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Inequality in opportunity of access to antenatal care in Cameroon: multilevel modelling, spatial analysis and decomposition methods

Anne Darline Youmbi[1], Betrand Fesuh Nono[2*] and Christian Zamo Akono[1,3]

Abstract

In Cameroon, major inequalities exist in women's access to antenatal care (ANC), yet underlying circumstance drivers remain understudied. Using recently available Demographic and Health Survey data, we conducted multilevel model and spatial analyses to identify circumstance factors driving ANC disparities across the country's diverse regions. Drawing on a novel integration of theoretical frameworks, we evaluated how circumstances like geographic, economic and educational barriers combined to shape inequities. Both Shapley and Fields decomposition techniques apportioned contributors to ongoing inequality. Results from our study provide the first direct comparison of these approaches in Cameroon, finding a strong positive correlation between methods. Our findings show that ANC utilization overall was suboptimal, varying substantially between urban and rural areas. Key circumstance factors which disproportionately constrained disadvantaged groups' opportunities for care included household wealth, level of education of the woman and spouse, and place of residence. Policy-relevant insights emerge from disentangling multifaceted opportunity gaps. Targeted interventions should address modifiable barriers facing underserved populations to promote more equal maternal health nationwide. Our multidisciplinary analytical approach offers lessons for analysing complex health disparities in diverse low-resource settings.

Keywords Access to ANC, Circumstances, Inequality of opportunity, Logistic mixed regression, Spatial analysis, Shapley and fields decompositions, Correlation, Cluster bootstrap

JEL Classification C19, C31, C55, D63, I14

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Graphical abstract

Inequality in opportunity of access to antenatal care in Cameroon: multilevel modelling, spatial analysis and decomposition methods

Context

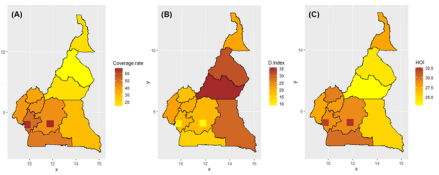
In its report on recommendations for antenatal care for a positive pregnancy experience, WHO (2016) envisions a world in which "every pregnant woman and child receives quality care throughout pregnancy, during childbirth and during the postnatal period".

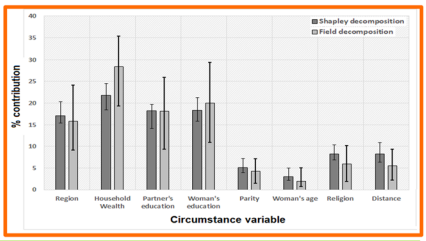
Cameroon is one of the countries in sub-Saharan Africa where the Maternal Mortality Ratio remains worrying despite the commitments made and the actions carried out by stakeholders (CDHS, 2018). The CDHS (2018) report points out that 72% of women declared having encountered at least one difficulty in accessing healthcare.

Methods

Using recently available Demographic and Health Survey data, we conducted multilevel model and spatial analyses to identify circumstance factors driving ANC disparities across the country's diverse regions. Drawing on a novel integration of theoretical frameworks, we evaluated how circumstances like geographic, economic and educational barriers combined to shape inequities. Both Shapley and Fields decomposition techniques apportioned contributors to ongoing inequality.

Results





Conclusion: Our findings show that ANC utilization overall was suboptimal, varying substantially between urban and rural areas. Key circumstance factors which disproportionately constrained disadvantaged groups' opportunities for care included household wealth, level of education of the woman and spouse, and place of residence. Policy-relevant insights emerge from disentangling multifaceted opportunity gaps. Targeted interventions should address modifiable barriers facing underserved populations to promote more equal maternal health nationwide. ...

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References: WHO (2016), CDHS (2018) , Paes de Barros et al. (2009) , Shapley (1953) and Fields (2003) .

1 Introduction

Maternal mortality has dropped significantly around the world in recent years. In effect, falling from 342 to 211 maternal deaths per 100,000 live births between 2000 and 2017, the global maternal mortality rate has thus fallen by 38% over this period (WHO, 2019). However, despite this improvement, around 830 women still die worldwide every day from preventable causes related to pregnancy or childbirth (WHO, 2019). Unfortunately, the majority of deaths occur in low-income countries (86% in South Asia and Sub-Saharan Africa), with more than half (66%) in Sub-Saharan Africa. For women in these countries, the lifetime risk of dying during pregnancy or childbirth is 1 in 37 compared to 1 in 4800 in Europe and North America (WHO, 2019).

Improving maternal health was one of the eight Millennium Development Goals (MDGs) adopted by the international community in 2000. Under the fifth MDG, signatory countries pledged to reduce by three quarters the maternal mortality. Noting the possible acceleration of the decline in maternal mortality, the countries pledged to continue the efforts undertaken within the framework of the Sustainable Development Goals (SDGs). In this regard, the third SDG aims to "enable everyone to live in good health and to promote the well-being of all at all ages". This objective, combined with the tenth on the reduction of inequalities within countries and between countries, aims not only to promote the health of populations, but also health equity.

Pregnancy and childbirth are the main factors of high maternal mortality. In its report on recommendations for antenatal care (ANC) for a positive pregnancy experience, WHO (2016) envisions a world in which "every pregnant woman and child receives quality care throughout pregnancy, during childbirth and during the postnatal period". Antenatal care is therefore an essential link in the continuum of maternal health care and is essential for reducing maternal and perinatal mortality. According to Wagstaff (2004), approximately 74% of maternal deaths can be avoided if access to antenatal care and services is universal. Moreover, according to Chakraborty et al. (2003), antenatal care tends to improve the use of postnatal care and services. It is therefore crucial to improve and make equitable access to antenatal care (particularly in developing countries) in order to substantially reduce maternal and neonatal mortality.

Until 2015, the World Health Organization (WHO) recommended that pregnant women make at least four antenatal visits during their pregnancy, with the first visit taking place between the eighth and sixteenth week of

amenorrhea. In 2016, this recommendation was reviewed to at least eight antenatal visits to a qualified professional, the first taking place before the twelfth week.

Cameroon is one of the countries in sub-Saharan Africa where the Maternal Mortality Ratio (MMR) remains worrying despite the commitments made and the actions carried out by stakeholders. Falling from 689 to 474 maternal deaths per 100,000 births between 1998 and 2004, Cameroon's maternal mortality rate was over 782 in 2011 and then fell to 467 in 2018 (National Institute of Statistics (Cameroon) and ICF, 2020). Moreover, this same survey shows that the coverage of antenatal care by trained health personnel is 87%, out of which 65% of women made at least four antenatal visits, and for 41% of the latter, the first antenatal visit took place in the first trimester of pregnancy.

Overall, although these indicators have relatively improved in Cameroon, significant disparities persist in the country, not only between regions, but also between different social and economic groups. In addition, many barriers prevent women from accessing health care, especially during pregnancy and childbirth. The CDHS-V (2018) report (National Institute of Statistics (Cameroon) and ICF, 2020) points out that 72% of women declared having encountered at least one difficulty in accessing health care. The problems were observed more in rural areas (82%) than in urban areas (65%); more among women in the lowest quintile (88%) than among those in the highest quintile (56%); more among women with no level of education (85%) than among those at university level or beyond (51%).

The disparities observed can be a source of inequality between citizens and therefore arouse a feeling of social injustice. It therefore deserves particular attention from both the scientific community and political decision-makers. The study of the sources of unequal access to antenatal care thus takes on its full importance in the development of policies and programs based on scientific evidence. This will improve access and especially equity in the use of this care and consequently improve maternal health and also infant and child health in the country.

Building on the social welfare function of Sen (1976), and recent developments of Roemer (1998), De Barros et al. (2009) developed the concept of Human Opportunity Index (HOI). They used this index to determine the degree of accessibility and to quantify the disparities in access opportunities to certain basic social services in Latin America. For Roemer (1998), inequalities can come either from *effort factors* or from *circumstantial factors*. Effort factors are factors for which the individual is held responsible: inequalities due to these factors are considered justifiable (but not always desirable) and should be rewarded. Circumstantial factors rather speak of inequalities of opportunity that are treated as sterile, useless, inequitable and should be compensated by society (Peragine, 2004; Roemer, 2001).

In order to better guide the decision-making of governments with a view to reducing these inequalities of opportunity, this article aims to identify the explanatory factors of disparities in access to antenatal care in Cameroon. It is articulated in three sections. The first section is devoted to the literature review. The second section presents the methodology and the data. The results are presented in the third section and discussed in the fourth section.

2 Literature review

2.1 Theoretical revue

Pregnancy is a special state of health. Indeed, it is not a disease, but the fragility it causes exposes the pregnant woman to the development of certain diseases that can be fatal for her and/or for the baby she is carrying. The request for antenatal care is therefore intended to be a somewhat specific form of request for care, involving both preventive and curative care. Thus, the pregnant woman faces two alternatives given the resources at her disposal and the constraints to which she is subjected: to seek antenatal health care from a professional, or not to seek it.

From the 1970s, Grossman, particularly in his seminal article of 1972, contributed the most to the idea that health is an economic good and underlined the need to separate the production of care and the health production. Grossman's approach is based on the maximization of a utility function under budget, time and individual preference constraints. He developed two sub-models: one treats health as an investment good that increases the production and earning capacity of the individual, while the other treats it as a consumer good improving the level of usefulness of life. In the latter model, the level of health of an individual is not exogenous to him, but depends, at least in part, on the resources allocated to his production.

Cropper (1977) thinks that preventive care allows individuals to identify their state of health and therefore to seek curative care. He considers preventive care as necessary investment inputs for increasing the stock of health capital and reducing the probability of disease. Viscusi (1990) on the other hand points out the importance of uncertainty in the face of health risk. He showed that individuals do not always correctly assess the importance of health risks, even in the presence of "perfect" information on these risks. These individuals may thus be led to make choices of non-prevention, due to individual factors relating in particular to the variability of preferences.

As Bodjongo (2021) points out, when the individual controls the risk, the information has an influence on the demand for prevention, but the main concern is to know the type of information to be provided to individuals to encourage them to preventive behaviour towards health risks. According to Kenkel (1990), the best-informed consumers will make health investment decisions based on the perceived marginal benefit–cost comparison. The latter will therefore tend to resort to preventive care because they do not underestimate the marginal product of medical care.

The question of inequality constantly returns to the heart of political debates. According to Majnoni d'Intignano and Ulmann (2001), there are three principles of equality: the utilitarian principle, the liberal principle and the theory of social justice. Utilitarians favour equal distribution among all according to the Marxist principle: "to each according to his needs". On the contrary, liberals attack to respect individual preferences according to the "to each according to his rights" principle. The theory of social justice, for its part, finds its foundations in the universal uncertainty about the future and responds to the Rawlsian principle: "to each according to his merit".

Since 1971, Rawls is indeed one of the philosophers who has contributed the most to the theory of social justice. Following his work in 1971, it has become reasonable to consider the evaluation of social situations no longer in terms of individual utility, but in terms of resources and opportunities. To him, the optimal distribution of primary goods, in particular basic social services such as health services, should be as equal as possible in the sense that inequality can only be tolerated if it acts for the benefit of the most disadvantaged. He also considers that the efforts of individuals must have an impact on their social situation.

Sen (1980) has been interested in equality of ability. Instead of measuring opportunities in terms of good or well-being like Rawls, he proposed *functionings*. For him, having a capacity amount to being able to exercise a set of functionings, representing for him what a person manages to achieve with what he possesses. He considers that if abilities are uniformly distributed, then the remaining inequality may be due to individual preferences.

According to Roemer's (1998), inequality of opportunity refers to differences in life chances or outcomes for individuals that are due to factors outside of their control or choice, such as the socioeconomic status they were born into. In this study, we focus on Roemer's (1998) "Circumstances versus Effort" framework, an approach to equality which is based on the idea that the sources of an individual's desired outcome, such as good health, can be separated into circumstances and efforts. Particularly, we used the "Circumstances" component of the framework which, for him, are the factors beyond an individual's control, and inequalities arising from such factors should be compensated. Contrarily, he considers effort to be affected by individual preferences and choices, and inequalities arising from different efforts are morally and normally acceptable.

2.2 Empirical review

Studies on the explanatory factors of access to health care in general and on the care during pregnancy in particular involve several disciplines, including medicine, demography, sociology, anthropology and economics. Thus, the approaches can be different and we distinguish, among others, the care demand approach, the supply approach and the global approach which is a combination of these two.

According to the approach relating to demand, the explanatory factors of access to care are considered through the characteristics of pregnant women or those of the households in which these women live. These include socio-economic characteristics, in particular the standard of living of the household, the level of education of the woman and/or that of the head of the household, the place of residence, exposure to the media, age and parity of women, subscription to insurance, religion (Andrade et al., 2012; Balde, 2020; Prusty et al., 2015; Sarode, 2010; Tsafack & Kasiwa, 2013; Vecino-Ortiz, 2007; Wado, 2018).

In the supply approach, the availability and characteristics of health services influence the use of care. In other words, the non-existence of the supply, its insufficiency and/or its characteristics influence the demand for care. The therapeutic choices of pregnant women are designed to depend on the effectiveness of the care supplied, the travel distance to the antenatal care service, the waiting time between arrival at a health facility and consulting a medical personnel, the cost of the services and the quality of the interaction between the therapist and the patient (Dahab & Sakellariou, 2020; Sibiya, 2018; Wilunda et al., 2017; Nyathi et al., 2017; WHO, 2006). However, due to the quality of the data available in several countries, there are fewer studies relating to the supply approach than those relating to the demand approach.

The World Bank report on equity and development in 2006 led to the popularization and implementation of the concept of equal opportunity in basic social services. However, although health care is essential for the fulfilment and improvement of the quality of life of populations, work relating to the introduction of the concept of inequality of opportunity in the field of access to health care is relatively rare, particularly with regard to access to antenatal care, even more so in developing countries.

According to Mujaddad and Anwar (2020), the socio-economic factors that contribute significantly to the inequality of opportunity for access to antenatal care in the districts of Punjab in Pakistan are: education of the head of household, level household wealth, place of residence and characteristics of the woman such as her age and access to the media. They further showed that demographic factors such as birth order and birth interval contribute significantly to inequality of opportunity. Other household characteristics such as ethnicity and gender of the household head did not make a significant contribution in many districts. For Tsawe et al. (2020), inequality of opportunity has declined over time in Sierra Leone. Antenatal services were the most egalitarian among other maternal and reproductive health indicators. The standard of living of the household, the level of education of the woman and the place of residence are the factors contributing the most to the inequality of opportunity to use maternal and reproductive health services.

In this paper, we rely on the "Circumstances" component of Roemer's (1998) "Circumstances versus Effort" framework mentioned and described in the last paragraph in Sect. 1.1. The relative contribution of each circumstance variable to the inequality of opportunity is crucial in identifying which underlying inequalities matter most. The Shapley value (Shapley, 1953) methodology, which is computed using the dissimilarity index, is generally used to quantify this relative contribution. Later on, Fields (2003) proposed a procedure which is rather based on decomposing the total variation in the log-odds of access to a given service. As at now, we are not aware of any study which tries to compare (theoretically or empirically) these two different decomposition methodologies, hence, a secondary objective of this paper.

3 Methodology

3.1 Relationship between access to antenatal care and other covariates

Based on the WHO standard for antenatal health, we created a binary response variable Y that represents access to antenatal care. It takes into account the number of antenatal consultations with a health professional and whether the first consultation took place during the first trimester of pregnancy. We remark here that the WHO recommendations on prenatal care were certainly revised in 2016 (WHO, 2016), but the application of these recommendations was not automatic throughout the national territory. Indeed, at the time of the survey in 2018, the standard in force in most of the country provided for each woman to use at least four ANC. The CDHS-V (2018) report was also written in this logic. As a result, very few women made eight visits during pregnancy. Indeed, 264 out of the 4700 women in our database made at least eight visits, which is a proportion of 5.6%. Hence, we resorted to the variable taking the value 1 if the pregnant woman has had at least four consultations and the first during the first trimester of pregnancy, and 0 otherwise (CDHS-V (2018) report). Prior to identifying significant correlates of access to antenatal care in Cameroon, Chi-squared tests of independence were conducted between access to antenatal care and each of the circumstance variables, ignoring, at first site, the clustered nature of the data. To better appreciate such dependence, univariate logistic mixed regression models with random intercepts for enumeration areas were also performed, with the results represented in the form of unadjusted odds ratios.

3.2 Measurement of the Human Opportunity Index for access to antenatal care

The Human Opportunity Index (HOI) combines into a unique indicator two main components: the average coverage rate of the access to antenatal care, and the Dissimilarity Index (D-index) that quantifies the inequality of opportunity in access to antenatal care for each circumstance variable (De Barros et al., 2009). The D-index is estimated in three steps. In the first step, given a set of k circumstance variables $X_{ij1}, X_{ij2}, \ldots, X_{ijk}$, the probability P_{ij} of a pregnant woman i in a given enumeration area j to have access to antenatal care is estimated according to a logistic mixed regression model of the form:

$$log\left(\frac{Pr(Y_{ij}=1|X_{ij1},X_{ij2},\ldots,X_{ijk},U_j)}{1-Pr(Y_{ij}=1|X_{ij1},X_{ij2},\ldots,X_{ijk},U_j)}\right)=\beta_0+\sum_{r=1}^{k}\beta_r X_{ijr}+U_j, \quad (1)$$

where U_j is assumed to be an unobserved zero mean Gaussian random effect for the enumeration area j, with common variance σ_U^2, that is $U_j \sim N(0,\sigma_U^2)$, $j=1,\ldots,m$, and the U_j's are independent from each other. The vector of $k+1$ coefficients $\boldsymbol{\beta}=(\beta_0,\ldots,\beta_k)$ is estimated via maximum likelihood using the **`glmer`** function in the **`R`** package **`lme4`**. The model adjusting for sample weights by introducing the weights variable provided by DHS into our models through the **`weights`** argument in the **`glmer`** function to help produce estimates that are representative of the target population. The expression for the likelihood is an integral over the random effects space which is approximated here using adaptive Gauss-Hermite quadrature with 25 quadrature points. In the second

step, the estimated coefficients obtained from the model are used to predict the probability of access to antenatal care for each woman i in a given enumeration area j in the sample, that is:

$$\widehat{P}_{ij} = \frac{exp(\widehat{\beta}_0 + \sum_{r=1}^{k} \widehat{\beta}_r X_{ijr} + \widehat{U}_j)}{1 + exp(\widehat{\beta}_0 + \sum_{r=1}^{k} \widehat{\beta}_r X_{ijr} + \widehat{U}_j)},$$

where $\widehat{\boldsymbol{\beta}} = (\widehat{\beta}_0, \ldots, \widehat{\beta}_k)$ is the maximum likelihood estimate of $\boldsymbol{\beta}$ and $\widehat{U}_j$ is the predicted random effect for enumeration area j, for $j = 1, \ldots, m$, with m the total number of enumeration areas. Finally, using these predicted probabilities, the World Bank, 2006) defines the D-index which, in this context, is given by the formula:

$$\widehat{D} = \frac{1}{2\overline{P}} \sum_{j=1}^{m} \sum_{i=1}^{n_j} w_{ij} \left| \widehat{P}_{ij} - \overline{P} \right|,$$

where $\overline{P}$, the average frequency (called hereafter *average coverage rate*) of access to antenatal care in the sample, is given by:

$$\overline{P} = \sum\nolimits_{j=1}^{m} \sum_{i=1}^{n_j} w_{ij} \widehat{P}_{ij},$$

with n_j the sample size for enumeration area j and $w_{ij} = 1/N$ where $N = \sum_{j=1}^{m} n_j$ is the total sample size. Following De Barros et al. (2009), the D-index measures the dissimilarity in access to antenatal care for groups defined by circumstance characteristics compared with the overall coverage rate of the population as a whole. It can be interpreted as the proportion of opportunities that needs to be redistributed across the groups of circumstances in order to ensure equal opportunity of access to antenatal health care for all pregnant women. This index ranges between 0 and 1 (or 0 and 100 as a percentage). A D-index of zero indicates perfect equality, implying that access to antenatal care is the same among the general population no matter one's particular circumstance. In contrast, a D-index of one (or 100%) indicates extreme inequality, implying that a group is completely excluded from the access.

Posterior to estimating the average access to antenatal health care $\overline{P}$ and the dissimilarity D-index, the Human Opportunity Index (HOI) is then computed according to the formula:

$$\text{HOI} = \overline{P}(1 - D),$$

where D is the D-index. From the formula, HOI will generally lie between 0 and $\overline{P}$, that is $0 \leq HOI \leq \overline{P}$. When the coverage rate $\overline{P}$ is close to HOI (D close to 0), the distribution of opportunities is fair. When the difference between the two is significant, the gap reflects inequality (World Bank, 2016). Thus, intervention can aim to increase coverage ($\overline{P}$) or to reduce dissimilarity (D). The HOI is therefore a synthetic measure of the inequality of opportunity in access to basic services. This index is inspired by Sen (1976) and argues that a development process in which society tries to provide basic opportunities equally, requires ensuring that the majority of individuals have access to these development opportunities. It requires a better distribution across disadvantaged groups. The HOI makes it possible to address the following concerns:

(i) How many opportunities are available (basic service coverage rate)?
(ii) How equitably are these opportunities distributed (i.e. whether the distribution of basic service coverage is related to exogenous circumstances)?

3.3 Decomposition of the inequality in opportunity

To capture the contribution of each circumstance in this inequality, different methods have been proposed, depending principally on the nature of the dependent variable. In this article, we present the decomposition methods in Shapley (1953) and Fields (2003) for binary outcomes in logistic mixed regression models and compare the results obtained empirically through a correlation test. The former uses the D-index as computed in Sect. 2.2, while the latter is based on decomposing the total variation in the log-odds of access to antenatal care. We implement these decompositions methods in the **R** version 4.1.2 software.

3.3.1 Shapley decomposition of inequality in opportunity: an adaptation to clustered data

The idea behind applying the Shapley decomposition is to identify how much the measure of inequality of opportunity will change when adding a circumstance to different pre-existing set of circumstances. The change in inequality as a result of adding (or dropping) a circumstance appears to be a reasonable indicator of the contribution of the circumstance to inequality of opportunity (Hoyos and Narayan, 2012). Following Shapley (1953), the marginal impact of a given circumstance c_r is estimated according to the equation:

$$D_{c_r} = \sum_{S \subseteq N/(c_r)} \frac{|S|!(|N| - |S| - 1)!}{|N|!} [D(S \cup \{c_r\}) - D(S)],$$

where N is the set of all the circumstances, S is a subset of N, $D(S)$ is the D-index estimated, as in Sect. 2.2, from all circumstances in S, $D(S \cup \{c_r\})$ is the D-index estimated from all circumstances in S and the circumstance c_r, with $r = 1, \ldots, k$, while $|.|$ represents cardinality and $|S|!$ represents the factorial of $|S|$. Note that $\sum_r D_{c_r} = D(N)$, hence, the contribution of a circumstance c_r to the D-index is estimated by:

$$\theta_{c_r} = \frac{D_{c_r}}{D(N)}, \text{with} \sum_r \theta_{c_r} = 100\%.$$

3.3.2 Fields decomposition of inequality in opportunity: an adaptation to clustered data

Following Fields (2003), the calculation of the relative contributions of the circumstances variables to the inequality is done according to the steps that follow. First, a ratio $Z_{ij} = \frac{P_{ij}}{1-P_{ij}}$ representing the relative odds of $Y_{ij} = 1$ (access to antenatal care) against $Y_{ij} = 0$ (no access) is defined. Thus, the higher Z_{ij} is, the greater the odds that the pregnant woman will have access to antenatal care. An estimate $\widehat{Z}_{ij}$ of Z_{ij} is given by the equation:

$$\log\left(\widehat{Z}_{ij}\right) = \widehat{\beta}_0 + \sum_{r=1}^{k} \widehat{\beta}_r X_{ijr} + \widehat{U}_j, \tag{2}$$

where $\widehat{\beta}_r$ is the estimate of β_r for model (1). Hence, $\widehat{Z}_{ij}$ depends on $\widehat{\beta}_0$, the circumstances $X_{ij1}, X_{ij2}, \ldots, X_{ijk}$ and the predicted random intercept $\widehat{U}_j$. Since $Z_{ij} = \frac{P_{ij}}{1-P_{ij}}$ is a monotonic increasing function in the probabilities P_{ij}, the inequality of the estimated variable $\widehat{Z}_{ij}$ will be equivalent to the inequality of the predicted probability $\widehat{P}_{ij}$. Thus, the inequality of opportunity explained by the circumstance variables can be measured by calculating the inequality of the variable $\widehat{Z}_{ij}$. Secondly, taking the variance of both sides of (2), we get, following Fields (2003) and Son (2013):

$$\text{Var}\left(\log(\widehat{Z}_{ij})\right) = \sum_{r=1}^{k} \widehat{\beta}_r \text{Cov}(X_{ijr}, \log(\widehat{Z}_{ij})) + Cov(\widehat{U}_j, \log(\widehat{Z}_{ij})),$$

which decomposes the inequality in opportunity (measured by variance of logarithms) in terms of the contributions made by each of the individual circumstance variables and the random intercept term which is enumeration area. The part of the inequality explained by the k circumstance variables is then given by

$$\text{Var}\left(\log(\widehat{Z}_{ij})\right) - \text{Cov}(\widehat{U}_j, \log(\widehat{Z}_{ij})) = \sum_{r=1}^{k} \widehat{\beta}_r \text{Cov}(X_{ijr}, \log(\widehat{Z}_{ij})).$$

Hence, the rth circumstance's contribution to this part of inequality in opportunity is $\widehat{\beta}_r \text{Cov}(X_{ijr}, \log(Z_{ij}))$. Thus, the fraction of the contribution of the rth circumstance to this part is then given by the equation:

$$C_r = \frac{\hat{\beta}_r \text{Cov}\left(X_{ijr}, \log\left(Z_{ij}\right)\right)}{\text{Var}\left(\log\left(\hat{Z}_{ij}\right)\right) - \text{Cov}(\hat{U}_j, \log\left(\hat{Z}_{ij}\right))} = \frac{\hat{\beta}_r \text{Cov}\left(X_{ijr}, \log\left(Z_{ij}\right)\right)}{\sum_{r=1}^{k} \hat{\beta}_r \text{Cov}\left(X_{ijr}, \log\left(\hat{Z}_{ij}\right)\right) - \text{Cov}\left(\hat{U}_j, \log\left(\hat{Z}_{ij}\right)\right)}, \tag{9}$$

where C_r is the percentage of the contribution of circumstance r to the inequality of opportunity and $\sum_r C_r = 1$. We note here that the significance of the random intercept for the multivariate mixed logistic regression model was checked via the likelihood-ratio test, by comparing the mixed model with an ordinary logistic regression model through the **anova** function in the **R** package **stats**. We remark that the mixed model analysis applied to the Fields decomposition approach can also give, as bi-product, an estimate of the percentage contribution of enumeration area C_e to the total inequality as $C_e = \text{Cov}(\widehat{U}_j, \log(\widehat{Z}_{ij}))/\text{Var}\left(\log(\widehat{Z}_{ij})\right)$. This gives an advantage of the Fields approach over the Shapley approach where an estimate of the contribution of the enumeration area random effects may not be plausible.

3.3.3 A cluster bootstrap resampling plan for estimating confidence intervals for the shapley and fields decomposition of inequality in opportunity

Nonparametric bootstrap confidence intervals estimates for the decompositions of inequality in opportunity can be computed using the *Cluster Bootstrap Resampling* plan described in Field and Welsh (2007). The resampling bootstrap is computed here as follows:

1. Assume the data set $(Y_{ij}, X_{ij1}, X_{ij2}, \ldots, X_{ijk})_{i=1,\ldots,n_j, j=1,\ldots,m}$ has m clusters (enumeration areas) numbered from 1 to m. Generate randomly *with replacement* a sample of size m from these clusters numbers, that is $1^*, \ldots, m^*$.
2. Create a bootstrap sample data set $(Y_{ij}, X_{ij1}, X_{ij2}, \ldots, X_{ijk})_{i=1,\ldots,n_j, j=1^*,\ldots,m^*}$ from the original data. Compute the Shapley or Fields decomposition D_* using this data set.
3. Repeat Steps 1 and 2 a large number of times, say, R times (we considered $R = 1000$) to get B bootstrap

estimates $D_1, \ldots, D_R$ of the Shapley or Fields decomposition.

4. A 95% confidence interval estimate for the Shapley or Fields decomposition estimate $\widehat{D}$ by the 2.5 and 97.5 percentiles of the sample of B bootstrap samples will be:

$$\widehat{\mathrm{CI}}_{95\%,R}\left(\widehat{D}\right) = [D_{r,0.025}, D_{r,0.975}],$$

where $D_{r,\alpha}$ is the empirical quantile of order α in the sample$D_1, \ldots, D_R$, gotten from the ordering $D_{(1)} < D_{(2)} < \cdots < D_{(R)}$ of that sample. A more accurate bias corrected and accelerated (Bca) method (Efron and Tibshirani, 1993; Davison and Hinkley, 1997) produces an interval based on different sample quantiles that depend on the data. The Bca method is the default method in most software packages as it generally produces narrower intervals. One can also get asymptotic variances following Bigotta et al. (2015).

3.4 Source of data

This study uses data from the fifth Cameroon Demographic and Health Survey (CDHS-V) carried out in 2018 (the latest so far) by the National Institute of Statistics (INS) in close collaboration with the Cameroon Ministry of Public Health (National Institute of Statistics (Cameroon) and ICF, 2020).

The survey used a two-stage stratified sampling design to produce statistically representative estimates at the national, regional and urban/rural levels (National Institute of Statistics (Cameroon) and ICF, 2020). In the first stage, enumeration areas (EAs) were selected from a master sampling frame constructed from the 2005 Census. A total of 670 EAs were selected, with probabilities proportional to size. In the second stage, a complete household listing operation was carried out in all of the 670 selected EAs. A fixed number of 28 households were then systematically selected from each cluster or EA. All women aged 15–49 who were either permanent residents of the selected households or visitors present in the household on the night before the survey were eligible to be interviewed. The women's questionnaire gathered information on reproductive health, maternal and child health, nutrition, etc. Weighting was used in the analysis to account for the sampling design and to ensure the results were representative of the population of Cameroon. The weighting variable is provided by DHS.

We used the individuals' recode file format of the DHS in this research. A total of 4700 women identified in 469 of the 470 randomly selected enumeration areas were eligible for this study. These are women aged between 15 and 49, and their spouses aged between 15 and 64. They are women in a couple or marriage relationship and have given birth at least once in the last 5 years preceding the survey. Information on ANC attendance is provided only for the most recent live birth within the 5-year recall period (CDHS-V (2018) report). The country has 10 regions plus the cities of Yaoundé and Douala previously excluded from the Center and Littoral regions, respectively (CDHS-V (2018) report). Figure 1 shows the study area.

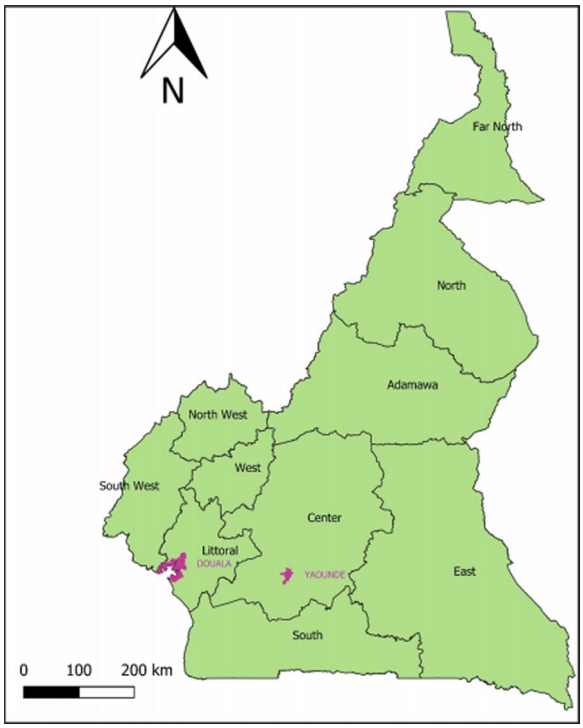

Fig. 1 Study zone: Map of Cameroon showing the ten regions of the country with the main cities (Yaoundé and Douala)

3.5 Description of variables

The dependent variable retained in the context of this study is "Access to antenatal care" noted later Access to ANC, already defined above as Y_{ij}. Data from the CDHS-V (2018) show that only 35.8% of pregnant women have access to antenatal care. We note for this variable 4700 observations and 24 (0.51%) missing values. No imputation was performed on this variable. Inspired by the definitions of Roemer (1998), Checchi and Perragine (2005), and the existing literature on inequality of opportunity, the circumstance variables retained here are presented in the following table:

According to the CDHS-V report, the insecurity situation in the South-West region made it impossible to cover all the areas of the region. Hence, the data for this

Table 1 Circumstance variables considered for this study

Variables	Description
Region	There are 12: the 10 regions (or areas of study) plus the cities of Yaoundé and Douala previously excluded from the Center and Littoral regions, respectively
Place of residence	These are urban and rural areas. Each enumeration area has a rural part and an urban part
Woman's age	It ranges between 15 and 49 years old; it is an indicator of the level of risk of pregnancy. These ages are grouped into seven classes: 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49
Religion	A distinction is made between Catholics, Protestants, other Christians, Muslims, animists and those who have no defined belief. The first three modalities will be grouped together to form the Christian modality
Household wealth	We distinguish the modalities Very poor, Poor, average, rich and very rich
Woman's education	It takes the modalities: No level, Primary, Secondary, Higher
Parity	May help to suspect a possible link between family planning problems and access to health care during pregnancy. Four classes are made up: the primiparous class (1 child), the pauciparous class (2–3), the multiparous class (4–5) and the large multiparous class (more than 6 children)
Partner's education	It takes the modalities: No level, Primary, Secondary, Higher
Household head gender	It permits to handle who takes the decisions in the household. It takes two values: male and female
Partner's age	It ranges between 15 and 64 years old; it is an indicator of the level of risk of pregnancy. These ages are grouped into five classes: 15–24, 25–34, 35–44, 45–54, 55–64
Distance to health facility	It was asked to pregnant women if distance to health facility constitutes a big problem. It takes two modalities: big problem, not a big problem
Enumeration area	The variable characterizing clusters in the study sample

region are not representative of the entire region but essentially reflect the urban location. As in Pons-Duran et al. (2019), "female education" will be retained as a circumstance variable in the context of this work (Table 1).

4 Results

4.1 Association between access to ANC and some circumstances

Table 2 presents the results of descriptive analyses of access to ANC according to the socioeconomic characteristics of the woman, those of her partner and those of the household in which she lives. It reports the proportions and number of women who had access to ANC according to the different circumstance variables. These associations are supported by Chi-squared tests of independence, with significance level set at 5%. Access to ANC was found to be significantly dependent on all those circumstances.

Access to ANC was highest in the city of Yaoundé (66.2%), followed by the city of Douala (65.8%), then the regions of Littoral (46.1%) and West (45.7%), while the least access was observed in the North (14.9%), Adamawa (22.6%) and Far North (22.5%) regions. The proportion of women having access to ANC was significantly higher among women living in urban areas (48.2%) than among those living in rural areas (25.9%). Access to ANC increased significantly with the standard of living of the household: 15% among the poorest, 26.4% among the poor, 31.6% among the middle, 48.8% among the rich and 66.2% among the very rich. Also, the proportion of women having access to ANC increased with the level of education of the woman: 14.3% among women with no level of education, 31.3% among those with a primary level, 49.4% among those with a secondary level and 72.8% among those with a higher education level. Similarly, trends were observed with the level of education of the partner. Access to ANC was also found to be greater among Christians (42%), than among animists (22.5%) and muslims (22.7%). Access to ANC was greater when the head of household was a woman (41.6%), compared to when the head was a man (35.1%). Within the age range from 15 to 39 years, the proportion of women with access to ANC increased with the woman's age: 26% among the 15–19 age group, 35.0% among the 20–24 group, 35.1% among the 25–29 age group, 38.2% among the 30–34 age group and 38.4% among the 35–39 age group. A decline in this proportion was observed above 40 years, with 35.2% among the 40–44 age group and 23.3% among the 45–49 age group. Similarly trends were observed with the age of the partner with a peak at the group 45–54 years. Among the women who declared distance to be a problem for access to health facility, only 27.2% of women actually had access to ANC during pregnancy, as oppose to 42.9% of women for whom distance was not a big problem.

Table 3 presents unadjusted and adjusted correlates of access to ANC based on univariate and multivariate logistic mixed regression analyses, respectively. Based on the Akaike information criterion for variable selection through the `stepcAIC` function in the `R` package

Table 2 General characteristics of the study population with respect to access to ANC

	Access	No	Yes	Individuals	*P*-value
Region	Adamawa	305 (77.4)	89 (22.6)	396	< 0.0001
	Centre (without Yaounde)	294 (59.5)	200 (40.5)	494	
	Douala	97 (34.2)	187 (65.8)	287	
	East	300 (68.6)	137 (31.4)	438	
	Far-North	535 (77.5)	155 (22.5)	690	
	Littoral (without Douala)	146 (53.9)	125 (46.1)	272	
	North	519 (85.1)	91 (14.9)	610	
	North-West	151 (63.2)	88 (36.8)	241	
	South	240 (60.3)	158 (39.7)	400	
	South-West	52 (59.8)	35 (40.2)	88	
	West	247 (54.3)	208 (45.7)	455	
	Yaounde	107 (33.8)	210 (66.2)	329	
Place of residence	Rural	1901 (74.1)	666 (25.9)	2572	< 0.0001
	Urban	1092 (51.8)	1017 (48.2)	2128	
Household wealth	Poorest	773 (85.0)	136 (15.0)	911	< 0.0001
	Poorer	777 (73.6)	278 (26.4)	1056	
	Middle	731 (68.4)	338 (31.6)	1071	
	Richer	460 (51.2)	438 (48.8)	909	
	Richest	252 (33.8)	493 (66.2)	753	
Partner's education	No education	776 (86.6)	120 (13.4)	899	< 0.0001
	Primary	1057 (70.7)	437 (29.3)	1497	
	Secondary	942 (53.8)	809 (46.2)	1763	
	Higher	128 (32.8)	262 (67.2)	392	
Woman's education	No education	986 (85.7)	165 (14.3)	1152	< 0.0001
	Primary	1062 (68.7)	483 (31.3)	1552	
	Secondary	878 (50.6)	856 (49.4)	1746	
	Higher	67 (27.2)	179 (72.8)	250	
Religion	Animist	62 (77.5)	18 (22.5)	80	< 0.0001
	Christian	1844 (58.0)	1334 (42.0)	3201	
	Muslim	1027 (77.3)	302 (22.7)	1330	
	Other	60 (67.4)	29 (32.6)	89	
Household head gender	Female	371 (58.4)	264 (41.6)	635	0.0018
	Male	2622 (64.9)	1419 (35.1)	4065	
Woman's age	15–19	292 (73.7)	104 (26.3)	398	0.0007
	20–24	628 (65.1)	337 (34.9)	971	
	25–29	807 (62.9)	476 (37.1)	1292	
	30–34	640 (61.5)	400 (38.5)	1042	
	35–39	417 (61.7)	259 (38.5)	679	
	40–44	170 (64.9)	92 (35.1)	264	
	45–49	39 (72.2)	15 (27.8)	54	
Parity	1	460 (59.7)	310 (40.3)	779	< 0.0001
	[2–3]	1021 (59.6)	693 (40.4)	1722	
	[4–5]	774 (65.2)	413 (34.8)	1192	
	6+	738 (73.4)	267 (26.6)	1007	
Partner's age	15–24	152 (70.7)	63 (24.3)	215	< 0.0001
	25–34	1040 (61.9)	639 (38.1)	1679	
	35–44	1131 (62.8)	671 (37.2)	1802	
	45–54	515 (32.7)	1061 (67.3)	1576	
	55–64	155 (76.0)	49 (24.0)	204	

Table 2 (continued)

	Access	No	Yes	Individuals	*P*-value
Distance to health facility	Not a big problem	1502 (57.1)	1127 (42.9)	2648	< 0.0001
	Big problem	1491 (72.8)	556 (27.2)	2052	

cAIC4, while controlling for multicollinearity using **vif** function in the package **car** and global significance of each correlate through the **anova** function in the **R** package **stats**, the final model excluded three circumstances in the underlying multivariate logistic mixed regression model: "Place of residence", "Household head gender" and "Partner's age".

In univariate logistic mixed regression analyses, unadjusted correlates of access to ANC included "Region", "Place of residence", "Household wealth", "Partner's education", "House", "Woman's education", "Parity", "Woman's age", "Religion" and "Distance". In multivariate logistic mixed regression analysis, compared with living in the Adamawa region, women living in Yaoundé were more likely to having access to ANC (Odds Ratio [OR] = 1.53, 95% Confidence Intervals [CI] 1.00–2.33, p-value = 0.0493), as oppose to lesser odds for those living in South–West (OR = 0.44, CI 0.25–0.79, p-value = 0.0057) and the North (OR = 0.55, CI 0.37–0.81, p-value = 0.0024).

The odds of access to ANC increased significantly with increased household wealth. With women from very poor households as reference, women from poor household had the least odds of access to ANC (OR = 1.34, CI 1.03–1.76, p-value = 0.0305), followed by those living in middle, rich and very rich households with respective odds of 1.42 (CI 1.08–1.88, p-value = 0.0136), 2.16 (CI 1.6–2.92, p-value = < 0.0001), and 3.02 (CI 2.15–4.25, p-value = < 0.0001).

Similar trends were also observed with the level of education of the woman and that of her partner. Compared to women with no level of education, increasing odds of access to ANC were observed for women with primary (OR = 1.45, CI 1.12–1.88, p-value = 0.0047), secondary (OR = 1.83, CI 1.38–2.44, p-value < 0.0001) and higher level of education (OR = 2.41, CI 1.54–3.78, p-value = 0.0001). Also, compared to women whose partners had no level of education, increasing odds of access to ANC were observed for women whose partners had primary (OR = 1.34, CI 1.02–1.76, p-value = 0.0357), secondary (OR = 1.80, CI 1.35–2.39, p-value = 0.0001) and higher level of education (OR = 2.09, CI 1.42–3.08, p-value = 0.0002).

Compared to women in the 15–19 years age group, women in the 20–24, 25–29, 30–34, 35–39 and 40–45 age groups observed increasing odds of access to ANC, respectively, 1.29 (CI 0.95–1.74, p-value = 0.0987), 1.48 (CI 1.08–2.03; p-value = 0.0161), 1.63 (CI 1.16–2.31; p-value = 0.0054), 1.86 (CI 1.27–2.71; p-value = 0.0014), 1.82 (CI 1.16–2.85; p-value = 0.0085) and 2.01(CI 0.96–4.23; p-value = 0.0657). Additionally, access to ANC decreased with increased parity. Finally, compared to women for whom distance was not a big problem, those who indicated that distance was a big problem observed a lesser odds of access to ANC with value 0.75 (CI 0.64–0.87; p-value = 0.0001).

4.2 Spatial analysis of measures of inequality of opportunity in access to antenatal care

Table 4 shows that overall, the opportunity for women to have access to antenatal care was low and inequitable in Cameroon.

The average coverage of access to antenatal care in Cameroon was estimated at 35.93% ($\overline{P} = 0.3593$), while 23.97% of available antenatal care should be redistributed in order to establish, for all women, equal opportunities to have access to antenatal care during pregnancy ($D = 0.2397$), hence a Human Opportunity Index of the order of 27.32% (HOI = 0.2732). In addition, Moran Index revealed a significant spatial autocorrelation of the rate of coverage of access to ANC in Cameroon (p-value < 0.001). On the other hand, no significant spatial autocorrelations were observed for the Human Opportunity Index and the Dissimilarity Index (p-value > 0.05).

The coverage rate ($\overline{\boldsymbol{P}}$), $\boldsymbol{D-index}$ and HOI were also estimated separately for each of the regions in the study zone. These measures are displayed spatially in Fig. 2. The square boxes in those figures represent the towns of Yaoundé and Douala in the Centre and Littoral regions, respectively. We used a unique colour scheme so as to show a higher value as the colour gets darker.

Figure 2a presents the variations of the coverage rate of access to ANC across the regions of Cameroon. Figure 2a (as in Table 2) shows that the northern part of the country is globally a vulnerable group in terms of access to ANC (vulnerable groups are those with coverage rate less than the average coverage rate of $\overline{P} = 35.93\%$). Indeed, Table 2 reports 14.36%, 22.39% and 22.69% of access to ANC, respectively, for the *North*, the *Adamawa* and

Table 3 Unadjusted and adjusted correlates of access to ANC based on univariate and multivariate logistic mixed regression (with random intercepts for enumeration areas) analyses, respectively

Circumstance variables	Category	Unadjusted odds-ratio			Adjusted odds-ratio		
		OR	95% CI	*p*-value	OR	95% CI	*p*-value
Region (Ref = Adamawa)	Centre (without Yaounde)	2.4	1.62–3.56	< 0.0001	1.11	0.76–1.62	0.5938
	Douala	6.71	4.39–10.24	< 0.0001	1.36	0.88–2.09	0.1674
	East	1.54	1.02–2.30	0.0381	0.89	0.61–1.32	0.5693
	Far-North	0.97	0.66–1.41	0.8559	1.1	0.77–1.56	0.6167
	Littoral (without Douala)	3.08	2.00–4.75	< 0.0001	1.18	0.77–1.8	0.4446
	North	0.58	0.38–0.88	0.0097	0.55	0.37–0.81	0.0024
	North–West	1.96	1.25–3.06	0.0032	0.82	0.53–1.26	0.3596
	South	2.27	1.51–3.42	0.0001	0.87	0.58–1.28	0.4721
	South–West	2.16	1.19–3.94	0.0117	0.44	0.25–0.79	0.0057
	West	2.85	1.93–4.21	< 0.0001	1.2	0.83–1.75	0.3312
	Yaounde	6.77	4.46–10.28	< 0.0001	1.53	1.00–2.33	0.0493
Place of residence (Ref = Rural)	Urban	3.04	2.49–3.73	< 0.0001			
Household wealth (Ref = Very poor)	Poorer	1.94	1.51–2.51	< 0.0001	1.34	1.03–1.76	0.0305
	Middle	2.61	2.02–3.39	< 0.0001	1.42	1.08–1.88	0.0136
	Richer	5.33	4.1–6.95	< 0.0001	2.16	1.6–2.92	< 0.0001
	Very rich	11.24	8.54–14.86	< 0.0001	3.02	2.15–4.25	< 0.0001
Partner's education (Ref = No level)	Primary	2.4	1.88–3.08	< 0.0001	1.34	1.02–1.76	0.0357
	Secondary	4.78	3.75–6.11	< 0.0001	1.80	1.35–2.39	0.0001
	Higher	10.59	7.68–14.63	< 0.0001	2.09	1.42–3.08	0.0002
Woman's education (Ref = No level)	Primary	2.66	2.13–3.33	< 0.0001	1.45	1.12–1.88	0.0047
	Secondary	5.48	4.39–6.87	< 0.0001	1.83	1.38–2.44	< 0.0001
	Higher	15.12	10.56–21.82	< 0.0001	2.41	1.54–3.78	0.0001
Religion (Ref = Animist)	Christian	1.93	1.06–3.65	0.0351	1.02	0.56–1.87	0.9426
	Muslim	0.8	0.44–1.54	0.4976	0.75	0.40–1.38	0.3558
	Other	1.42	0.64–3.19	0.3937	0.95	0.42–2.12	0.8907
Household head gender (Ref = Female)	Male	0.87	0.71–1.06	0.1684			
Woman's age (Ref = 15–20 years)	20–24	1.29	0.96–1.73	0.0879	1.29	0.95–1.74	0.0987
	25–29	1.39	1.04–1.85	0.0248	1.48	1.08–2.03	0.0161
	30–34	1.42	1.06–1.91	0.0183	1.63	1.16–2.31	0.0054
	35–39	1.42	1.04–1.93	0.0279	1.86	1.27–2.71	0.0014
	40–44	1.23	0.84–1.8	0.2882	1.82	1.16–2.85	0.0085
	45–49	1.17	0.56–2.35	0.6657	2.01	0.96–4.23	0.0657
Parity (Ref = 1)	[2–3]	0.93	0.76–1.13	0.4656	0.81	0.65–1.01	0.0623
	[4–5]	0.76	0.61–0.94	0.0120	0.68	0.52–0.89	0.0043
	6 +	0.58	0.46–0.73	< 0.0001	0.59	0.43–0.80	0.0008
Partner's age (Ref = 15–24 years)	25–34	1.35	0.96–1.91	0.0903			
	35–44	1.31	0.93–1.85	0.1276			
	45–54	1.24	0.86–1.80	0.2585			
	55–64	0.9	0.55–1.46	0.6655			
Distance to health facility (Ref = Not a big problem)	A big problem	0.58	0.5–0.67	< 0.0001	0.75	0.64–0.87	0.0001

NB: The enumeration areas random intercept variance for the multivariate mixed logistic regression model is 0.084, which is significantly different from 0 according to the likelihood-ratio test (*p*-value = 0.0129) through the anova function in the `R` package `stats`

the *Extreme-North* regions. Higher coverage rates were observed in *Littoral* (without *Douala*) with 47.33%, S*outh* (45.19%) and in *Center* (without *Yaoundé*) with 40.93%. As expected, the cities of *Yaoundé* and *Douala* had the highest coverage rates, 67.0% and 66.18%, respectively.

Table 4 Inequality of opportunity in access to antenatal care in Cameroon and Moran's index values by indicator parameter and spatial independence test

Indicator parameter	Estimate	Moran's I		Standard deviation	*P*-value
		Observed	Expected		
$\overline{P}$	0.3593	− 0.326	− 0.111	0.059	0.0003
$\overline{P}$*		− 0.338	− 0.111	0.060	0.0002
D − index	0.2397	− 0.215	− 0.111	0.059	0.0791
D − index*		− 0.147	− 0.111	0.056	0.5270
HOI	0.2732	− 0.215	− 0.111	0.059	0.0791
HOI*		− 0.180	− 0.111	0.057	0.2300

Unstarred values indicate that the Centre and Littoral regions do not include the main towns (Yaoundé and Douala, respectively), while starred values indicate that the results for the Centre and Littoral regions are actually those for the main towns

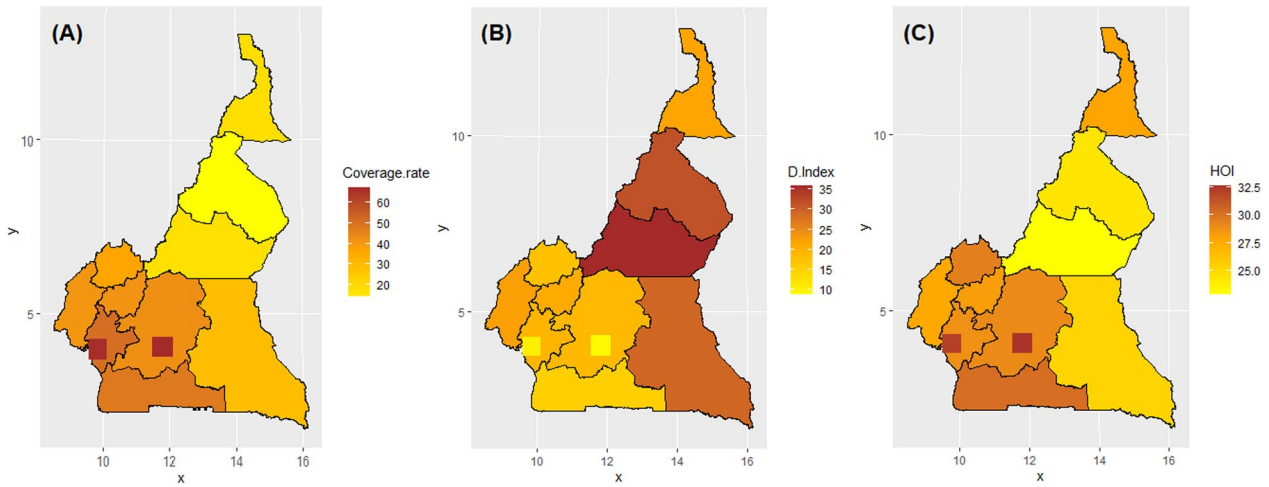

Fig. 2 Variations in coverage rate, inequality in access to ANC and HOI across regions in Cameroon based on the CDHS-V (2018) data. *Legend* The main towns of Yaoundé and Douala are represented by square boxes in the Centre and Littoral regions, respectively

Figure 2b presents spatial variations in the inequality of access to ANC across regions in the country. Inequality of opportunity in access to ANC was least in the main towns of Yaoundé (8.62%) and Douala (10.0%). The highest inequalities were observed in *Adamawa* (35.91%), then *North* (31.67%) and *East* (29.12%) regions. The D-index was lowest in the South (15.22%), then North-West (17.29%) and the Center (without Yaoundé) with 18.68%.

According to Fig. 2c, HOI was lowest in the *Adamawa* (22.86%), followed by the *North* (24.37%) and the *East* (25.28%) regions. Conversely, HOI was highest in the South, North West and Centre (without Yaoundé), with values of 30.23%, 29.50% and 29.0%, respectively. Apart from these, the cities of Yaoundé and Douala had the highest HOI scores (32.58% and 32.10%, respectively).

4.3 Decomposition of the inequality of opportunity in access to antenatal care in Cameroon: a comparison of shapley and fields decomposition methods

The decomposition of the inequality of opportunity makes it possible to estimate the level of contribution of each circumstance factor to the inequality.

Using the Akaike information criterion for variable selection through the **`stepcAIC`** function in the **`R`** package **`cAIC4`**, while controlling for multicollinearity using **`vif`** function in the **`R`** package **`car`** and global significance of each correlate through the **`anova`** function in the **`R`** package **`stats`**, the final model excluded three circumstances in the underlying logistic mixed regression model: "Place of residence", "Household head gender" and "Partner's age".

Table 5 Contributions of circumstances to inequality of opportunity in access to antenatal care in Cameroon

Circumstance	Shapley		Fields	
	Contribution (%)	95% CI	Contribution (%)	95% CI
Region	17.07	15.34–20.31	15.82	9.12–24.17
Household wealth	21.81	18.47–24.51	28.38	19.34–35.36
Partner's education	18.24	14.13–19.69	18.08	9.33–25.94
Woman's education	18.29	15.78–21.24	19.99	10.93–29.43
Parity	5.14	3.97–7.20	4.23	1.482–7.20
Woman's age	3.02	2.19–5.02	2.00	0.76–5.09
Religion	8.22	6.87–10.36	5.94	1.94–10.21
Distance	8.21	6.37–10.88	5.56	2.22–9.35

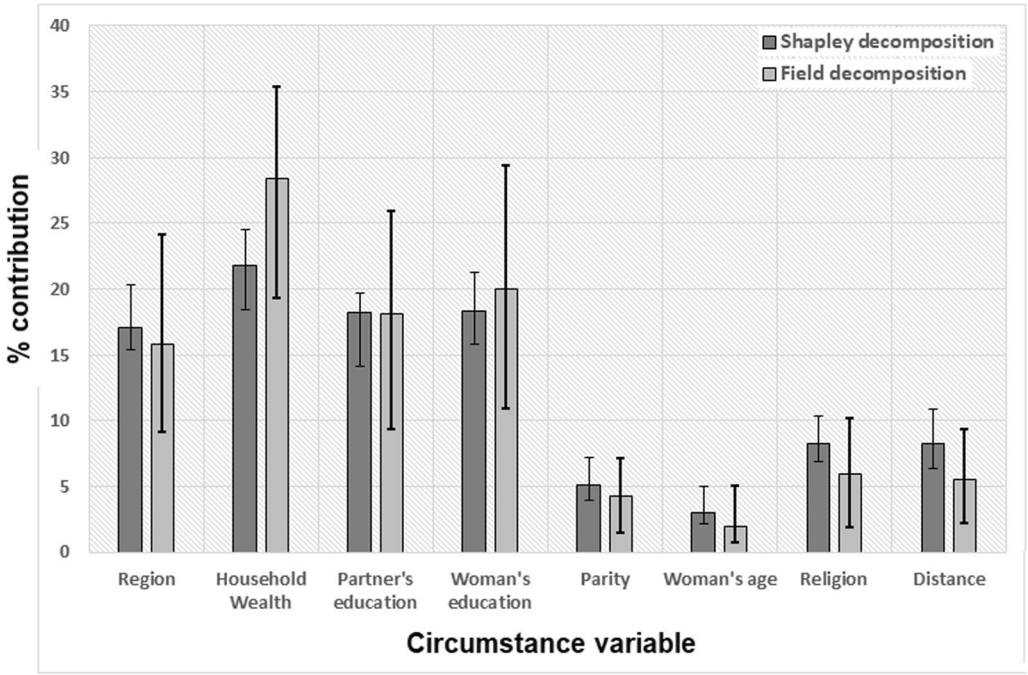

Fig. 3 Percentage contribution of circumstance variables to inequality based on Shapley and Fields decomposition methods

Table 5 and Fig. 3 show contributions of the different circumstances based on Shapley and Fields decomposition techniques, alongside 95% bootstrap percentile confidence intervals based on 1000 bootstrap samples. The Pearson's product-moment correlation test [after Shapiro–Wilk normality tests which confirmed Gaussianity of the distributions of the two decompositions (Shapley: W = 0.891, p-value = 0. 2416; Fields: W = 0.905, p-value = 0.3232)] was used to compare decompositions from both approaches. The results show a strong positive linear correlation between Fields and Shapley decompositions of inequality of access to ANC in Cameroon (Pearson's correlation = 0.973, CI 0.856–0.995, p-value < 0.0001). Both approaches show that "Household wealth" is the circumstance that contributes the most to the inequality of opportunity of access to ANC in Cameroon [21.81% (CI 18.47–24.51) for Shapley versus 28.38% (CI 19.34–35.36) for Fields]. That was followed by "Woman's education" [18.29% (CI 15.78 -21.24) for Shapley and 19.99% (CI 10.93–29.43) for Fields] and "Partner's education" [18.24% (CI 14.13–19.69) for Shapley and 18.08% (CI 9.33–25.94) for Fields]. The "Region of residence" also markedly contributed to inequality, with 17.07% (CI 15.34 -20.31) for Shapley and 15.82% (CI 9.12–24.17) for Fields. The circumstances "Religion", "Distance", "Parity" and "Woman's age" (in decreasing order) contributed the

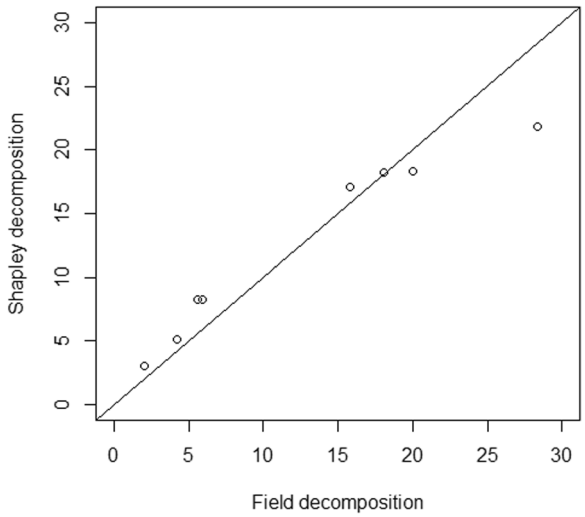

Fig. 4 A plot of Shapley against Fields values

least to the inequality of opportunity in access to antenatal care in Cameroon.

Though a strong positive linear correlation between Shapley and Fields decomposition methods, Fig. 4 shows that the relation may not actually be linear. In effect, Shapley values tend to be higher than Fields values when contributions were small, more or less equal when contributions were moderate, while Fields values tend to be slightly higher than Shapley values when contributions were high. These can be observed from Table 5 and Fig. 3. Additionally, Shapley confidence intervals tend to be narrower than Fields. However, it is known in the literature that variance of logs is not a 'good' measure of inequality as it fails to satisfy some desirable properties of inequality measures, in particular the 'transfers' principle (Cowell, 1988; Foster & Ok, 1999). On the other hand, the Fields approach has an advantage over the Shapley approach in estimating the contribution of the enumeration area random effects in a mixed model setting.

5 Discussion

Household wealth was found to be the factor contributing the most to the inequality of opportunity in access to antenatal care in Cameroon. The cost of care could therefore constitute a source of exclusion for the poorest: the poorer a woman is, the lesser she will use health services during pregnancy. Financial wealth thus allows pregnant women to meet the costs of health care during pregnancy and to better monitor them. This result is in line with those in Mamadou Saliou Balde and Balde Saliou (2020), Dahad and Sakellariou, (2020), Prusty et al. (2015), Kochou and Rwenge (2014), Nanfosso and Kawasi (2013), Andrade et al. (2012), Singh et al., (2011), Sirpe (2011), Pathak et al. (2010).

The levels of education of the woman and the spouse also play an important role in this inequality. It was observed that the more these levels of education increase, the higher the chances of access to ANC. The significance of these circumstances highlights the role of education, not only in the perception of the importance of antenatal consultations, but also in its impact on socioeconomic status, which can promote access to basic social services like antenatal care. Indeed, education facilitates communication with the medical staffs, limits the frustrations that the pregnant woman could experience during the various visits, and allows better compliance with the prescriptions of the health staff. This affirms the results of Balde (2020), Wado (2018), Tsafack and Kasiwa (2013), Andrade et al. (2012), Sarode (2010) and Vecino-Ortiz (2007). However, given that the education years for pregnant women and their spouses may be over and it will be hard for them to go back to school, "awareness campaigns" on health concerns may be useful. Educating couples through information campaigns specifically targeted towards expectant mothers and their spouses may go a long way towards improving the health status and health follow-up of future mothers.

The region of residence also contributed largely to the inequality of opportunity to have access to antenatal care in Cameroon. This result could raise not only the problem of habits and customs relatively specific to each region, but also the problem of the distribution of infrastructures and human resources in health across the national territory. The latter may force many women either to limit or delay their use of antenatal health services or to seek alternatives that are more accessible to them, including traditional care or care from individuals with questionable qualifications.

Distance to health facilities also contributed quite significantly to inequality of access. Women who indicated that distance was not a big problem to them were more likely to have access to ANC services compared to women for whom distance was a big problem. This finding ties with that in Wilunda et al. (2017), Nyathi et al. (2017), Dahab and Sakellariou (2020) and Sibiya (2018).

Parity and age were the circumstances which contributed the least to inequality. Access to antenatal care was positively linked to the woman's age and negatively linked to the number of live births she has already had. Indeed, older women are more likely to develop complications before, during or after childbirth, hence the need for better care during pregnancy. These results confirm those in Eloundou and Yaye (2017), Vecino-Ortiz (2007) and Chakraborty et al. (2003). Also, the more children a woman had, the lesser she used antenatal care during her pregnancy. This could be because the woman may feel she has gained experience with her previous pregnancies,

and tend either not to make the recommended number of consultations with a health professional, or to resort to this treatment late.

6 Conclusion

For any woman, giving birth to a child should be a normal situation, a source of joy and a moment of social fulfilment. Unfortunately, due to the great disparities in access to health care during pregnancy, it still happens that in Cameroon some women give lives at the risk of their own. Addressing this issue is part of the 2030 plan of action for humanity adopted by the United Nations General Assembly in 2015. By focusing on two Sustainable Development Goals: SDG 3 (ensure healthy lives and promote well-being for all at all ages) and SDG 10 (reduce inequality within countries and from one country to another), this work aimed at assessing the inequality of opportunity in access to antenatal care in Cameroon and determining the circumstances that are the sources of this inequality. Using data from the 2018 CDHS-V, after a descriptive analysis of the characteristics of women with access to antenatal care, the Human Opportunity Index was constructed and, using Fields' and Shapley's methodology, the contribution of the circumstance variables to the inequality of opportunity in access to antenatal care in Cameroon was evaluated.

These analyses show that access to health care during pregnancy is not only low, but also inequitable in Cameroon. Though the Shapley and Fields decomposition methodologies used to determine the level of contributions of the different circumstances are different, our analysis shows that both results were comparable. We recall that the former decomposition relies on the dissimilarity index, while the latter is based on decomposing the total variation in the log-odds of access to antenatal care. To the best of our knowledge, this is the first study which tries to compare results from these two decomposition methods. Further investigations need to be performed to validate the correlation between the two methods.

Results from this study show that the main circumstances that explain this inequality of opportunity are the standard of living of the household, the level of education of the pregnant woman and that of her spouse, the region of residence, distance to health facilities, the age of the woman and the parity reached.

In order to improve access to antenatal care and significantly reduce inequality in access to antenatal care in Cameroon, the government may have to strengthen its actions, for example, further reducing cost of ANC, or even making it free, especially for the most disadvantaged. In addition, the government should strengthen measures to facilitate access to education for all, especially for women. The government and its partners may also raise public awareness of good practices in reproductive health, especially young women. Moreover, further reflection should enable the government and its partners to carry out targeted actions, particularly for the North and South-West regions. As distance also constitutes a major barrier to access ANC services, the adoption of urgent measures, such as increasing the number of health facilities and access roads to those facilities may help reduce this barrier.

Abbreviations

ANC	Antenatal care
HOI	Human Opportunity Index
CDHS-V	Cameroon Demographic Health Survey
D-index	Dissimilarity index
MMR	Maternal mortality ratio
WHO	World Health Organization
MDG	Millennium Development Goals
SDG	Sustainable development goals

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Author contributions

ADY, BFN, CZA conceptualized and investigated the study and helped in writing—original draft and writing—review and editing; BFN, ADY contributed to data curation, analysis and interpretation and methodology. All authors read and approved the manuscript.

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Availability of data and materials

The data set used and analysed during the current study are available from the DHS program, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of DHS program.

Declarations

Competing interests

The authors declare that they have no competing interests.

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References

Andrade, M. V., Noronha, K., Singh, A., Rodrigues, C. G., & Padmadas, S. S. (2012). Antenal care use in Brazil and India: Scale, outreach and socioeconomic inequality. *Health & Place, 18*(5), 942–950.

Balde, M. S. (2020). Prenatal healthcare and assisted delivery in Guinea. *Européan Scientific Journal, 16*(16), 1857–7881. https://doi.org/10.19044/esj.v16n16p21

Bigotta, M., Krishnakumar, J., & Rani, U. (2015). Further results on the regression based approach to inequality decomposition with evidence from India. *Empirical Economics, 48*(3), 1233–1266.
Bodjongo, M. J. M. (2021). Poverty, beliefs about HIV-AIDS transmission, and the gap in HIV-AIDS testing among women between rural and urban areas in Cameroon. *Journal De Gestion Et D'economie De La Santé, 39*(3–4), 158–182.
Chakraborty, N., Islam, M. A., Chowdhury, R. I., Bari, W., & Akhter, H. H. (2003). Determinants of the use of maternal health services in rural Bangladesh. *Health Promotion International, 18*(4), 327–337. https://doi.org/10.1093/heapro/dag414
Cowell, F. A. (1988). Inequality decomposition: Three bad measures. *Bulletin of Economic Research, 40*(4), 309–312.
Cropper, M. L. (1977). Health, investment in health, and occupational choice. *Journal of Political Economy, 85*(6), 1273–1294.
Dahab, R., & Sakellariou, D. (2020). Barriers to accessing maternal care in low income countries in Africa: A systematic review. *International Journal of Environment Research and Public Health, 17*(12), 4292. https://doi.org/10.3390/ijerph17124292
De Barros, R. P., Ferreira, F. H. G., Molinas Vega, J. R., & Chanduvi, J. S. (2009). *Measuring inequality of opportunity in latin America and the Caribbean*. World Bank.
Eloundou, M. P. B., & Waïbaï, Y. H. (2017). Contraintes à l'accès aux soins de santé Maternelle dans la ville de Maroua. *The International Journal of Engineering and Science, 6*(1), 13–21.
Field, C. A., & Welsh, A. H. (2007). Bootstrapping clustered data. *Journal of the Royal Statistical Society, Series B, 69*(3), 369–390. https://doi.org/10.1111/j.1467-9868.2007.00593.x
Foster, J., & Ok, E. A. (1999). Lorenz Dominance and the variance of logarithms. *Econometrica, 67*(4), 901–907. https://doi.org/10.1016/S0147-9121(03)22001-X
Grossman, M. (1972). On the concept of health capital and the demand for health. *Journal of Political Economy, 80*(2), 223–255.
Kenkel, D. (1990). Consumer health information and demand of medical care. *Review of Economics and Statistics, 72*(3), 587–595.
Kochou, S. H., & Rwenge, M. J. (2014). Social factors of the nonuse or the inadequate use of prenatal care in Côte d'Ivoire. *African Evaluation Journal, 2*(1), 12.
Majnoni d'Intignano, B., & Ulmann, P. (2001). *Health economics*. Presse Universitaire de France.
Mujaddad, H. G., & Anwar, M. (2020). Inequality of opportunity in access to antenatal care in districts of Punjab, Pakistan. *Ilkogretim Online, 19*(4), 5235–5250.
Nyathi, L., Tugli, A. K., Tshitangano, T. G., & Mpofu, M. (2017). Investigating the accessibility factors that influence antenatal care services utilisation in Mangwe district, Zimbabwe. *African Journal of Primary Health Care and Family Medicine, 9*(1), 1–5.
Nanfosso, R. T., & Kasiwa, J. M. (2013). The determinants of demand for prenatal care in the Democratic Republic of Congo: Counting data approach/Les determinants de la demande de soins prenataux en Republique democratique du Congo: Approche par donnees de comptage. *African Evaluation Journal*. https://doi.org/10.4102/aej.v1i1.26
Pathak, P. K., Singh, A., & Subramanian, S. V. (2010). Economic inequalities in maternal health care: Prenatal care and skilled birth attendance in India, 1992–2006. *PLoS ONE, 5*(10), e13593. https://doi.org/10.1371/journal.pone.0013593
Peragine, V. (2004). Ranking income Distributions according to equality of opportunity. *The Journal of Economic Inequality, 2*(1), 11–30. https://doi.org/10.1023/B:JOEI.0000028404.17138.1e
Pons-Duran, C., Lucas, A., Narayan, A., Dabalen, A., & Menéndez, C. (2019). Inequalities in sub-Saharan African women's and girls' health opportunities and outcomes: Evidence from the Demographic and Health Surveys. *Journal of Global Health, 9*(1), 010410. https://doi.org/10.7189/jogh.09.010410
Prusty, R. K., Gouda, J., & Pradhan, M. R. (2015). Inequality in the utilization of maternal healthcare services in Odisha, India. *International Journal of Population Research, 531485*, 10. https://doi.org/10.1155/2015/531485
Rawls, J. (1971). *A theory of justice*. Belknap Press/Harvard University Press.
Roemer, J. E. (1998). *Equality of opportunity*. Harvard University Press.
Sarode, V. M. (2010). Does illiteracy influence pregnancy complications among women in the slums of greater Mumbai. *International Journal of Sociology and Anthropology, 2*(5), 82–93.
Sen, A. K. (1976). Real national income. *Review of Economic Studies, 43*(1), 19–39.
Sen, A. K. (1980). Equality of what? In S. McMurrin (Ed.), *The tanner lectures on human values.* (Vol. 1). Cambridge University Press.
Shapley, L. (1953). A value for n-Person games. In H. Kuhn & A. Tucker (Eds.), *Contributions to the theory of games II* (pp. 307–317). Princeton University Press.
Sibiya, M. N., Ngxongo, T. S. P., & Bhengu, T. J. (2018). Access and utilisation of antenatal care services in a rural community of eThekwini district in KwaZulu-Natal. *International Journal of Africa Nursing Sciences, 8*, 1–7.
Singh, A., Padmadas, S. S., Mishra, U. S., Pallikadavath, S., Johnson, F. A., & Sirpe, G. (2011). Les facteurs explicatifs du recours aux soins de santé prénatals au Burkina Faso. *Mondes En Développement, 1*, 27–40.
Son, H. H. (2013). Inequality of human opportunities in developing Asia. *Asian Development Review, 30*(2), 110–130.
Tsawe, M., & Susuman, A. S. (2020). Examining inequality of opportunity in the use of maternal and reproductive health interventions in Sierra Leone. *Journal of Public Health, 42*(2), 254–261. https://doi.org/10.1093/pubmed/fdz023
Vecino-Ortiz, A. I. (2007). Determinants of demand for antenatal care in Colombia. *Health Policy, 86*(2–3), 363–372. https://doi.org/10.1016/j.healthpol.2007.12.002
Viscusi, W. K. (1990). Do smokers underestimate risks? *Journal of Political Economy, 98*(6), 1253–1269. https://doi.org/10.1086/261733
Wagstaff, A., & Claeson, M. (2004). *The millennium development goals for health: Rising to the challenges*. World Bank.
Wilunda, C., Scanagatta, C., Putoto, G., Montalbetti, F., Segafredo, G., Takahashi, R., Mizerero, S. A., & Betran, A. P. (2017). Barriers to utilisation of antenatal care services in South Southan: A qualitative study in Rumbek North County. *Reproductive Health, 14*(1), 65. https://doi.org/10.1186/s12978-017-0327-0
World Bank. (2006). *World Development Report 2006: Equity and development*. World Bank.
Wado, Y. D. (2018). Women's autonomy and reproductive health-care-seeking behavior in Ethiopia. *Women & Health, 58*(7), 729–743. https://doi.org/10.1080/03630242.2017.1353573
Checchi, D., & Peragine, V. (2005). Regional disparities and inequality of opportunity: The case of Italy. *IZA Discussion Papers, Leibniz Information Centre for Economics,* No. 1874.
Fields, G. S. (2003). Accounting for income inequality and its change: A new method, with application to the distribution of earnings in the United States. In *Worker well-being and public policy* (Vol. 22, pp. 1-38). Emerald Group Publishing Limited.
National Institute of Statistics (Cameroon) and ICF (2020). 2018 Cameroon DHS Summary Report. Rockville, Maryland, USA: NIS and ICF. https://dhsprogram.com/pubs/pdf/SR266/SR266.pdf
Roemer, J. E. (2001). Does democracy engender equity? *Cowles Foundation Discussion Papers* No.1281R.
WHO. (2016). WHO recommendations on antenatal care for a positive pregnancy experience. Geneva
WHO. (2019). Trends in maternal mortality 2000 to 2017: estimates by WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division: executive summary. World Health Organization. https://apps.who.int/iris/handle/10665/327596. Licence: CC BY-NC-SA 3.0 IGO.

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