Multivariate Analysis of Fertility: an Application of the Generalized Poisson Regression Model

Adelaide Agyeman [1] | *CSIR-Science and Technology Policy Research Institute, Accra, Ghana*

Abstract

Total fertility rate (TFR) is a standard measure commonly used to estimate fertility levels and trends. However, TFR is a period measure and does not offer reasons for observed variations in fertility rates and trends. Using data from the 2017 Ghana Maternal Health Survey (GMHS), this study examines current fertility levels and trends of ever-married women and employs a generalized Poisson regression (GPR) model to analyze the determinants of fertility. Findings suggest that the current fertility level of 5.4 for ever-married women is high. The results also reveal that age at first marriage, educational level, household wealth, area of residence, use of contraceptives; and ownership and use of a bank account are significant determinants of total fertility ($p<0.05$) and are thus factors that affect the fertility levels of women. The study concludes that the GPR analysis provides a clearer picture of the nature and determinants of fertility compared to the standard TFR analysis.

Keywords

Total fertility, generalized Poisson regression model, determinants, sub-Saharan Africa

JEL code

C52, R2

INTRODUCTION

Population growth is a key evolving global challenge (Glenn et al., 2014) and current trends have sparked debates on its possible adverse effect on the achievement of the United Nations' Sustainable Development Goals (SDGs) in especially developing countries (Jatana and Currie, 2020). According to a 2017 report by United Nations Development Programme (UNDP) and United Nations Research Institute for Social Development (UNRISD), developing countries which are experiencing rapid population growth are likely to face the challenge of providing quality social services, including health and education, as well as decent employment opportunities (Trends, 2017). Ghana's current 2.2% population growth rate is much higher than the world rate of 1.1% and is thus a disturbing trend (World Bank, 2019).

In most settings and in the long term, total fertility rate (TFR) which represents the average number of children per woman is one of the key determinants of the population dynamics and growth and can be

[1] CSIR-Science and Technology Policy Research Institute, P.O.Box, CT. 519 Cantonments, Accra, Ghana. E-mail: nesiagyeman@yahoo.com, phone: (+233)302210773856.

an excellent indicator of the future population growth or decline for a country (UN DESA, 2019). Recent studies, report of declining TFR trends worldwide with statistics indicating that since 1950 the global fertility rate has halved to about 2.4 (Murray et al., 2018). In spite of declining fertility rates globally, sub-Sahara Africa remains the region with the highest fertility at 4.6 children per woman (UN DESA, 2020). Although, TFR is a simple and comparable summary measure used extensively to acquire information on the current and total fertility trends and dynamics and track fertility rates (Pol and Thomas, 2002), it can hardly offer a holistic explanation for the observed changes in fertility rates and trends.

The theory of fertility and empirical evidence indicate that fertility levels and trends depend largely on demographic, socio-economic and cultural factors (Becker and Lewis, 1973; Wang and Famoye, 1997; Caudill and Mixon, 1995; Bongaarts et al., 1984). The key socio-economic and demographic characteristics, that have been used to explain the observed changes in fertility rates and trends include, age at first marriage, education, income or wealth, region, area of residence, contraception, marital-status and religion (Shapiro and Gebreselassie, 2013; Bijlsma and Wilson, 2017; Pandey and Kaur, 2015; Schoumaker, 2019). Empirical findings have revealed that, lack of educational opportunities or low levels of education (Martin, 1995), relatively low levels of contraceptive use (Bongaarts, 2017; Gyimah et al., 2012; Ekane, 2013; Wang et al., 2017; UN DESA, 2020), high levels of poverty and insecurity (Mbacke, 2017; Mansanja et al., 2016), early average age for marriage (Clifton and Frost, 2011; Garenne, 2004; Head et al., 2014) and residing in a rural area (Kulu, 2013; Ekane, 2013; Lerch, 2019) are key factors contributing significantly to the high levels of fertility in sub-Saharan Africa.

In several empirical studies on female fertility, the number of children ever born (CEB) to women in their reproductive years is modeled as a function of other social and economic variables (Wang and Famoye, 1997; Melkersson and Rooth, 2000). CEB is essentially a count discrete random variable and the standard Poisson regression model described in the context of generalized linear models by McCullagh and Nelder (1989) has been widely used to model such data (Winkelmann and Zimmermann, 1994). A key assumption of the standard Poisson regression model states that the variance and the mean should be equal (equi-dispersion; Cameron and Trivedi, 1998). However, it is well-known that count data often exhibit over-dispersion (i.e., the variance is greater than its mean) or in less common cases, under-dispersion (i.e., the variance is smaller than its mean). In situations where the equi-dispersion assumption of the standard Poisson regression model is violated, the parameter estimates can still be consistent but inferences based on the estimated standard errors will be incorrect and misleading (Winkelmann and Zimmermann, 1995; Harris and Yang, 2012; Famoye et al., 2004). Alternatively, the generalized Poisson regression (GPR) model has shown statistical advantages over the standard Poisson regression model in terms of its ability in modeling either over-dispersed or under-dispersed count data sets. The GPR model also provides a flexible approach for analyzing count random variables as a function of other variables (Singh et al., 2000). Wang and Famoye (1997), and Wilkermann and Zimmermann (1994) modeled household fertility data using the generalized Poisson regression model and found out that the GPR model yielded more efficient estimates and provided a better fit to their household fertility data.

To develop a clearer understanding of the underlying factors that affect total fertility of women, it is necessary to examine the socio-economic and demographic factors that significantly influence fertility levels and trends using versatile multivariate statistical methods. The objectives of this study were to analyze current fertility levels and trends of ever-married women and assess the key socio-economic and demographic characteristics influencing household fertility using the generalized Poisson regression model.

1 MATERIALS AND METHODS

1.1 Data

In this study we utilized data from the 2017 Ghana Maternal Health Survey (GMHS), a nationally representative survey in which 26 324 households were interviewed. A two-stage stratified probabilitysampling method was used in the GMHS to select respondents that covered the then ten administrative regions of Ghana (Western, Central, Greater Accra, Volta, Eastern, Ashanti, Brong Ahafo, Northern, Upper East, and Upper West). Out of the total number of households surveyed under the GMHS, interviews were successfully completed with 25 062 women aged between 15 and 49 years. This study, however, purposively selected 17 126 ever-married women (married, living together, separated, divorced and widowed) for the analysis because of the use of "age at first marriage" as an explanatory variable.

1.2 Variables

The dependent variable for this study is a count variable denoting the number of children ever born (CEB) to ever married woman between the ages of (15–49) and it takes on non-negative integer values (Table 1). The mean number of children ever born alive to women in that age group 15–49 was calculated as:

$$\text{CEB} = \sum jP_j \,, \tag{1}$$

where, j is the number of children P_j is the proportion of ever-married women age 15–49 who have given birth to a total of j children.

The explanatory variables are also presented in Table 1.

Table 1 Variable definitions

Variable	Description
Total children ever born (CEB)	Total number of children to female respondents between the age of (15–49) years
Age	Age of female respondents (15–49)
Age squared	Age squared of female respondents
Age at first marriage	Age at which ever married women aged between 15–49 years get married
Education	Educational attainment of female respondents 0 = No Education 1 = Primary 2 = Secondary 3 = Tertiary
Residence	Area of residence 0 = Urban 1 = Rural
Region	1 = Western 2 = Central 3 = Greater Accra 4 = Volta 5 = Eastern 6 = Ashanti 7 = Brong Ahafo 8 = Northern 9 = Upper East 10 = Upper West

Table 1 continuation

Variable	Description
Ownership and use of bank accounts	Financial Inclusion 0 = No bank account 1 = Has and uses a bank account
Wealth	The index is a proxy for income and is based on assets (e.g., television, bicycle) housing characteristics, water and sanitation characteristics 1 = Lowest 2 = Second 3 = Third 4 = Fourth 5 = Fifth
Contraceptive use	0 = Never used contraceptives 1 = Ever-used contraceptives
Marital Status	0 = Never Married 1 = Ever Married

Note: Age squared variable is used to account for the non-linearity associated with age-related variables.
Source: GMHS author's calculation

1.3 Statistical Framework

Total fertility rate (TFR) which measures the average number of births a group of women would have by the time they reach age 50 if they were to give birth at the current age-specific fertility rates was used to estimate the current fertility level of ever-married women (Croft et al., 2018).

TFR was calculated as:

$$TFR = \sum_{\alpha=15-19}^{45-49} ASFR \times 5\,, \tag{2}$$

where, ASFR is the age-specific fertility rate for ever-married women whose age corresponds to the five-year age groups covering the reproductive years 15–49. As a convention, the following five-year age groups were used (15–19, 20–24, 25–29, 30–34, 35–39, 40–44, and 45–49). The ASFR was calculated as the number of live births per 1000 ever-married women in a specific age group (in five-year age groups) in the period 1 to 36 months preceding the 2017 GMHS, divided by the number of women of that age group in the same period. ASFR is calculated as follows:

$$ASFR = \frac{b_i}{p_i} \times 1\,000\,, \tag{3}$$

where, b_i is the number of live births to ever-married women in a specified age group i and p_i is the number of women in the same age group i (15–19, 20–24, 25–29, 30–34, 35–39, 40–44, and 45–49). ASFRs were calculated for the three years preceding the 2017 GMHS survey based on interview date and detailed birth histories (i.e., birth date of each woman (whether or not she has given birth) and birth dates of children). TFRs were computed using a Stata module by Schoumaker (2013).

1.4 Generalized Poisson Regression Model

Total fertility of a woman is often modeled using children ever born (CEB) data as the dependent variable. The relationship between total fertility and other socioeconomic and demographic variables of women was modeled using the generalized Poisson regression (GPR) model given by Frome et al. (1973), and proposed by Famoye (1993). The distribution of the generalized Poisson regression model has a probability density function given by:

$$f(y_i,\alpha,\mu_i)=\left(\frac{\mu_i}{1+\alpha\mu_i}\right)^{y_i}\frac{(1+\alpha y_i)^{y_i-1}}{y_i!}\exp\left[\frac{-\mu_i(1+\alpha y_i)}{1+\alpha\mu_i}\right],\; y=0,1,2,3,\ldots n\,, \tag{4}$$

where, α is a dispersion parameter and the expected value and variance of the CEB count variable (y) conditional on a set of explanatory variables x_i (age, age at first marriage, women's educational level, women's income, women's employment status, area of residence, etc.,) is modeled as:

$$E(Y_i\,|\,x_i)=\mu_i\,, \tag{5}$$

$$V(Y\,|\,x_i)=\mu_i(1+\alpha\mu_i)^2\,. \tag{6}$$

When the dispersion parameter α = 0, the probability function in (2) reduces to the Poisson regression (PR) model. When α>0, the GPR model represents CEB count data with over-dispersion and when α<0, the GPR model represents CEB count data with under-dispersion.

The mean of the dependent variable (CEB) is denoted as $\mu_i=\mu_i(x_i)=\exp(x_i\beta)$, where x_i is a (k–*1*) dimensional vector of covariates and β is a k dimensional vector of regression coefficients. The estimation of the regression coefficients β is obtained by the maximum likelihood approach. The log-likelihood function of the GPR model is written as:

$$\text{Ln}\;L(\alpha,\beta;y_i)=\left[y_i\log\left(\frac{\mu_i}{1+\alpha\mu_i}\right)+(y_i-1)\log(1+\alpha y_i)-\frac{\mu_i(1+\alpha y_i)}{1+\alpha\mu_i}-\log(y_i!)\right]. \tag{7}$$

1.5 Goodness of Fit and Test for Dispersion

The PR and GPR models were compared using the Akaike Information Criterion (AIC; Akaike, 1974) and the Bayesian Information Criterion (BIC; Schwarz, 1978) goodness-of-fit measures defined as:

$$AIC=2k-2\ln(L), \tag{8}$$

$$BIC=k\ln(n)-2\ln(L), \tag{9}$$

where, L is the likelihood function, k is the number of estimated parameters in the model. The best model was selected based on the minimum AIC and BIC values.

The adequacy of the GPR model over the PR model was assessed by testing the following hypothesis:

$$H_0:\alpha=0,\; H_a:\alpha\neq 0. \tag{10}$$

This test of hypothesis determines whether the dispersion parameter (α) is statistically different from zero. The rejection of H_0 recommends the use of the GPR model rather than the standard Poisson regression model. The asymptotic normal Wald *t*-statistic was used to test for the significance of the dispersion parameter. The statistic is computed as:

$$W = \frac{\hat{\alpha}}{se(\hat{\alpha})}, \tag{11}$$

where, $\hat{\alpha}$ is the maximum likelihood estimate of α and *see* $(\hat{\alpha})$ is its corresponding standard error. The Wald *t*-statistic was compared with the *t*-distribution with $n–k–1$ degrees of freedom, where k is the total number of parameters in the GPR model.

Interpretation of the coefficients of the generalized Poisson regression model was done using incidence rate ratios (IRRs). The IRRs were obtained by exponentiating the regression coefficients of the generalized Poisson Regression model.

All analyses were conducted using Stata version 14.0 (StataCorp, College Station, Texas 77845 USA).

2 RESULTS

2.1 Current Fertility and Trends

The results from the descriptive statistics showed that the mean number of children ever born (CEB) to ever-married woman age 15–49 during the 2017 Ghana Maternal Health Survey (GMHS) was 3.2 (Table 2). The results also indicate that the mean age among women was 33.8 years and the mean age

Table 2 Description of key characteristics used in the analysis (sample size = 17 126)

Characteristics	Proportion of 1's	Characteristics	Proportion of 1's
Age		**Area of residence**	
15–19	0.0236	Urban	0.5137
20–24	0.1217	Rural	0.4863
25–29	0.1900		
30–34	0.1977	**Region**	
35–39	0.1863	Western	0.1246
40–44	0.1430	Central	0.0918
45–49	0.1349	Greater-Accra	0.1688
Mean $\pm\sigma$: 33.78 ± 8.25		Volta	0.0822
		Eastern	0.1014
Age at first marriage		Ashanti	0.1878
>15 years	0.0953	Brong Ahafo	0.0961
15–19 years	0.4076	Northern	0.0822
20–24 years	0.3079	Upper-East	0.0382
<24 years	0.1893	Upper-West	0.0269
Mean $\pm\sigma$: 20.26 ± 5.02			
		Contraceptive use	
Education		Never used contraceptive	0.7057
No Education	0.2546	Ever used contraception	0.2943
Primary	0.5643		
Secondary	0.1179	**Financial inclusion**	
Tertiary	0.0633	Has no account at the bank	0.3199
Children ever born (CEB)		Has and uses account at the bank	0.6801
Mean $\pm\sigma$: 3.22 ± 2.18			

Table 2 continuation

Characteristics	Proportion of 1's	Characteristics	Proportion of 1's
		Contraceptive use	
Education		Never used contraceptive	0.7057
No Education	0.2546	Ever used contraception	0.2943
Primary	0.5643		
Secondary	0.1179	**Financial inclusion**	
Tertiary	0.0633	Has no account at the bank	0.3199
Children ever born (CEB)		Has and uses account at the bank	0.6801
Mean $\pm\sigma$: 3.22 ± 2.18			
Wealth Quintile			
Lowest	0.1839		
Second	0.1976		
Third	0.2003		
Fourth	0.2090		
Fifth	0.2091		

Source: GMHS author's calculation

at first marriage was 20.3 (Table 2). The low age at first marriage suggests a high level of fertility among the respondents in the survey. The results further revealed that about a quarter (26%) of the women aged between 15 and 49 years had no formal education and more than half (56%) of the sampled women had primary education (Table 2). This partly explains why the age at first marriage is quite low, since women with low levels of education are more likely to marry earlier than their more educated counterparts. Arguably, women who marry at a younger age are also likely to give birth to more children than women who marry at a late age. Table 2 also shows that, about 15% of the women interviewees within the childbearing age of 15–49 years, were living in the three Northern Regions of Ghana (Northern, Upper East and Upper West), where prevalence of poverty is the highest in the country. In addition, about 49% of the sampled women lived in rural areas, which was also observed to have a higher poverty rate than urban areas. The proportion of women in the poorest wealth quintile was about 18% (Table 2). It is worth noting that a large proportion (71%) of the women had never used any family planning method (Table 2). This may probably be due to the fact that socio-cultural, religious norms and practices impact significantly on the use of contraception in most developing countries, including Ghana.

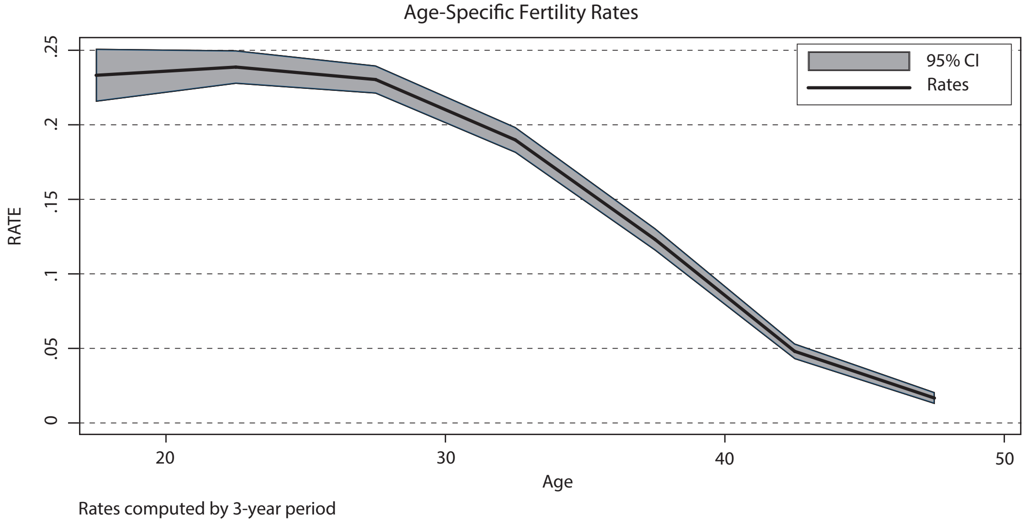
The results in this study also showed that age-specific fertility rates (ASFRs) for the 3 years preceding the 2017 survey peaked among women between 25 and 29 years and declined with age thereafter (Figure 1). This is a clear indication that, starting from age 15, a woman's fertility increases up to a point and then declines. Total fertility rates (TFRs) for the three years preceding the 2017 survey and the mean number of children born to ever married women aged between (15–49 years) for some key socio-demographic characteristics are presented in Table 3. The results indicate that the overall total fertility rate for ever-married women in Ghana is 5.4 children per woman, with rural women having 5.7 children compared to 5.1 children for urban women (Table 3). This is a slight decrease from 5.9 children per woman in 2014 (DHS 2014 – the preceding demographic health survey) which indicates that on average, a woman who has ever been married in Ghana is likely to give birth to 5.4 children by the end of her child bearing years, with higher fertility levels for women living in the rural areas. The high level of fertility rate among ever-married women has important implications for family planning. Ever married women with no formal education have a higher TFR of 6.0 compared to those with tertiary level of education, who have a TFR of 4.8 (Table 3). This indicates that the lower the level of a woman's educational attainment, the more children she is likely to bear over her lifetime and vice versa. It also means that, the TFR of women in this study is inversely related to their educational attainment. Regional differences in TFR were also observed among the women within the child bearing age range of 15–49. The results showed that the Northern Region had the highest fertility rate of 6.7 compared to 4.6 for the Greater Accra Region (Table 3). This may probably be due to prevailing factors such as the low use of and/or access to contraceptives, persistent poverty, low levels of education, early marriages and religious and cultural factors in the Northern Region. Results from this study also indicate that, in Ghana the TFR for women who have ever been married decreases with increasing wealth, from 6.5 births among women in the poorest wealth quintile to 4.4 births among women in the richest wealth quintile (Table 3). These results point to a negative relationship between household wealth and fertility of women in their child bearing years. The results further showed that, contrary to expectations, fertility trends among ever married women in Ghana has increased by about 15% from 4.6 births per woman in 2002 to 5.4 births per woman in 2017 (Figure 2). This may probably be due to the low levels of contraceptive use, cultural and religious beliefs among married women in most parts of sub-Saharan Africa, including Ghana.

Table 3 Total fertility rate and mean number of children ever born (CEB) to ever-married women age 40–49, according to background characteristics, Ghana MHS 2017

Characteristics	Total fertility rate (TFR)	Mean number of CEB to ever-married women age 40–49
Education		
No education	6.0	5.6
Primary	5.3	4.5
Secondary	4.6	3.1
Tertiary	4.8	2.7
Area of residence		
Urban	5.1	3.9
Rural	5.7	5.6
Region		
Western	5.7	4.9
Central	5.6	5.2
Greater Accra	4.6	3.4
Volta	5.4	4.7
Eastern	5.2	4.6
Ashanti	5.5	4.6
Brong-Ahafo	5.3	5.1
Northern	6.7	6.3
Upper East	5.7	5.5
Upper West	5.6	5.9
Wealth Quintile		
First	6.5	6.3
Second	5.7	5.5
Third	5.2	4.9
Fourth	4.8	4.1
Fifth	4.4	3.1
Total fertility rate (TFR)	5.4	4.7

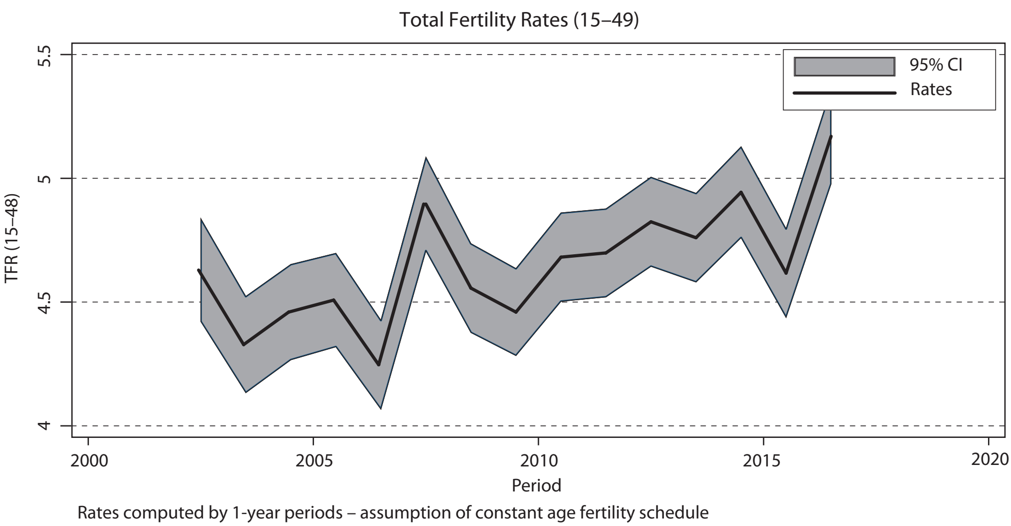
Note: Total fertility rate (TFR) of ever-married women for age 15–49 years are for the periods 1–36 months prior to interview.
Source: GMHS author's calculation

Figure 1 Age-specific fertility rate for the 3-year period preceding the survey, Ghana 2017 MHS



Source: GMHS author's calculation using the TFR STATA module by Schoumaker (2013)

Figure 2 Total marital fertility rate (15–49) for the 15 calendar years preceding the survey, Ghana 2017 MHS



Source: GMHS author's calculation using the TFR STATA module by Schoumaker (2013)

2.2 Multivariate analysis of fertility: comparison of the Poisson and Generalized Poisson Regression Models

The regression coefficients of the parameters, their standard errors and z-values of both the PR and the GPR models are presented in Table 4. Goodness-of-fit measures such as Akaike's Information Criteria (AIC) and the Schwarz's Bayesian Information Criteria (BIC) are also given in Table 4. The results showed similar parameter estimates for both models, with the GPR depicting lower standard errors compared to the PR (Table 4). This means that although estimates from both models are consistent, the GPR model obtained more precise estimates of the relationship between total household fertility and its determinants than the PR model. Estimates for the goodness-of-fit measures (AIC and BIC) also showed that the GPR model provided a better fit for the household fertility data than the PR model. For instance, the GPR model had smaller AIC (GPR = 57 072.32; PR= 58 344.53) and BIC (GPR = 57 258.28; PR = 58 522.747) values than the PR model (Table 4). The results further revealed that, in both the PR and GPR models, almost all the variables used in the study were significant at $p<0.05$ level for six (6) out of ten regions, with the exception of the Eastern, Ashanti, Brong Ahafo and Northern Regions (Table 4). The results also showed that, the variables: age; having and using a bank account; living in a rural area; and using a family planning method; have significant and positive effects on total fertility (Table 4). This suggests that, for example, the total fertility rate of women living in rural areas may be higher than that of their counterparts living in the urban areas.

The results of the test for the dispersion parameter (δ) which shows whether the mean is greater, equal to or less than the variance are presented in Table 5. The results showed that the estimated dispersion parameter from the generalized Poisson regression model was negative (–0.2360), which is an indication of under-dispersion (Table 5). This means that the variance of the Poisson distribution was smaller than its mean suggesting that there was less variation in the data than predicted. The asymptotic chi-square distribution of the likelihood ratio test statistic with 1 degree of freedom for testing the null hypothesis of (δ) = 0 was 1 274.21 and the dispersion parameter which is used to assess the adequacy of the GPR model over the PR model, was significantly different from zero ($p<0.001$, Table 5), indicating that the PR is not a suitable model for the 2017 Ghana household fertility data used.

Table 4 Determinants of fertility: estimates of Poisson and Generalized Poisson Regression Models

Characteristic	Poisson Regression (PR)			Generalized Poisson Regression (GPR)		
	Estimate	Standard error (SE)	*Wald z*-value	Estimate	Standard error (SE)	*Wald z*-value
Constant	–2.6146	0.0918	–28.47*	–2.6216	0.0734	–35.69*
Age	0.2219	0.0051	43.29*	0.2189	0.0041	53.36*
Age squared	–0.0024	0.0001	–34.09*	–0.0024	0.0001	–41.64*
Age at first marriage	–0.0323	0.0010	–33.82*	–0.0300	0.0008	–39.75*
Education						
No education (ref)						
Primary	–0.0690	0.0108	–6.36*	–0.0709	0.0089	–8.00*
Secondary	–0.2478	0.0202	–12.28*	–0.2600	0.0165	–15.80*
Tertiary	–0.2613	0.0278	-9.39*	–0.2848	0.0228	–12.51*
Area of residence						
Urban (ref)						
Rural	0.0338	0.0110	3.07*	0.0352	0.0089	3.96*
Region						
Western (ref)						
Central	0.0372	0.0184	2.02*	0.0441	0.0150	2.94*
Greater Accra	–0.0879	0.0181	–4.86*	–0.0854	0.0148	–5.79*
Volta	–0.0704	0.0190	–3.69*	–0.0677	0.0156	–4.33*
Eastern	–0.0296	0.0181	–1.63	–0.0238	0.0148	–1.60
Ashanti	0.0161	0.0159	1.01	0.0216	0.0130	1.67
Brong-Ahafo	–0.0177	0.0183	–0.97	–0.0179	0.0150	–1.19
Northern	0.0230	0.0195	1.18	0.0185	0.0161	1.15
Upper East	–0.1664	0.0258	–6.45*	–0.1360	0.0188	–7.22*
Upper West	–0.0866	0.0280	–3.09*	–0.0843	0.0231	–3.65*

Table 4 continuation

Characteristic	Poisson Regression (PR)			Generalized Poisson Regression (GPR)		
	Estimate	Standard error (SE)	*Wald z*-value	Estimate	Standard error (SE)	*Wald z*-value
Wealth Index						
Lowest (ref)						
Second	–0.1125	0.0139	–8.11*	–0.1045	0.0114	–9.17*
Third	–0.1891	0.0155	–12.22*	–0.1788	0.0125	–14.28*
Fourth	–0.2803	0.0174	–16.08*	–0.2772	0.0143	–19.41*
Fifth	–0.3772	0.0207	–18.22*	–0.3721	0.0169	–21.97*
Contraceptive use						
Never used contraceptive (ref)						
Ever used contraceptive	0.1421	0.0095	14.89*	0.1255	0.0079	15.95*
Financial inclusion						
Has no account at bank (ref)						
Has and uses account at the bank	–0.0783	0.0115	–6.81*	–0.0717	0.0092	–7.82*
Goodness-of-fit						
Log-likelihood		–29 149.2640			–28 512.1610	
AIC		58 344.5300			57 072.3200	
BIC		58 522.7400			57 258.2800	

Note: * significant at *p<0.05* level
Source: GMHS author's calculation

Table 5 Test for dispersion for a Generalized Poisson Regression Model

Statistic	Estimate
Dispersion parameter (δ)	–0.2099±0.0048
Likelihood-ratio test of (δ) = : chi2(1)	1 274.2100
Prob> = chi2	0.0000

Source: GMHS author's calculation

2.3 Demographic and socio-economic determinants of fertility

For an easy interpretation of the regression coefficients of the explanatory variables used, incidence rate ratios (IRR) of the generalized Poisson regression model are presented in Table 6. The results showed that age was significant ($p<0.05$) and positively related to the number of children ever born to ever married women in this study (Table 4). This indicates that number of children ever born to women increases with age. The coefficient of age squared was also significant at $p<0.05$ and indicates that the relationship between age and number of children ever born to women is not linear. The positive coefficient for age and the negative coefficient for age squared suggest that number of children ever born increases with age until it reaches a point (peak) and then declines thereafter. Based on the IRR results in Table 6, on average, a one year increase in age increased the number of children ever born to a woman by a factor of 1.2447 or 25%, holding all other variables constant and the effect was statistically significant at ($p<0.05$).

A woman's age at first marriage was inversely related to the number of children ever born and significant at $p<0.05$ (Table 4). The results further showed that a one year increase in age at first marriage reduced the number of children ever born by a factor of 0.9705 or 3%, while holding all other variables constant

(Table 6). This implies that as age at first marriage increases, the number of children ever born to a woman decreases. The results further revealed that, a woman's highest educational level was statistically significant and negatively related to the number of children ever born (Table 4), indicating that more educated women have less children. Based on the results in Table 6, women with tertiary education had about 25% less children than women with no education. This suggests that women with no formal education or low levels of education are likely to have more children than their highly educated counterparts.

The results also showed that the effect of women who reside in rural areas on the number of children ever born was significant ($p<0.05$) and positive. This indicates that women in rural areas give birth to more children on average than women who reside in urban areas. A finding that may be attributable to factors such as: low levels of education; early ages at first marriage; no or low use of contraceptives; and low standards of living. Regional differences were also observed for number of children ever born to ever married women in this study. For instance, the results in Table 6 indicate that ever married women who live in the Northern region of Ghana had about 2% more children than those living in the Western region.

The generalized Poisson regression analysis also showed that wealth index (type of consumer goods owned) was significantly ($p>0.05$) and inversely related to the number of children ever born (Table 4). Rich women had 31% less children than poor women (Table 6). This implies that, as the wealth index increases, women who are in the richest wealth quintile are more likely to have less children than those in the poorest wealth quintile.

The analysis further showed that the effect of having and using a bank account on the number of children ever born to ever married women was negative and statistically significant (Table 4). Women who had accounts at banks or financial institutions had about 7% less children than those who did not have and use a bank account (Table 6). This shows that women who are economically empowered have less children than those who are not. This is because economically empowered women tend to have greater access to income and equal opportunities in decision making, especially relating to the number of children they want to have.

The results also showed that the effect of contraceptive use on the number of children ever born was positive and significant ($p<0.05$, Table 4). Women who had ever used contraceptives had 13% more children than those who had never used contraceptives. One good reason for this paradox could be that ever-married women in Ghana only use contraceptives when they have had their desired number of children, indicating low contraceptive prevalence in this study.

Table 6 Incidence Rate Ratios: Generalized Poisson Regression Model

Characteristic	**Incidence Rate Ratios (IRR)**		
	Estimate	**Standard error (SE)**	***Wald z*-value**
Constant	0.0727	0.0053	–35.69*
Age	1.2447	0.0051	53.36*
Age squared	0.9976	0.0001	–41.64*
Age at first marriage	0.9705	0.0007	–39.75*
Education			
No education (ref)			
Primary	0.9316	0.0083	–8.00*
Secondary	0.7710	0.0127	–15.80*
Tertiary	0.7521	0.0171	–12.51*
Area of residence			
Urban (ref)			
Rural	1.0359	0.0092	3.96*

Table 6			continuation
Characteristic	**Incidence Rate Ratios (IRR)**		
	Estimate	**Standard error (SE)**	***Wald z*-value**
Region			
Western (ref)			
Central	1.0450	0.0157	2.94*
Greater Accra	0.9181	0.0135	–5.79*
Volta	0.9345	0.0146	–4.33*
Eastern	0.9765	0.0145	–1.60
Ashanti	1.0219	0.0133	1.67
Brong-Ahafo	0.9823	0.0148	–1.19
Northern	1.0187	0.0164	1.15
Upper East	0.8728	0.0164	–7.22*
Upper West	0.9192	0.0212	–3.65*
Wealth Quintile			
Lowest (ref)			
Second	0.9007	0.0103	–9.17*
Third	0.8363	0.0105	–14.28*
Fourth	0.7579	0.0108	–19.41*
Fifth	0.6893	0.0117	–21.97*
Contraceptive use			
Never used contraceptive (ref)			
Ever used contraceptive	1.1338	0.0089	15.95*
Financial inclusion			
Has no account at bank (ref)			
Has and uses account at the bank/financial institution	0.9308	0.0085	–7.82*
Goodness of fit tests			
Log-likelihood		–28 512.1610	
AIC		57 072.3200	
BIC		57 258.2800	

Note: * significant at $p<0.05$ level
Source: GMHS author's calculation

3 DISCUSSION

The study estimated current fertility levels and trends of ever married women in Ghana and assessed the influence of socio-economic and demographic characteristics on household fertility using the generalized Poisson regression model.

3.1 Current fertility and trends

Total fertility rate (TFR) is a standard measure of population growth that has been widely used to measure the average number of children per woman during her reproductive years. Currently, fertility rates are declining globally, however, marked differences between fertility levels in developed and developing countries have been observed, with an estimated high total fertility rate of 4.6 births per woman in sub-Saharan African compared to about 1.6 births per woman in developed countries (UN DESA, 2020). Possible reasons given for the high fertility rates in sub-Saharan countries include low use of contraceptives, early marriages and generally lower levels of female education (Nargund, 2009). The high fertility rates observed in sub-Saharan countries is purported to give rise to continued rapid population growth, poverty, low educational attainment, low family incomes, poor health, and lack of access to education (Birdsall and Griffin, 1988; Trends, 2017). The results in this study indicate that the TFR of 5.4 children per woman among ever married women in Ghana is high. The results also showed substantial socioeconomic and geographical variations in fertility rates. For instance, the fertility rate among women who resided in rural areas (5.7) was relatively higher than those who dwelt in urban areas (5.1). Similar results have been reported by Shapiro and Tambashe (2002) for sub-Saharan Africa.

Contrary to numerous reports on declining global fertility trends (UN DESA, 2017), stalling fertility trends – "a change from downward fertility trends to flat or even slightly rising trends for usually a few years" (Garenne, 2008) have been observed in sub-Saharan Africa (Schoumaker, 2019; Sayi, 2015; Agyei-Mensah, 2007). The fertility trend in this study depicts a slightly rising trend, with an increase of about 15% from year 2002 to year 2016. The results are consistent with findings by Shapiro and Gebreselassie (2007), Garenne (2008), and Bongaarts (2006) which show stalling of fertility decline based on fertility data from some countries in sub-Saharan Africa. Likely causes of stalled fertility declines observed in sub-Saharan Africa have been associated with demographic, socio-economic and proximate determinants of fertility such as decline in income per capita, less contraceptive use, low child mortality and stall in trends of education (Bongaarts, 2006; Kebede et al., 2019).

3.2 Multivariate analysis of fertility: comparison of the Poisson and Generalized Poisson Regression Models

In situations where under-dispersion or over-dispersion occur in the analysis of count data, Wang and Famoye (1997), Famoye (2015), Singh (2000), and Harris and Yang (2012) suggest that the use of the generalized Poisson regression model provides a better alternative to the standard Poisson regression model. The reasons being that GPR is able to adequately accommodate for under-dispersion or over-dispersion in the analyses of count data and that GPR has statistical advantages over the standard Poisson regression model. Multivariate analysis of this study revealed that the estimated dispersion parameter in the GPR model was negative and significant at $p<0.05$. This means that the conditional variance of the dependent variable (number of children ever born) given selected explanatory variables was significantly smaller than the associated conditional mean (an indication of under-dispersion) and implies that the generalized Poisson regression model is an appropriate model for the fertility data used in the study. The results further revealed that although both models provided similar parameter estimates, the standard errors of the PR model were over-estimated due to the presence of under-dispersion. Furthermore, the smaller values of the goodness-of-fit measures (AIC and BIC) for the GPR model showed that it offered a better fit to the data compared to the standard Poisson regression model. These results are consistent with findings by Wang and Famoye (1997), and Harris and Yang (2012) who modeled under-dispersed count data using the generalized Poisson model.

3.3 Demographic and socio-economic determinants of fertility

Typically, the educational attainment of a woman is expected to be directly related to her opportunity cost of time and inversely related to her fertility decision (Becker, 1981; Wang and Famoye, 1997). The results of this study indicate that the educational level of ever married women was statistically significant and negatively related to fertility. This suggests that the higher the educational level of a woman the less children she is likely to bear during her lifetime. These results are consistent with empirical evidence reported by Ali and Gurma (2018), and Monstad et al. (2008). Contrary to expectations, a number of studies have revealed that education does not have a uniform inverse relationship with fertility. Empirical findings indicate that conditioned on "society's socio-economic development, social structure, cultural context and stage in the fertility transition", education is positively related with fertility at lower levels of education in sub-Saharan Africa (Martin, 1995). Others have also found that education's relationship with fertility is generally weak in poor, illiterate and rural societies and grows stronger in more prosperous societies (Diamond et al., 1999; United Nations, 1995).

The average woman's best reproductive years are in her 20s and gradually decline in the 30s, particularly after age 35 (Dunson et al., 2002). Age at first marriage is therefore an important determinant of fertility for ever-married women and has important implications for population growth (Bongaarts et al., 1984). According to results from a United Nations report, a younger age at marriage is associated with high fertility rates because women who marry at younger ages are exposed to a longer childbearing period and are likely to bear more children than their older counterparts (UN DESA, 2014). The results in this study showed that a woman's age at first marriage was significantly and inversely related to her fertility. This suggests that women who marry at a younger age are likely to give birth to more children than women who marry late. Similar results have been reported by Nag and Singhal (2013), Palamuleni (2011), Solanke (2015), Kabir et al. (2001), Bongaarts (1982).

Rural–Urban fertility differences have been found in a number of studies, making area of residence a major determinant of fertility (Shapiro and Tenikue, 2017; Eloundou-Enyegue and Giroux, 2012; Casterline, 2015; Yousif, 2001). Women who live in rural areas are expected to have more children than those who live in urban areas because of the *high* direct financial cost of raising children in urban areas and the opportunity costs involved in moving the children from farm to urban areas (Learch, 2019). According to Becker (1976, p. 190), it is cheaper to raise children on a farm than in an urban community. The results of this study showed that the relationship between women who resided in rural areas and fertility was significant and positive, indicating that women who live in rural areas have higher fertility than urban women. This is in agreement with studies by Casterline (2015), and Yousif (2001; 1996) who suggest that low levels of education, low use of contraceptives and early marriages by rural women could be possible reasons for the rural-urban differences in fertility.

The relationship between wealth and fertility vary substantially across societies, with a more positive effect in high fertility areas (Colleran and Snopkowski, 2018). A significant and inverse relationship between household wealth and fertility was observed in this study. This finding indicates that women in the poorer quintiles are likely to give birth to more children thereby having higher fertility than women in the richer quintiles. Similar results have been reported (Mansanja et al., 2016; Colleran and Snopkowski, 2018) and are also in line with Becker and Lewis's economic fertility model that predicts a likely substitution effect from quantity to quality of children with rising family wealth. A possible reason could be that poor women consider children as household assets and forms of investment, thus egging them on to have more children. Conversely, other studies have found that the relationship between wealth and fertility is much more likely to be positive than negative (Stulp and Barret, 2016). This variation may generally be associated with cultural, religious, demographic and socio-economic backgrounds that pertain in different societies (Higgins, 2015; Ezeh et al., 2009; Stulp and Barret, 2016).

Empirical analyses have also shown that at higher levels of financial development, women prefer to trade quantity of children for quality of children (Idris et al., 2018). Studies by Becker and Lewis (1973), and Wang and Famoye (1997), have emphasized that an increase in quality per child implies an increase in costs of raising a child which decreases fertility. The results of this study revealed that ownership and use of bank accounts by an ever-married woman was significantly and negatively related to fertility. The results suggest that a woman's ownership and use of a bank account is associated with lower fertility. Studies by Filoso and Papagni (2011), Lehr (1999), Cigno and Rosati (1992) have confirmed that having access to the financial market is inversely related to the fertility decisions of women. One explanation for the inverse relationship between a woman's ownership and use of a bank account and fertility is that, as her financial situation improves, a woman prefers to have less but higher quality children.

Several studies have established that an inverse relationship exists between contraceptive use and fertility rates with women who ever used contraceptives having less children than those who never used contraceptives (Becker and Costenbader, 2001; Ross and Winfrey, 2002). Contraceptive use has therefore, become a major determinant of fertility due to its ability to reduce the world's total fertility rate (Creanga et al., 2011). Contrary to these findings, results in this study showed that women who had ever used contraceptives had more children ever born than those who did not use contraceptives, suggesting that they probably used contraceptives after they had their desired number of children. Similar patterns have been observed in studies by Gyimah et al. (2012), UN DESA (2015), Howse and Nanitashvili (2014), and Wang et al. (2017). The positive relationship between contraceptive use and fertility among ever-married women in sub-Saharan Africa, primarily results from sociocultural factors that undermine the relevance of family planning services and encourage high levels of fertility (Gyimah et al., 2012; Ekane, 2013).

CONCLUSION

Undertaking research to acquire information on the key socio-economic and demographic factors that influence fertility trends and dynamics is essential in monitoring population growth and developing policies and programs that aim at managing a nation's population. This study estimated the current fertility level and trend of ever-married women between the ages of 15 and 49 years and modeled the socio-economic and demographic determinants of household fertility using the generalized Poisson regression model. The results presented showed that the current fertility level for ever-married women in Ghana is 5.4, which is quite high according to United Nations (UN) underlying definition which states that, "high fertility is total fertility levels above 5 children per woman". In addition, a stall in fertility trend was observed which is consistent with previous results in sub-Saharan African countries. The generalized Poisson regression model was used to identify some of the key socio-economic and demographic factors influencing the high fertility level and stall in fertility trend. The results revealed that, lack or low levels of education, early ages at first marriage, belonging to the poorer household wealth quintiles, dwelling in a rural area, not using contraceptives, not owning and using a bank account contributed to the high fertility level observed in this study. The multivariate analysis has thus provided a clearer picture of the key socio-economic and demographic factors influencing the high fertility level than can be obtained from analysis of total fertility rates.

It is recommended that, cross-sectoral engagement between the National Population Council and the ministries responsible for health, education, gender and employment can help decision-makers to design efficient and effective coherent policies aimed at reducing the prevailing high fertility levels and hence the population growth. For instance, policies that promote longer periods spent schooling might prevent women from engaging in early marriages. Early marriages, generally expose women to a longer childbearing period which can result in high fertility rates. Promotion of higher educational attainment levels may also offer better access to economic and social opportunities. At medium or high levels of economic and social development, children will no longer be considered as economic assets and forms of investment as economically advantaged women will substitute quantity of children with quality. Perhaps, more educated women who have better access to economic and social opportunities may take control of their fertility decisions by using contraceptives to reduce high fertility levels and hence population growth. Lastly, empowering women through financial inclusion (e.g., owning and using a bank account) could help women to make their own fertility decisions and have less children.

ACKNOWLEDGEMENTS

I am grateful to Professor Bruno Schoumaker for providing me with useful information on the calculation of TFRs using STATA.

References

AKAIKE, H. A new look at the statistical model identification. *IEEE Transactions on Automatic Control,* 1974, 19(6), pp. 716–723. doi:10.1109/TAC.1974.1100705, MR 0423716

AGYEI-MENSAH, S. New times, new families: the stall in Ghanaian fertility. In: *African Population Conference*, Arusha, Tanzania, 2007.

ALI, F. R. M. AND GURMU, S. The impact of female education on fertility: a natural experiment from Egypt. *Review of Economics of the Household*, 2018, 16(3), pp. 681–712.

BECKER, S. AND COSTENBADER, E. Husbands' and Wives' Reports of Contraceptive Use. *Studies in Family Planning,* 2001, 32(2), pp. 111–129.

BECKER, G. S. *A treatise on the family*. Cambridge, MA: Harvard University Press, 1981.

BECKER, G. S. *The economic approach to human behavior*. Chicago, IL: The University of Chicago Press, 1976.

BECKER, G. S. AND LEWIS, H. G. On the interaction between the quantity and quality of children. *Journal of Political Economy,* 1973, 81, pp. 279–288.

BIJLSMA, M. J. AND WILSON, B. A new approach to understanding the socio-economic determinants of fertility over the life course. *Stockholm Research Reports in Demography*, 2017, 8.

BIRDSALL, N. M. AND GRIFFIN, C. C. Fertility and poverty in developing countries. *Journal of Policy Modeling*, 1988, 10(1), pp. 29–55.

BONGAARTS, J. The effect of contraception on fertility: Is sub-Saharan Africa different? *Demographic Research*, 2017, 37, pp. 129–146.

BONGAARTS, J. The causes of stalling fertility transitions. *Studies in Family Planning,* 2006, 37(1), pp. 1–16.

BONGAARTS J., FRANK, O., LESTHAEGHE, R. The proximate determinants of fertility in sub-Saharan Africa. *Population and Development Review*, 1984, 10(3), pp. 511–537.

BONGAARTS, J. The Fertility Inhibiting Effects of the Intermediate Fertility Variables. *Studies in Familiy Planning*, 1982, 13, pp. 179–189.

CAMERON, A. C. AND TRIVEDI, P. K. *Regression Analysis of Count Data*. New York, NY: Cambridge University Press, 1998.

CIGNO, A. AND ROSATI, F. C. The effects of financial markets and social security on saving and fertility behaviour in Italy. *Journal of Population Economics*, 1992, 5(4), pp. 319–341.

CASTERLINE, J. B. Fertility Transition: Middle East and North Africa. In: *International Encyclopedia of the Social & Behavioral Sciences*, 2015, pp. 73–79.

CLIFTON, D. AND FROST, A. *World's women and girls, 2011 data sheet*. Washington, DC: Population Reference Bureau, 2011.

COLLERAN, H. AND SNOPKOWSKI, K. Variation in wealth and educational drivers of fertility decline across 45 countries. *Population Ecology*, 2018, 60(1–2), pp. 155–169.

CREANGA, A. A., GILLESPIE, D., KARKLINS, S., TSUI, A. O. Low use of contraception among poor women in Africa: an equity issue. *Bulletin of the world Health Organization*, 2011, 89, pp. 258–266.

CROFT, T. N., AILEEN, M. J., MARSHALL, COURTNEY K. A. ET AL. *Guide to DHS Statistics*. Rockville, Maryland, USA: ICF, 2018.

DIAMOND, I., NEWBY, M., VARLE, S. Female education and fertility: Examining the evidence. In: BLEDSOE, C. AND CASTERLINE, J. (eds.) *Women's education and fertility in developing countries*, Washington, DC: National Academy Press, 1999.

DUNSON, D. B., COLOMBO, B., BAIRD, D. D. Changes with age in the level and duration of fertility in the menstrual cycle. *Human reproduction*, 17(5), 2002, pp. 1399–1403.

EKANE, D. *Fertility trends in sub Saharan Africa* [online]. Unpublished doctoral dissertation, Department of Social Work, Stockholm University, 2013. <http://urn.kb.se/resolve?urn=urn:nbn:se:su:diva-87305>.

ELOUNDOU-ENYEGUE, P. AND GIROUX, S. Demographic Change and Rural-Urban Inequality in Sub-Saharan Africa: Theory and Trends. In: KULCSÁR LÁSZLÓ, J. AND CURTIS KATHERINE, J. (eds.) *International Handbook of Rural Demography,* Heidelberg London, New York: Springer Dordrecht, 2012, pp. 125–135.

EZEH, A. C., MBERU, B. U., EMINA, J. O. Stall in fertility decline in Eastern African Countries: regional analysis of patterns, determinants and implication. *Philosophical Transactions of the Royal Society B: Biological Sciences,* 2009, 364*(*1532), pp. 2991–3007.

FAMOYE, F. A multivariate generalized Poisson regression model. *Communications in Statistics-Theory and Methods*, 2015, 44(3), pp. 497–511.

FAMOYE, F. AND WANG, W. Censored generalized Poisson regression model. *Computational statistics & data analysis*, 2004, 46(3), pp. 547–560.

FAMOYE, F. Restricted generalized Poisson regression model. *Communications in Statistics – Theory and Methods*, 1993, 22, pp. 1335–1354.

FILOSO, V. AND PAPAGNI, E. *Fertility choice and financial development (No. 2)*. Belgium: Economics and Econometrics Research Institute, 2011.

FROME, E. L., KUTNER, M. H., BEAUCHAMP, J. J. Regression analysis of Poisson distributed data. *Journal of the American Statistical Association*, 1973, 68, pp. 935–940.

GARENNE, M. Situations of fertility stall in sub-Saharan Africa. *African Population Studies,* 2008, 23(2).

GARENNE, M. Age at marriage and modernisation in sub-Saharan Africa. *Southern Africa Journal of Demography*, 2004, 9(2), pp. 59–79.

GHANA STATISTICAL SERVICE (GSS), GHANA HEALTH SERVICE (GHS). *Ghana Maternal Health Survey 2017*. Accra: GSS, GHS and ICF, 2018.

GLENN, J. C., GORDON, T. J., FLORESCU, E. *State of the Future*. Washington, DC: The Millenium Project, 2014.

GYIMAH, S. O., ADJEI, J. K., TAKYI, B. K. Religion, Contraception, and Method Choice of Married Women in Ghana [online]. *Journal Religion Health*, 2012, 51, pp. 1359–74. <https://doi.org/10.1007/s10943-011-9478-4 PMID: 21567266>.

HARRIS, T., YANG, Z., HARDIN, J. W. Modeling underdispersed count data with generalized Poisson regression. *The Stata Journal*, 2012, 12(4), pp. 736–747.

HEAD, S. K., ZWEIMUELLER, S., MARCHENA, C., HOEL, E. *Women's lives and challenges: Equality and empowerment since 2000*. Rockville, MD: ICF International, 2014.

HIGGINS, K. L. *Economic Growth and Sustainability: Systems Thinking for a Complex World.* San Diego, London and Waltham: Elsevier Publishing, 2015.

HOWSE, K. AND NANITASHVILI, N. *Contraceptive Methods by Younger Women: Sub-Saharan Africa* [online]. Population Horizons Factsheet No. 12, 2014. <http://www.ageing.ox.ac.uk/download/150>.

IDRIS, A. R., HABIBULLAH, M. S., DIN, B. H. Does financial development contribute to fertility decline in Malaysia? An empirical investigation. *Journal Ekonomi Malaysia*, 2018, 52(1), pp. 209–221.

JATANA, N. AND CURRIE, A. *Hitting the Targets: the case for ethical and empowering population policies to accelerate progress towards the Sustainable Development Goals.* Population Matters 135–137 Station Road, London, E4 6AG, UK, 2020.

KABIR, A., JAHAN, G., JAHAN, R. Female Age at Marriage as a Determinant of Fertility. *Journal of Medical Sciences,* 2001, 1, pp. 372–376.

KEBEDE, E., GOUJON, A., LUTZ, W. Stalls in Africa's Fertility decline partly result from disruptions in female education. *Proceedings of the National Academy of Sciences*, 2019, 116(8), pp. 2891–2896.

KULU, H. Why Do Fertility Levels Vary between Urban and Rural Areas? *Regional Studies*, 2013, 47(6), pp. 895–912. doi: 10.1080/00343404.2011.581276

LERCH, M. Fertility Decline in Urban and Rural Areas of Developing Countries. *Population and Development Review*, 2019, 45(2), pp. 301–320.

LEHR, C. S. Banking on fewer children: Financial intermediation, fertility and economic development. *Journal of Population Economics*, 1999, 12, pp. 567–590.

MARTIN, T. C. Women's education and fertility: Results from 26 demographic and health surveys. *Studies in Family Planning*, 1995, 26(4), pp. 187–202. doi:10.2307/2137845

MANSANJA, G. F., LWANKOMEZI, E., EMMANUEL, C. The Effects of Declining Fertility on Household Socioeconomic Conditions in Tanzania: A Comparative Study of Urban versus Rural Areas of Kwimba District, Mwanza Region. *International Journal of Population Research,* 2016. doi: 10.1155/2016/4716432

MCCULLAGH, P. AND NELDER, J. A. *Generalized Linear Models*. 2nd Ed. London: Chapman and Hall, 1989.

MELKERSSON, M. AND ROOTH, D. O. Modeling female fertility using inflated count data models. *Journal of Population Economics*, 2000, 13(2), pp. 189–203.

MONSTAD, K., PROPPER, C., SALVANES, K. G. Education and fertility: Evidence from a natural experiment. *Scandinavian Journal of Economics*, 2008, 110(4), pp. 827–852.

MURRAY, C. J., CALLENDER, C. S., KULIKOFF, X. R., SRINIVASAN, V., ABATE, K. H., ABDELALIM, A. Population and fertility by age and sex for 195 countries and territories 1950–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*, 2018, 392(10159), pp. 1995–2051.

NAG, A. AND SINGHAL, P. Impact of education and age at marriage on fertility among Uttar Pradesh migrants of Ludhiana, Punjab, India. *The Anthropologist*, 2013, 15(2), pp. 225–230.

NARGUND, G. Declining birth rate in Developed Countries: a radical policy re-think is required. *Facts, views & vision in ObGyn*, 2009, 1(3), p. 191.

PALAMULENI, M. Socio-Economic and Demographic Determinants of Age at Marriage in Malawi. *International Journal of Sociology and Anthropology*, 2011, 3, pp. 224–235.

PANDEY, R. AND KAUR, C. Modelling fertility: an application of count regression models. *Chinese Journal Population Resource Environment,* 2015, 13(4), pp. 349–357.

ROSS, J. A. AND WINFREY, W. L. Unmet need for contraception in the developing world and the former Soviet Union: an updated estimate. *International Family Planning Perspectives*, 2002, pp. 138–143.

SAYI, T. *Stall in fertility decline in Zimbabwe*. Extended abstract presented at the 7th African Population Conference, Pretoria, South Africa, 2015.

SCHOUMAKER, B. Stalls in Fertility Transitions in sub-Saharan Africa: Revisiting the Evidence. *Studies in family planning*, 2019, 50(3), pp. 257–278.

SCHOUMAKER B. A Stata module for computing fertility rates and TFRs from birth histories: tfr2 [online]. *Demographic Research*, 2013, 28, pp. 1093–144. <https://doi.org/10.4054/DemRes.2013.28.38>.
SHAPIRO, D. AND TENIKUE, M. Women's education, infant and child mortality, and fertility decline in urban and rural sub-Saharan Africa. *Demographic Research*, 2017, 37(21), pp. 669–708.
SHAPIRO, D., KREIDER, A., VARNER, C., SINHA, M. Stalling of fertility transitions and socioeconomic change in the developing world: Evidence from the Demographic and Health Surveys. In: TABUTIN, D. AND MASQUELIER, B. (eds.) Ralentissements, résistances et ruptures dans les transitions démographiques, *Actes de la Chaire Quetelet 2010*, Louvain-la-Neuve, Belgium, Presse de l'Université de Louvain, 2013, pp. 47– 64.
SHAPIRO D. AND TAMBASHE, B. O. Fertility transition in urban and rural sub-Saharan Africa: Preliminary evidence of a three-stage Process. *Journal of African Policy Studies*, 2002, 8(2–3), pp. 105–130.
SCHWARZ, G. Estimating the dimension of a model. *Annals of Statistics,*1978, 6, pp. 461–464.
SINGH, K. P., WULU, J. T., BARTOLUCCI, A. A. *A Note on Generalized Poisson Regression Model* [online]. 2000. <https://www.mssanz.org.au/MODSIM01/Vol%204/Singh2.pdf>.
SOLANKE, B. L. Marriage age, fertility behavior, and women's empowerment in Nigeria. *Sage Open*, SAGE Publications Inc., 2015, 5(4). doi:10.1177/2158244015617989
STULP, G. AND BARRETT, L. Wealth, fertility and adaptive behaviour in industrial populations. P*hilosophical Transactions of the Royal Society B: Biological Sciences*, 2016, 371(1692). doi:10.1098/rstb.2015.0153
TRENDS, G. *Challenges and Opportunities in the Implementation of the Sustainable Development Goals*. United Nations Development Programme and United Nations Research Institute for Social Development, 2017.
UNITED NATIONS DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS (Population Division). *World Fertility and Family Planning 2020: Highlights*. ST/ESA/SER.A/440, 2020.
UNITED NATIONS, DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS (Population Division). *World Population Prospects: The 2019 Revision*. DVD Ed., 2019.
UNITED NATIONS DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS. *Trends in Contraceptive Use Worldwide: 2015* [online]. ST/ESA/SER.A/349, New York: United Nations, 2015. <http://www.un.org/en/development/desa/population/publications/pdf/family/trendsContraceptiveUse2 015Report.pdf>.
UNITED NATIONS, DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS (Population Division). *World Fertility Report 2013: Fertility at the Extremes*. United Nations publication, 2014.
UNITED NATIONS, DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS (Population Division). *World Fertility Report*. *2015 – Highlights*. ST/ESA/SER, 2017.
UNITED NATIONS. *Women's education and fertility behavior: recent evidence from the demographic and health surveys*. New York: United Nations, Population Division, 1995.
WANG, W. AND FAMOYE, F. Modeling household fertility decisions with generalized Poisson regression. *Journal of Population Economics*, 1997, 10, pp. 273–283.
WANG, W., STAVETEIG, S., WINTER, R., ALLEN, C. *Women's marital status, contraceptive use, and unmet need in Sub-Saharan Africa, Latin America, and the Caribbean* [online]. DHS Comparative Report No. 44, Rockville, Maryland: ICF, 2017. <http://dhsprogram.com/pubs/pdf/CR44/CR44.pdf>.
WINKELMANN, R. AND ZIMMERMANN, K. F. Recent developments in count data modelling: Theory and application. *Journal of Economic Surveys,* 1995, 9, pp. 1–24.
WINKELMANN, R. AND ZIMMERMANN, K. F. Count data models for demographic data. *Mathematical Population Studies*, 1994, 4, pp. 205–221.
WORLD BANK. *World development indicators* [online]. 2019. <http://databank.worldbank.org/data /source/world-development-indicators>.
YOUSIF, H. M. *Fertility Transition: Middle East and North Africa in International Encyclopedia of the Social & Behavioral Sciences* [online]. 2001, pp. 5588–5593. <https://doi.org/10.1016/B0-08-043076-7/02139-2>.
YOUSIF, H. M., GOUJON, A., LUTZ, W. *Future Population and Education Trends in the Countries of North Africa*. Research Report RR-96-11,Laxenburg, Austria: International Institute for Applied Systems Analysis, 1996.