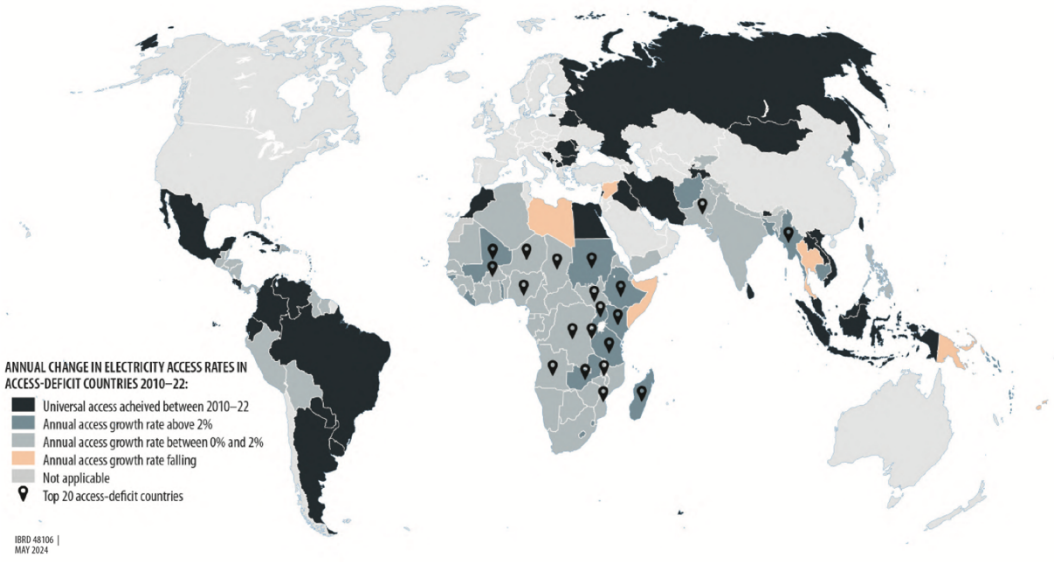
slight increase from 2010. The region faces economic challenges such as inflation, high-interest rates and low affordability.

In 2022, 80% of those without electricity lived in rural areas, despite faster progress in rural areas than in urban settings. Significant improvements were mainly in Central and Southern Asia, where the rural population without access dropped from 383 million in 2010 to 24 million in 2022. Progress in other regions was slower.

Eighteen of the 20 countries with the highest electricity access deficits are in Sub-Saharan Africa, with Nigeria (86 million), the Democratic Republic of Congo (78 million), and Ethiopia (55 million) together accounting for nearly one-third of the global deficit. Efforts to achieve universal access should focus on these countries, including improved data collection and the use of analytical tools to guide decision-making.

In particular, over 40% of individuals living in Africa do not have access to electricity, and 70% lack access to clean cooking facilities. With Africa projected to accommodate one-fifth of the global population by 2030, ensuring universal access to modern energy while addressing escalating energy demands stands as a central objective for African governments. In Figure 1, annual change in electricity access rates in access-deficit countries between 2010 and 2022 are reported.

Figure 1. Annual change in electricity access rates in access-deficit countries (2010-22)



Source: World Bank 2024.

But several barriers challenge Africa in achieving sustainable energy solutions. The continent is affected by government instability and a poor international collaboration that negatively impacts on the development of the country. As a consequence, Africa is seen as an unattractive territory where to make investments.

Similarly, Latin America faces challenges that struggle the succeed of the 2030 Agenda for Sustainable Development. The region is affected by political instability, authoritarian tendencies and a weak international collaboration finalized at the achievements of SDG. Consequently, the environment created for sustainable development is particularly hostile.

Moreover, the lack of effective government engagement and limited civil society participation limit the ability to advance toward sustainable development[10].

However, Latin America is considered a global leader in clean energy[11] thanks to the contribution of Paraguay, Uruguay and Costa Rica, which produce nearly 100% of their electricity from renewable sources. Countries in the region emit fewer greenhouse gases compared to the rest of the world[12]. In terms of per capita CO2 emissions, Latin America also ranks favorably. Venezuela, for instance, is the country with the highest per capita CO2 emissions in the region. According to the International Energy Agency (IEA)[13], 30% of the total energy consumption in Latin America comes from renewable energy, primarily hydropower, which is in stark contrast to the global average of just 12% from renewables.

Despite Latin America's leadership in clean energy and its significant production of renewable electricity, the region is still characterized by a notable gap in energy access. Millions of people still lack access to electricity and clean cooking solutions, particularly among rural, indigenous and Afro-descendant communities. This gap exists because of a combination of factors: geographic isolation, inadequate infrastructure, economic

[10] https://sdg.iisd.org/commentary/guest-articles/reviving-commitment-to-sdgs-in-latin-america-urgent-call-to-action/

[11] https://credendo.com/it/knowledge-hub/lamerica-latina-e-la-chiave-di-volta-della-transizione-verde-globale-mentre-la

[12] Cardenas, M., Orozco, S., (2022), "The challenges of climate mitigation in Latin America and the Caribbean: Some proposals for action", UNDP LAC PDS N°.40.

[13] https://www.iea.org

inequalities and limited policy implementation aimed at reaching the most vulnerable populations.

While Latin America excels in generating clean energy and maintaining relatively low greenhouse gas emissions, the benefits are disproportionally distributed. Urban centers and wealthier populations typically have better access to these resources, whereas rural and marginalized groups face higher barriers due to economic constraints, remote locations and lack of targeted investment in decentralized energy solutions.

Thus, even as Latin America leads in sustainable energy production, there is a pressing need to extend the reach of these achievements to all segments of the population to ensure inclusive and equitable access to energy. Addressing these disparities will be key to fulfilling the region's potential as a true global leader in both energy production and energy access.

The Asia-Pacific region, home to 58 diverse economies, includes both developed and least-developed countries and accounts for about 60% of the world’s population, totaling 4.5 billion people. The region generates approximately one-third of the global GDP and consumes half of the world's energy, while also housing major oil and gas producers. As the leading region in energy demand growth, and with significant disparities in energy access, the Asia-Pacific's decisions will greatly influence the global progress toward sustainable energy goals, including Sustainable Development Goal 7 (SDG 7).

While substantial progress has been made in expanding electricity access, with significant achievements over the past decade, around 231 million people still lack access to electricity, particularly in some Pacific Island nations. Even though the region is on track to nearly achieve universal electricity access by 2030, disparities remain: 2 billion people still depend on polluting and harmful cooking fuels and technologies.

In order to see constant progresses in electricity access, governments in the Asia-Pacific region must uphold their commitments, focusing particularly on off-grid solutions and creating regulatory frameworks that support integration between on-grid and off-grid systems.

The lack of access to affordable, reliable, sustainable and modern energy services not only causes poverty but also directly affects human development. The Human Development Index (HDI), which measures a country's overall achievement in health,

education and standard of living, is deeply connected to the access to energy. In fact, countries which struggle with energy poverty often show lower HDI scores. For this reason, the next paragraph will focus on the Human Development Index and its correlation with energy access.

1.2 Human Development Index (HDI) and Inequality Adjusted Human Development Index (IAHDI)

The first Human Development Report (HDR) recognized that *development* encompasses more than the mere increase of income and wealth. It defined human development as "the process of expanding people's choices"[14]. The report emphasized that, in theory, the choices available to individuals could be limitless and subject to change over time. However, at all stages of development, there are three fundamental dimensions[15]:

1. enabling people to live a long and healthy life;
2. gaining knowledge;
3. accessing resources for a decent standard of living.

This emphasis on these core dimensions marked a significant contribution to the broader discourse on development, asserting that all three are *essential* components of human development.

In this context, the report introduced the Human Development Index (HDI), which is defined as “a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and having a decent standard of living”[16]. To each dimension is associated a specific indicator. In the most recent iterations of the HDRs, adult literacy rates and combined school enrollment ratios serve as indicators of the knowledge dimension, life expectancy at birth as the indicator of a healthy life and an adjusted Gross Domestic Product (GDP) per capita as the indicator for the standard of living.

Each dimension of the HDI is measured on a scale from 0 to 1, where 0 represents the minimum and 1 the maximum value assigned to the corresponding indicator. The overall HDI is then calculated as the arithmetic mean of these three indices. For each

[14] UNDP (1990), Human Development Report 1990. Oxford University Press, New York.
[15] UNDP (1990), Human Development Report 1990. Oxford University Press, New York.
[16] https://hdr.undp.org/data-center/human-development-index#/indicies/HDI

component (i) of the HDI, the individual indices for a given country can be computed using a standardized formula:

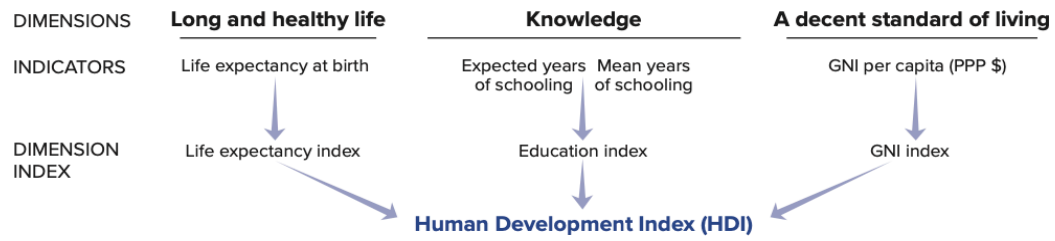
HDI(i) = (Actual xi value – minimum xi value) / (Maximum xi value – minimum xi value)

The maximum and minimum values for each indicator are set as follows:

1. life expectancy at birth ranges from 25 to 85 years;
2. adult literacy from 0% to 100%;
3. combined enrollment ratios from 0% to 100%; and real GDP per capita in PPP dollars ranges from PPP$100 to PPP$40,000[17].

In Figure 2 a detailed representation of the components that build the Human Development Index, divided into three dimensions measured by a specific index is represented.

Figure 2. Components of the Human Development Index (HDI)



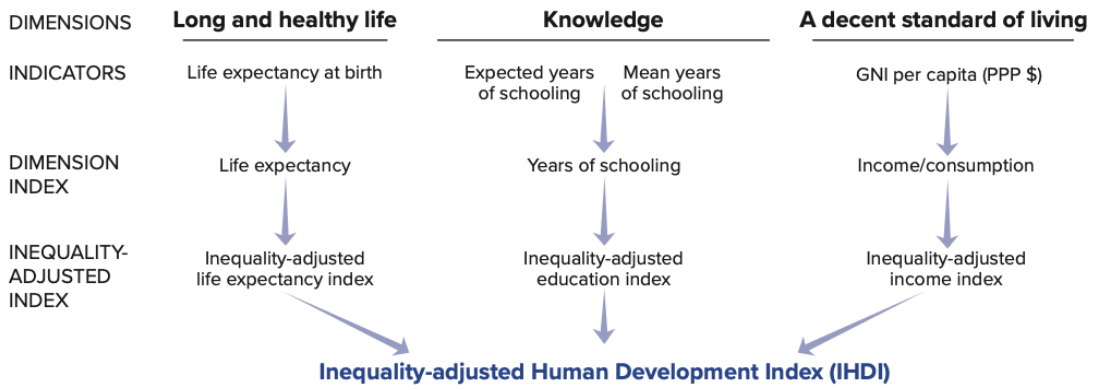
Source: United Nations Development Program (UNDP).

Over time, several adjustments have been made to the calculation of the Human Development Index (HDI), as represented in Figure 3. The most significant changes were introduced in the second HDR in 1991. Initially, the knowledge dimension was measured solely by adult literacy rates. However, the 1991 report combined this with the mean years of schooling, assigning a weight of 2/3 to literacy and 1/3 to schooling years. For the standard-of-living dimension, the first report used the logarithm of income, adjusted for purchasing power parity (PPP), and set a zero weight for income exceeding the average poverty line of a selected group of industrialized countries. In the 1991 HDR, a

[17] UNDP (1997), Human Development Report 1997, Oxford University Press, New York.

less severe utility adjustment was implemented using the Atkinson adjustment formula to reflect diminishing returns at higher income levels, based on PPP-GDP per capita.

Figure 3. Components of the Inequality-Adjusted Human Development Index (IAHDI)



Source: United Nations Development Program (UNDP).

By 1994, the "goalposts" for each indicator were fixed to allow for consistent comparisons over time, and the threshold value for the standard-of-living index was revised accordingly. The 1995 report further refined the data for the knowledge indicator by replacing the mean years of schooling with the combined enrollment ratio across primary, secondary, and tertiary education levels. This modification was driven by the ease of data collection rather than any fundamental change in the concept, and the weighting of the formula remained the same.

Despite these adjustments, the fundamental method for calculating the HDI has remained largely consistent since the 1991 report. Most changes have been minor refinements to the composite indices rather than significant conceptual developments in the original framework.

But does energy accessibility improve human development?

A study conducted by three Australian researchers[18] investigates the relationship between energy access and human development across 79 countries in the world's three most energy-deprived regions: South Asia, Sub-Saharan Africa and Latin America & the Caribbean examining how energy access influences specific components of human

[18] Alex O. Acheampong - researcher at the University of Newcastle, Australia - Michael Odei Erdiaw-Kwasie - researcher at the University of Southern Queensland, Toowoomba, Australia - and Matthew Abunyewah - researcher at the University of Newcastle, Australia.

development, such as education (human capital) and health outcomes (including life expectancy, maternal mortality and under-five mortality rates) and focusing on the role of economic growth as a critical pathway through which energy access might affect human development.

These regions exemplify global energy poverty, with an estimated 591 million people in Sub-Saharan Africa, 255 million in South Asia and 14 million in Latin America and the Caribbean lacking access to electricity.

The sustainable energy policies adopted in these areas are therefore essential in steering worldwide efforts towards achieving Sustainable Development Goal 7 (SDG 7), which aims to ensure access to affordable, reliable, sustainable and modern energy for all.

In addition to facing severe energy shortages, these regions also display low levels of human development, with average Human Development Index (HDI) scores in 2018 of 0.541 for Sub-Saharan Africa, 0.642 for South Asia, and 0.759 for Latin America and the Caribbean[19].

First, the results for the overall sample show that access to electricity significantly improves the Human Development Index (HDI), life expectancy and maternal mortality rates, although it does not have a significant effect on human capital or under-five mortality. Meanwhile, access to clean energy positively impacts the HDI but unexpectedly worsens under-five mortality rates and has no significant effect on human capital, life expectancy or maternal mortality.

Second, the analysis shows that access to electricity interacts with economic growth to positively influence HDI, human capital, life expectancy and both maternal and under-five mortality rates. Similarly, clean energy access, when combined with economic growth, enhances these same dimensions of human development. These findings suggest that expanding access to energy can increase productivity and promote economic growth. As economic growth accelerates, firms can hire more employees, boosting household incomes and improving overall living standards. In addition, energy access enables households to engage in more productive activities that generate income and improve quality of life. The study also identifies employment, industrialization,

[19] UNDP (2019), Human Development Report 2019, Oxford University Press, New York.

economic growth, ICT and gender empowerment as key channels through which energy access can drive human development.

Third, the comparative analysis highlights regional differences. In South Asia, access to electricity does not significantly impact HDI, life expectancy or under-five mortality, but it does improve maternal mortality rates while worsening human capital outcomes.

In Sub-Saharan Africa, electricity access significantly enhances HDI and life expectancy but shows no significant effect on human capital, maternal mortality or under-five mortality.

In Latin America and the Caribbean, access to electricity significantly improves HDI, human capital, life expectancy and maternal mortality but has an insignificant impact on under-five mortality. Meanwhile, clean energy access negatively affects most indicators of human development in South Asia but shows more mixed results in Sub-Saharan Africa and Latin America and the Caribbean.

This study demonstrates that energy factors significantly impact human development outcomes. In particular, the impact of energy access on human development varies depending on the presence or absence of mediating factors and there is no universal solution for tackling energy poverty; instead, policies must be adapted to the specific needs and contexts of different countries[20].

In 2016, Dr Julia K Steinberger[21], published an article entitled "Energising Human Development"[22], in which the dependence of human development on energy is underlined. She conducted an analysis by comparing the HDI with per capita energy consumption demonstrating a strong correlation between them: as energy use increases, HDI tends to rise significantly. A small increase in energy consumption corresponds to a substantial improvement in HDI. However, as energy use continues to rise, the incremental benefits to human development become smaller, a phenomenon

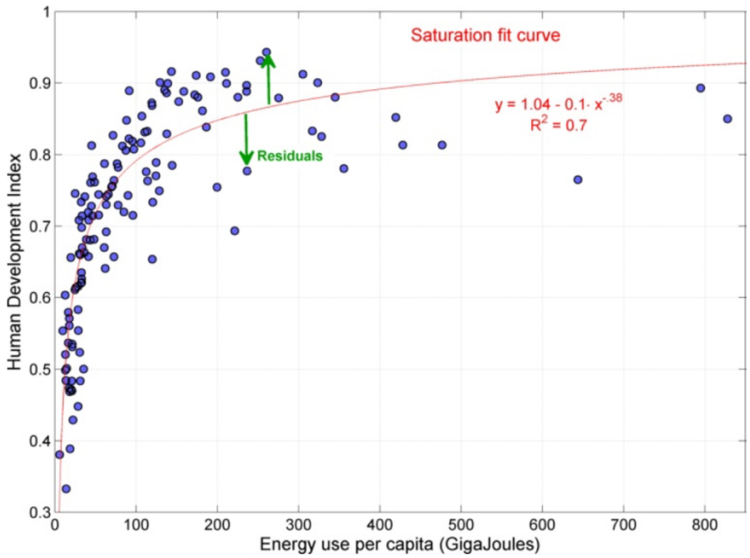
[20] Acheampong, A.O., Erdiaw-Kwasie, M.O., Abunyewah, M. (2021), "Does energy accessibility improve human development? Evidence from energy-poor regions", Energy Economics, Volume 96, 2021.

[21] Associate Professor in Ecological Economics, Sustainability Research Institute, University of Leeds, United Kingdom.

[22] https://hdr.undp.org/content/energising-human-development

economists refer to as "diminishing returns." Beyond a certain point, higher energy consumption does not show a statistically significant impact on HDI, indicating a saturation effect, as represented in Figure 4.

Figure 4. Human Development Index and primary energy use per capita in 2012



Source: Human Development Reports.

The steep gradient of the fit curve in Figure 4 indicates that energy use is much more effective in improving human development in less developed countries compared to highly developed ones, where its impact is less pronounced. This is because these countries typically have a larger gap between their current level of development and potential improvements. In contrast, in highly developed countries, the gains from additional energy use are smaller because these nations have already achieved a high level of human development, and further improvements require diminishing returns.

The HDI masks disparities in human development within a country, it does not consider how the achievements on health, education and income are distributed among people living in the analyzed country.

In this context, an Inequality-Adjusted Human Development Index has been introduced. The IAHDI is computed "as the geometric mean of dimension indices adjusted for inequality and shows the actual level of human development"[23]. This makes it a valuable

[23] https://www.undp.org/sites/g/files/zskgke326/files/migration/tr/faq_ihdi.pdf

tool for guiding policies aimed at reducing inequality and assessing the effectiveness of different strategies designed to address it.

However, it does not account for cases where the same individuals face multiple forms of deprivation or overlapping inequalities. Additionally, while indicators like income can have zero or even negative values, these have been adjusted to be uniformly non-negative across countries. Consequently, the measure of inequality can vary depending on the methodology used.

To further understand how human development is influenced by disparities in energy access, six measures obtained from the World Development Indicators (WDI) that assess the extent and severity of energy poverty will be analyzed.

Specifically, they include: (1) access to clean cooking fuels and technologies, measured by the percentage of the population with access to clean options; (2) rural access to clean cooking fuels and technologies; (3) urban access to clean cooking fuels and technologies; (4) overall electrification rates; (5) rural electrification rates; and (6) urban electrification rates.

To sum up, through the examination of the measures provided by the WDI, it will be easier to understand analytically the disparities between rural and urban areas and, more in general, in human development, because these dimensions are not fully captured by the Human Development Index and Inequality Adjusted Human Development Index.

1.3 Measures of energy poverty

This paragraph presents the key indicators used to measure energy poverty, which can be broadly categorized into two main groups: access to clean cooking fuels and technologies and electrification. Each of these categories can further be split into rural and urban areas, reflecting the distinct challenges and disparities in energy access faced by different population segments. This distinction underlines the fact that these countries are not fully harmonized, instead they are characterized by disproportion of access to modern services.

1.3.1 Access to clean cooking fuels and technologies

"Clean cooking must be a political, economic, and environmental priority, supported by policies and backed by investments and multi-sector partnerships. To make that kind of change, the level of commitment and the scale of investment matter"[24].

Clean cooking refers to the use of fuels that emit minimal pollutants during combustion, including biogas, liquefied petroleum gas (LPG), electricity, ethanol, natural gas and solar power. The adoption of these clean cooking fuels has the potential to significantly enhance quality of life by improving health outcomes, protecting the environment, empowering women and reducing both time and financial costs associated with cooking. A complete transition to these clean energy sources has been demonstrated to substantially elevate overall well-being, happiness and life satisfaction[25].

According to the 2023 report[26] by the International Energy Agency (IEA), approximately 2.3 billion people worldwide living in 128 countries continue to lack the resources or technologies required to transition to cleaner-burning fuels. In this context, the adoption of clean cooking methods offers a practical and accessible solution to mitigate these health risks.

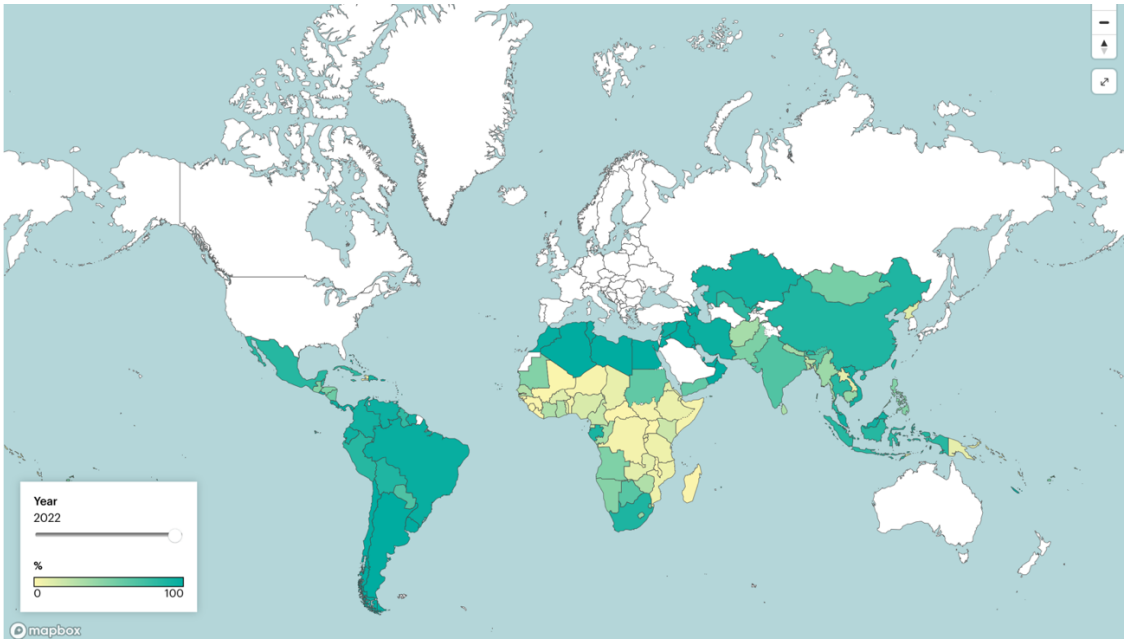
The geographical map of the world in Figure 5 illustrates the stark contrast in access to clean cooking solutions across different regions. Countries where a significant portion of the population has access to clean cooking fuels are marked in green, indicating substantial progress towards safer, more sustainable energy practices. Conversely, countries highlighted in yellow show where access remains limited or insufficient, particularly in regions like sub-Saharan Africa, parts of South Asia and rural areas in other developing nations. This visual representation underscores the uneven distribution of clean cooking access and the urgent need for targeted interventions to bridge these gaps.

[24] Puliti Riccardo. Global Director, Energy and Extractive Industries and Regional Director for Infrastructure, Africa

[25] Wanglin, M., Puneet, V., Hongyun, Z. (2022), "Cooking fuel choices and subjective well-being in rural China: Implications for a complete energy transition, Energy Policy", Volume 165, 2022.

[26] IEA (2023), A Vision for Clean Cooking Access for All, IEA, Paris https://www.iea.org/reports/a-vision-for-clean-cooking-access-for-all

Figure 5. Access to clean cooking solutions across different regions



Source: International Energy Agency (IEA)

Progress in providing access to clean cooking has been faster in Asia but remains slow in sub-Saharan Africa. While the number of people without access to clean cooking has decreased globally from 3 billion in 2010 to 2.3 billion in 2022, driven by advances in Asia and Latin America, the situation has worsened in sub-Saharan Africa, where clean cooking efforts have not kept pace with population growth. Currently, around 1 billion people on the continent—approximately four out of every five—still depend on highly polluting cooking fuels.

While Asia is likely to continue improving access to clean cooking, most African countries are not projected to achieve universal access even by the 2050s. Under current policies, the global number of people lacking access to clean cooking is expected to decline to 1.8 billion by 2030. However, despite rapid progress in Asia, sub-Saharan Africa may end the decade with a similar number of people without clean cooking access as today[27].

The absence of clean cooking methods causes 3.7 million premature deaths each year, affecting women and children[28] globally. In Africa alone, women and children represent 60% of these early deaths due to smoke inhalation and indoor air pollution,

[27] https://www.iea.org/reports/sdg7-data-and-projections/access-to-clean-cooking
[28] https://ecostandard.org/news_events/clean-cooking-in-africa-is-finally-starting-to-get-the-spotlight-it-deserves/

primarily caused by traditional cooking practices that lead to respiratory and cardiovascular diseases.

Beyond health risks, the lack of access to clean cooking methods restricts many women and girls from pursuing education, earning an income or starting a business, all of which could provide financial independence.

There is also a significant economic cost associated with lost time and productivity related to the fact that, when needed, a significant amount of hours is spent collecting firewood and other fuels used as a mean of cooking. On average, households without access to clean cooking fuels and technologies spend about five hours daily collecting the materials and preparing meals. This activity causes a negative repercussion on women, who are more exposed to risks of violence and assault during the food procurement.

In order to reduce the loss given by the economic cost associated with time and productivity, a solution must be found. According to IEA, Liquefied petroleum gas (LPG) represents the dominant solution, providing clean cooking access for nearly half of the households that will gain access by 2030. Over the past decade, 70% of the people who achieved clean cooking access used LPG. Electric cooking is expected to become the primary method for one in eight new households by 2030. However, while electric cooking offers the advantage of reducing dependence on fuel imports, it faces obstacles related to low electricity access rates and unreliable power grids in some areas[29].

In rural regions where fuel and electricity infrastructure are often inadequate, improved cookstoves (ICS) are being used as an interim measure to provide immediate health benefits and save time. If minimum performance standards are maintained, these cookstoves can reduce fuel consumption by 20-70% and significantly decrease harmful smoke and emissions. Continuous efforts to provide modern cooking alternatives aim to replace ICS as the main cooking method in homes by 2040.

At this end, on 14 May 2024 at UNESCO in Paris the Summit on Clean Cooking in Africa was held by the IEA with the objective of "making 2024 a pivotal year for achieving universal access to clean cooking"[30].

[29] https://www.iea.org/reports/sdg7-data-and-projections/access-to-clean-cooking

[30] https://www.iea.org/news/the-clean-cooking-declaration-making-2024-the-pivotal-year-for-clean-cooking

The declaration affirms clean cooking as a critical priority and pledges to take concrete steps to advance the agenda through action, awareness-raising and collaboration and highlights the importance of a coordinated effort focusing on three critical pillars: financing, policy frameworks and partnerships. It commends the announcement of USD 2.2 billion in funding from both public and private sectors to support clean cooking initiatives.

1.3.2 Electrification

According to the International Energy Agency (IEA) "Electrification means replacing technologies or processes that use fossil fuels, like internal combustion engines and gas boilers, with electrically-powered equivalents, such as electric vehicles or heat pumps. These replacements are typically more efficient, reducing energy demand, and have a growing impact on emissions as electricity generation is decarbonised"[31].

Electrification is a key strategy outlined in the Net Zero Emissions by 2050 Scenario (NZE) to achieve significant CO2 emissions reductions. Integral to this strategy is the goal of extending electricity access to approximately 785 million people who currently lack it and providing clean cooking solutions to 2.6 billion people without such options. Ensuring universal energy access by 2030 is critical, with an estimated cost of around USD 40 billion annually equivalent to about 1% of average yearly energy sector investments. This investment not only facilitates emissions reductions but also yields substantial co-benefits, including improved indoor air quality and enhanced health outcomes[32].

To achieve universal electricity access, special attention must be given to rural areas. While the number of people without electricity decreased from 1 billion in 2016 to a record low of 770 million in 2019, progress has been much slower in rural areas. The electrification rate in urban areas is around 97%, compared to just 82% in rural areas. Consequently, about 84% of the global population without electricity access resides in rural regions. In many low-income and lower-middle-income countries, the disparity between rural and urban electrification rates is substantial, sometimes differing by an entire order of magnitude. Rural and sparsely populated areas often face significant

[31] https://www.iea.org/energy-system/electricity/electrification
[32] IEA (2021), "Net Zero by 2050, A Roadmap for the Global Energy Sector", 2021.

delays in receiving electrification, even though off-grid projects, once initiated, tend to be successfully completed[33].

Achieving SDG7, is particularly challenging in rural areas due to the higher per capita costs of electrification and the existing disparity between rural and urban access rates, especially in Africa.

Comparing electrification rates provided by the World Development Indicators (WDI)[34] across Eastern and Southern Africa, Latin America and the Caribbean and South Asia reveals significant regional differences in access to electricity and the progress made from 2000 to 2021.

In 2000, the Electrification measured with the percentage of population with access to electricity in South Asia was 58%, which increased to 99% in 2021.

Latin America and the Caribbean also achieved a high level of overall electrification, with access increasing from 91% in 2000 to 98% in 2021.

In contrast, Eastern and Southern Africa lagged significantly behind, with an overall electrification rate of only 20% in 2000, which increased to 48% in 2021. While the rate more than doubled, it remains much lower than in South Asia and Latin America and the Caribbean.

Rural electrification measured with the percentage of rural population with access to electricity data further highlights the disparities between these regions. In South Asia, rural electrification surged from 47% in 2000 to 98% in 2021.

Similarly, in Latin America and the Caribbean, rural electrification rates were relatively high, rising from 70% in 2000 to 96% in 2021.

By contrast, Eastern and Southern Africa experienced much slower growth in rural electrification. Starting from a low base of 9% in 2000, the rural electrification rate only increased to 33% by 2021.

Urban access to clean cooking fuels and technologies measured with the percentage of urban population with access to clean fuels and technologies for cooking levels were highest across all three regions, but differences remain. In South Asia, the

[33] Akbas, B., Kocaman, A.S., Nock, D., Trotter, P.A. (2022), "Rural electrification: An overview of optimization methods", Renewable and Sustainable Energy Reviews, Volume 156, 2022.
[34] https://databank.worldbank.org/source/world-development-indicators

urban electrification rate increased from 90% in 2000 to 100% in 2021. Similarly, in Latin America and the Caribbean, urban electrification was already high at 98% in 2000 and reached 100% by 2021.

In Eastern and Southern Africa the rate increased from 54% in 2000 to 76% in 2021. Despite the progress, this region remains behind both South Asia and Latin America and the Caribbean in achieving universal urban access.

CHAPTER II: GENDER EQUALITY AND EDUCATION

In the previous chapter, the global situation of energy poverty has been analyzed, focusing on the distinction between access to clean cooking fuels and technologies and electrification in three macro areas: Africa, Latin America and the Caribbean and South Asia.

Chapter II aims to highlight the consequences of a poor energy access. In fact, as seen in Chapter I, “beyond health risks, the lack of access to clean cooking methods restricts many women and girls from pursuing education, earning an income or starting a business, all of which could provide financial independence”.

In this sentence, three words need to be underlined, specifically: women, girls and education.

Women and girls are disproportionately affected by energy poverty, since cooking methods often falls into their responsibility. Therefore, addressing energy poverty is strictly connected to Sustainable Development Goal 5 (SDG 5), which focuses on achieving gender equality and empowering all women and girls.

This topic will be central in paragraph 1 and 2 of Chapter II, where SDG 5 will be described and then measured by the Gender Inequality Index (GII).

Then, paragraphs 3 and 4 will focus on Education, another important domain where energy poverty has severe implications. As mentioned before, the time spent on fuel collection and household responsibilities, restricts many women and girls from pursuing education, making the connection between energy poverty and education more evident. Sustainable Development Goal 4 (SDG 4) will be described by the Gender Parity Index (GPI) for primary, secondary and tertiary levels.

By addressing these topics together, Chapter II aims to demonstrate the connections between energy poverty, gender inequality and education.

2.1 SDG 5

According to the Department of Economic and Social Affairs, the 5th goal of Sustainable Development is to "Achieve gender equality and empower all women and girls".

Gender equality is not only a fundamental human right, but also a prerequisite for sustainable development. Even though some advances in this field have been done, gender inequalities remain deeply associated to all societies. Women often experience limited access to quality employment, occupational segregation and continue to face significant wage disparities compared to men. In many contexts, women are deprived of fundamental rights such as access to education and healthcare, and they are subjected to violence and various forms of discrimination.

In Europe, a Gender Equality Strategy 2020-2025 has been planned to make significant progress by 2025 towards a gender-equal Europe.

President Ursula von der Leyen affirms that "The promotion of equality between women and men is a task for the Union, in all its activities, required by the Treaties. Gender equality is a core value of the EU, a fundamental right and key principle of the European Pillar of Social Rights. It is a reflection of who we are. It is also an essential condition for an innovative, competitive and thriving European economy. In business, politics and society as a whole, we can only reach our full potential if we use all of our talent and diversity. Gender equality brings more jobs and higher productivity – a potential which needs to be realised as we embrace the green and digital transitions and face up to our demographic challenges"[35].

What are the key objectives of the Gender Equality Strategy for Europe?

"The key objectives are ending gender-based violence; challenging gender stereotypes; closing gender gaps in the labour market; achieving equal participation across different sectors of the economy; addressing the gender pay and pension gaps; closing the gender care gap and achieving gender balance in decision-making and in politics"[36].

However, no Member State has fully achieved gender equality and progress remains slow. In fact, the average salary of women in EU is 16% less than men per hour; only 67%

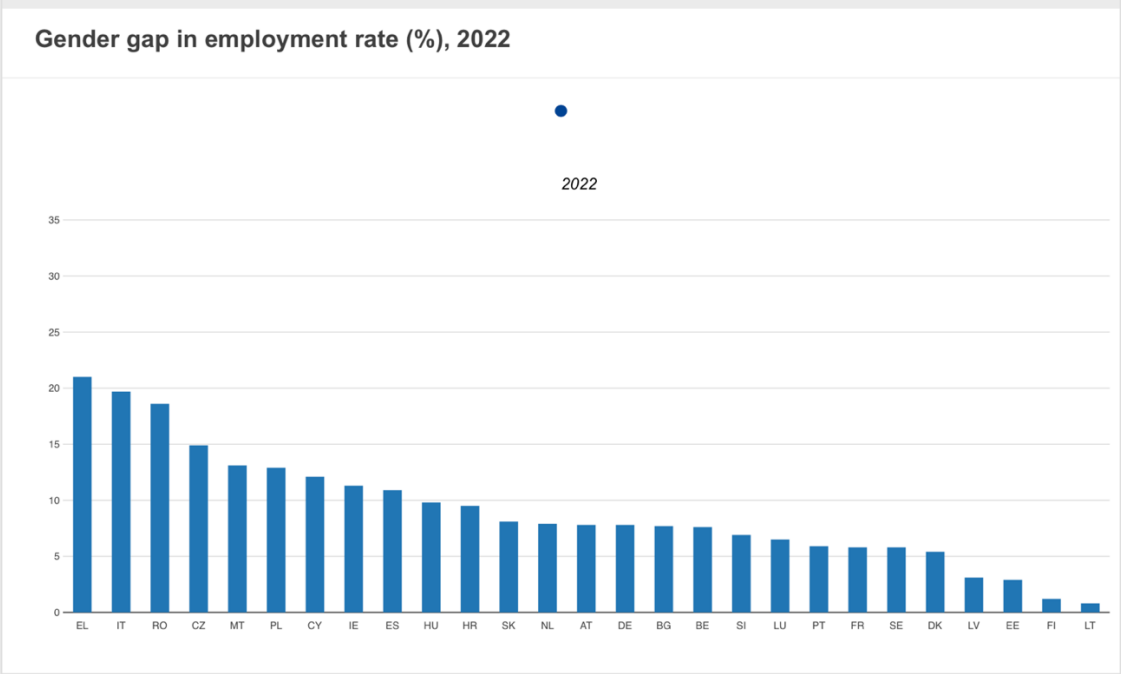
[35] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, "A Union of Equality: Gender Equality Strategy 2020-2025", Brussels, 2020.

[36] European Commission (2024), "2024 report on gender equality in the EU".

of women un the EU are employed, compared to 78% of men; 75% of unpaid care and domestic work is done by women[37].

Figure 6 shows the gender gap in employment rate in 2022 in Europe, underlining the difference in the percentage of men and women who are employed. Countries like Lithuania, Finland and Estonia present the smallest gaps (5%), while Greece and Italy the highest (20%).

Figure 6. Gender gap in employment rate (2022)



Source: European Commission.

Analyzing a wider area, in order to fight against these disparities and to lead and coordinate United Nations efforts on gender equality, UN Women was founded in 2010 and a UN Women Strategic Plan 2022-2025 has been defined.

"UN Women focuses on priority areas that are fundamental to women's equality, and that can unlock progress across the board"[38].

The priorities of the Strategic Plan involve:

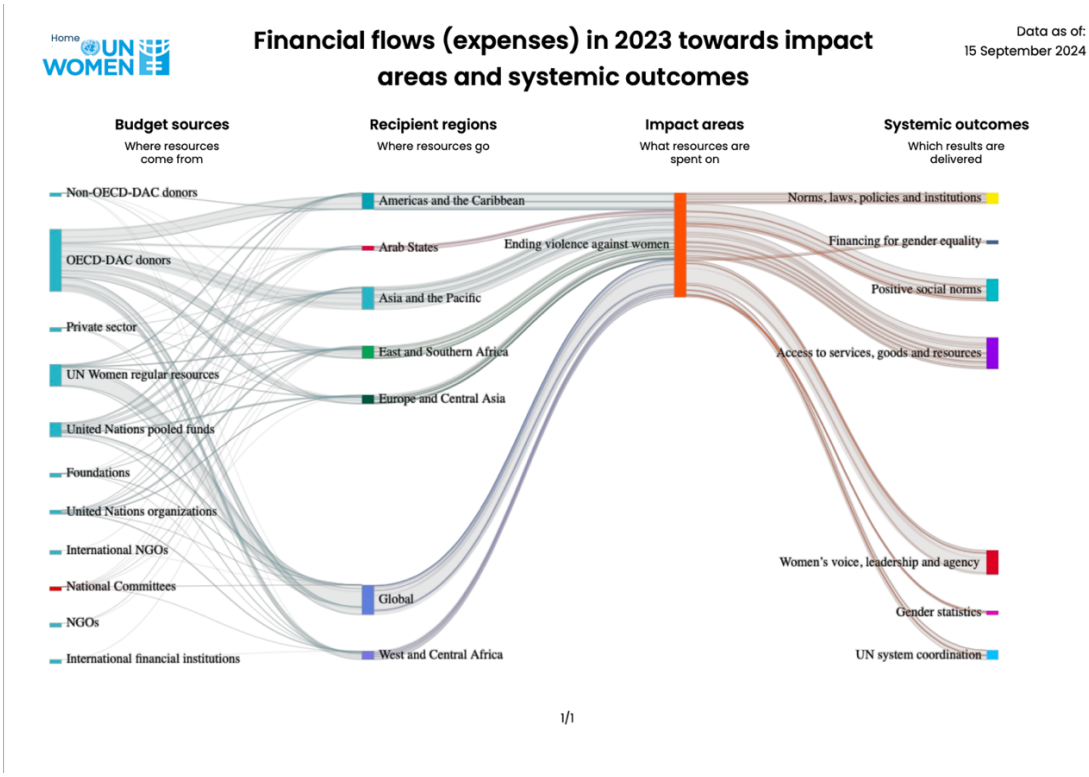
[37] European Commission (2020), "Striving for a Union of Equality, The Gender Equality Strategy 2020-2025", March 2020.

[38] https://www.unwomen.org/en/what-we-do

- ending violence against women: all women and girls live a life free from all forms of violence;
- women's economic empowerment;
- governance and participation in public life.

Figure 7 shows how financial flows have been addressed. In 2023 the majority of the resources came from OECD-DAC donors, UN Women and United Nations pooled funds who invested the most in America and the Caribbean, Asia and the Pacific and East and Southern Africa on ending violence against women.

Figure 7. Financial flows in 2023 towards impact areas and systemic outcomes



Source: UN Women.

Before analyzing the situation in the recipient regions, which are the same mentioned in Chapter I, it is important to define what gender equality is and which the components behind this indicator are.

According to the European Institute for Gender Equality, this expression refers to rights, responsibilities and opportunities that have to be equally distributed across women, men, girls and boys. Their interests, needs and priorities have to be equally

taken into consideration, and their importance does not depend on whether they are female or male[39].

The core domains accounted for gender equality are work, money, knowledge, time, power, health, violence and intersecting inequalities. In order to deeply and concretely understand the situation, the following indicators taken by the World Bank[40] will be analyzed:

- women who were first married by age 18 (% of women ages 20-24);
- maternal mortality ratio;
- adolescent fertility rate (births per 1000 women ages 15-19);
- proportion of seats held by women in national parliaments (%).

In Africa, gender disparities become more evident during adolescence, when many girls are forced to marry early and face the risk of adolescent pregnancy with a consequent abandon of school[41].

In particular, countries like Mozambique, Madagascar and Burkina Faso have very high percentages of women ages 20-24 who were first married by the age 18, respectively 48.4% (2023), 38.8% (2021) and 38.2% (2021).

These results are emphasized by the adolescent fertility rate (births per 1000 women ages 15-19). In fact, Sub-Saharan Africa in 2022 shows a 98.72 rate.

Moreover, women and girls have less access to formal employment, earn lower wages and have limited influence on government policies. The proportion of seats held by women in national parliaments was 27.03% in 2023, a percentage that is slowly increasing through the years.

In South Asia and Pacific regions, according to the Asian Development Bank, the stark reality is that close to 100 million women across Asia are considered "missing" due to gender-based discrimination. This is a result of unequal access to healthcare and nutrition, neglect and pre-birth sex selection. Maternal mortality rates in South Asia are among the highest globally, with 500 women dying per 100 000 live births[42].

[39] https://eige.europa.eu/publications-resources/thesaurus/terms/1059?language_content_entity=en
[40] https://datatopics.worldbank.org/world-development-indicators/themes/people.html
[41] https://www.unicef.org/esa/gender-equality
[42] https://www.adb.org/features/12-things-know-2012-gender-equality

In particular, Nepal, Yemen and Afghanistan report high early marriage rates (lower than the ones for Africa), respectively 34.9%, 29.6% and 28.7%. For what concerns the adolescent fertility rate, in Asia and the Pacific in 2022 was registered a 20.10 rate measured by births per 1000 women ages 15-19.
On the other hand, looking at the proportion of seats held by women in national parliaments in 2023, a 18.22% was reported.

In Latin America and the Caribbean, gender inequality remains a significant issue, with legal and social barriers that continue to affect women's rights. In 18 countries across the region, husbands have the legal authority to stop their wives from working. Additionally, 49 countries lack proper legislation to protect women from domestic violence. Around 21% of women and girls aged 15 to 49 reported experiencing physical and/or sexual violence by an intimate partner in the past years. Furthermore, early marriage is a concern, with 29% of women aged 20 to 24 having been married before turning 18, and 7% before the age of 15[43].
Women's political participation is gradually improving, in 2023 35.70% of seats in national parliaments were held by women.

2.2 Gender Inequality Index

The Gender Inequality Index, as represented in Figure 8, can be described as the sum of three components, specifically reproductive health, empowerment and labour market, distributed across female and men.
It assumes value 0 when the components are equally distributed between female and male, and value 1 when the dimensions are distributed poorly between genders and can be interpreted as "a percentage loss to potential human development due to shortfalls in the dimensions included"[44].

More specifically, health is measured by the Maternal Mortality Ratio and the Adolescent Birth Rate**,** which belong to the Female Reproductive Health Index.

[43] UN Women (2018), "Turning promises into action: gender equality in the 2030 agenda for sustainable development".
[44] UNDP (2015), "Gender Inequality Index (GII)", HDR, 2015.

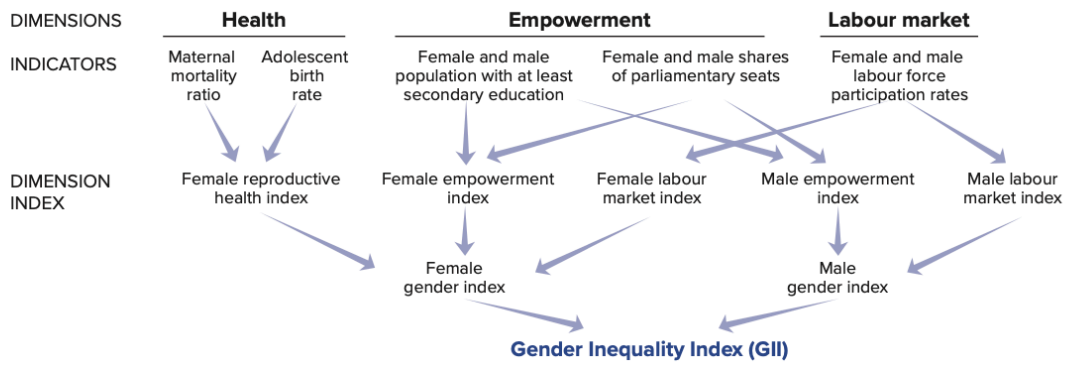
Empowerment is measured by the Female and Male Population with at least secondary education and Female and male shares of parliamentary seats**.** Both indicators are associated to two dimensions: Female Empowerment Index and Male Empowerment Index.

Labour Market is measured by Female and Male Labour Force Participation Rates which are associated to two dimensions: Female Labour Market Index and Male Labour Market Index.

Then, it is useful to filter the indexes for genders, obtaining Female Gender Index and Male Gender Index.

Their sum gives birth to the Gender Inequality Index (GII).

Figure 8. Components of Gender Inequality Index



Source: United Nations Development Program (UNDP).

In mathematical and methodological terms, the Gender Inequality Index might be associated to the Inequality Adjusted Human Development Index analyzed in Chapter I. But also an association in terms of correlation between the two indexes can be found. In fact, according to UNDP research, "Losses in HDI and the Gender Inequality Index are highly correlated (0.87), indicating that unequal distribution of human development is strongly associated with gender inequality"[45].

Focusing on the dimensions that define the Gender Inequality Index, one may notice that the only dimension that does not consider the male sphere is Health, clearly because there cannot be an equivalent for them. As a consequence, the indicator might

[45] UNDP (2015), "Gender Inequality Index (GII)", HDR, 2015.

not be equally balanced. While for Empowerment and Labour market the indicators are compared between female and male, for the Health dimension the Maternal Mortality Ratio and the Adolescent birth rate are compared to societal goals. These goals are considered to be a utopia, in fact they set standards that do not reflect the reality as the absence of maternal death and of adolescent pregnancy.

Another important observation that one may notice, regards the fact that some essential indicators are not included in the definition of what gender inequality is. In particular, sexual abuse, women who were first married at an early age, asset ownership, the involvement of women in decision making at a community level and the time that women spend in housekeeping in addition to the hours dedicated to their job are not captured by the GII. Unfortunately, these dimensions are affected by a limited availability of data.

2.3 SDG 4

According to the Department of Economic and Social Affairs, the 4th goal of Sustainable Development is to "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all"[46].

More specifically, the aim can be divided into some subcategories:

- equal access to quality education for pre-primary education in order to ensure access to early childhood development;
- equal access to quality primary and secondary education;
- equal access to quality tertiary education.

Once achieved an equal access to the three levels of education for all people, including those living in vulnerable situations, the aim becomes to ensure an education that permits to develop skills in order to face future jobs and entrepreneurship with a high level of literacy[47].

To obtain these results, investing in quality education and training represents the basis for improving people's lives, and therefore for contributing to sustainable development. Only through access to education by the entire population it is possible

[46] https://sdgs.un.org/goals/goal4
[47] https://sdgs.un.org/goals/goal4#targets_and_indicators

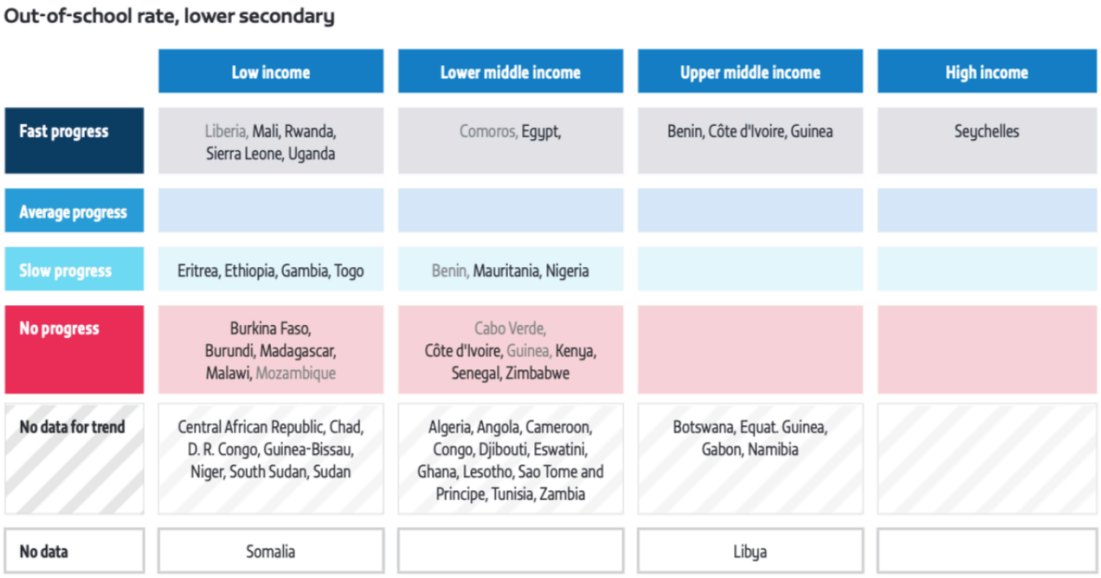
to ensure economic and sustainable growth. Clearly, the focus is on the right to education of people belonging to vulnerable categories, on the eradication of illiteracy and on the promotion of education for sustainable development.

A key role is played by businesses by promoting and investing in education and training. They can contribute to this goal within their own organization through training programs for employees and externally through investments in the education system and programs. Investments in training of their staff increase entrepreneurial opportunities for a company, creating new markets and new customers, and promoting greater qualification and productivity of workers. At the same time, a more qualified population will have access to better professional opportunities and higher salaries. The greater disposable income for people will, in turn, be a positive element for the markets and for the well-being of society in general. Some companies, such as those operating in the education sector or in the telecommunications sector, are more connected to SDG 4, but all types of organizations can make their contribution. The contribution of companies might be evaluated through the average hours of training per year per employee; percentage of employees' children who have access to safe and affordable daycare services; number, type and impact of the company's initiatives to raise awareness and train on the topic of sustainability.

However, access to education still remains a challenge, especially in Africa, where in 2022, 288 million school-age children were out of school, especially in countries affected by conflict[48].

[48] https://www.undp.org/africa/press-releases/new-africa-sdgs-report-shows-slow-progress-calls-greater-action-meet-targets#:~:text=SDG%204%3A%20Quality%20Education,in%20countries%20affected%20by%20conflict.

Figure 9. Out-of-school rate



Source: UNESCO.

As described in Figure 9, most of the countries in Africa are making slow progresses or no progress at all in increasing the school lower secondary enrollment rate for children. Another consistent category is “No data for trend”. In fact, a limitation that affects the quality of the outcomes for this continent is the poor data collection that often does not permit to have reliable results.

Noteworthy is the situation in Sub-Saharan Africa where the highest rates of educational exclusion in the world are reached. More than 20% of children aged 6 to 11 are not enrolled in school, with the situation worsening for older age groups. Around one-third of adolescents aged 12 to 14 are not attending school, and for youth aged 15 to 17, nearly 60% are out of the education system, according to data from the UNESCO Institute for Statistics (UIS)[49].

A key focus in this region is addressing the education of girls. UIS reports that approximately 9 million girls between the ages of 6 and 11 will never attend school, compared to 6 million boys. This gender gap begins early, with 23% of girls being excluded from primary education compared to 19% of boys. As they move into adolescence, the exclusion rate rises to 36% for girls, compared to 32% for boys.

[49] https://uis.unesco.org

But which are the obstacles to learning in Africa that cause its highest rate of educational exclusion?

DW collected some answers from children attending primary school in Nigeria in order to have a realistic representation of the conditions.

"There are no toilets, desks, or even chairs in my school. And the school is very far from my home. I think our teachers are dedicated, but it's very hard to learn with nothing to help us"[50]said Umaru Harisa, a primary school student in Nigeria.

"I should have continued with my studies instead of falling pregnant" referred Akhona Wanda, a teen mother in South Africa.

From these affirmations, some causes can be extrapolated. First of all, there is a lack of proper school structures aggravated by the skepticism of Western-style education, coupled with the belief that educating girls is unnecessary. Moreover, as seen in Chapter I, it is important to take into consideration two indicators, namely women who were first married by age 18 (% of women ages 20-24) and adolescent fertility rate (births per 1000 women ages 15-19).

All these factors have contributed to creating a difficult environment for fostering learning.

Another important point to underline as a limit to education is the fact that in 2019 9,272 schools closed due to insecurity. In countries such as Burkina Faso, Cameroon, the Central African Republic, Chad, the Democratic Republic of the Congo, Mali, Niger, and Nigeria, there were threats and attacks against students, teachers, and schools, jeopardizing the development of children, youth, and families[51].

In South Asia, besides this, other problems emerge. According to UNICEF, classrooms are largely teacher-centered and focused on rote memorization, with many children still experiencing corporal punishment and discrimination. Girls, especially in Afghanistan and Pakistan, encounter significant barriers to accessing education, and across the region, they face limited opportunities for securing meaningful employment. Enhancing the quality of teaching, learning, and skills development can help lower dropout rates, improve the progression from early childhood education to primary and

[50] https://www.dw.com/en/africa-right-to-education-remains-a-challenge/a-60518000

[51] https://timeforafrica.it/i-conflitti-in-africa-occidentale-impediscono-listruzione-di-2-milioni-di-bambini/

secondary schooling, and facilitate smoother transitions from education to the workforce.

Gender disparity in education remains a significant challenge in South Asia, primarily caused by biases, which are deeply rooted in the socio-cultural field. At the primary level, 5.9 million girls are out of school, compared to 5.5 million boys. Gender discrimination, combined with divisions based on caste, class, religion, and ethnicity, is the primary factor preventing girls from attending school. Additionally, addressing the specific needs of girls, such as access to hygiene and sanitation facilities, is crucial.

Girls from the poorest households are the least likely to ever enter a classroom. Among the region's out-of-school girls, 81% are unlikely to ever begin their education, compared to 42% of boys. Enrolling girls in school also significantly reduces the likelihood of early marriage[52].

In addition to all the issues already discussed, Latin America and the Caribbean have to deal with natural disasters and their consequences. The more recent crisis is the one that followed the Covid-19 pandemic. A report entitled "The urgency of educational recovery in Latin America and the Caribbean" was published by UNESCO in 2024, demanding for an immediate response in order to prevent long term consequences affecting the learning of students. Today 9.6 million children and adolescents are out of school, many of whom either temporarily dropped out or had minimal engagement with their education during 2020. One in three young people fails to complete upper secondary education, a level identified by SDG4 as the minimum requirement for achieving sustainable growth with equity[53].

To sum up, the global education landscape reveals significant challenges that hinder the achievement of equitable and sustainable learning for all. Sub-Saharan Africa faces the highest levels of educational exclusion, driven by inadequate school infrastructure, socio-cultural biases, and regional instability, all of which disproportionately affect girls. Similarly, South Asia deals with deeply rooted gender disparities and socio-economic divisions that prevent millions of girls from accessing education and increase the likelihood of early marriage. Latin America and the

[52] https://www.unicef.org/rosa/what-we-do/education/gender-equality-primary-and-secondary-education

[53] UNESCO (2024), La urgencia de la recuperación educativa en América Latina y el Caribe.

Caribbean, while struggling with natural disasters and the Covid-19 pandemic, also see millions of children disengaged from education. Across all these regions, barriers such as gender inequality, poor school infrastructure, security threats, and socio-economic divides have created environments where learning is severely compromised.

What is important to underline, is the fact that the gender that suffers the most from this situation is the female sphere. Globally, 119 million girls are not attending school, including 34 million of primary school age, 28 million of lower-secondary school age, and 58 million of upper-secondary school age. In conflict-affected countries, girls are more than twice as likely to be out of school compared to those in countries not affected by conflict[54]. As seen, the reasons for this disparity are numerous. Barriers to girls' education, such as poverty, child marriage, and gender-based violence differ across countries and communities. In many cases, poor families prioritize boys over girls when it comes to investing in education. In some areas, schools fail to provide safe environments or meet girls' hygiene and sanitation needs. In others, teaching methods are not gender-responsive, leading to persistent gender gaps in both learning outcomes and skills development.

In this context, a clear correlation between access to education and gender inequality emerges, particularly highlighted by the indicators discussed in section 3.1, namely women who were first married by age 18, maternal mortality ratio and adolescent fertility rate (births per 1000 women ages 15-19).

Given the significant role assumed by women in these outcomes, it is important to focus on gender equality in education measured with gender parity index.

2.4 Gender Parity Index (GPI)

The Gender Parity Index is an indicator that reflects gender equality and is closely associated with SDG 4. In particular, the Gender Parity Index (GPI) in primary education is calculated as the ratio of female students enrolled at the primary level to male students enrolled at the same level.

[54] https://www.unicef.org/education/girls-education

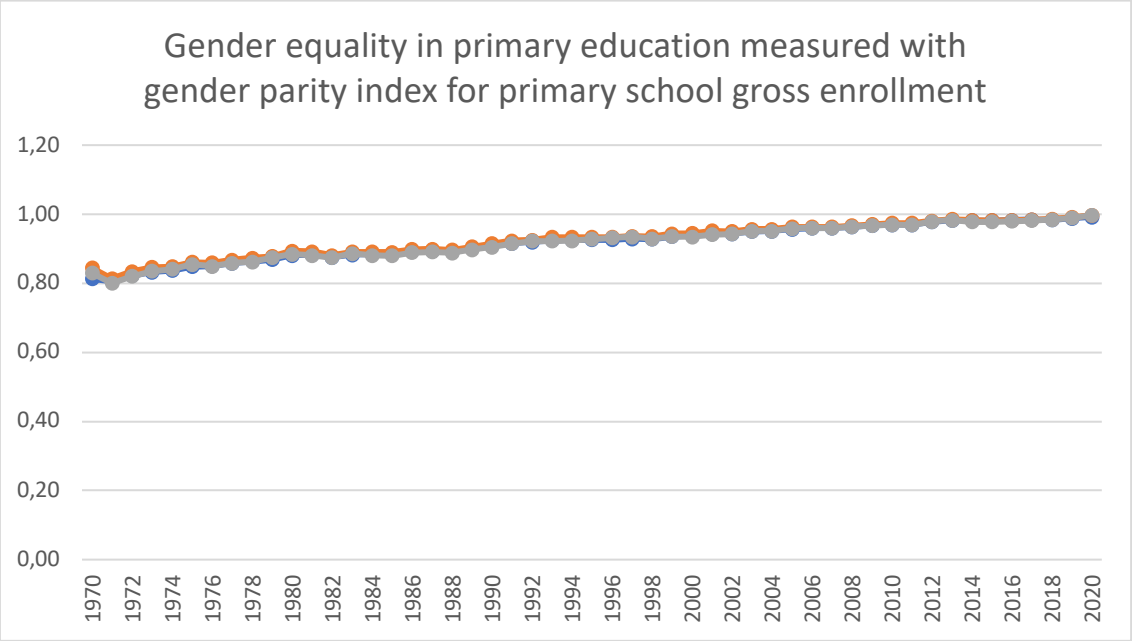
It is divided into three categories characterized by a different educational level: primary, secondary and tertiary education.

A GPI of 1 indicates gender parity, while a value less than 1 (GPI < 1) suggests that there are fewer girls enrolled compared to boys. This situation can arise from various factors, including cultural norms that prioritize boys' education over girls', leading families to invest more in boys' schooling. Economic factors can also play a significant role; families facing financial constraints may choose to invest more in boys, particularly in economically challenging contexts. Additionally, early marriage can interrupt girls' education, while safety concerns during the journey to school may discourage families from sending girls to school. The lack of adequate facilities, such as separate sanitation for girls, can further limit their participation, and systematic biases within educational systems can result in less support for females' education.

When the GPI is less than 1, it indicates a serious lack of access to education for girls, which creates long-term inequalities. Limited education for girls reduces their economic opportunities and perpetuates cycles of poverty. The absence of educational opportunities for girls also affects community health, gender equality, and the empowerment of future generations. This disparity signals the need for targeted policies to improve enrollment and completion rates for girls in education.

Looking at Africa, Latin America and the Caribbean and South Asia, the behavior of gender parity index over time appears to be very similar. In particular, focusing on primary education, in Graph 1 it is possible to see the evolution of the index from 1970 to 2020. The lines overlap for all the time series and never crosses the value 1, highlighting the fact that boys enrolled in primary education have on average been always higher than girls.

Graph 1. Evolution of Gender Equality in Primary Education measured with Gender Parity Index for Primary School Gross Enrollment (1970-2020)



Source: WDI.

A GPI < 1 intrinsically generates a low status for women that limits their opportunities and freedoms, reducing their interactions with others and their ability to behave independently. This restricts the transfer of new knowledge and negatively impacts their self-esteem and self-expression. Women's status is a crucial determinant of two key caregiving resources: their physical and mental health, as well as their autonomy and control over household resources. Consequently, low status diminishes women's ability to act in their own and their children's best interests, and research has established a connection between women's status and child malnutrition.

However, in the last 10 years progresses have been made in order to reach the value of equity and today the overall situation in Latin America and the Caribbean and South Asia rotates around value 0,997, instead in Africa it is near 0,992.

But why is it important to evaluate gender parity on school enrollment? Education is defined by Amartya Sen[55] as the direct link between illiteracy and women's security. The Nobel Prize in Economics affirms that "if we continue to leave vast sections

[55] Amartya Kumar Sen (born November 3, 1933, in Santiniketan) is an Indian economist and philosopher who was awarded the Nobel Prize in Economics in 1998.

of the people of the world outside the orbit of education, we make the world not only less just, but also less secure […] not to be able to read or write or count or communicate is a tremendous deprivation. The extreme case of insecurity is the certainty of deprivation, and the absence of any chance of avoiding that fate"[56].

Sen's perspective highlights the deep impact that education has on both justice and security, particularly for women. By linking illiteracy directly to insecurity, he emphasizes that education is not merely a tool for personal development, but a fundamental necessity for ensuring a more equitable and safer world. The deprivation caused by illiteracy extends beyond the individual; it destabilizes societies by spreading inequality and vulnerability generating repercussions globally.

A consequence of this lack of literacy and communication is the state of deprivation, which in turn gives birth to insecurity. This deprivation represents a deeper systemic failure that leaves entire groups powerless to change their circumstances or to escape cycles of poverty and marginalization.

Addressing illiteracy, especially among women, is essential for creating a more secure and just world. Education empowers individuals, enabling them to claim their rights and improve their living conditions. It is defined by dr. Azza Karam[57] as "the pathway to gender equality".

Schools play a crucial role in advancing gender equality. They serve as empowering environments for all students, in particular the education that girls receive in schools significantly influences their future opportunities and life paths.

Which are the reasons of this gender-based discrimination in education?

The answer can be found in Amartya Sen's words "Gender-based discrimination in education is, in effect, both a cause and a consequence of deep-rooted differences in society. Disparities, whether in terms of poverty, ethnic background, disability, or traditional attitudes about their status and role, all undermine the ability of women and girls to exercise their rights."

[56] UNICEF and UNESCO (2013), "The World We Want – Making Education a Priority in the Post-2015 Development Agenda: Report of the Global Thematic Consultation on Education in the Post-2015 Development Agenda", 2013.

[57] Dr. Azza Karam (PhD) served as Former Secretary General of Religions for Peace.

In order to properly address the factors that influence gender-based discrimination in education, with a focus on primary education, it becomes necessary to evaluate together all the indicators analyzed in Chapter I and Chapter II.

CHAPTER III: AN ECONOMETRIC ANALYSIS OF PANEL DATA

Given all the instruments, Chapter III aims to present a detailed econometric analysis focusing on three main areas, which were the core of this thesis, mainly Africa, Latin America and the Caribbean and South Asia. Each region will be analyzed by means of econometric models in order to identify the key factors that influence Gender equality in primary education measured with gender parity index for primary school gross enrollment, considering both the regional characteristics and the broader socioeconomic context. Special attention will be given to the role of access to clean cooking and electricity, as well as the interaction effects between these variables and urbanization.

3.1 Methodology and Data

This study uses panel data for a total of 103 countries from Africa, Latin America and the Caribbean and South Asia for the period 1970 - 2023[58] to examine the factors that influence gender equality in primary education, specifically measured by the Gender Parity Index (GPI) for gross enrollment in primary schools in energy-poor regions.

Table 2 provides the definitions and sources of the variables involved in the analysis.

Table 2. Definition and Source of Variables

Variables	Definition	Source
School enrollment primary	Gender equality in primary education measured with gender parity index for primary school gross enrollment	WDI
Access to clean cooking	Access to clean cooking fuels and technologies measured with the percentage of the population with access to clean fuels and technologies for cooking	WDI
Rural access to clean cooking	Rural access to clean cooking fuels and technologies measured with the percentage of rural population with access to clean fuels and technologies for cooking)	WDI
Urban access to clean cooking	Urban access to clean cooking fuels and technologies measured with the percentage of urban population with access to clean fuels and technologies for cooking	WDI
Access to electricity	Access to electricity (% of population)	WDI
Rural access to electricity	Rural access to electricity (% of rural population)	WDI
Urban access to electricity	Urban access to electricity (% of urban population)	WDI
Literacy rate, youth female	Female literacy measured with youth female literacy rate as a percentage of females ages 15–24	WDI
Labor force participation rate	Female employment measured with female employers as a percentage of female employment	WDI
Women married at 18	Women who were first married by age 18 (% of women ages 20-24)	WDI
Sexual abuse	Proportion of women subjected to physical and/or sexual violence in the last 12 months (% of ever-partnered women ages 15-49)	WDI
Adolescent fertility rate	Adolescent fertility rate (births per 1,000 women ages 15-19)	WDI

[58] 59 countries from Africa, 35 countries from Latin America and the Caribbean, 9 countries from South Asia.

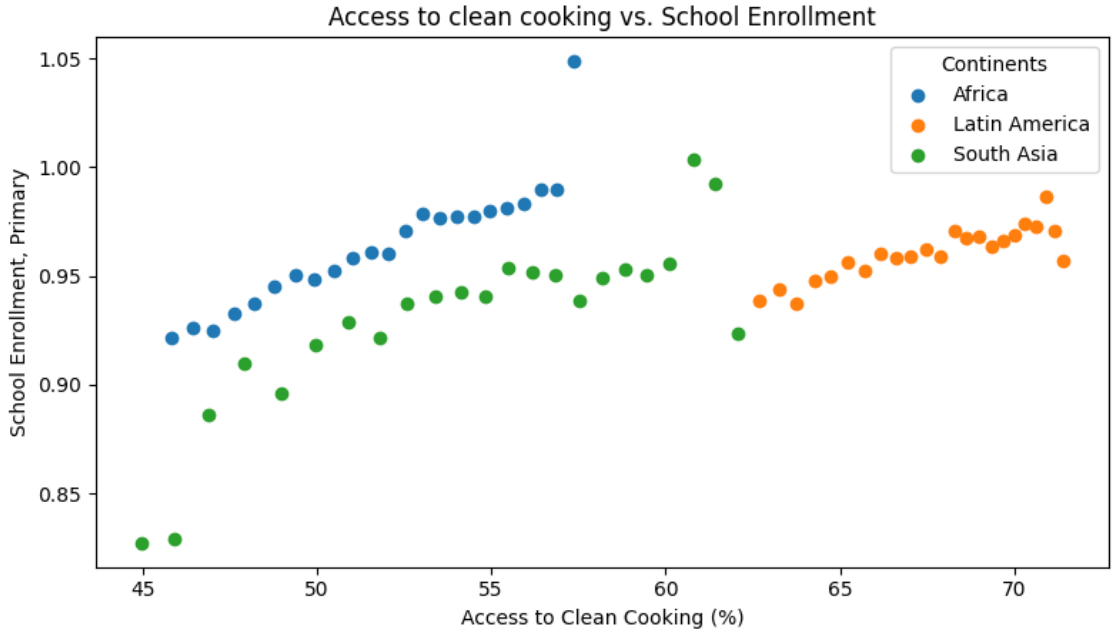
Maternal mortality ratio	Maternal mortality ratio (modeled estimate, per 100,000 live births)	WDI

Source: WDI.
Note: WDI represents World Development Indicators.

In Chapter I energy poverty has been analyzed, reporting two key indicators for its evaluation, mainly access to clean cooking fuels and technologies and access to electricity.

Graph 2 shows the relationship between Gender equality in primary education measured with gender parity index for primary school gross enrollment and Access to clean cooking fuels and technologies measured with the percentage of the population with access to clean fuels and technologies for cooking.

Graph 2. Access to clean cooking vs School Enrollment



Source: WDI

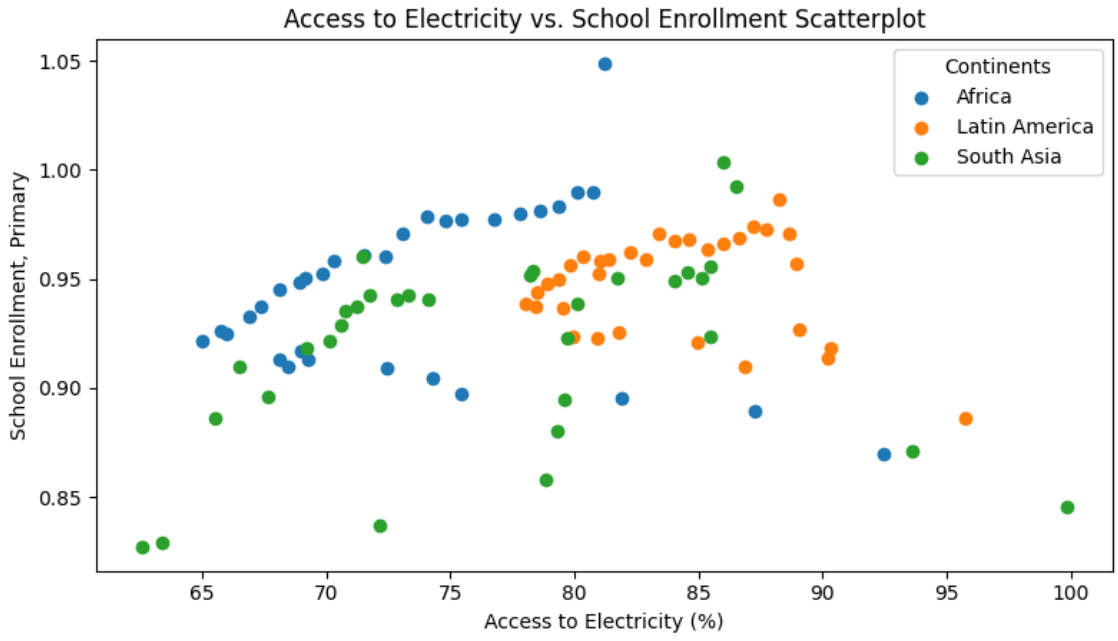
In Africa as access to clean cooking increases (from around 45% to 60%), the primary school enrollment rate for girls increases. The graph underlines an upward trend and suggests a positive relationship between access to clean cooking and gender parity in primary education. Regions with higher access to clean cooking tend to reach a gender parity index equal to 1.00, meaning that gender parity has been achieved.

In South Asia the relationship seems similar to Africa, even though school enrollment starts at a lower base (around 0.85) and increases more slowly as access to clean cooking improves.

In Latin America access to clean cooking is higher (around 65%) and maintains an enrollment rate closer to 1.00, this behavior indicates better gender parity in primary education compared to Africa and South Asia. The points are more clustered, showing less variability in gender parity and suggesting that the region has already achieved relatively higher levels of both clean cooking access and gender parity in primary education.

Graph 3 shows the relationship between Gender equality in primary education measured with gender parity index for primary school gross enrollment and Access to electricity.

Graph 3. Access to Electricity vs School Enrollment



Source: WDI.

In Africa access to electricity is lower and ranges from 65% to 85%. As electricity access improves, there seems to be a slight positive trend in gender parity, with school enrollment rates approaching or exceeding 1.00. However, there is still a spread of

values, suggesting varying levels of gender parity in primary education, even at similar electricity access rates.

South Asian countries tend to have an electricity access that ranges between 65% and 85%.

School enrollment for girls (relative to boys) remains consistently lower than in Africa or Latin America, with many points below 1.00, indicating a persistent gender gap in education.

Despite improvements in electricity access, there does not appear to be a strong relationship between electrification and school enrollment parity in South Asia.

Latin American countries have the highest levels of access to electricity, often above 85%.

Gender parity in primary education is relatively stable, with most points between 0.90 and 1.00 indicating more gender-equal enrollment in primary schools.

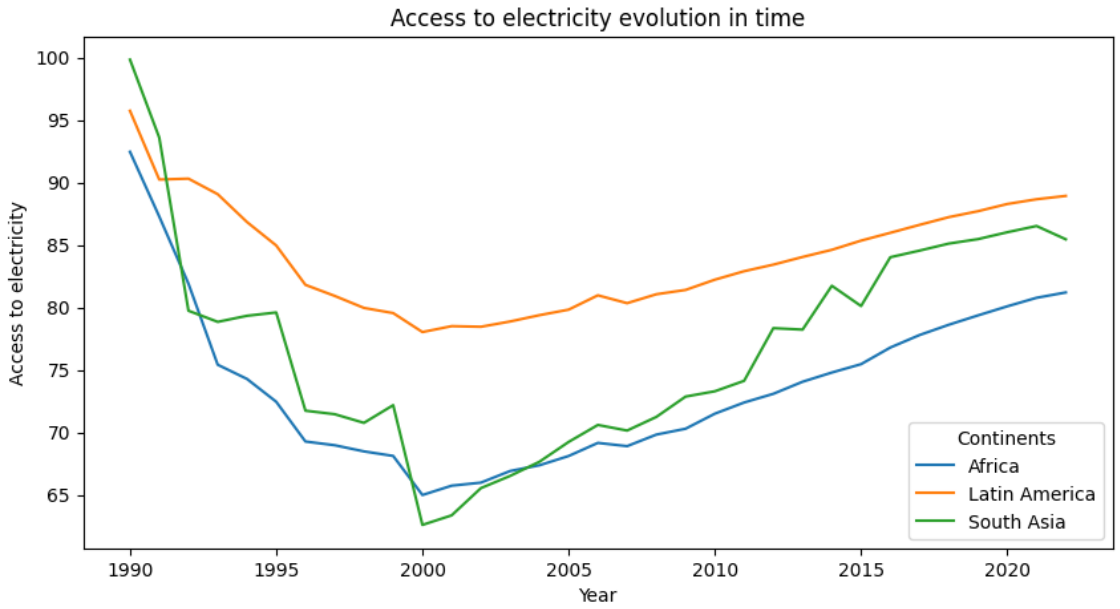
The relationship between electricity access and gender parity in primary education is not as pronounced, probably because the region has already achieved near-universal access to electricity and high levels of gender parity.

In general, access to electricity may be one of several factors that influence gender parity in primary education. While the scatter plot shows some positive association between electrification and gender equality in school enrollment in regions like Africa and Latin America, the picture is more complex for South Asia.

Noteworthy is the situation in South Asia, with the lowest values of gender parity in school enrollment in relation to access to electricity. According to the scatterplot a weak relationship between electricity and school enrollment parity emerges.

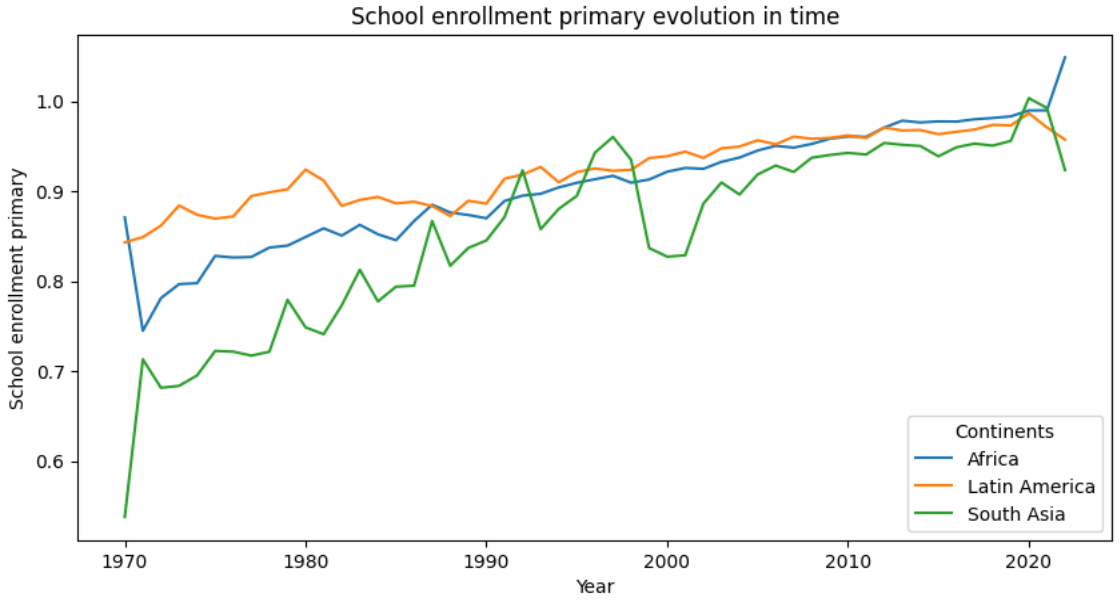
In Graph 4 is represented the evolution of access to electricity over time and in Graph 5 the evolution of gender parity in school enrollment. An unexpectedly correlated behavior appears in 2000, when to a dramatic drop in access to electricity corresponds a decrease in gender parity school enrollment.

Graph 4. Access to electricity evolution time



Source: WDI.

Graph 5. School enrollment evolution in time



Source: WDI.

In order to understand the wages in which access to clean cooking fuels and technologies and access to electricity affect gender parity in education, it is necessary to take into consideration other factors.

For this reason Literacy rate, Labor force participation rate, Women married at 18, sexual abuse, Adolescent fertility rate and Maternal mortality ratio have been analyzed.

Before presenting the results, it is important to explain the methodology adopted. An Ordinary Least Squares (OLS) with random effects has been used and this can be explained by the presence of panel data, which accounts for unobserved heterogeneity across units.

The first issue encountered was related to the problem of missing data mentioned in Chapter II, unfortunately the dimensions of Women married at 18, Sexual abuse and Maternal mortality ratio are affected by a limited availability of data. In order to address this problematic, during the Data Cleaning phase, NaN values were added for missing data.

A second issue that needed to be addressed was multicollinearity. Through the calculation of Variance Inflation Factors (VIF) for each independent variable, emerged that Access to clean cooking, Rural access to clean cooking, Urban access to clean cooking, Access to electricity, Rural access to electricity and Urban access to electricity were strongly autocorrelated, with VIF value up to 102 for Access to clean cooking. At this point, three approaches could be embarked:

1) Testing for heteroskedasticity through Breusch Pagan Test, White Test and the evaluation of robust standard errors;
2) Construction of a dummy variable, namely Urban access to clean cooking and Urban access to electricity, which assumed value 1 if the threshold of 60% was met; 0 otherwise. And then the creation of two interaction variables given by the product of Access to clean cooking and Access to electricity with their dummies.
3) Simplifying the model by removing highly collinear variables.

In particular, the first step gave evidence of the presence of heteroskedasticity, p-values of both Breusch Pagan Test and White Test resulted to be statistically significant, consequently H0 (homoskedasticity) was rejected. Then, robust standard errors with HAC were computed. HAC stands for heteroskedasticity and autocorrelation consistent, so they correct for both heteroskedasticity and autocorrelation by means of lag window to model autocorrelation among errors, reducing the impact of autocorrelation and heteroskedasticity on standard errors. In addition, they are considered a valid tool in presence of panel data because when more units in time are observed, errors might be

both heteroskedastic and autocorrelated in time. Using HAC standard errors, more accurate and robust estimates can be obtained.

Despite the use of HAC standard errors, in this study multicollinearity still needed to be adjusted. With this aim, two dummy variables and interaction terms were created. The use of the threshold is due to the fact that rural and Urban access to clean cooking are not two complementary measures, they are evaluated on the percentage of rural and urban population respectively. For this reason a threshold of 60% on Urban access to electricity was introduced. The same interpretation is valid for the variables Rural access to electricity and Urban access to electricity. The output was unexpected: p-values of the dummy variables from OLS regression were NaN values. This might be associated to the fact that the interaction terms already incorporate the effect of the dummy variables, making the dummy variables themselves redundant. Moreover, the Condition Number was infinite (Cond. No = inf) suggesting perfect collinearity between dummies and the interaction terms. In order to address the problem, dummy variables have been dropped and NaN values have been solved.

However, a strong multicollinearity persisted, so a simplified model was proposed.

In the next paragraph a detailed representation of the results for each area will be presented.

3.2 Empirical findings

In Table 3 are shown the results for using Gender equality in primary education measured with gender parity index for primary school gross enrollment as the dependent variable. Three models are presented, divided for area of interest, namely Africa, South Asia and Latin America and the Caribbean, and 12 independent variables are used. In the first column of each country is reported the coefficient of the OLS regression while in the second column in parentheses are indicated the robust standard errors with HAC. A significance level of 0.05 was applied and indicated with ** when p-value < 0.05, underlining the fact that the variable is statistically significant.

Table 3. OLS regression

Variables	Gender equality in primary education measured with gender parity index for primary school gross enrollment					
	Africa		South Asia		Latin America and the Caribbean	
Access to clean cooking	-0.0045**	(0.002)	0.0016**	(0.001)	0.0078**	(0.001)
Rural access to clean cooking	0.0033**	(0.001)	0.0019**	(0.001)	-0.0035**	(0.001)
Urban access to clean cooking	0.0010	(0.001)	-1.5e-05	(0.000)	-0.0030**	(0.001)
Access to electricity	0.0004	(0.001)	0.0047**	(0.000)	-0.0075**	(0.002)
Rural access to electricity	-0.0002	(0.000)	-0.0004	(0.001)	0.0019**	(0.001)
Urban access to electricity	0.0003	(0.001)	0.0017**	(0.000)	0.0164**	(0.004)
Literacy rate, youth female	0.0004**	(0.000)	0.0012**	(0.000)	0.0007**	(0.000)
Labor force participation rate	0.0014**	(0.001)	0.0018**	(0.000)	0.0010**	(0.000)
Women married at 18	-0.0002	(0.000)	0.0006	(0.001)	-0.0001	(0.000)
Sexual abuse	0.0007**	(0.000)	-0.0015**	(0.001)	-0.0010**	(0.000)
Adolescent fertility rate	0.0006**	(0.000)	-0.0011	(0.001)	-0.0007**	(0.000)
Maternal mortality ratio	-0.0003**	(3.98e-05)	0.0003**	(9.28e-05)	-6.529e-06	(2.44e-05)
Constant	0.8395	(0.056)	8.307e-06	(4.41e-06)	-0.2722	(0.275)
Observations	2837		353		1603	
R squared	0.125		0.618		0.369	

Source: WDI
Heteroskedasticity robust standard errors in parentheses.

** $p < 0.05$.

A detailed interpretation of the results follows, with a focus on the statistically significant values.

In Africa Access to clean cooking has a negative and significant effect on gender parity in primary education, ceteris paribus, meaning that to a one percentage point increase in the population with access to clean cooking fuels and technologies, corresponds a 0.0045 decrease in gender parity in primary school enrollment. The p-value gives evidence of the fact that this relationship is statistically significant.

Rural access to clean cooking has a positive and significant effect on gender parity in primary education, ceteris paribus, meaning that to a one percentage point increase in the rural population with access to clean cooking fuels and technologies, corresponds a 0.00333 increase in gender parity in primary school enrollment. The positive and significant coefficient of the p-value underlines the statistically significance of the relationship between the variables.

On the other side, Urban access to clean cooking is not statistically significant, showing no strong evidence of relationship between variables.

Not significant are also Access to electricity, Rural access to electricity and Urban access to electricity.

Literacy rate, youth female has a positive and significant effect on gender parity in primary education, ceteris paribus, meaning that to a one percentage point increase in the literacy rates among young females, corresponds a 0.0004 increase in gender parity in primary school enrollment.

The same accounts for Labor force participation, to a one percentage point increase corresponds a 0.0014 increase in gender parity in primary school enrollment.

A controversial effect involves Sexual abuse, in fact the regression indicates that to a one percentage point increase in sexual abuses, corresponds a 0.0007 increase in gender parity in primary school enrollment and this effect is statistically significant.

Similarly, for what concerns Adolescent fertility rate, a negative and significant effect is associated to a one percentage point increase, in fact to this increment, corresponds an increase of 0.0006.

While, to a one percentage point increase in Maternal mortality ratio corresponds a 0.0003 decrease in gender parity in primary school enrollment.

R-squared is relatively low, the independent variables can only explain 12.5% of the variability in gender equality in primary education. This can be explained by the large number of observations (2837), there might be many factors that are not captured by this single model. Moreover, the problem of missing data emerges and causes a measurement error that influences the low R-squared and also the reliability of coefficients. In particular, the relationships between Sexual abuse and School enrollment primary and Adolescent fertility rate and School enrollment primary, can be interpreted as unconventional. In some cases, this can be associated to reverse causality, meaning that improvements in gender parity in education can lead to more conscious and aware women, that are capable to report abuses influencing the results; or more educated females may have more access to healthcare and to a consequent reporting of the rate. In other cases, there might be a problem of omitted variables, an example could be the presence of policies for gender equality in education in countries with reporting mechanisms for sexual abuses.

While for Africa the reliability of the coefficients is taken into discussion because of the low R-squared, this problem should not be encountered for South Asia, where R-squared is 0.618, meaning that the independent variables can explain 61.8% of the variability in gender equality in primary education.

Access to clean cooking shows a positive and significant relationship with gender equality in primary education, ceteris paribus, meaning that to a one percentage point increase in the population with access to clean cooking fuels and technologies, corresponds a 0.0016 increase in gender parity in primary school enrollment. The p-value gives evidence of the fact that this relationship is statistically significant.

Similarly, Rural access to clean cooking has a positive and significant effect on gender equality in primary education, ceteris paribus, meaning that to a one percentage point increase in the rural population with access to clean cooking fuels and technologies, corresponds a 0.0019 increase in gender parity in primary school enrollment. The p-value underlines the fact this relationship is statistically significant.

Urban access to clean cooking, instead, has a very small negative and not significant coefficient, implying no direct impact on gender equality in primary school enrollment.

Access to electricity, behaves similarly to Access to clean cooking, showing a positive and significant effect on gender equality in primary school enrollment, meaning that to a one

percentage point increase in the population with access to electricity, corresponds a 0.0047 increase in gender equality in primary school enrollment.

Opposite is the behavior of Rural access to electricity and Urban access to electricity compared to Rural access to clean cooking and Urban access to clean cooking.

In fact, Rural access to electricity shows a small negative and not significant coefficient, meaning that its increase does not directly affect gender equality in primary school enrollment. Instead, Urban access to electricity shows a positive and significant impact, to a one percentage point increase in the urban population with access to electricity, corresponds a 0.0017 increase in gender parity in primary school education.

Literacy Rate, youth female and Labor force participation also show a positive and significant effect on gender parity in primary education.

While Women married at 18 and Adolescent fertility ratio suggest no direct relationship with the dependent variable.

Contrarily to Africa, in South Asia Sexual abuse has a negative and significant impact on gender parity in primary school education: to a one percentage point increase in sexual abuse, corresponds a 0.0015 decrease in gender parity.

Curious is the behavior of Maternal mortality ratio, that shows a positive and significant impact.

With South Asia, it is demonstrated how a higher R-squared affects the reliability of the results and suitability of the model.

In the third regression Latin America and the Caribbean has been analyzed. The R-squared indicates that 36.9% of the variability in gender equality in primary education is explained, which is lower than R-squared computed for South Asia, but higher than R-squared found for Africa. Also the number of observations for Latin America and the Caribbean (1603) stays in the middle.

Looking at the coefficients, they appear to be in contrast with what discovered for Africa and South Asia. The coefficients of Access to clean cooking, Rural access to clean cooking, Urban access to clean cooking are all significant, but while the first one has positive effects, the other two have negative impacts on the dependent variable, meaning that to an overall increase in the population with access to clean cooking fuels and technologies corresponds an increase of gender parity in education, but to an increase

of the rural and urban population with access to clean cooking fuels and technologies corresponds a decrease in gender parity in primary education.

An opposite behavior emerges from Access to electricity, Rural access to electricity and Urban access to electricity. While the first one has negative effects, the other two have positive impacts on the dependent variable. This means that to an overall increase in the population with access to electricity corresponds a decrease of gender parity in education, but to an increase of the rural and urban population with access to electricity corresponds an increase in gender parity in primary education.

This might sound controversial, the overall access to clean cooking fuels and technologies and electricity should logically include both rural and urban areas.

Literacy rate, youth female and Labor force participation rate are both positive and significant, to their one percentage point increase, corresponds an increase in gender parity for primary education.

Sexual abuse and Adolescent fertility rate are both negative and significant, meaning that to a one percentage point increase of the independent variables mentioned, corresponds a decrease in the dependent variable.

Women married at 18 and Maternal mortality ratio are both insignificant.

The first problem that emerges in all scenarios is multicollinearity. This issue might be the reason why the overall access to clean cooking and to electricity and their urban and rural factors have controversial effects in Africa and Latin America and the Caribbean. In order to address this problem, binary indicators have been introduced. The binary assumes value 1 when urban and 0 otherwise by means of a threshold. Then, an interaction variable has been created and the binaries removed. Also the independent variable Maternal mortality ratio has been excluded from these regressions, as it gave signals of collinearity. Table 4 shows the results obtained for the three scenarios, including South Asia.

Table 4. OLS regression with interaction variables

Variables	Gender equality in primary education measured with gender parity index for primary school gross enrollment					
	Africa		South Asia		Latin America and the Caribbean	
Access to clean cooking	0.0009**	(0.000)	0.0030**	(0.000)	-7.572e-07	(0.000)
Access to clean cooking x Urban access to clean cooking binary	-0.0006**	(0.000)	0.0005**	(0.000)	-0.0011**	(0.000)
Access to electricity	-2.505e-06	(0.000)	0.0055**	(0.000)	0.0018**	(0.001)
Access to electricity x Urban access to electricity binary	0.0010**	(0.000)	0.0024**	(3.44e-05)	-9.741e-05	(0.000)
Literacy rate, youth female	0.0002	(0.000)	8.6e-05	(0.000)	-0.0003	(0.000)
Labor force participation rate	-0.0020**	(0.001)	-1.313e-05	(0.000)	-0.0018	(0.001)
Women married at 18	-0.0008**	(0.000)	0.0023**	(0.000)	0.0012**	(0.001)
Sexual abuse	-0.0019**	(0.000)	-0.0036**	(0.000)	0.0011**	(0.001)
Adolescent fertility rate	0.0004**	(0.000)	0.0001	(0.000)	-0.0024**	(0.000)
Constant	0.9156	(0.047)	5.325e-05	(3.08e-06)	1.1229	(0.142)
Observations	1182		154		674	
R squared	0.076		0.104		0.470	

Source: WDI.

Heteroskedasticity robust standard errors in parentheses.

** $p < 0.05$.

After having computed binary and interaction variables, significant differences have emerged.

Focusing on Access to clean cooking and Access to electricity and their interaction with binary variables, the following evidences are noteworthy.

In Africa, Access to clean cooking shifted from a negative to a positive coefficient indicating that an increase in the overall access to clean cooking fuels and technologies generates an increase in gender equality in primary education; however, the interaction term is negative and significant, it means that in urban areas, access to clean cooking still has a positive effect on gender parity in primary education, but it increases less proportionally than in rural areas, in other words the effect in urban areas is weaker than in rural ones. Why?

The United Nations has planned that by 2050, 68% of the global population will reside in urban areas, with approximately 90% of this growth to be seen in Asia and Africa.[59]

Africa, looking at the past, has always been predominantly a rural area until colonialism arrived and the decline of traditional agricultural traditions began. As a consequence, people moved to urban areas which were affected by a rapid expansion that brought significant challenges: spatial disproportion, injustices, inadequate housing, high crime rates.

In the last two decades, the urban population of Africa almost doubled, from 290 million to 570 million [60] causing an uncontrolled expansion with significant environmental issues, among all deforestation and climate change. African cities are often characterized by the lack of essential urban infrastructure, bad public transportation services, poor sanitation and frequent power shortages. [61]

Given this context, the complex urban challenges might be one of the causes for which access to clean cooking fuels and technologies in urban areas affects gender parity in primary education with a weaker impact compared to rural areas.

Looking at the other variables, in Africa noteworthy is the behavior of the independent variable Women married at 18, that assumes statistical significance after

[59] UN (2018), World Urbanization Prospects, vol. 12.

[60] UN-HABITAT (2022), Envisaging the Future of Cities, World Cities Report 2022

[61] Todes, A. (2017), “Shaping peripheral growth? Strategic spatial planning in a South African city-region”, Habitat International, Volume 67, pp. 129-136

the introduction of interaction variables, meaning that to a one percentage point increase in early marriages, corresponds a decrease in gender parity in primary school education.

Interesting is also the new coefficient of Sexual abuse, now its one percentage point increment is associated to a negative effect on gender parity.

Complex remains the effect of Adolescent fertility rate on gender parity in primary education, but this can be partially explained by the fact that this study takes into consideration primary education, so girls ranging between 6 to 12 years old. However, a change in the dependent variable was made and gender equality in tertiary education was taken into consideration, obtaining a negative and significant coefficient (-0.0002).

The situation in South Asia is quite different. The R-squared of the new model (0.104) is significantly lower than the one obtained in the first regression (0.618), this result attributes a weaker power to the new model, indicating its inefficiency in capturing the variability in gender parity in primary school education. However, stronger positive effects emerge for access to clean cooking fuels and technologies and electricity, underlining the positive role of urban access which on the other hand is less pronounced than the role of rural access.

This can be partially explained by taking in consideration the fact that urban areas offer more educational opportunities and resources than rural ones for both genders. In fact, rural areas start from a more disadvantaged position and when an improvement in access to clean cooking fuels and technologies and electricity is introduced, it has larger effects on increasing gender parity in education. In particular, in South Asia 12% of the children aged between 5 to 14 years old are estimated by UNICEF to be involved in child labor, this represents over 41 million children[62] and can be interpreted as 41 million children that help families sustain the cost of life by means of their workforce. Families living in rural areas face important economic challenges that influence the possibility to sustain educational costs for their children.

To sum up, rural areas of South Asia start from a disadvantaged position. The introduction of improved access to clean cooking fuels and technologies and electricity

[62] https://www.unicef.org/rosa/what-we-do/child-protection/child-labour-and-exploitation

would have greater impacts on gender parity in education rather with respect to an increase in the urban area.

For Latin America and the Caribbean, a problem in the first regression was met: the impact of the overall access to clean cooking fuels and technologies and electricity was of opposite sign with respect to its subcategories rural and urban, generating controversial behavior; in fact, the overall access to clean cooking fuels and technologies and electricity should logically include both rural and urban areas. In the new model Access to clean cooking shifted from a positive and significant coefficient, to a negative and no significant value. However, its interaction with the binary variable generates a negative and significant coefficient, suggesting that in urban areas, access to clean cooking fuels and technologies has a weaker impact on gender parity in primary education in comparison to rural areas.

In 2015 Latin America and the Caribbean was experiencing the most significant urban growth in the world according to the Inter-American Development Bank. The country was involved in a rapid process of urbanization causing a complex scenario of challenges. In particular, problems of inadequate urban planning, pollution, social inequities, high unemployment, crime and weak institutional and fiscal capacities influenced the region. Linked to these difficulties, emerges another issue: trust in government.

In 2022, according to the Organization for economic Co-operation and Development, only 36.3% of the population in Latin America and the Caribbean had trust in the national government[63].

On the other hand, Access to electricity shifted from a negative and significant value to a positive and significant new value; however, its interaction with the urban access to electricity binary shows insignificant implications. This might signify that while electricity is important for improving educational outcomes, the specific subcategory does not significantly alter its impact.

Noteworthy are Sexual abuse and Adolescent fertility rate. The first one shifted from a negative and significant coefficient to a positive and significant value. This can be associated to reverse causality, meaning that improvements in gender parity in education can lead to more conscious and aware women, that are capable to report

[63] OECD (2024), Government at a Glance: Latin America and the Caribbean 2024, OECD Publishing, Paris, https://doi.org/10.1787/4abdba16-en.

abuses influencing the results; or more educated females may have more access to healthcare and to a consequent reporting of the rate. In other cases, there might be a problem of omitted variables, an example could be the presence of policies for gender equality in education in countries with reporting mechanisms for sexual abuses.

For what concerns Adolescent fertility rate, the negative impact in the new model is stronger than in the first regression, meaning that higher adolescent fertility is associated to a worse gender parity in education.

This models, in contrast with the first one, presents a higher R-squared (0.470). This result attributes a stronger power to the new model.

In conclusion, all scenarios give evidence of the complex interplay between access to clean cooking fuels and technologies and access to electricity and gender parity in primary education. As urbanization continues to characterize the demographic landscape, targeted strategies that address both rural and urban challenges need to be implemented in order to achieve equal educational opportunities for all genders.

However, it is important to underline the fact that the presence of a high number of missing data affects the models. This issue has been addressed as a last step of the study, dropping the independent variables with NaN values, obtaining very simple models with just statistically significant variables and a low level of multicollinearity. Only three independent variables were kept, namely Access to clean cooking, Adolescent fertility rate and Literacy rate youth female, as reported in Table 5. As a result, adolescent fertility rate has a negative and significant impact on gender equality in primary education, while access to clean cooking fuels and technologies and the literacy rate for youth females have a positive and significant impact on the dependent variable. This behavior is shared by all countries taken in consideration in this study.

Table 5. OLS regression, simple model

Variables	Gender equality in primary education measured with gender parity index for primary school gross enrollment					
	Africa		South Asia		Latin America and the Caribbean	
Access to clean cooking	0.0010**	(0.012)	0.0019**	(0.000)	0.0015**	(0.000)
Literacy rate, youth female	0.0004**	(5.79e-05)	0.0018**	(0.000)	0.0008**	(8.62e-05)
Adolescent fertility rate	-0.0002**	(7.33e-05)	-0.0046**	(0.000)	-0.0004**	(0.000)
Constant	0.8511	(0.012)	1.1772	(0.056)	1.1229	(0.142)
Observations	3040		404		1704	
R squared	0.072		0.440		0.328	

Source: WDI.

Heteroskedasticity robust standard errors in parentheses.

** $p < 0.05$.

As a result, adolescent fertility rate has a negative and significant impact on gender equality in primary education, while access to clean cooking fuels and technologies and the literacy rate for youth females have a positive and significant impact on the dependent variable. This behavior is shared by all countries taken in consideration in this study.

CONCLUSION

In this study, the examination of the interplay between energy poverty, gender equality and education has been analyzed, focusing on regions characterized by important challenges, mainly Africa, South Asia and Latin America and the Caribbean.

The research started from the investigation of the behavior of access to clean cooking fuels and technologies and electricity. Then, a focus on gender parity and education followed, with the aim to understand the interaction between all variables in the three scenarios taken in consideration.

The results of the analysis demonstrated that access to energy plays a central role, however, in order to deeply understand the effects of this variable on gender parity in education, a more specific distinction has been made, precisely the distinction between rural and urban areas. A feature has been noticed: the influence of urban access to clean cooking fuels and technologies presented a weaker impact on gender parity in education comparing to rural areas. This was noticed in Africa and South Asia. Latin America and the Caribbean showed contrasting behaviors, with urban and rural access to energy having different implications for gender parity in education.

In conclusion, it is important to focus on the socio-economic contexts that characterize each area in a unique way. Regional disparities, infrastructural problems, sanitation system, religion, political system, criminality, spatial disproportion, injustices, inadequate housing should be taken into account when designing policies with the aim to address energy poverty in developing countries to improve gender parity in education. Achieving meaningful improvements will require long-term strategies and a collaboration between sectors in order to act with a common scope.

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