Caesarean Delivery Use in Ethiopia: A Spatial and Hierarchical Bayesian Analysis

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Abstract

Background: Access to emergency obstetric care (EmOC) is very important for reducing maternal mortality. A geographically linked data analysis using population and health facility data is potentially valuable to map caesarean delivery use, and to identify inequalities in service access and provision. Thus, this study aimed to assess the spatial patterns of caesarean delivery use, and to identify associated factors among pregnant women in Ethiopia.

Method: A secondary data analysis of the 2016 Ethiopia Demographic and Health Survey linked with the 2014 Ethiopian Service Provision Assessment was conducted. A hierarchical Bayesian analysis was carried out using the SAS MCMC procedure. A spatial analysis was performed to identify the hot spot areas of caesarean delivery use with ArcGIS.

Results: Women who had four or more ANC visits were 4.077 (95% Credible Interval (CrI): 1.909, 8.179) times more likely to use caesarean delivery compared to those who had no ANC visits. Pregnant women living in rural areas were 60% less likely to deliver via caesarean section. About 50% of the variability in the rate of caesarean delivery was accounted for by location. The spatial analysis found that Addis Ababa, Dire Dawa and the Harari region had clusters of high caesarean delivery rates.

Conclusion: There were significant variations in the use of caesarean delivery services across the different regions of Ethiopia. The findings have important policy implications. The Ethiopian government has to increase the distribution of EmOC facilities and/or to establish a faster transportation system to allow pregnant women to reach EmOC facilities when caesarean delivery is indicated.

Keywords: Caesarean delivery, obstetric care, spatial variations, Ethiopia

Plain English summary

Access to maternal healthcare services is very important for reducing maternal mortality. Many low-income countries include multiple ethnic and religious groups which can lead to perceptions of bias in the distribution of resources, such as healthcare resources. We aimed to map the health facilities that provide caesarean delivery to identify any inequalities in access to caesarean delivery in Ethiopia.

We used two datasets from Ethiopia to map maternal health facilities that provide caesarean services along with the number of people in need of these services. We also examined other factors that were associated with caesarean delivery service access and use.

We found a wide geographic variation in caesarean delivery use across the different regions of Ethiopia. Women living in rural areas were 60% less likely to deliver via caesarean section with high rates of caesarean delivery use clustered in Addis Ababa, followed by Dire Dawa and the Harari region. Women who had four or more antenatal care visits were four times more likely to use caesarean delivery compared to those who had no antenatal visits.

Our findings have important policy implications, with identified gaps in the distribution of maternal health facilities that provide caesarean services. Priority should be given to communities that need special attention, such as hard to reach communities.

Introduction

Access to EmOC is important for reducing maternal mortality (1). Emergency obstetric care is grouped into two broad categories: Basic Emergency Obstetric and Neonatal Care (BEmONC) and Comprehensive Emergency Obstetric Care (CEmOC) (2). The United Nations Handbook on emergency obstetric care recommends that there should be at least five EmOC facilities, including one CEmOC facility, per 500,000 population (2). However, countries with high and moderate numbers of maternal deaths reported an insufficient number of EmOC facilities (3). In a systematic review, it was found that the global met need for EmOC was 45%; the gap in coverage was very high between low (21%) and high-income (99%) countries (4).

The World Health Organization (WHO) stated that a caesarean section rate above 10% at the population level was not associated with a reduction in maternal and newborn deaths (5, 6). A medically indicated caesarean section is effective in saving the lives of mothers and newborns; however, it should not be performed to achieve a specific rate (7). On the other hand, to classify hospital-level caesarean sections, the WHO conducted two systematic reviews (8, 9) and concluded that the Robson classification system (10) could be taken as a global standard for healthcare facilities (7). Robson classifies all women into one of ten mutually exclusive categories. These categories are based on the five basic obstetric variables: parity, the onset of labour, gestational age, fetal presentation and number of fetuses (10).

Demand and supply-side factors are important in determining the use of caesarean delivery. With regard to the demand side factors, it has been found that individual, household, and community-level factors are significantly associated with utilization of maternal health services (11-14). Similarly, the supply-side factors, such as availability and quality of services, a facility's readiness to provide services, and a provider's competency and caring behaviour are determinants of utilization of maternal health services. However, health facilities in many developing countries are underperforming in these areas (3).

In Ethiopia, from 2000 to 2016, there was a slight increase in the national rate of caesarean section from 0.7% in 2000 to 1.9% in 2016 (15). However, differences remained depending on different attributes. In 2016, the rate of caesarean section in urban areas was 10.6% as compared to 0.9% in rural areas. The highest rate of caesarean section (21.4%) was accounted for by the capital city – Addis (16). The rate of caesarean section was higher among private health facilities than public health facilities (15, 17). Despite these findings, the overall availability and use of caesarean services in relation to geographic location, demographic and other factors are not known. It is therefore difficult to identify the areas where there is an unmet need, and to identify the types of intervention that might help to meet the need for caesarean sections.

A linked analysis of population and health facility data enables the examination of the link between population healthcare needs, their healthcare utilization and the health service environment (18, 19). In Ethiopia, the population data can be accessed from the Ethiopia Demographic and Health Survey (EDHS) (20) and the health facility data from Ethiopian Service Provision Assessment Plus (ESPA+) survey (21). Thus, mapping of the combined data on caesarean delivery use and health facility distribution would provide important information for program managers and decision-makers about the distribution of health facilities and services in relation to the population, and would identify the communities that need special attention. This study aimed to assess the spatial variations in the use of caesarean delivery in Ethiopia. Furthermore, it aimed to identify the potential factors associated with caesarean delivery use throughout the country, using national population and health facility data.

Methods

Data sources

This study used two data sets; the 2016 EDHS and the 2014 ESPA+ survey.

Population data

The 2016 EDHS was used to obtain national population data. It contained population socio-demographic characteristics, health service use and morbidity/mortality data. The survey used a stratified multistage sampling technique. Enumeration Areas (EAs) were used as sampling frames. In addition to population information, the latitude and longitude coordinates of each EA was recorded. Data were collected from 645 clusters (EAs) (16).

In this analysis, 6,954 women who gave birth in the five years preceding the survey in the 622 EAs were included. A total of 239 women who gave birth in the five years preceding the survey in the other 23 EAs were excluded from the analysis since these clusters had no geographic coordinate available.

Health facility data

The 2014 ESPA+ survey provided national health facility data covering different aspects of the availability and readiness of health services. In addition to this, the data set contained the latitude and longitude coordinates of each health facility. The survey used a combination of census and simple random sampling techniques (22). Due to their importance and limited numbers, all hospitals were included in the survey. Details of the sampling procedure are discussed elsewhere (19).

In this analysis, only hospitals that were able to provide a caesarean delivery service were included. Amongst the 214 hospitals, 179 hospitals, which reported providing caesarean delivery services, were included.

Data linking method

This study used an Euclidean buffer link to link population and health facility data (19). This is regarded as the method of choice for linking a census of health facilities with population data (18, 19, 23). Details of this method are discussed elsewhere (19). The administrative boundaries of Ethiopia, obtained from Natural Earth (24), were used.

Health service environment and measurements

Using the SPA survey, four health service environment variable scores were computed. These were the average distance to the nearest caesarean delivery facilities, comprehensive obstetric care availability score, readiness to provide comprehensive obstetric care score, and a general health facilities readiness score. Using principal component analysis, availability and readiness scores were computed for the nearest hospital providing caesarean delivery. The SCORE procedure in SAS was used to compute availability and readiness scores. The comprehensive obstetric care indices were created using the World Health Organization's 'Service Availability and Readiness Indicators' (25, 26). Details of computing these scores were discussed elsewhere (19).

With regarding to General Service readiness, six service readiness dimensions were used: communication equipment, external supervision, client opinion and feedback, quality assurance, emergency transport, and client latrine. The first two principal components (health facility management system and infrastructure) were used to compute two general service readiness scores (19).

For hospitals providing caesarean delivery, indices of comprehensive obstetric care availability and readiness scores were created. Two comprehensive obstetric care availability scores (basic and comprehensive components) were created using seven variables. Similarly, two comprehensive obstetric care readiness scores (equipment and supplies, and skilled personnel) were computed using nine dichotomous variables (19).

A woman was considered to have used caesarean delivery if her most recent birth in the five years preceding the survey was via caesarean section.

Statistical analysis

Bayesian hierarchical model

The EDHS survey employed a multistage cluster sampling technique: women were nested within EAs and then EAs were nested within regions. Considering this hierarchical nature of the data, a three-stage Bayesian hierarchical model was used. Women's data within the respective EAs were also linked with the health facility data. In this model, the probability of caesarean delivery is allowed to vary both

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between EAs and between regions. To model the between-EA and between-region variability, the logarithms of the odds ratios of caesarean delivery was assumed to have a normal distribution. The means of the normal distribution of log odds ratios across EAs and regions, therefore, represent the average effect in the EAs and regions, and the variances represent the variability among EAs and regions.

Bayesian inference allows for the combination of existing knowledge with new information according to established rules of probability. In this study, a non-informative prior that would not have an influence on the posterior distribution was chosen (27, 28). For each fixed effect, a non-informative prior that follows a normal distribution with large variance ($\sigma^2 = 1000$) and a zero mean ($\mu = 0$) was used. Similarly, for the random effects, non-informative priors that were set up to follow a normal distribution with a zero mean and different variances were used. The variances for the random effects were set up to follow an inverse gamma distribution with a shape parameter of $\alpha = 0.01$ and a scale parameter $\beta = 0.01$. The MCMC procedure (PROC MCMC) in SAS was used to estimate the Bayesian hierarchical generalized linear mixed models. The study used a simulation size of 100,000 iterations after removing the first 25,000 iterations (burn-in iterations). One of every 25 samples was kept, which gave the MCMC sample size of 4,000 for computing the posterior quantities of interest. This analysis procedure enabled the identification of potential factors associated with the rate of caesarean delivery with an equal-tail 95% credible interval and p-value < 0.05.

The model building process was started with the unconditional model (a model containing no predictors) and more complex models were gradually built by checking improvements in model fit after each model is estimated (29). A Deviance Information Criterion (DIC) was calculated using the posterior mean estimates of the parameters to select the best fitting model. The unconditional (empty) model was used to calculate the intra-class correlation coefficient (ICC), which estimates how much variation in the use of caesarean delivery exists between EAs (level-2 units) and between regions (level-3 units).

Three variance estimates were used to calculate EA ICC and region ICC. The formula for calculating each of these ICCs is similar to the formula used for two-level ICC calculations. However, the denominator now has three elements (residual variance, EA variance and region variance) which form the total variance in the model. The two equations for the EA ICC (ICC_{EA}) and region ICC (ICC_R) are below.

$$ICC_{EA} = \frac{\sigma_{EA}^2}{\sigma_e^2 + \sigma_{EA}^2 + \sigma_R^2}$$

$$ICC_R = \frac{\sigma_R^2}{\sigma_e^2 + \sigma_{EA}^2 + \sigma_R^2}$$

The ICC_{EA} tells us how much of the total variation in caesarean delivery exists between EAs. On the other hand, ICC_R indicates the total variation in caesarean delivery that exists between regions (30). In hierarchical generalized linear mixed models, it is assumed that there is no level-1 error variance; however, to calculate the intra-class correlation coefficient, a slight modification is made. The level-1 residual variance (ε) follows a logistic distribution and is standardized with a mean of zero and variance $= \pi^2/3$ (31). Therefore, for three-level random intercept hierarchical generalized linear mixed model with an intercept variance of σ_{EA}^2 and σ_R^2, the intra-class correlation coefficient (Rho) is given by;

$$ICC_{EA} = \frac{\sigma_{EA}^2}{\pi^2/3 + \sigma_{EA}^2 + \sigma_R^2} \text{ and } ICC_R = \frac{\sigma_R^2}{\pi^2/3 + \sigma_{EA}^2 + \sigma_R^2} \text{ (31)}.$$

Spatial analysis

ArcGIS 10.6.1 was used to carry out the spatial analysis. The Ethiopian Polyconic Projected Coordinate System was used to flatten the Ethiopian map (19). Hot spot analysis was carried out to identify spatial clusters of caesarean delivery use. The unit of spatial analyses were DHS clusters/EAs.

Three procedures were followed to carry out the spatial analysis as discussed elsewhere (19). First, the Global Moran's I statistic, which is a global measure of spatial autocorrelation (32) was carried out. Second, the Incremental Spatial Autocorrelation was used to determine the critical distance at which there is maximum clustering (19). The average distance *(15 kilometres)* at which a feature has at least one neighbour was calculated. This gave 155 kilometres at which clustering of caesarean delivery use peaked. Lastly, the Getis-Ord Gi* statistic was used to identify statistically significant spatial clusters of high caesarean delivery rates (hot spots) and low caesarean delivery rates (cold spots). A False Discovery Rate (FDR) correction method was applied to account for multiple and spatial dependence tests in Local Statistics of Spatial Association (19, 33). Statistical significance was determined based on z-scores and p-values (19).

Results

Sociodemographic and obstetric characteristics

The sociodemographic and obstetric characteristics of the women were not presented in this paper. These characteristics were published in the antenatal care paper published in BMC Pregnancy and Childbirth (34). The same number of women with the same sociodemographic and obstetric characteristics were included in this paper.

Hospital characteristics

Amongst the 214 hospitals, 200 (93.46%) reported providing normal delivery care. Out of the 200 hospitals, 179 (89.50%) provided caesarean delivery. The national average distance of caesarean delivery providing hospitals to the 2016 EDHS EAs was 33.27 km. The 2016 EDHS sampled EAs in the Somali region had the longest distance to caesarean delivery providing hospitals, 71.36 km. Conversely, on average, EDHS EAs in Addis Ababa were 1.54 km away from the hospital providing caesarean delivery (Fig 1).

Caesarean delivery rate

In Ethiopia, the rate of caesarean delivery was found to be 3.65% (urban 12.70%, 1.14% rural). The prevalence of caesarean deliveries were 7.34% in the public and 30.20% in private health facilities. The rate of caesarean delivery varied across the different regions and city administrations of the country; the highest caesarean delivery rate was reported in Addis Ababa (21.87%) followed by Harari (11.19%) and Dire Dawa (8.31%). The map (Fig 2) showed that there is regional variation in caesarean delivery rates.

Hospital to the population proportion

There is a huge difference in the proportion of hospitals per one-million population in each region. In the Amhara, Oromia and SNNP regions, approximately one hospital is expected to serve a population of one million. In the Tigray region, it was estimated that six hospitals serve a population of one million. In the two city administrations (Addis Ababa and Dire Dawa) and the Harari region, an average of 14 hospitals serve a one-million population. The rates of caesarean delivery per EDHS EA also varied depending on the number of, and distance to, caesarean delivery providing hospitals in each region (Fig 3).

Spatial epidemiology of caesarean delivery

There is strong evidence to support spatial clustering in the utilization of caesarean delivery among pregnant women in Ethiopia (Global Moran's I = 1.15, Z-score = 38.26, P-value < 0.0001). Most of the

hot spot areas were located in Addis Ababa, Dire Dawa and Harari, and in some areas of the Oromia, Amhara, Somali and SNNP regions. The majority of the cold spot areas were located in the Gambela, Benishangul-Gumuz and Tigray regions followed by Amhara and SNNP regions. This clustering was supported by the Getis-Ord Gi* statistic when conducting the spatial analysis (Fig 4).

Determinants of caesarean delivery use

The calculated EA level intra-class correlation coefficient (ICC_{EA}) was 15.80%. This indicated that about 16% of the variation in using caesarean delivery exists between EAs. Similarly, the estimated region level ICC (ICC_R) indicated that 33.81% of the variation in the rate of caesarean delivery exists between regions. This indicated that only 50.39% of the variability is accounted for by the differing characteristics of the women, or other unmeasured factors. A practically meaningful proportion of the variance in caesarean delivery use exists at the EA and region levels, providing support for the use of a three-level analytical model.

Women's age and education, spouses education, parity, and the number of ANC visit a woman had were strong individual-level predictors of caesarean delivery use. A one-year increase in the age of a woman was associated with a 12% increase in the odds of caesarean delivery use. Women who attained higher education were 3.913 times more likely to deliver via caesarean section as compared to those who had no education. A woman whose husband attained a secondary level of education was 98% more likely to deliver via caesarean section as compared to those whose husband had no education. Women who had four or more ANC (ANC4+) visits were 4.077 times more likely to use caesarean delivery as compared to those who had no ANC visits. On the other hand, a one-child increase in the number of live births a woman had was associated with a 30% decrease in the odds of caesarean delivery use (Table 1).

At the EA level (level 2), only one variable was significantly associated with the use of caesarean delivery. Those pregnant women who were living in rural areas were 60% less likely to deliver via caesarean section (Table 1). At the region level (level 3), the number of caesarean section providing hospitals did not show statistical significance in the use of caesarean delivery.

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Table 1:Factors associated with caesarean delivery use among pregnant women in Ethiopia, 2016 (N = 6,954)

Predictors		AOR (95% CrI)
Level-1 predictor variables		
Women's education	No education	1.00
	Primary	1.948 (1.204, 3.007)
	Secondary	1.893 (1.048, 3.162)
	Higher	3.913 (2.139, 6.747)
Husbands' or partners' education	No education	1.00
	Primary	1.070 (0.632, 1.717)
	Secondary	1.979 (1.088, 3.336)
	Higher	1.396 (0.782, 2.330)
Number of ANC visits	No visits	1.00
	1 – 3 visits	2.717 (1.209, 5.641)
	>= 4 visits	4.077 (1.909, 8.179)
Age in years		1.117 (1.079, 1.155)
Parity		0.700 (0.608, 0.793)
Level-2 predictor variables		
Residence	Urban	1.00
	Rural	0.397 (0.242, 0.632)
Level-3 predictor variables		
Number of caesarean section providing hospitals per region		0.992 (0.967, 1.014)

AOR = Adjusted Odds Ratio; CrI = Credible Interval

NB: This model is the final model adjusted for individual, EA- and region-level factors

Finally, the majority of the between-EA and between-region variances were explained by this model. The proportional change in variance indicated that the addition of predictors to the empty model explained an increased proportion of variation in caesarean delivery use. The variance estimates between-EAs decreased from 1.03 in the empty model to 0.05 in the final random-intercept and random-slope model. The proportion of the between-EAs variance explained by the final model was 94.77%. Similarly, the variance estimates between-regions decreased from 2.21 in the empty model to 0.25 in the final random-intercept and random-slope model. The proportion of the between-region variance explained by the final model was 88.59%. In addition to this, the empty model showed that 15.80% (ICC_{EA}) and 33.81% (ICC_R) of the variability in the odds of caesarean delivery use was explained by EA-level and region-level characteristics, respectively. The between-EA variability declined over successive models, from 15.80% in the empty model to 1.49% in the final model. Similarly, the

between-region variability decreased from 33.81% in the empty model to 7.00% in the final model (Table 2).

Table 2: Variations in caesarean delivery use in Ethiopia: random slope and random intercept model

Random effects (Measure of variation for caesarean delivery use)	Model 1	Model 6
Region-level variance (SE)	2.21 (0.47)	0.25 (0.16)
P value	<0.05	<0.05
EA-level variance (SE)	1.03 (0.47)	0.05 (0.01)
P value	<0.05	<0.05
Variance in women's education (SE)		0.05 (0.02)
P value		<0.05
Variance in husband/partner's education (SE)		0.05 (0.03)
P value		<0.05
Variance in number of ANC visits (SE)		0.14 (0.05)
P value		<0.01
Variance in age (SE)		0.08 (0.04)
P value		<0.05
Variance in parity (SE)		0.09 (0.06)
P value		>0.05
Variance in residence (SE)		0.09 (0.06)
P value		>0.05
Variance in number of cs hospitals (SE)		0.09 (0.06)
P value		>0.05
ICC_{EA} (%)	15.80	1.49
ICC_R (%)	31.81	7.00
Explained variance (PCV_{EA}) (%)	Reference	94.77
Explained variance (PCV_R) (%)	Reference	88.59
DIC	3121.21	1606.01

SE = Standard Error; ICC_{EA} = Intra-Class Correlation for EA; ICC_R = Intra-Class Correlation for region; PCV_{EA} = Percentage Change in Variance for EA; PCV_R = Percentage Change in Variance for region; CrI = Credible Interval; DIC = Deviance Information Criteria; Model 1 is the null model, a baseline model without any determinant variable; Model 6 is the final model adjusted for individual, EA- and region-level factors

Discussion

This is the first study to provide a comprehensive assessment of the unmet need for caesarean section in Ethiopia by location, service type and demographics. This study aimed to assess the spatial variations in the use of caesarean delivery in Ethiopia. Furthermore, it aimed to identify the potential factors associated with caesarean delivery use throughout the country, using the national population and health facility data. In Ethiopia, the rate of caesarean delivery was 3.65%, showing that there has been an increase in the national rate of cesarean delivery since 2011 (1.5%) (35). Despite this overall improvement, there were large differences in caesarean delivery use by geographic area. The highest caesarean delivery rate was reported among women in urban areas (12.70%) with a much lower rate in non-urban areas (1.14%). In addition, caesarean rates were higher in private compared to public facilities.

The national rate of caesarean delivery was lower than the WHO recommendation of a population level caesarean section rate of 10% (36). The rate of caesarean delivery in Addis Ababa was higher than the WHO estimate and the national average; it was reported that the rate of caesarean delivery was 21.87%. However, this finding was similar to the 2011 report of 21.8%, indicating that there has not been any further increase in the use of caesarean delivery since that time (35). This figure is also comparable with a previous study conducted in Addis Ababa, which reported that 19.2% of women gave birth via caesarean section (37). The rate of caesarean section in Addis Ababa was 10.68 – 21.22% higher than other administrative regions of Ethiopia. This might be attributable to the increased access to caesarean section providing facilities in Addis Ababa as compared to the other administrative regions in the country. Furthermore, the highest rate of caesarean section in Addis Ababa might be due to some caesarean sections being performed without a medical indication. For instance, in a study conducted in Addis Ababa, it was found that 6.9% of caesarean deliveries performed had no medical indication (37).

By contrast, with the exception of the Harari region (11.19%) and Dire Dawa city administration (8.31%), the rest of regional administrations in Ethiopia had low rates of caesarean section (0.65 – 2.72%). This could be due to the fact that the majority of the women in these regions are living in rural areas where access to obstetric care facilities is limited. In a systematic review and meta-analysis carried out in low and middle-income countries, limited geographic access to obstetric care facilities was found to be negatively associated with health facility delivery (38). In many sub-Sahara Africa countries, inadequate access to caesarean section facilities and lack of skilled birth attendants are the main barriers in the use of obstetric care services (39-42). For example, in Ethiopia, only 2.4% of births in Oromia, 3.6% in SNNP, 4.1% in Benishangul-Gumuz, 5.0% in Somali and 5.8% in Afar regions were attended by medical doctors (16). Thus, due to the limited obstetric care access and lack of skilled birth

attendants, the majority of the women in these regions might not have access to caesarean section and thus could not use the service though they were medically eligible.

The rates of caesarean delivery in private health facilities (30.20%) were much greater than caesarean births in public hospitals (7.34%). These rates are much higher than the WHO recommended a maximum limit of 15% (43, 44). Similarly, in Ethiopia, the rates of caesarean section were higher among women who delivered at private facilities than public health facilities (15, 17). Other studies (45-50) also support this finding, as caesarean section rates in private health facilities are greater than caesarean deliveries in public health facilities. This suggests that some or most of the profit-making private health facilities are doing unnecessary caesarean deliveries. This should be a big concern and needs further research about why caesarean deliveries are selectively high in private health facilities. Though it needs further research, it could also be possible that women who have enough money and who know they are going to need a caesarean section (or who think they will) choose to use a private rather than a public hospital (51-55).

High rates of caesarean delivery were detected in Addis Ababa, Dire Dawa and the Harari region. In a study conducted in Mozambique, it was found that the likelihood of having a caesarean section was significantly associated with living in urban areas (39). This might be due to the differences in the distribution of caesarean delivery providing hospitals in the country. The majority of EmOC facilities, both public and private, are concentrated in urban areas. These three areas are urban centres covering small geographical areas as compared to the rest of the regional administrations in the country. In this study, it was found that there was a large difference in the proportion of hospitals per one-million population. These three cities had the highest proportion of hospitals as compared to the other regions in the country. This indicates that Ethiopia did not meet the United Nations recommendation of having at least five EmOC facilities, including one CEmOC facility, per 500,000 population (2).

In this study, even though distance was not significantly associated with caesarean delivery, the national average distance of caesarean delivery providing hospitals to the EDHS clusters was 33.27 km (ranging from 0.11 to 318.70 km). This indicates that pregnant women and their families are expected to travel about 33 kilometres on average to give birth through caesarean section. In a systematic review and meta-analysis carried out in low and middle-income countries, it was found that having access to obstetric care facilities within 5 km distance and/or 60 minutes of walk was significantly associated with higher odds of health facility delivery. However, every one-hour and one-kilometre increase in travel time and distance, respectively, was inversely associated with the use of obstetric care delivery (38).

Different individual and cluster level variables were found to be significant in the use of caesarean delivery among pregnant women in Ethiopia. Amongst the cluster level variables, only rural residence was significantly less likely for pregnant women to have caesarean delivery as compared to urban residents. This is consistent with a study carried out in India where more caesarean section births were observed among urban women as compared to women who resided in rural areas (50). This could be due to the local inaccessibility of caesarean delivery providing facilities in rural areas where most of them are clustered in urban centres. However, this finding is inconsistent with other previous studies (56, 57) in which rural women had a high rate of caesarean delivery. This inconsistency with the previous studies might be attributable to a high number of obstetric complications referred to CEmOC facilities. This could also be related to the low number of ANC visits among rural women, which could help them to get prepared for skilled delivery service and to identify pregnancy complications ahead of time at each ANC visit.

Amongst the individual-level factors, a single-year increase in the age of women was significantly associated with the odds of having a caesarean delivery. This is consistent with other studies done in Ethiopia (56, 58), Brazil (59) and England (60) where the chance of undergoing caesarean section increased with age. This could be explained by the probability of pregnancy complications as the age of a woman increases (61-63). Researchers found that advanced maternal age was significantly associated with adverse pregnancy outcomes (61), prolonged labour (62) and medical conditions, such as hypertension and diabetes (64, 65). These adverse conditions, in turn, could also increase emergency obstetric care interventions, such as caesarean sections. Older women should be aware that they might be at increased risk of needing a caesarean section. Therefore, ensuring that they are near to a medical facility that provides the service or arranging a faster transport should be emphasized.

In Ethiopia, amongst the individual-level variables, both women's and husbands'/partners' level of education was significantly associated with the odds of caesarean delivery. Similarly, the rates of caesarean deliveries were higher among women with a secondary and higher level of education (17). In a systematic review and meta-analysis of observational studies on women's preference for caesarean section, it was found that 15.6% of women preferred to give birth via caesarean section (66). This indicates that women's education could influence the mode of delivery preference. Therefore, it is important to counsel pregnant women about the potential benefits and risks of caesarean delivery.

In this study, a single unit increase in the number of live births that a woman had was significantly associated with a 30% decrease in the odds of having a caesarean delivery. In a study carried out in India, a higher rate of operative deliveries were reported among primigravida women as compared to multigravidas (67). This could be related to the progress of labour as multiparas could have faster labour

progress as compared to nulliparous women (68). In a study carried out on the effect of parity on uterine activity in labour, it was found that the parous uterus takes significantly less effort to effect vaginal delivery as compared to nulliparous women (69). On the other hand, the increase in the duration of labour could be associated with adverse maternal and neonatal outcomes. These adverse conditions might require emergency obstetric care interventions, such as caesarean section. This indicates that women with their first pregnancy should be given more emphasis during their ANC visits and prepare them to plan skilled delivery care. Furthermore, emphasis should also be given to all pregnant women to have ANC contacts and to continue the service as per the WHO recommendation. This service, in the meantime, will prepare them for skilled delivery care and make them ready for any obstetric complications.

The odds of having caesarean delivery was significantly associated with increases in the number of antenatal care visits a woman had. Consistent with a previous study carried out in India (50), four or more ANC visits were associated with high rates of caesarean delivery. This raises a question of why caesarean rate increases with a further increase in ANC visits. While it was not included in the EDHS survey instrument, it would be beneficial to examine the indication for caesarean section, and whether caesarean deliveries were related to pregnancy complications. Further research is needed to determine why caesarean sections increase along with an increase in ANC visits in Ethiopia. Unless there are no medical indications for caesarean section, antenatal care visits are a good opportunity to counsel and prepare pregnant women to encourage vaginal deliveries (70). This finding has programmatic implications as ANC visits should be used as an opportunity to increase institutional deliveries and the care providers should counsel pregnant women regarding medical indications of caesarean section and the associated risks. Therefore, it has to be emphasized that ANC contacts should be used to avoid unnecessary caesarean sections.

Availability of caesarean deliveries and hospitals readiness to provide caesarean deliveries did not show significant associations with caesarean delivery. This could be due to chance or bias which we could not determine. In the descriptive statistics, it was observed that there was no difference among clusters with regard to the above-mentioned variables. However, these variables have enormous importance and should not be understated. Due to the local inaccessibility of emergency obstetric care facilities, pregnant women and their families are expected to travel a long distance for childbirth (18). Countries with an insufficient number of EmOC facilities were found to have a high number of maternal deaths (3). As per the United Nations recommendation, there should be at least five EmOC facilities, including one CEmOC facility, per 500,000 population (2) and governments should work to achieve this goal.

This study linked population and health facility data together to identify both the demand and supply-side determinants of caesarean delivery use. In most studies, these were studied separately. This study used Bayesian inferences to solve the issues of small sample size, which is the limitation of classical statistics. Bayesian analysis provides a natural and principled way of combining prior information with data. It provides inferences that are conditional on the data and obeys the likelihood principle, which is not the case in classical statistics. In addition to the Bayesian hierarchical analysis, this study used hot spot analysis to identify geographical variations of caesarean delivery use. Investigating caesarean delivery use geographically is very important for informed decision making and monitoring and evaluation purposes.

This study was not without limitations; however, most of these limitations were minimized (19). Removing DHS clusters without geographic location information might under or overestimate caesarean delivery use. Misclassification errors associated with DHS geographic coordinates displacement were the major limitations of this study (19). This could avoid the influence of distance on caesarean delivery use if DHS cluster coordinates were not displaced. The estimated average straight-line distance to the nearest caesarean delivery facility and its influence on service use would be different. With regard to Bayesian analysis, it has several limitations. First, there is no correct way to choose a prior as it does not tell us how to select a prior. This study used a non-informative prior that would not have an influence on the posterior distribution. Second, Bayesian analysis often comes with a high computational cost (memory and time), especially in models with a large number of parameters. However, these limitations did not have a huge impact on the study findings. The shrinkage effect of non-informative priors on the posterior distribution is minimal as compared to informative priors.

Conclusion

In Ethiopia, the national rate of caesarean delivery was low. However, there is a big difference in caesarean delivery rates in private and public health facilities. Women's education and the number of ANC visits, and urban residence were associated with the use of caesarean delivery. Furthermore, a wide geographical variation in the use of caesarean delivery across the country was found. Hot spots of caesarean delivery were identified in the three cities: Addis Ababa, Dire Dawa and the Harari region. This study has policy implications for the government of Ethiopia. The first implication is to increase the distribution of EmOC facilities per population density and/or to establish a faster transportation system to allow pregnant women to reach EmOC facilities. The other implication of this study is that ANC providers should empower and counsel pregnant women about the potential benefits and risks of caesarean delivery to encourage appropriate access to the service. Lastly, as observed from the

hierarchical Bayesian analysis, there is a need for gaining a more detailed understanding of the findings for an increased in caesarean section rate with an increasing number of ANC visits.

Abbreviations

ANC	Antenatal Care
BEmONC	Basic Emergency Obstetric and Neonatal Care
CEmOC	Comprehensive Emergency Obstetric Care
CRS	Coordinate Reference System
DHS	Demographic and Health Survey
DIC	Deviance Information Criterion
EAs	Enumeration Areas
EDHS	Ethiopia Demographic and Health Survey
EmOC	Emergency Obstetric Care
ESPA+	Ethiopia Service Provision Assessment Plus
FDR	False Discovery Rate
GIS	Geographic Information Systems
HGLM	Hierarchical Generalized Linear Model
ICC	Intra-class Correlation Coefficient
MCMC	Markov Chain Monte Carlo
MCSE	Monte Carlo Standard Error
SNNPR	Southern Nations, Nationalities and Peoples Region
SPA	Service Provision Assessment
TFR	Total Fertility Rate
WGS84World	Geodetic System 84
WHO	World Health Organization

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the Human Research Ethics Committee, The University of Newcastle. We also got the Ethiopian Public Health Institute (EPHI) and the Measure DHS program approval to access the datasets.

Consent for publication

Not applicable.

Availability of data and material

Not applicable.

Competing interests

The authors declared that they have no competing interests.

Funding

Not applicable.

Authors' contributions

TKT, CC, RS, DL conceptualized the design of the analysis. TKT developed and drafted the manuscript. CC, TG, RS and DL participated in critically revising the intellectual contents of the manuscript. All authors read, provided feedback and approved the final manuscript.

References

1. De Brouwere V, Tonglet R, Van Lerberghe W. Strategies for reducing maternal mortality in developing countries: what can we learn from the history of the industrialized West? Tropical medicine & international health. 1998;3(10):771-82.
2. WHO, UNFPA, UNICEF, AMDD. Monitoring emergency obstetric care: a handbook. Geneva, Switzerland: WHO; 2009.
3. Paxton A, Bailey P, Lobis S, Fry D. Global patterns in availability of emergency obstetric care. International Journal of Gynecology & Obstetrics. 2006;93(3):300-7.
4. Holmer H, Oyerinde K, Meara J, Gillies R, Liljestrand J, Hagander L. The global met need for emergency obstetric care: a systematic review. BJOG: An International Journal of Obstetrics & Gynaecology. 2015;122(2):183-9.
5. Betran AP, Torloni MR, Zhang J, Ye J, Mikolajczyk R, Deneux-Tharaux C, et al. What is the optimal rate of caesarean section at population level? A systematic review of ecologic studies. Reprod Health. 2015;12(1):57.
6. Ye J, Zhang J, Mikolajczyk R, Torloni M, Gülmezoglu A, Betran A. Association between rates of caesarean section and maternal and neonatal mortality in the 21st century: a worldwide population-based ecological study with longitudinal data. BJOG: An International Journal of Obstetrics & Gynaecology. 2016;123(5):745-53.
7. World Health Organization. WHO Statement on Caesarean Section Rates. Geneva: WHO/RHR/15.02; 2015.

8. Betran AP, Vindevoghel N, Souza JP, Gülmezoglu AM, Torloni MR. A systematic review of the Robson classification for caesarean section: what works, doesn't work and how to improve it. PLoS ONE. 2014;9(6):e97769.
9. Robson M, Hartigan L, Murphy M. Methods of achieving and maintaining an appropriate caesarean section rate. Best Practice & Research Clinical Obstetrics & Gynaecology. 2013;27(2):297-308.
10. Robson MS. Classification of caesarean sections. Fetal and maternal medicine review. 2001;12(1):23-39.
11. Sepehri A, Sarma S, Simpson W, Moshiri S. How important are individual, household and commune characteristics in explaining utilization of maternal health services in Vietnam? Soc Sci Med. 2008;67(6):1009-17.
12. Babalola S, Fatusi A. Determinants of use of maternal health services in Nigeria-looking beyond individual and household factors. BMC pregnancy and childbirth. 2009;9(1):43.
13. Gabrysch S, Cousens S, Cox J, Campbell OM. The influence of distance and level of care on delivery place in rural Zambia: a study of linked national data in a geographic information system. PLoS Medicine. 2011;8(1):e1000394.
14. Zegeye K, Gebeyehu A, Melese T. The role of geographical access in the Utilization of institutional delivery service in rural Jimma Horro District, Southwest Ethiopia. Prim Health Care. 2014;4(1):2167-1079.1000150.
15. Yisma E, Smithers LG, Lynch JW, Mol BW. Cesarean section in Ethiopia: prevalence and sociodemographic characteristics. The Journal of Maternal-Fetal & Neonatal Medicine. 2017:1-6.
16. Central Statistical Agency (CSA) [Ethiopia], ICF. Ethiopia Demographic and Health Survey 2016. Addis Ababa, Ethiopia, and Rockville, Maryland, USA: CSA and ICF; 2016.
17. Gebremedhin S. Trend and socio-demographic differentials of Caesarean section rate in Addis Ababa, Ethiopia: analysis based on Ethiopia demographic and health surveys data. Reprod Health. 2014;11(1):14.
18. Burgert-Brucker CR, Prosnitz D. Linking DHS household and SPA facility surveys: Data considerations and Geospatial Methods. DHS Spatial Analysis Reports No. 10: ICF International; 2014.
19. Tegegne TK, Chojenta C, Getachew T, Smith R, Loxton D. Service environment link and false discovery rate correction: Methodological considerations in population and health facility surveys. PLoS ONE. 2019;14(7):e0219860.
20. Wang W, Winter R, Mallick L, Florey L, Burgert-Brucker C, Carter E. The Relationship between the Health Service Environment and Service Utilization: Linking Population Data to Health Facilities Data in Haiti and Malawi. DHS Analytical Studies No. 51. Rockville, Maryland, USA: ICF International; 2015.
21. Hozumi D, Fronczak N, Minichiello SN, Buckner B, Fapohunda B, Kombe G, et al. Profiles of Health Facility Assessment Methods. Report of the International Health Facility Assessment Network (IHFAN). MEASURE Evaluation, USAID; 2008.
22. Ethiopian Public Health Institute, ICF International. Ethiopia Service Provision Assessment Plus (ESPA+) Survey 2014. Addis Ababa, Ethiopia and Rockville, Maryland USA: Ethiopian Public Health Institute and ICF International; 2014.
23. Skiles MP, Burgert CR, Curtis SL, Spencer J. Geographically linking population and facility surveys: methodological considerations. Population health metrics. 2013;11(1):14.
24. Natural Earth. Free vector and raster map data   [cited 31/05/2019. Available from: https://www.naturalearthdata.com/downloads/10m-cultural-vectors/.
25. World Health Organization. Service availability and readiness assessment (SARA): an annual monitoring system for service delivery: reference manual. 2015.
26. World Health Organization. Service Availability and Readiness Assessment (SARA): an annual monitoring system for service delivery.: Health Statistics and Information Systems, WHO; 2013.
27. Babapulle MN, Joseph L, Bélisle P, Brophy JM, Eisenberg MJJTL. A hierarchical Bayesian meta-analysis of randomised clinical trials of drug-eluting stents. 2004;364(9434):583-91.
28. Ojo OB, Lougue S, Woldegerima WAJPo. Bayesian generalized linear mixed modeling of Tuberculosis using informative priors. 2017;12(3):e0172580.

29. Ene M, Leighton EA, Blue GL, Bell BA, editors. Multilevel models for categorical data using SAS® PROC GLIMMIX: the basics. SAS Global Forum 2015 Proceedings; 2015.
30. Hox JJ, Moerbeek M, Van de Schoot R. Multilevel analysis: Techniques and applications: Routledge; 2017.
31. Tom A, Bosker TASRJ, Bosker RJ. Multilevel analysis: an introduction to basic and advanced multilevel modeling: Sage; 1999.
32. Anselin L. Local indicators of spatial association—LISA. Geographical analysis. 1995;27(2):93-115.
33. Caldas de Castro M, Singer BH. Controlling the false discovery rate: a new application to account for multiple and dependent tests in local statistics of spatial association. Geographical Analysis. 2006;38(2):180-208.
34. Tegegne TK, Chojenta C, Getachew T, Smith R, Loxton D. Antenatal care use in Ethiopia: a spatial and multilevel analysis. BMC pregnancy and childbirth. 2019;19(1):399.
35. Central Statistical Agency [Ethiopia], ICF International. Ethiopia Demographic and Health Survey 2011. Addis Ababa, Ethiopia and Calverton, Maryland, USA: Central Statistical Agency and ICF International; 2012.
36. Betran A, Torloni M, Zhang J, Gülmezoglu A. WHO Statement on caesarean section rates. BJOG: An International Journal of Obstetrics & Gynaecology. 2016;123(5):667-70.
37. Bayou YT, Mashalla YJ, Thupayagale-Tshweneagae G. Patterns of caesarean-section delivery in Addis Ababa, Ethiopia. Afr. 2016;8(2):1-6.
38. Tegegne TK, Chojenta C, Loxton D, Smith R, Kibret KT. The impact of geographic access on institutional delivery care use in low and middle-income countries: Systematic review and meta-analysis. PLoS ONE. 2018;13(8):e0203130.
39. Long Q, Kempas T, Madede T, Klemetti R, Hemminki E. Caesarean section rates in Mozambique. BMC pregnancy and childbirth. 2015;15(1):253.
40. Cavallaro FL, Cresswell JA, França GV, Victora CG, Barros AJ, Ronsmans C. Trends in caesarean delivery by country and wealth quintile: cross-sectional surveys in southern Asia and sub-Saharan Africa. Bulletin of the World Health Organization. 2013;91:914-22D.
41. Hounton SH, Newlands D, Meda N, De Brouwere V. A cost-effectiveness study of caesarean-section deliveries by clinical officers, general practitioners and obstetricians in Burkina Faso. Human Resources for Health. 2009;7(1):34.
42. Fesseha N, Getachew A, Hiluf M, Gebrehiwot Y, Bailey P. A national review of cesarean delivery in Ethiopia. International Journal of Gynecology & Obstetrics. 2011;115(1):106-11.
43. Moore B. Appropriate technology for birth. The Lancet. 1985;326(8458):787.
44. Chaillet N, Dubé E, Dugas M, Francoeur D, Dubé J, Gagnon S, et al. Identifying barriers and facilitators towards implementing guidelines to reduce caesarean section rates in Quebec. Bulletin of the World Health Organization. 2007;85:791-7.
45. Vieira GO, Fernandes LG, de Oliveira NF, Silva LR, de Oliveira Vieira T. Factors associated with cesarean delivery in public and private hospitals in a city of northeastern Brazil: a cross-sectional study. BMC pregnancy and childbirth. 2015;15(1):132.
46. Almeida Sd, Bettiol H, Barbieri MA, Silva AAMd, Ribeiro VS. Significant differences in cesarean section rates between a private and a public hospital in Brazil. Cad Saude Publica. 2008;24:2909-18.
47. Rebelo F, Da Rocha CMM, Cortes TR, Dutra CL, Kac G. High cesarean prevalence in a national population-based study in Brazil: the role of private practice. Acta Obstet Gynecol Scand. 2010;89(7):903-8.
48. Mendoza-Sassi RA, Cesar JA, Silva PRd, Denardin G, Rodrigues MM. Risk factors for cesarean section by category of health service. Revista de saúde pública. 2010;44(1):80-9.
49. Beogo I, Rojas BM, Gagnon M-P. Determinants and materno-fetal outcomes related to cesarean section delivery in private and public hospitals in low-and middle-income countries: a systematic review and meta-analysis protocol. Systematic reviews. 2017;6(1):5.

50. Singh P, Hashmi G, Swain PK. High prevalence of cesarean section births in private sector health facilities-analysis of district level household survey-4 (DLHS-4) of India. BMC Public Health. 2018;18(1):613.

51. Potter JE, Berquó E, Perpétuo IH, Leal OF, Hopkins K, Souza MR, et al. Unwanted caesarean sections among public and private patients in Brazil: prospective study. Bmj. 2001;323(7322):1155-8.

52. Sufang G, Padmadas SS, Fengmin Z, Brown JJ, Stones RW. Delivery settings and caesarean section rates in China. Bulletin of the World Health Organization. 2007;85:755-62.

53. Lo JC. Patients' attitudes vs. physicians' determination: implications for cesarean sections. Soc Sci Med. 2003;57(1):91-6.

54. McCourt C, Weaver J, Statham H, Beake S, Gamble J, Creedy DK. Elective cesarean section and decision making: a critical review of the literature. Birth. 2007;34(1):65-79.

55. Kamal SM. Preference for institutional delivery and caesarean sections in Bangladesh. Journal of health, population, and nutrition. 2013;31(1):96.

56. Abebe FE, Gebeyehu AW, Kidane AN, Eyassu GA. Factors leading to cesarean section delivery at Felegehiwot referral hospital, Northwest Ethiopia: a retrospective record review. Reprod Health. 2015;13(1):6.

57. Al-Mulhim A, Abu-Heija AT, Ali AHM, Bahnasy A. Factors Affecting the Rate and the Indications of Primary Caesarean Section. Bahrain Med Bul. 2001;23(4):160-2.

58. Gutema H, Shimye A. cesarean section and associated factors at mizan aman general hospital, southwest Ethiopia. J Gynecol Obstet. 2014;2(3):37-41.

59. D'orsi E, Chor D, Giffin K, Angulo-Tuesta A, Barbosa GP, Gama AdS, et al. Factors associated with cesarean sections in a public hospital in Rio de Janeiro, Brazil. Cad Saude Publica. 2006;22:2067-78.

60. Patel RR, Peters TJ, Murphy DJ. Prenatal risk factors for Caesarean section. Analyses of the ALSPAC cohort of 12 944 women in England. Int J Epidemiol. 2005;34(2):353-67.

61. Kenny LC, Lavender T, McNamee R, O'Neill SM, Mills T, Khashan AS. Advanced maternal age and adverse pregnancy outcome: evidence from a large contemporary cohort. PLoS ONE. 2013;8(2):e56583.

62. Greenberg MB, Cheng YW, Sullivan M, Norton ME, Hopkins LM, Caughey AB. Does length of labor vary by maternal age? American journal of obstetrics and gynecology. 2007;197(4):428. e1-. e7.

63. Zaki MN, Hibbard JU, Kominiarek MA. Contemporary labor patterns and maternal age. Obstetrics and gynecology. 2013;122(5):1018.

64. Khan MN, Islam MM, Shariff AA, Alam MM, Rahman MM. Socio-demographic predictors and average annual rates of caesarean section in Bangladesh between 2004 and 2014. PLoS ONE. 2017;12(5):e0177579.

65. Lin H-C, Sheen T-C, Tang C-H, Kao S. Association between maternal age and the likelihood of a cesarean section: a population-based multivariate logistic regression analysis. Acta Obstet Gynecol Scand. 2004;83(12):1178-83.

66. Mazzoni A, Althabe F, Liu NH, Bonotti AM, Gibbons L, Sánchez AJ, et al. Women's preference for caesarean section: a systematic review and meta-analysis of observational studies. BJOG: an international journal of obstetrics & gynaecology. 2011;118(4):391-9.

67. Nupur Shah, Nandita Maitra, Pagi SL. Evaluating role of parity in progress of labour and its outcome using modified WHO partograph. Int J Reprod Contracept Obstet Gynecol. 2016;5(3):860-3.

68. Anjel Vahratian, Matthew K. Hoffman, James F. Troendle, Zhang J. The impact of parity on course of labor in a contemporary population. Birth. 2006;33(1):12-7.

69. Arulkumaran S, Gibb D, Lun K, Heng S, Ratnam S. The effect of parity on uterine activity in labour. BJOG: An International Journal of Obstetrics & Gynaecology. 1984;91(9):843-8.

70. United Nations. The Millennium Development Goals Report 2015. New York: United Nations; 2015.

Figure Legends
Figure 1: The average distance of the demographic and health survey clusters to caesarean delivery providing hospitals in Ethiopia, 2016 (n = 179)
Figure 2: Caesarean delivery use among pregnant women in Ethiopia, 2016
Figure 3: Distribution of hospitals and caesarean delivery rate in Ethiopia, 2016
Figure 4: Clusters of high and low caesarean delivery rates in Ethiopia, 2016

Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

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In your methods section, say that you used the STROBE cross sectionalreporting guidelines, and cite them as:

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		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1, 2
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4, 5
Objectives	#3	State specific objectives, including any prespecified hypotheses	4,5
Methods			
Study design	#4	Present key elements of study design early in the paper	5
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants.	5
	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6

Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	5, 6
Bias	#9	Describe any efforts to address potential sources of bias	6
Study size	#10	Explain how the study size was arrived at	5, 6
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	5, 6
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	6 - 8
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	6 - 8
Statistical methods	#12c	Explain how missing data were addressed	5 - 8
Statistical methods	#12d	If applicable, describe analytical methods taking account of sampling strategy	5 - 8
Statistical methods	#12e	Describe any sensitivity analyses	n/a

Results

Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	9
Participants	#13b	Give reasons for non-participation at each stage	n/a
Participants	#13c	Consider use of a flow diagram	n/a
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	9
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	9
Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	9
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9 – 12
Main results	#16b	Report category boundaries when continuous variables were categorized	9 – 12
Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	n/a

Discussion

Key results	#18	Summarise key results with reference to study objectives	11
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	11 – 17

Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	11 – 17
Generalisability	#21	Discuss the generalisability (external validity) of the study results	11 – 17
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

Figures

Mean Cluster distance to Hospitals
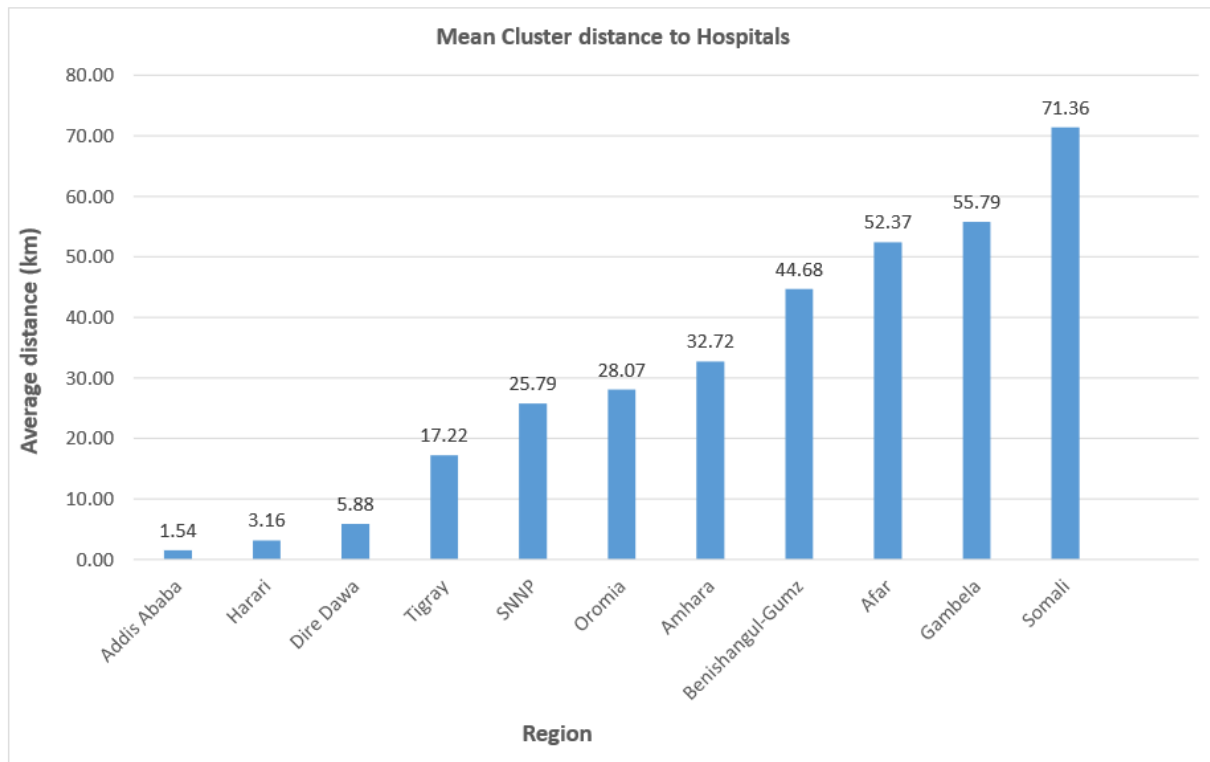
SNNP: Southern Nations, Nationalities and Peoples

Figure 1

The average distance of the demographic and health survey clusters to caesarean delivery providing hospitals in Ethiopia, 2016 (n = 179)
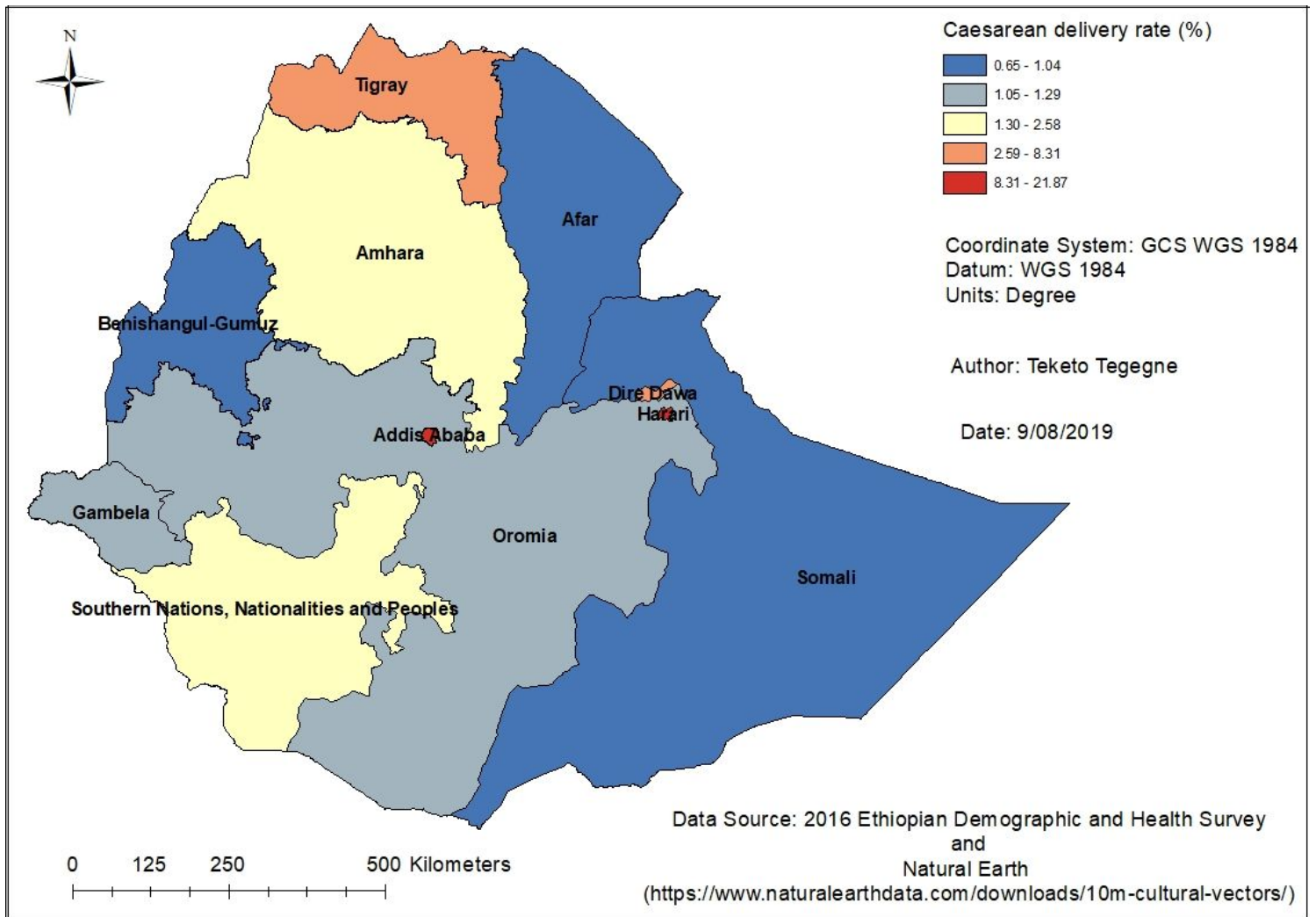
Figure 2

Caesarean delivery use among pregnant women in Ethiopia, 2016 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.
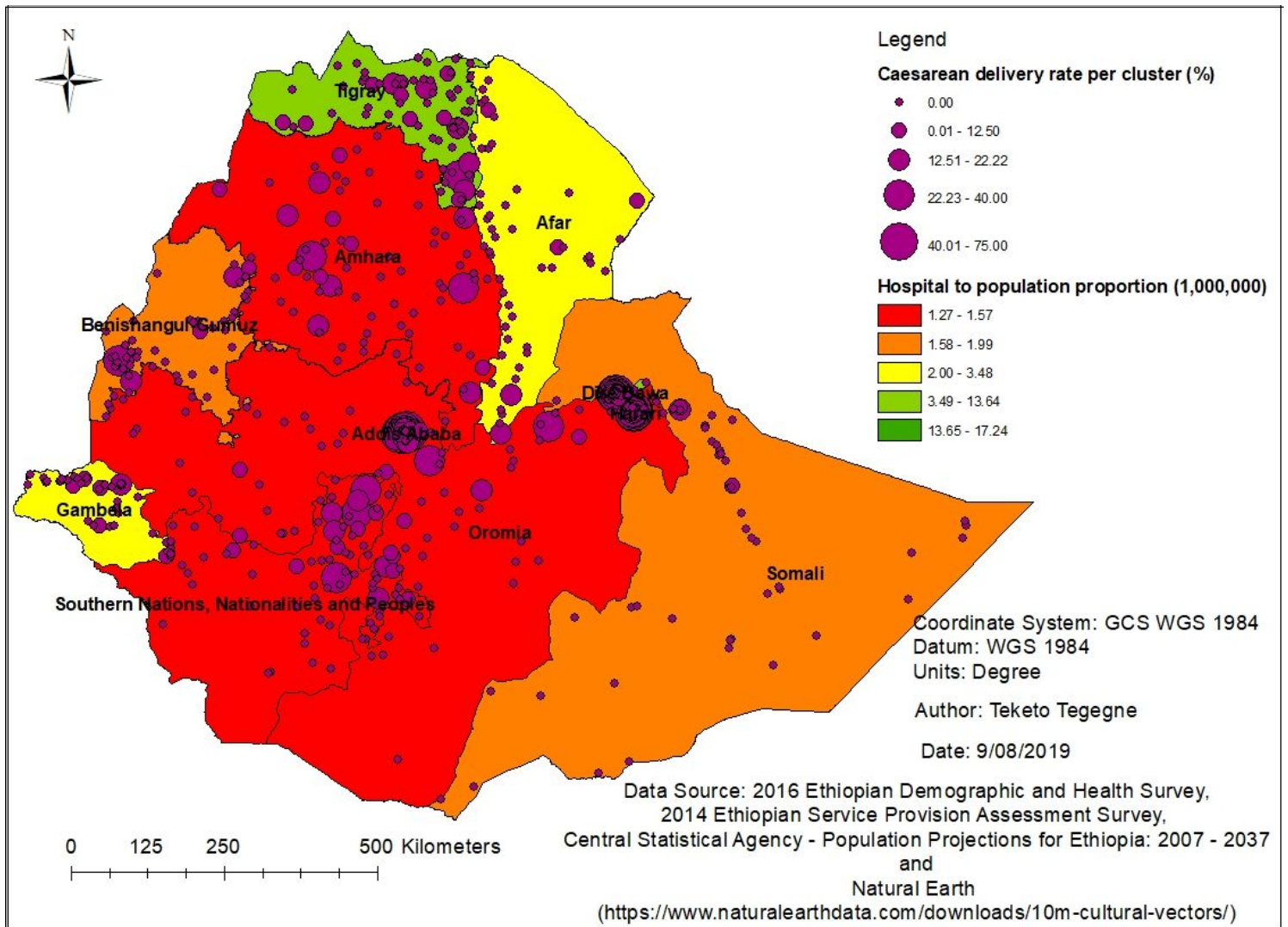
Figure 3

Distribution of hospitals and caesarean delivery rate in Ethiopia, 2016 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.
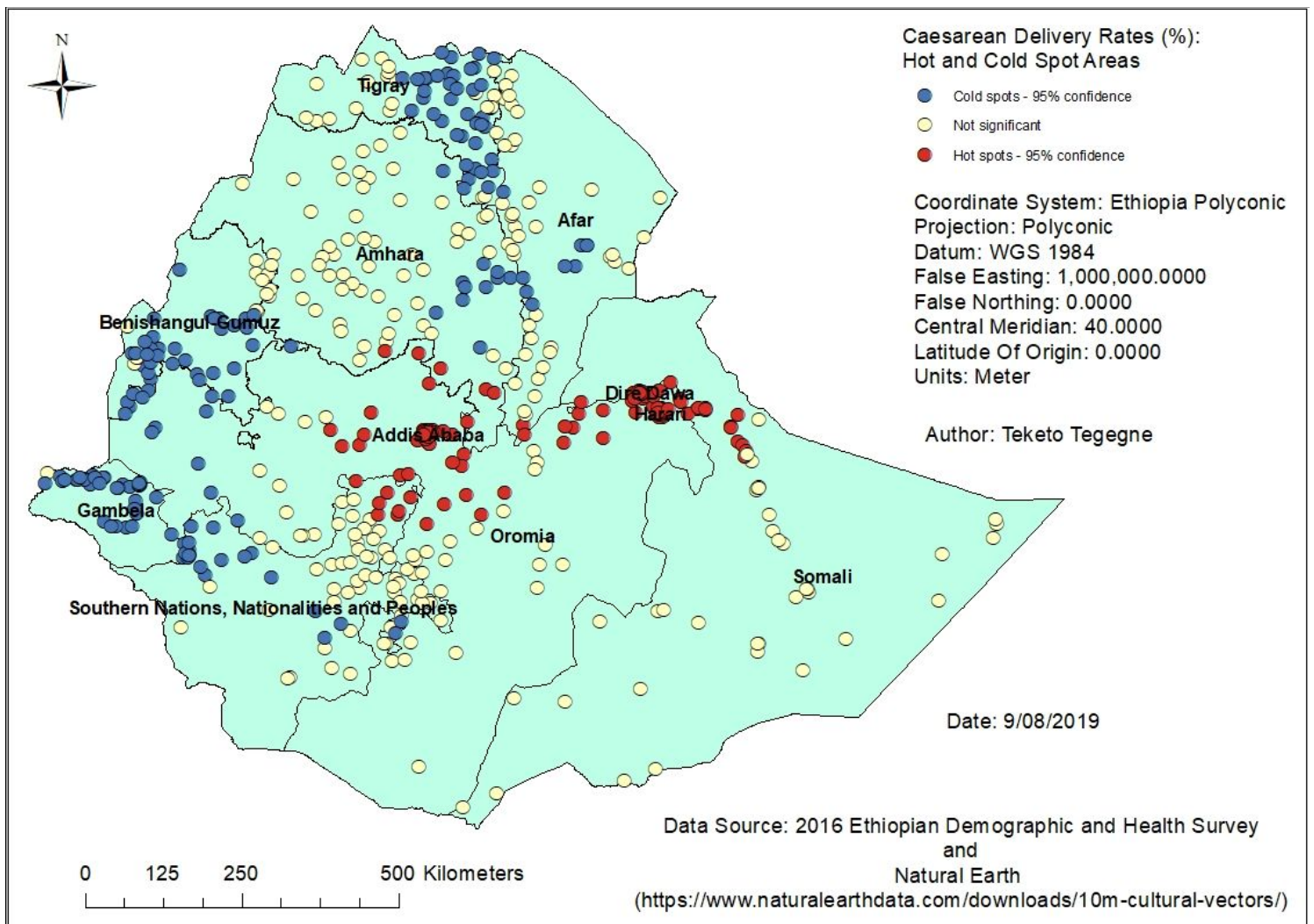
Figure 4

Clusters of high and low caesarean delivery rates in Ethiopia, 2016 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.