Effect of access to electricity on spatial inequalities in the area of education in Cameroon

By Pierre LOTY
Administrative Research Assistant at the Ministry of Economy, Planning and Regional Development (MINEPAT) in Yaoundé (Cameroon)

Abstract

Access to electricity in Cameroon has witnessed steady increase, rising from 29% in 1991 to 65% in 2022. However, the most powerful electricity generating facilities (hydroelectric dams) are located in the southern part of the country, where the wettest regions and the largest rivers are found. It is interesting to examine how the energy gap could influence educational outcomes in the northern and southern areas.

Some studies have shown a positive relation between access to electricity and educational outcomes in Africa. But the relation has not yet been investigated at subnational level. Changing the level of analysis, it is interesting to show at community level how inland communities situated far from coastal areas have less access to electricity and education, compared to communities located around large cities closer to coastal areas.

This article attempts to answer the following research question: What is the effect of access to electricity on spatial inequalities in the area of education in Cameroon? The objective is to determine the spatial variations of the effect of access to electricity on educational attainment and gender gaps. The hypothesis of the study is that the positive effect of access to energy on educational attainment is much more felt in southern areas of Cameroon where environmental factors are more conducive to electric power supply.

The results show that the northern areas are still in the first stage of the educational transition (primary school incomplete and gender gaps increasing) while the southern areas are in the second stage of the transition (primary school complete and gender gaps narrowing). The study recommends the construction toilet and sanitation facilities in schools located in remote rural areas. Such equipment could work with renewable energy (solar electric power) able to power electrical deep well pump necessary to provide enough water for school toilets and sanitation.

Keywords: access to electricity; spatial inequalities; educational attainment; gender gaps

Introduction

Worldwide, 1.5 billion people did not have access to electricity in 1998 (Ritchie et al., 2019). This figure has fallen to 1.1 billion in 2015 (Marangoly George, 2015). However, the improvement at global level hides important variations between regions. For instance, access to electricity has improved in South Asia while worsening in Sub-Saharan Africa, home to three-quarters of the world's population without access to electricity (Ritchie et al., 2019). The increasing demand for electricity in Sub-Saharan Africa is related to high fertility levels translating into rapid population growth.

In this line of thought, the world governments and international agencies outlined the 7th Sustainable Development Goal aiming to ensure access to affordable, reliable, sustainable and modern energy for all by 2030. The target 7.5 aims to expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries (United Nations, 2015).

In Cameroon, access to electricity has witnessed steady increase, rising from 29% in 1991 to 41% in 1998, 47% in 2004, 54% in 2011, 62% in 2018 and 65% in 2022. However, there are striking spatial disparities at subnational level. While universal access has almost been achieved in large cities (Yaoundé and Douala), only 37% of rural households had access to electricity in 2022 (National Institute of Statistics, 2020; National Institute of Statistics, 2023). In response, the National Development Strategy covering the 2020-2030 period aims to increase the supply of hydroelectric energy and photovoltaic energy (MINEPAT, 2020).

The Head of State's 2025 New Year message to the nation further noted the importance of electric power supply for the development of economic activities and the improvement of the living standards of households. President Paul BIYA mentioned the need to narrow the energy gap between the southern and northern regions of our country through the interconnection of the southern and northern electrical grids (PRC, 2025).

The energy gap between the southern and northern regions of Cameroon is due to environmental factors. The southern part of the country, characterized as humid and equatorial (temperatures ranging from 20-25°C) comprises the wettest regions (over 400 mm of rainfall per month). Conversely, the Northern part of the country, characterized as semi-arid and dry (temperatures ranging from 25-30°C) receives less than 100 mm of rainfall per month (World Bank, 2021).

The variations between northern and southern climates translate into variations in the flow rate of rivers. Thus, the most powerful rivers are found near coastal areas in the southern part of the

country. For instance, the Sanaga stands as the largest river in Cameroon (over 920-975 km), with a 140 000 km^2 basin. Flows range from 473 m^3/s (March) to 57 000 m^3/s (October), with a mean of 2 072 m^3/s (Balarin, 1985). Not surprisingly, the most powerful electricity generating facility in Cameroon (the Nachtigal hydroelectric dam) has been built on the Sanaga river, with an installed capacity of 420 MW (EDF, 2025).

It should be mentioned that hydropower is clean and renewable. It doesn't release harmful pollutants into the air or water. Granted, there are some environmental considerations that come with building large hydropower facilities like dams and reservoirs. Still, hydropower plants, once operational, do not harmfully impact the environment (EnergySage, 2022). Consequently, greater reliance on hydroelectric power implies that the increasing demand of energy driven by population growth does not translate into higher pollutant level.

Spatial inequality in electric power supply can influence the economic and social development. Specifically, it is interesting to analyze how educational attainment is determined by access to electricity. It is noteworthy that sub-Saharan Africa, as the single area of the world with high concentration of poverty, is characterized by low access to electricity as well as low educational attainment. At subnational level, we expect remote and underserved local communities to face both lack of energy and severe school dropouts.

It should be recalled that Cameroon is a developing country facing numerous challenges regarding the supply and demand of education (MINEPAT, 2009). The average number of education years for youths age 18 years stands at 8.7 years (UNESCO-IICBA, 2024), well below the target of the fourth Sustainable Development Goal aiming at complete primary and secondary education (13 years of schooling) for boys and girls by the year 2030 (United Nations, 2015). Moreover, the average educational level remains below the target of the National Development Strategy aiming to achieve completion of the first cycle of the secondary education (10 years of schooling) by 2030 (MINEPAT, 2020).

Several authors delved into demographic, socioeconomic and sociocultural factors useful to understand disparities in the supply and demand of education (Pilon, 1996; Lange and Yaro, 2003; Altinok, 2006; Kobiané and Pilon, 2008; Nganawara, 2016; Barry and Slifer-Mbacké, 2017; Kana, 2018; Asadi, 2020; Niang, 2022).

Besides, there are few studies examining educational trends in sub-Saharan Africa. In this line of thought, some authors examined the general pattern of educational outcomes in Africa, pointing to a positive trend in the long term (improvement of educational attainment across

generations) and striking disparities due to gender inequalities (Barro and Lee, 2015; Psaki et al., 2018; Friedman et al., 2020; Baten et al., 2021; Evans et al., 2021; Loty et al., 2022).

Moreover, some studies have challenged the role of gender inequality in the explanation of educational trends, pointing to the greater role played by socioeconomic status. In other words, educational gaps between the poor and the rich are greater than educational gaps between boys and girls (Eloundou-Enyegue et al., 2009). Accordingly, poor girls will be the last to complete the educational transition (positive trend from low educational attainment for older women to high educational attainment for younger women). Consequently, authors concluded that educational investments should be directed toward poor girls (Eloundou-Enyegue et al., 2009; Psaki et al., 2018).

However, the specific effect of access to electricity as socioeconomic factor of educational trends remains understudied. Available studies have shown a positive relation between access to electricity and educational outcomes in Africa. For instance, Mouongue Kelly and colleagues (2023) concluded that electricity contributes positively to primary educational attainment in Central Africa. But the relation has not yet been investigated at subnational level.

This article takes another view of the problem by changing the level of analysis. At community level, it is interesting to show how inland communities situated far from coastal areas have less access to electricity and lower educational attainment rates, compared to communities located around large cities closer to coastal areas.

The community-level approach is relevant in the local context because openness to modern development did not occur evenly. The colonial powers had their first contacts with African communities through coastal areas where they developed industries, roads, railroads, and missionary schools. (Baten et al., 2021). Thus, spatial inequalities, already visible from the beginning of the XXth century, persist today with rural areas situated far in the hinterland facing more difficulties that those located closer to coastal areas.

Therefore, this article will examine the following research question: What is the effect of access to electricity on spatial inequalities in the area of education in Cameroon? The objective is to determine the spatial variations of the effect of access to electricity on educational attainment and gender gaps. The hypothesis of the study is that the influence of access to electricity on educational attainment is positive. This positive effect is much more felt in southern areas of Cameroon where environmental factors are more conducive to electric power supply.

The article contributes to the existing research as it points out the atomic fallacy (thinking that poor rural households without electricity will have the same pattern of educational gender gaps irrespective of the environment where they live). Moreover, the article is useful for policy making as it enhances the localization of development needs, thus enabling better targeting of local communities for high impact interventions.

The study comprises three parts. The first part examines the conceptual framework. The second part presents data and methods. The third part features a discussion of main findings and policy implications.

1. Conceptual framework to assess the educational effect of access to electricity

The conceptual framework for this study stresses the importance of contextual factors at local community level to understand how spatial inequalities in access to energy are associated with educational gender gaps. The contextual factors are the region and the type of place of residence. The study relies on a typology of local communities comprising five types of localities: rural northern areas, urban northern areas, rural southern areas, urban southern areas and large cities. The pattern of the relation between access to electricity and educational attainment for boys and girls is expected to vary according to the type of locality.

2. Measuring the educational effect of access to energy using generational time series

2.1 Sampling methodology of the Demographic and Health Survey (DHS)

The analysis is based on data from the Demographic and Health Survey conducted in Cameroon in 2011. Information were collected on 14,214 households comprised in a countrywide sample representing all 10 regions of Cameroon, including 6,490 urban households and 7,980 rural households. The unit of analysis for this study is the member of the household aged 25 years and over (post-school age) at the time of the survey. The analysis file was extracted from the DHS database containing information on individual members of the household. The sample size for this study is 26,731 people, including 12,540 men and 14,191 women.

The DHS survey was implemented by the Cameroon National Institute of Statistics with the support of the United States Agency for International Development (USAID-ICF-Macro). The DHS survey objective was to collect socioeconomic and health information, including household characteristics. The rich set of variables collected is helpful for conducting various multivariable analyses needing several confounding variables. The DHS VI methodology was used, with two-stage cluster sample and an overall response rate of 99.0%.

In the first stage, 580 enumeration areas were selected using probability proportional to size sampling (the size of the enumeration area being the number of households). In the second stage, households were selected using equal probability systematic sampling, based on an updated listing of households obtained from the 2005 census. Data collection procedures were pre-tested and training was provided for the field staff over a 3-week period in October 2009. The DHS survey report provides all details concerning survey design, management and data quality (National Institute of Statistics, 2012).

2.2 Questionnaires and data collection

In both countries, three questionnaires were designed respectively for households, women and men, reflecting DHS model questionnaires. The first section of the household questionnaire contains information about household members including their educational level. It should be noted that various State and non-governmental stakeholders contributed to frame the questionnaires. Procedures and questionnaires for standard DHS surveys have been reviewed and approved by the ICF International Institutional Review Board as well as the National Ethical Committee. Interviews were conducted only when the respondents provided voluntary informed consent. Moreover, experienced field reviewers verified questionnaire logic and coherence. Independent interviews helped to confirm that questions were asked accurately. High level field visits were carried out by survey supervisors to monitor data quality. Indeed, the standard DHS methodology used for this survey guarantees the credibility of the results of the analyses carried out based on DHS data.

2.3 Estimation of the dependent variable measuring educational attainment

In all households interviewed, the household head or his representative answered questions concerning the educational level for all members of the household, including adults aged 25 years and above (post-school age). At this age, virtually all individuals sampled had already stopped their studies and could therefore be asked about their final school level, measured by the number of education years. Furthermore, authors studying retrospective trends of educational attainment generally sample individuals aged 25 years and above (Baten et al., 2021).

Noteworthily, the number of education years is a quantitative variable adequate for statistical analysis. With this indicator, it is possible to estimate various statistics including the mean and standard error. The minimal value in the sample is 0 (unschooled people) while the maximal value is 17 (people who have completed the first year of the Master cycle).

2.4 Operationalization of the independent variable measuring the cohort effect

In all sampled households the household head or his representative answered questions concerning the age of household members, including adults aged 25 years and above. For the purpose of this analysis, people interviewed were regrouped into seven ten-year cohorts as this approach reduces issues related to age misreporting. The oldest cohort, coded with the value 0, refers to people of the age group 85-94+ years, born in 1917-1926. The youngest cohort, coded with the value 6, refers to people of the age group 25-34 years, born in 1977-1986.

2.5 Estimation of the independent variable measuring access to electricity

In all sampled households the household head or his representative answered questions concerning access to electricity. The resulting variable is coded as a dummy variable (0 for households without electricity and 1 for households with electricity).

2.6 Method used to measure educational trends

A time series is a set of observations x_t, each one being recorded at a specific time t (Brockwell et Davis, 2002; Viano et Philippe, 2004). On this basis, a generational time series is defined as a set of observations x_{C_t}, each one being recorded for a specific birth cohort C_t born at time t. The resulting educational time series is a set of observations representing the educational attainment of successive generations (educational trend). In this way, it is possible to measure educational trends across generations (Loty et al., 2022).

2.7 Method used to control educational trends based on generational time series

It is possible to control educational trends using explanatory variables. For instance, the gender effect is measured by disaggregating the generational time series of educational attainment into subseries for boys and girls. If the graph of boys' series is above the graph of girls' series, there is evidence of gender inequality. Furthermore, if the gap between the male and female graph series is increasing, there is evidence of worsening gender gaps. Conversely, gender gaps are narrowing if the gap between male and female graphs is decreasing across generations.

Similarly, the effect of access to energy on educational trends is measured by disaggregating the generational time series of educational attainment into subseries for boys and girls from households without electricity and boys and girls from households with electricity. The resulting family of educational trends graphically portrays the varying patterns of educational gender gaps according to access to electricity and type of locality.

2.8 Method used to visualize spatial inequality in the area of access to electricity

Using R Studio commands, a thematic map is designed to visualize the rate of access to electricity in the various types of localities in Cameroon. R Studio enables the creation of a spatial object populated with data on access to electricity. The spatial object is linked to a shapefile containing spatial coordinates used to match up electricity data and localities.

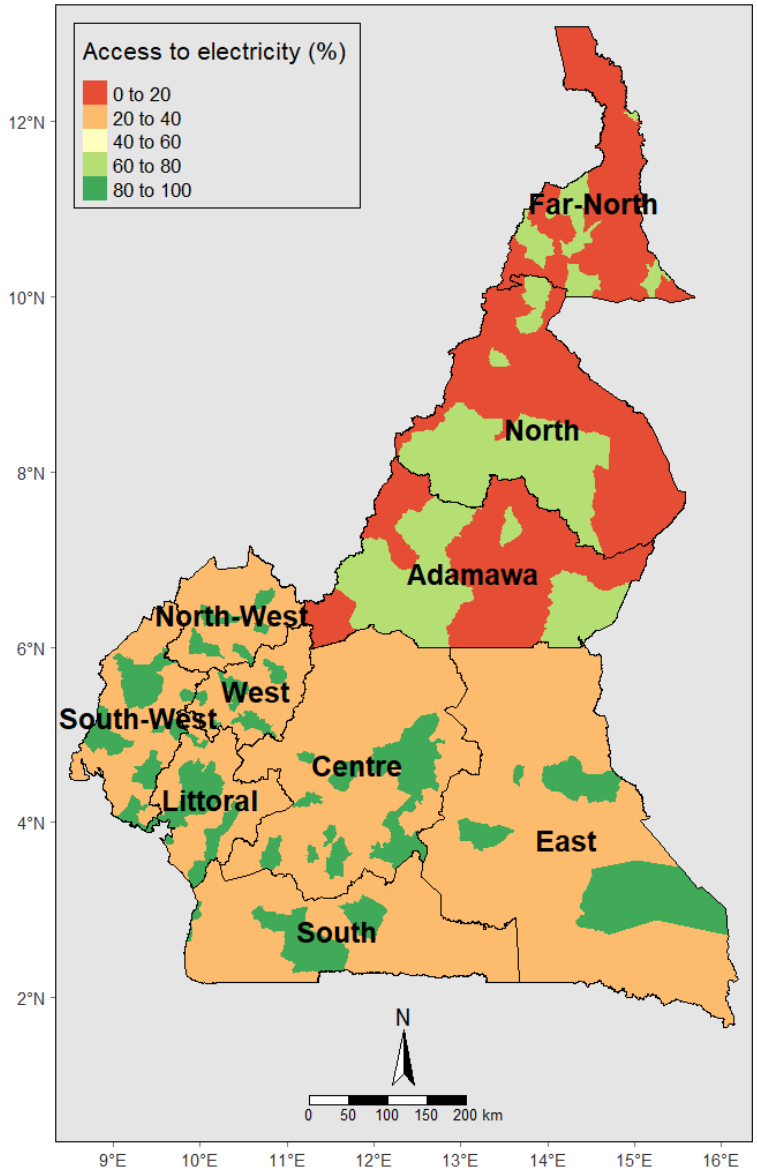
3. Results obtained by modelling the effect of access to electricity on educational outcomes

This part presents spatial inequalities in the area of access to electricity. Then, the effect of access to electricity on educational gender gaps is presented respectively in northern areas and southern areas of Cameroon.

3.1 Visualizing spatial inequalities in the area of access to electricity

Fig. 1 is a thematic map showing the energy gap between northern and southern communities. The areas in dark red are rural areas in the northern regions characterized by very low access to electricity (5.4%). The areas in light green represent urban areas in the northern regions with better access to electricity (66.25%). The areas in light red are rural areas in the southern regions where access to electricity is still inadequate (31.54%). The areas in dark green are urban areas in the southern regions where access to electricity is higher (86.9%) especially in large cities (98.33%).

Fig. 1: Thematic map portraying spatial variations in the rate of access to electricity between local communities in Cameroon



3.2 Effect of access to electricity on educational gender gaps in northern areas

The results obtained with generational time series clearly show a specific pattern of educational gender gaps for households living in northern areas of Cameroon as presented in Fig.2-Fig.5. Fig.2 features a graphical representation of educational trends for boys and girls without access to electricity in northern rural areas of Cameroon. Granted, educational attainment rates witnessed a positive growth across generations. Still, the educational growth rate is slow and the gender gap is worsening. The average years of education is 1.2 years for the younger female cohort compared to 3.7 years for the younger male cohort. Hence, this area of the country is

still in the first stage of the transition wherein children dropout before completing primary education.

Fig. 2: Long term trends of educational attainment for boys and girls without access to electricity in northern rural areas of Cameroon

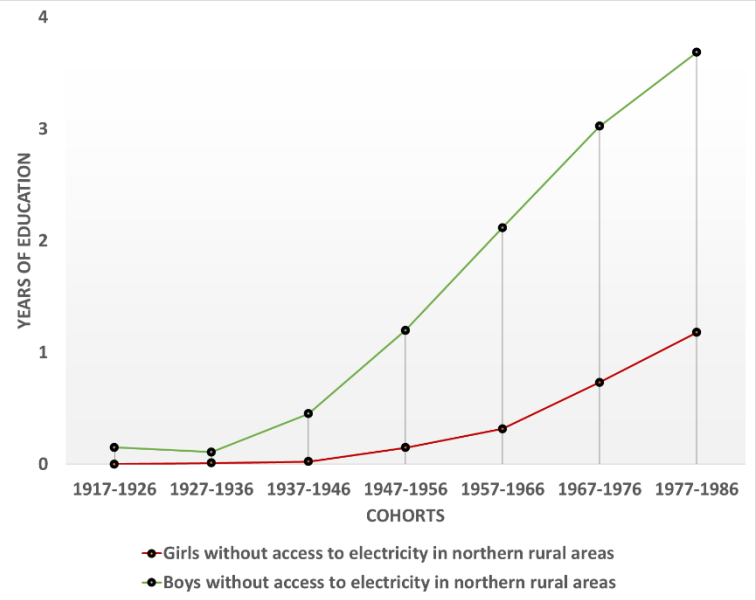


Fig.3 highlights educational trends for boys and girls with access to electricity in northern rural areas of Cameroon. This group represent a tiny minority of the population (5.4%) in northern rural areas. Educational attainment is higher for this group. The average number of years of education stands at 6.3 years for the younger male cohort (completion of primary education) and 2.8 years for the younger female cohort (high dropout rate in primary education). Hence, the same pattern of worsening gender gaps is observable for households with access to electricity. This shows the influence of contextual factors on educational attainment. In other words, the educational behavior of the minority having access to electricity is influenced by the behavior of the majority without access to electricity.

Fig. 3: Long term trends of educational attainment for boys and girls with access to electricity in northern rural areas of Cameroon

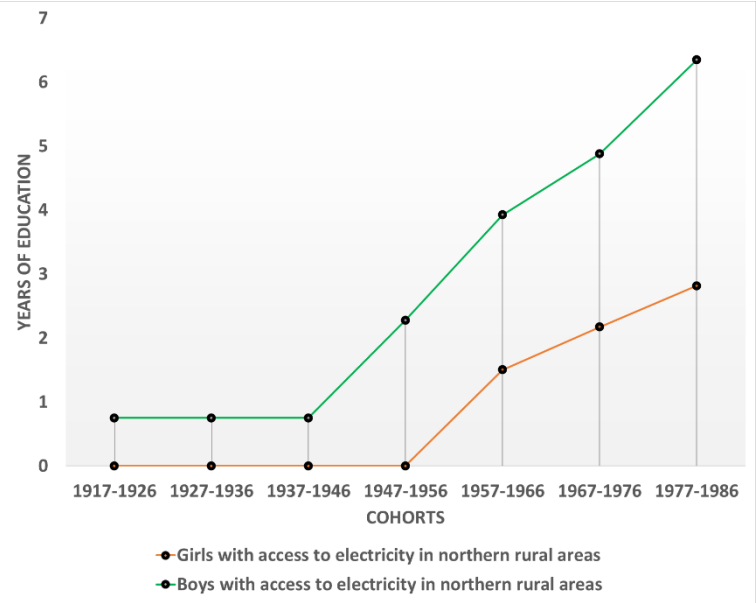


Fig.4 shows educational trends for boys and girls without access to electricity in northern urban areas of Cameroon. The average number of years of education is estimated at 4.9 years for the younger male cohort and 2.1 years for the younger female cohort. Hence, the educational pattern is broadly similar to the pattern witnessed in northern rural areas. Children typically dropout before completing primary education and gender gaps are worsening.

Fig. 4: Long term trends of educational attainment for boys and girls without access to electricity in northern urban areas of Cameroon

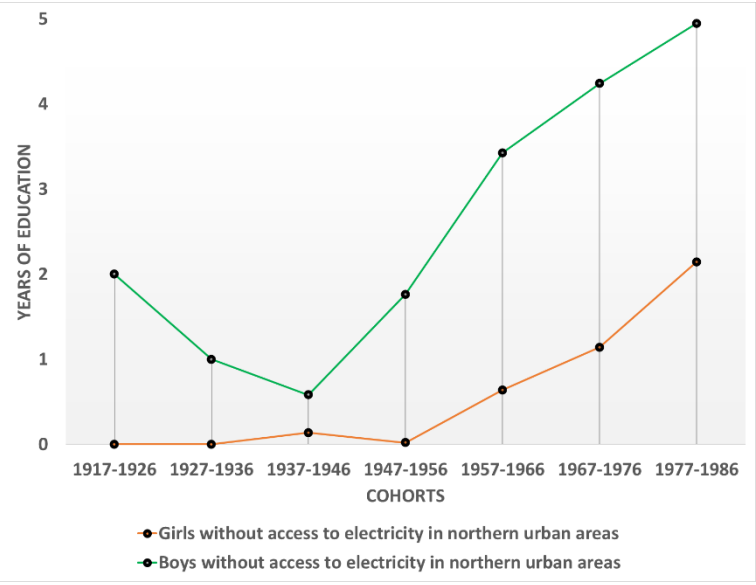
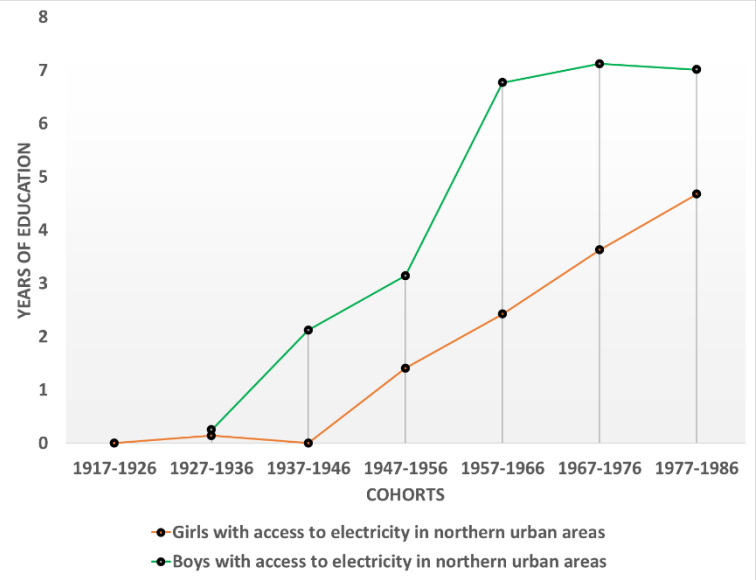


Fig.5 outlines educational trends for boys and girls with access to electricity in northern urban areas. This group represents two thirds of the population (66.25%) in northern urban areas. Educational attainment reached 7.0 years for the younger male cohort (beginning of the secondary education) and 4.7 years for the younger female cohort (primary education incomplete). Hence, the level of education is higher and gender gaps are contained. Thus, the general pattern observed in northern areas is altered in urban northern areas where the majority of people have access to electricity.

Fig. 5: Long term trends of educational attainment for boys and girls with access to electricity in northern urban areas of Cameroon



3.3 Effect of access to electricity on educational gender gaps in southern areas

Fig.6 highlights educational trends for boys and girls without access to electricity in southern rural areas of Cameroon. The average number of years of education stands at 6.5 years for the younger male cohort (completion of primary education) and 5.7 years for the younger female cohort (final year of primary education). Here, a different pattern is observable with higher educational growth rate and narrowing gender gaps. Hence, the southern areas are already in the second stage of the educational transition, characterized by growing attainment rates and reduction of gender gaps (Baten et al., 2021).

Fig. 6: Long term trends of educational attainment for boys and girls without access to electricity in southern rural areas of Cameroon

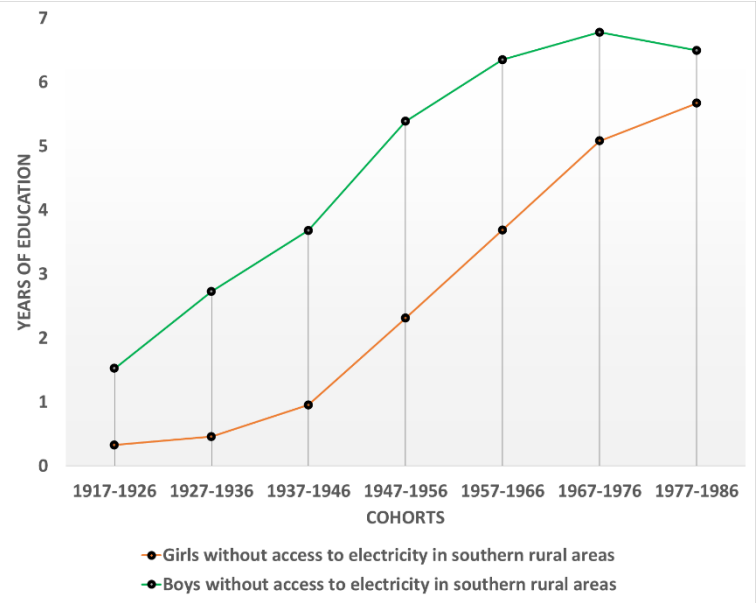


Fig.7 features educational trends for boys and girls with access to electricity in southern rural areas of Cameroon. This group represent a sizable share of the population in southern rural areas (31.54%). The average number of years of education stands at 8.0 years for the younger male cohort and 7.4 years for the younger female cohort (completion of primary education for both male and female). Thus, the southern pattern is characterized by higher educational attainment and narrowing gender gaps. This shows the greater influence of modernization in southern rural areas where one third of the population have access to electricity.

Fig. 7: Long term trends of educational attainment for boys and girls with access to electricity in southern rural areas of Cameroon

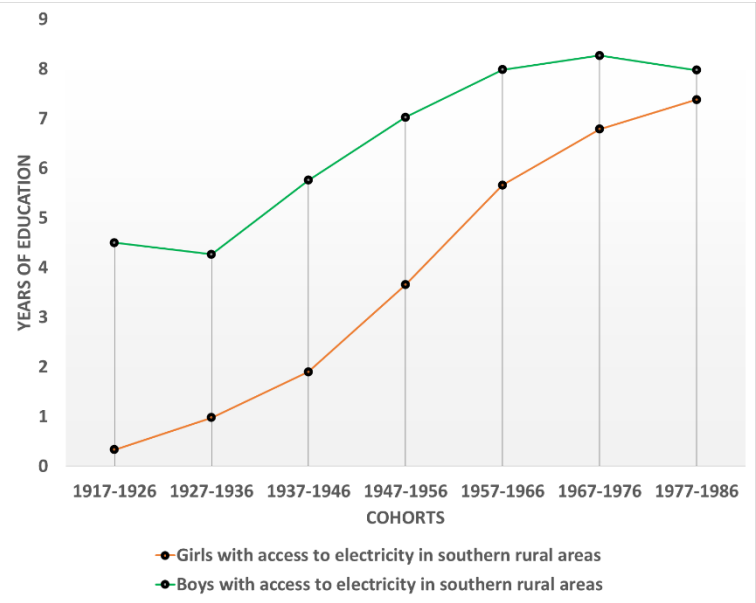


Fig.8 shows educational trends for boys and girls without access to electricity in southern urban areas of Cameroon. The average number of years of education stands at 6.8 years for the younger male cohort and 6.5 years for the younger female cohort (completion of primary education for both groups). The southern pattern is also visible for this group, with higher educational attainment and narrowing gender gaps. This is further indication that access to electricity influences education at contextual level. Those without electricity in southern urban areas are a tiny minority representing 13.1% of the local population. They are not in complete black out because they are located in suburban areas closer to coastal areas and historic cities. Consequently, they have higher educational outcomes compared to their counterparts in northern areas.

Fig. 8: Long term trends of educational attainment for boys and girls without access to electricity in southern urban areas of Cameroon

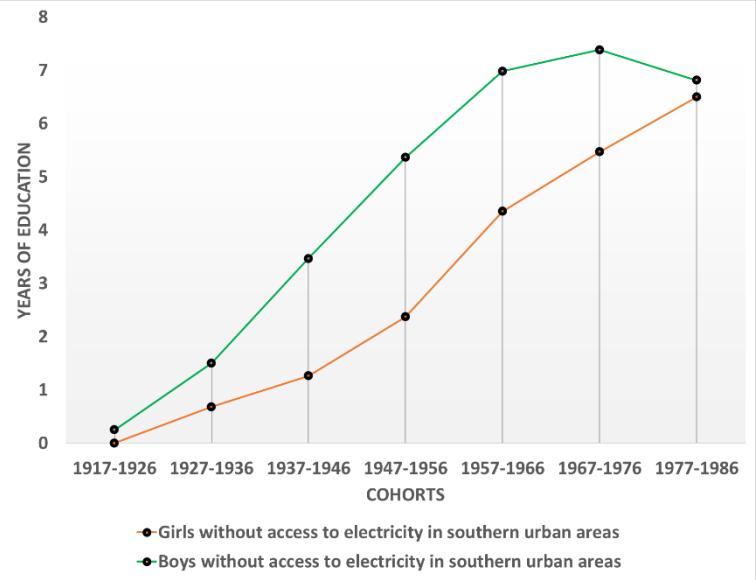


Fig.9 shows educational trends for boys and girls with access to electricity in southern urban areas of Cameroon. The average number of years of education stands at 9.6 years for the younger male cohort and 8.5 years for the younger female cohort (both groups are progressing toward completion of lower secondary education). The southern pattern is clearly visible for this group, with higher educational attainment and narrowing gender gaps. The vast majority of people in this type of locality have access to electricity (86.9%). They live around historic cities closer to the coastal area where openness to the modern world dates from the early XXth century.

Fig. 9: Long term trends of educational attainment for boys and girls with access to electricity in southern urban areas of Cameroon

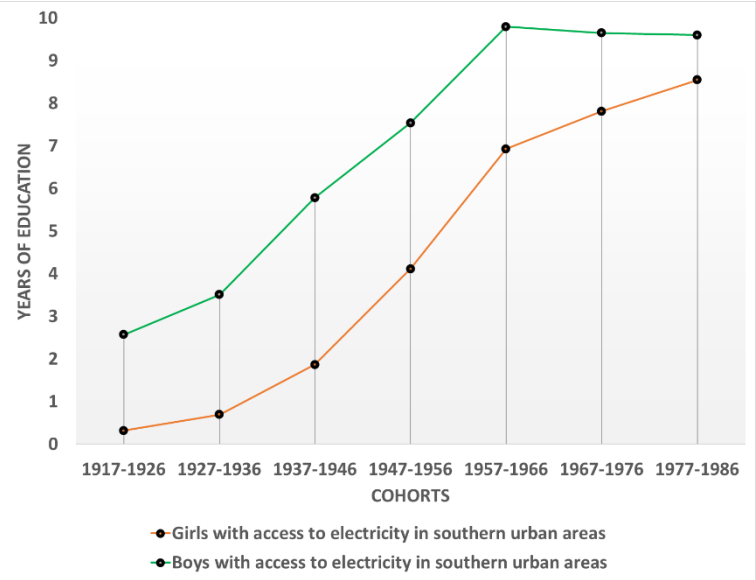
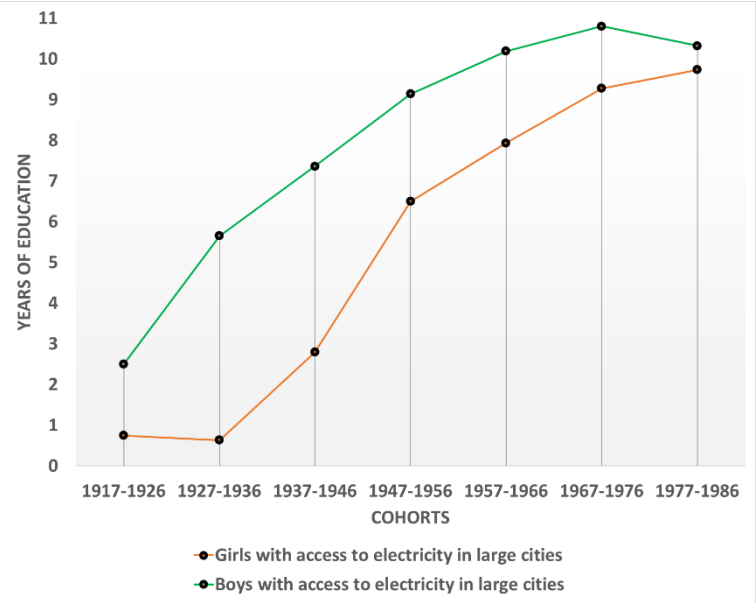


Fig.10 shows educational trends for boys and girls with access to electricity in large cities located in the southern part of Cameroon. The average number of years of education stands at 10.3 years for the younger male cohort and 9.7 years for the younger female cohort (both groups have virtually achieved universal completion of lower secondary education). It should be noted that 98.33% of the population in large cities have access to electricity. Thus, the effect of access to electricity is much weightier for this type of locality.

Fig. 10: Long term trends of educational attainment for boys and girls with access to electricity in large cities of Cameroon



3.4 Discussion

The results of this study show that spatial inequalities are striking between northern and southern regions both in terms of access to electricity and in terms of educational attainment and gender gaps. The hypothesis of the study is that the influence of access to electricity on educational attainment is positive and varies according to the type of locality. This hypothesis is verified.

It is noteworthy to recall that access to electricity impacts educational outcomes through various mechanisms. In rural northern areas where access to clean water is difficult, families would spend much time for domestic activities linked to water supply. Children typically would be involved in such domestic activities. As a result, there is a conflict between the time children spend for domestic activities and the time they spend for school attendance and study at home. This conflict would have a negative impact on educational outcomes.

The conflict is much more visible for girls since they are groomed to become good wives, especially in rural areas. As such, parents and communities responsible for bringing up girls would put emphasis on domestic activities. Consequently, difficulties linked to access to clean water negatively affect educational gender gaps.

In this line of thought, it is worth mentioning that electric power is necessary to provide drinking water supply networks that would reduce the time needed to obtain clean water. Indeed, the

distribution of clean water includes some critical components such as water pumping stations usually equipped with electric pumps. In a nutshell, access to electricity influences educational activities through access to clean water.

Furthermore, access to electricity directly impacts educational attainment because students need to study at night after school if they are to make good progress. Needless to say, children without access to electric light would not be able to study at home as children having access to electric light. Additionally, households located in areas without access to electricity are not able to provide their children with access to digital tools used for online education. At school level, areas without access to electricity typically have schools lacking computer equipment.

Without access to electricity, rural households sometimes rely on fuel-based lamps to supply their basic lighting needs. Kerosene is the predominant fuel used in the fuel-based lamps. But users of kerosene lamps have insufficient illumination for the education of their children. Besides, there are significant health impacts from household air pollution caused by kerosene lamps (Climate & Clean Air Coalition, 2014). Thus, lack of electricity harmfully impacts education through kerosene fuel use because children are more exposed to illness and less available for school activities (absenteeism).

Some limitations could be raised concerning the results of this study. First, a selection effect due to mortality among older cohorts was possible since more educated members of those cohorts were more likely to have survived at the time of the survey than their less educated counterparts. People who are more educated are more likely to survive because they earn relatively higher income and enjoy better life hygiene.

However, this limitation would rather reinforce our conclusions. Indeed, if the educational level of dead people is taken into account, we end up with a much lower completion rate for remote areas without access to electricity.

Conclusion

From the preceding, it is possible to answer our research question: What is the effect of access to electricity on spatial inequalities in the area of education in Cameroon? It is clear that access to electricity has a positive effect on educational attainment and gender gaps. However, this positive effect is much more felt in southern areas of Cameroon where environmental factors are more conducive to electric power supply. Thus, spatial inequalities are striking between northern and southern regions calling for specific policy to reduce the spatial gap.

In northern rural areas where access to electricity is scarce, it is necessary to increase investment in photovoltaic projects. In this regard, the government has launched a project to electrify one thousand localities with solar energy. Besides there is a project for the construction of 360 solar power plants in administrative units that are yet to be electrified (PRC, 2025).

The ongoing projects would be more effective is schools are a specifically equipped with solar energy infrastructures. Indeed, it is possible conduct electrification projects in rural localities without making sure schools in those localities have access to electricity. In the same vein, the National Development Strategy recommends a transition from construction of school buildings to construction and complete equipment of school facilities (MINEPAT, 2020). If rural schools have access to solar electric power, it would be possible to equip such schools with electrical deep well pump able to provide enough water for school toilets and sanitation.

It is necessary to emphasize the importance of school hygiene and sanitation facilities, especially for teenage girls. Some parents could be reluctant to send their teenage girls to schools without functional sanitation facilities. Thus, healthcare and security of children in school is critically linked to the quality of separate toilet facilities for boys and girls. This would limit the risks of sexual harassment and enhance the confidence of parents and female students.

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