Time to first birth and its Predictors among reproductive-age women in Ethiopia: inverse Weibull gamma shared frailty model

CURRENT STATUS: UNDER REVIEW

BMC Women's Health  □ BMC Series

Reta Dewau Yimer
Wollo University

✉ retadewau30@gmail.comCorresponding Author

Fantahun Ayeneh Mekonnen
University of Gondar College of Medicine and Health Sciences

Wullo Sisay Seretew
University of Gondar College of Medicine and Health Sciences

DOI:
10.21203/rs.3.rs-24244/v1

SUBJECT AREAS
Sexual & Reproductive Medicine

KEYWORDS
Time to first birth, predictors, reproductive age-women, Ethiopia, Inverse-Weibull, frailty
Abstract

**Background:** High maternal and child death with high fertility rate have been reported in Ethiopia. Extreme age at first birth is linked with both maternal and child morbidity and mortality. However, literatures showed there are limited studies on timing of first birth and its predictors in the area so far. Therefore, determining time to first birth and its predictors will help to design strategies to improve maternal and child survival.

**Methods:** A survey-based study was conducted among reproductive-age women in Ethiopia using Ethiopian demographic health survey (EDHS), 2016 data. Stratified two-stage cluster sampling technique was used for sampling. The Kaplan-Meier (KM) method was used to estimate time to first birth. Inverse Weibull gamma shared frailty model applied to model the data at 95% confidence interval (CI), adjusted hazard ratio (AHR) and median hazard ratio (MHR) were reported as effect size. Proportional hazard assumption checked using Schoenfeld residual test. Information Criteria was applied to select parsimonious model. Stratified analysis performed for interaction terms and statistical significance declared at p value<0.05.

**Results:** The overall median age at first birth found to be 20 years (IQR, 16-24 years). The independent predictors of time to first birth were: marriage 15-17 years (AHR=2.33, 95% CI:2.08-2.63), secondary education level (AHR=0.84, 95% CI:0.78-0.96), higher education level (AHR=0.75, 95% CI:0.65-0.85), intercourse before 15 years in the married stratum (AHR=23.81, 95% CI:22.22-25.64), intercourse 15-17 years in married stratum (AHR=5.56, 95% CI:5.26-5.88), spousal age difference (AHR=1.11, 95% CI :1.05-1.16), and use of contraceptives (AHR=0.91, 95% CI [0.86-0.97]). The median increase in the hazard of early childbirth at a cluster with higher early childbirth is 16% (MHR=1.16, 95% CI [1.13-1.20]) than low risk clusters.

**Conclusion:** In this study, first birth found to be at an early age. Early age at first marriage, at first sexual intercourse and their interaction terms, high spousal age difference, being Muslim were found to increase early motherhood. Conversely, living in most urban region, secondary and higher women education were identified to delay first birth. Investing on women education and protecting them from early marriage are required to optimize time to first birth. The contextual differences in time to first
birth are a novel finding which requires more study and interventions.

Background
Age at first birth refers to the age of a mother when she gave birth to her first child (1,2). Attaining the first child is one of the most important events in a woman's life. It indicates the beginning of the intensive responsibilities of maternity and childcare (3).

Roughly 1 in 10 childbirths contributed by young mothers worldwide and of these, developing countries accounting 95% of the share (4). Girls under 15 years account for 2 million (27%) of the 7.3 million births that occur to adolescent girls below 18 years each year in developing countries (5). When a woman became pregnant in the adolescent period, her present and future life rarely became for better (5,6). It results in discontinuation of education, fading of job prospects, an increased number of children, poor maternal and child health outcomes, gender inequity, poverty of adolescent mothers and their families and the communities at large (2,5,7–13). Worldwide over half a million (500,000) women aged 15–49 years die annually from preventable pregnancy-related complications (14). Furthermore, girls under 15 years are five times more likely to die and those 15–19 years are twice more likely to die than women aged 20–24 years in pregnancy or childbirth (15,16). Complications from Pregnancy and childbirth are the leading cause of decease (1 out of 7 girls) among under 19 years in low and middle-income countries (17).

Worldwide 20% of women give birth by the age of 18, in the poorest regions of the world, this rises to beyond a third (35%) (14). Childbirth is being delayed to a later age with the mean age at first birth 26.3 years in the United States America (USA) (29) to 30 years in Britain (3).

The median age at first birth in East Asia and Pacific was 20.2 years in Martial Island in 2007 and 23.4 years in Samoa in 2009 (8). The mean age at first birth is 17.92 years in Bangladesh (30), in Ghana 19.91 years in 2008 (31). The median age at first birth in Nigeria was 20 years in 2013 (20). In Ethiopia, more than a third (34%) of women age 20–49 give birth by the age of 18 and 54% by their age of 20 (18). The mean age of women at first birth was 18.47 years in Degua Tembien District, Tigray, Ethiopia (32).

There are numerous factors for this high prevalence of poor maternal and child health in third world
nations. This includes deep-rooted socio-cultural and religious practices, lower educational level and reduced income (13,15,16,19–21). Muslim women have their first births earlier than non-Muslim women (20,30).

Socio-demographic factors that were identified as a determinant of age at first birth in different studies include lower age at first sexual intercourse (9,24,31), high Spousal age difference (5,30,41). Some of the studies showed that the probability of age at first birth at a lower age is higher in a woman whose Spousal age difference had a wider gap (5,30,41). The younger age at first marriage is one of the most consistent findings across the studies as a risk factor for early age at first birth. The Socio-economic factors were identified as a predictor of age at first birth as consistent manner. As many studies showed that the probability of early age at first birth is higher in women with no or lower level education compared to women at a higher educational level (1,5,31,33,36,37,41–43,6,9,14,17,20,24,25,30). Most of the studies revealed that having poor and middle wealth index status was identified as the risk of age at first birth in early age (24,30–32,35–37,41,44). (5,6,33–38,9,14,17,20,21,25,30,31). The majority works of the literature revealed that the use of any contraception delay age at first birth (5,8,9,20,30,31,34,39,40)

On the other hand, advanced maternal age (> 30 years) at first birth is associated with an increased risk of fetal loss, chromosomal anomalies, multiple pregnancies, hypertension, diabetes mellitus, preterm birth, low birth weight, breast cancer and maternal mortality (16,22,23). Those who gave first birth at 30 years and above group were 33% at higher risk of mortality compared to those who gave first birth in the age group 20–24 years in Ohsaki Japan (16). The impacts of urbanization and modernization postponed the age at first birth in the later age in the developed world (9,18,24,25).

For most populations having first marriage at a lower age tend to have early childbearing and high fertility (6,20). On top of that in modern times many children are born before marriage with numerous health risks, like abortion and HIV (26). The prevalence of premarital conceptions is 1% in Tanzania (27) and 1.2% in Ethiopia (28).

Even though the timing of first birth measured by the age at first birth has a huge effect on maternal and child survival, both individual and cumulative levels of fertility, as well as extensive implications
on, women’s roles and social changes in general, studies conducted in Ethiopia on this topic are scarce. Furthermore, those limited studies conducted on teenage pregnancy and age at first birth after marriage did not account births outside marriage and first birth beyond adolescent period as well as studies on EDHS data do not account correlated nature of the data in the analysis. Thus, by considering the above limitations this study is designed to estimate time to first birth and identify predictors among all reproductive-age women regardless of their marital status in Ethiopia with taking into account the correlated nature of the data. So the study will serve as a baseline for the next researchers and program planners on improving both maternal and child health (Fig. 1).

Methods
Study design
Community based Cross sectional survey was conducted from January 18, 2016 to June 27, 2016 among reproductive-age women in Ethiopia

Study Area And Period
The study was conducted in Ethiopia one of the Sub-Saharan African country where the maternal mortality ratio 412 per 100,000 live births, skilled delivery coverage 28%, the median age at first marriage 17.1 years and the median age at first sexual intercourse 16.6 years, the contraceptive prevalence among married 36%, sexually active unmarried women 58% (28). The estimated population in 2016 was 102 million with a fertility rate of 4.46 and the second largest population in Africa. The majority (78%) of women lived in rural (28). The study was conducted from January 18-June 27, 2016.

Study Participants
The study included all reproductive age-women (15-49 years) found in the selected clusters of 2016 EDHS data collection period January 18, 2016 to June 27, 2016. Taking reproductive age-women (15-49 years) of Ethiopian in place of source population, reproductive age women living in selected clusters as study population and reproductive age-women (15-49 years) found in 2016, EDHS enumeration areas at least one night before data collection as per Sample population. Women declared infecund were excluded.

Operational Definitions
Access to media: Respondents were asked how often they read a newspaper, listened to the radio,
or watched television. Those who had exposure to one of them at least once a week are considered being regularly exposed to media (28,29).

**Time to first birth:** refers to the age of a mother in years when she gave birth to the first child after puberty (1,2,29)

**Censored:** Those women who did not give birth until the 2016 EDHS data collection end date.

**Event /Uncensored:** mothers who gave first birth until 2016 EDHS data collection end date.

**Declared infecund:** married or in union women for 5+ years, had no children in the past 5 years and never used contraception (45).

**Time to event/waiting time:** it is the time in years from puberty to age at first birth.

**Beginning time:** women at puberty (10 years from her birth date)

**Sampling Technique And Sample Size Determination**

The 2016 EDHS sample was selected using stratified two-stage cluster sampling design and census enumeration areas (EAs) were the sampling units for the first stage. The sample included 645 EAs, 202 in urban areas and 443 in rural areas with probability proportional to EA size and with independent selection in each sampling stratum. In the second stage of selection, a fixed number of 28 households per cluster were selected with an equal probability systematic selection from the newly created household listing. All women age 15–49 who were either permanent residents of the selected households or visitors who stayed in the household the night before the survey were interviewed. A total of 18,008 households were selected for the sample, of which 17,067 were occupied. Of the occupied households, 16,650 were successfully interviewed, yielding a response rate of 98%. In the interviewed households, 16,583 eligible women were identified for individual interviews. Interviews were completed with 15,683 women, yielding a response rate of 95% (28).

After the exclusion of primary infertile (57 women) from the data, the effective sample size became 15,626 (Fig. 2).

**Dependent And Independent Variable**

The dependent variable in the current study is time to first birth in years when a woman gave her first childbirth until data collection period. The independent variables included, socio-demographic and
reproductive health related factors (Age at first sexual intercourse, age at first marriage, Ever married, Spousal age difference); socio-economic and information related factors (respondent’s education, respondent’s occupation, Husband’s education, Husband occupation, Wealth index and Mass media exposure); Community level factors (region and residence) and Use of contraception as an immediate factor.

Data Source
For this study secondary data from the 2016 EDHS was used. The data set downloaded from the website https://dhsprogram.com after approval letter for use had obtained from the measure DHS. Variables were extracted from the EDHS 2016 individual women’s data set using a data extraction tool.

Measurement Of Variables
Dependent variable, time to first birth measured in years was taken from age at first birth for mothers at least gave their first birth and the age of respondent for event censored women. For the purpose of analysis those women gave birth event coded 1 (success) and those who did not give birth 0 (censored).

Independent variables age at first sexual intercourse and age at first marriage classified in to three categories; less than 15, 15–17 and 18 and above years, the highest age category taken as reference. Ever married coded as married and not married. Spousal age difference categorized as less than 5 years and 5 and above years. Respondent’s and husband education categorized into (no education, primary, secondary and higher education) and no education taken as reference. Respondent’s and husband occupation coded as not working, agriculture and non-agriculture with non-agriculture reference. Wealth index classified as (poorest, poor, middle, richer and richest) by taking poorest as comparison group. Mass media exposure (yes/no), and use of contraception (yes/no). The regions were classified into six categories because there socio-cultural and economic similarities and geographical relations of the regions. These are northern regions (Amhara and Tigray), Oromia, Southern Nations, Nationalities and Peoples (SNNP), eastern pastoralist referring to the pastoralist dominant Afar and Somali regions, western region semi pastoralist representing Gambella and
Benishangul-Gumuz, and most urban regions representing (Addis Ababa and Dire Dawa city administrations and Harari regions it is comparison group), while residence classified as urban and rural.

Data Quality Control
After all, questionnaires were finalized in English, they were translated into local languages (Amarigna, Tigrigna, and Oromiffa) and pretested at Bisheftu (28). Computer-assisted personal interview data collection system was carried out to collect data by trained EDHS data collectors and mobile version CSPro software was used for entering and capturing the data. For this study the same source population used for both those who gave birth or not to make comparable, the data collectors and study participants were blind to the study hypothesis since the analysis considered later. Control questions were used to check reliability of sensitive variables like age at first sex was controlled with age at first birth.

Data extraction checklist was prepared and data extracted using Stata version 14.0. Data was cleaned with (visual inspection, run frequency, and cross-tabulations and checking ranges), generated, recoded, labeled and label defined variables.

Data analysis
After the data was extracted, cleaned and weighted descriptive measures such as median, percentiles, graphs and frequency tables were used to characterize the study population. We estimated time to first birth using the Kaplan-Meier (K-M) method and compared across categorical predictor variables using log rank test. Schoenfeld residual test applied to check the proportional hazard assumption.

Exploratory data analysis made by plotting baseline hazard function over survival time to identify appropriate parametric baseline distribution and appropriately transformed survival function against a log of survival time were plotted to identify the best fit model to the straight line. Nested parametric models in generalized gamma (exponential, Weibull, lognormal, gamma and inverse-Weibull) were compared using likelihood ratio test and Wald test after fitting all predictor variables in generalized gamma those were significant at p value < 0.2 in bi-variable analysis. Non-nested models including
Gompertz and log-logistic were compared using AIC.

Proportional odds assumption was assessed by plotting the log odds of survival (using KM estimates) versus the log of survival time for categorical predictor variables.

Shared frailty model with baseline distributions (inverse-Weibull, log-logistic and lognormal) and frailty distributions gamma and inverse Gaussian were modeled by taking enumeration areas/clusters as a random effect for predictors of time to first birth among reproductive-age women in Ethiopia and efficient model was selected with the smallest AIC value.

Model adequacy was checked using Akaike Information Criteria (AIC), Cox-Snell residuals and $R^2$ type statistic.

Stratified analysis and chi-square test were applied for interaction terms. Finally adjusted hazard ratio (AHR) and adjusted time ratio (ATR) as a measure of effect size reported at 5% significant level and $p$-value < 0.05.

Stata 14.0/SE software for data extraction, cleaning and analysis and R software (version 3.4.4) for proportional odds assumption test and median hazard ratio calculation were used.

Measures of dependence in shared frailty modeling
See Supplementary Information.

Ethical considerations
Ethical clearance obtained from the ethical review board of the Institute of Public Health, College of Medicine and Health Sciences, University of Gondar. The written approval letter obtained from the Measure DHS International Program which authorized for the data-sets. Confidentiality of data maintained anonymously and the data used solely for the purpose of the current study.

Results
Baseline characteristics of study participants
A total of 15626 (weighted = 15635) women were included in the study. From the respondents one fifth (21.62) were adolescents. Of all, the majority (77.88%) of them were rural in residence. Of married women, 67.37% had more than 5 years of a spousal age difference. Around two-thirds (63%) of women married their first husband before their age of 18 years. Moreover, 26.24% of them married before the age of 15 years (table 1).
Table 1: Socio-demographic and reproductive health-related factors among reproductive age women in Ethiopia, EDHS 2016

| Variables categories | Weighted frequency | Weighted Percentage (%) |
|----------------------|--------------------|-------------------------|
| **Age distribution** |                    |                         |
| (N = 156356)         |                    |                         |
| < 20 years           | 3,380              | 21.62                   |
| 20–29 years          | 5,716              | 36.56                   |
| > 30 years           | 6,539              | 41.82                   |
| **Residence**        |                    |                         |
| urban                | 3447               | 22.12                   |
| Rural                | 12175              | 77.88                   |
| **Regions**          |                    |                         |
| Most urban           | 1042               | 6.74                    |
| Northern             | 4827               | 30.87                   |
| Oromia               | 5682               | 36.34                   |
| SNNp                 | 3282               | 21.00                   |
| Eastern-pasto        | 585                | 3.74                    |
| Western-Pasto        | 204                | 1.30                    |
| **Age at first intercourse** | | |
| (n = 15635)          |                    |                         |
| < 15 years           | 3027               | 19.36                   |
| 15–17 years          | 5062               | 32.38                   |
| > 18 years           | 7,546              | 48.26                   |
| **Age at first marriage** | | |
| (n = 11600)          |                    |                         |
| < 15 years           | 3044               | 26.24                   |
| 15–17 years          | 4256               | 36.69                   |
| > 18 years           | 4300               | 37.07                   |
| **Spousal age difference** | | |
| (n = 15635)          |                    |                         |
| < 5 years            | 3326               | 32.63                   |
| > 5 years            | 6,867              | 67.37                   |
| **Contraceptive**    |                    |                         |
| Ever not use         | 8895               | 56.95                   |
| Ever use             | 6727               | 43.05                   |
| **Religion**         |                    |                         |
| orthodox             | 6,762              | 43.25                   |
| Muslim               | 4,881              | 31.22                   |
| protestant           | 3,662              | 23.42                   |
| Others*              | 330                | 2.11                    |

*Others = catholic, traditional and other

Regarding socio-economic and information related characteristics of the respondents, 47.77% of them had no education and 49.91% have no formal occupation. More than 34% of the study participants had wealth index status below the middle level and only a quarter (26.37%) had regular media exposure (table 2).

Table 2: socio-economic and information related characteristics among reproductive age women in Ethiopia EDHS, 2016
| Predictors          | Categories         | Weighted Frequency | Weighted percentage (%) |
|--------------------|--------------------|--------------------|-------------------------|
| Education          | No education       | 7469               | 47.77                   |
|                    | Primary            | 5475               | 35.04                   |
|                    | Secondary          | 1802               | 11.61                   |
|                    | Higher             | 868                | 5.57                    |
| Occupation         | Not working        | 7799               | 49.91                   |
|                    | Agriculture employee | 3248             | 20.77                   |
|                    | None agriculture employee | 4576 | 29.32                   |
| Husband education  | No education       | 4750               | 46.60                   |
|                    | Primary            | 3765               | 36.94                   |
|                    | Secondary          | 971                | 9.53                    |
|                    | Higher             | 707                | 6.94                    |
| Husband occupation | Not working        | 802                | 7.87                    |
|                    | Agriculture employ | 6323               | 61.93                   |
|                    | Non-agri-employe   | 3078               | 30.20                   |
| Media exposure     | Yes                | 4115               | 26.37                   |
|                    | No                 | 11508              | 73.63                   |
| Wealth index       | Poorest            | 2630               | 16.82                   |
|                    | Poorer             | 2803               | 17.93                   |
|                    | Middle             | 2968               | 18.98                   |
|                    | Richer             | 3092               | 19.77                   |
|                    | Richest            | 4143               | 26.49                   |

**Time to first birth among study participants**

Over all 10274 (67.7%) women had given at least first birth. In general the median age of first birth found to be 20 years (IQR = 16–24). The total follow-up period for all 15,626 women was 146,290 person-years of observation. The median, minimum and maximum follow-up period was 8 years one year and 39 years after the age of puberty (10 years from her birth date), respectively. Among women had first birth below 20 years the median age was 18 years (IQR = 15–19), from those women giving first birth in the age bracket of 20–29 years median age was 23 years (IQR = 20–26) and of women celebrate their 30 years before giving birth (n = 533) only 49.5% able to give birth (Fig. 3).

The median time to first birth was at lower age for those women enter into sexual intercourse at lower age (< 15 years) 15 years (IQR = 13–17), too early married women (below 15 years) 16 years (IQR = 14–17) and women had no education 18 years (IQR = 15–21) years (table 3). The median age was relatively higher among women those had higher education level 27 years (IQR = 21- -).

**Predictors of time to first birth among reproductive-age women in Ethiopia, 2016 EDHS**

Differences in all predictor variables at baseline were determined using the Kaplan Meier failure function and the log-rank ($\chi^2$) test. The Kaplan Meier failure function with 95% confidence interval was constructed for age at first marriage and women education level (Fig. 4) and annex-1 (Fig. 9). In general, the pattern of the failure function lying below right side to other categories indicated that the group defined by the lower curve had a better survival before giving first birth than the group defined
by the above curves. Therefore women married at the age of 18 and above years and women with secondary and higher education level able to delay their first birth in the later age than married below 18 years and below secondary education level respectively as Kaplan Meier failure graph and a log-rank test at (p-value < 0.001) showed (Fig. 4). The log-rank test showed that all predictor variables had a significant survival difference at p-value < 0.001 (Table 3).

Table 3: Kaplan-Meier failure estimate and log rank test comparison of time to first birth among reproductive age women in Ethiopia, 2016 EDHS.

| Characteristics       | N (%)   | Ever given Birth | Median (IQR) years | Log-rank | p-value |
|-----------------------|---------|------------------|--------------------|----------|---------|
| Region                |         |                  |                    |          |         |
| Northern              | 4827 (30.87) | 3224 (66.8) | 19 [16–24] | 570.2    | <0.001  |
| Oromia                | 5682 (36.34) | 4130 (72.7) | 19 [16–22] |          |         |
| SNNPR                 | 3282 (21.00) | 2192 (66.8) | 20 [16–24] | 547.8    | <0.001  |
| Most-urban            | 1042 (6.74)  | 474 (45.5)   | 26 [19–34] | 1396.2   | <0.001  |
| Eastern-pasto         | 585 (3.74)  | 424 (72.4)   | 19 [16–22] | 354.1    | <0.001  |
| Western-semi Pasta    | 204 (1.30)  | 144 (70.7)   | 19 [16–22] |          |         |
| Education             |         |                  |                    |          |         |
| No education          | 7469 (47.77) | 6785 (90.9) | 18 [15–21] | 2545.8   | <0.001  |
| Primary               | 5475 (35.04) | 2865 (52.3) | 20 [17–24] |          |         |
| Secondary             | 1802 (11.61) | 593 (32.8)  | 26 [20–37] | 131.2    | <0.001  |
| Higher                | 868 (5.57)  | 344 (39.6)   | 27 [21–49] | 126.8    | <0.001  |
| occupation            |         |                  |                    |          |         |
| Not working           | 7799 (49.91) | 5243 (67.2) | 19 [16–23] | 461.0    | <0.001  |
| Agriculture           | 3248 (20.77) | 2522 (77.6) | 19 [15–21] |          |         |
| Non-agriculture       | 4576 (29.32) | 2822 (61.8) | 21 [17–27] |          |         |
| Wealth index          |         |                  |                    |          |         |
| Poorest               | 2630 (16.82) | 2060 (78.3) | 19 [16–22] | 903.9    | <0.001  |
| Poorer                | 2803 (17.93) | 2122 (75.7) | 19 [16–21] |          |         |
| Middle                | 2968 (18.98) | 2128 (71.7) | 19 [16–22] |          |         |
| Richer                | 3090 (19.76) | 2089 (67.6) | 19 [16–23] |          |         |
| Richest               | 4131 (26.49) | 2190 (53.0) | 22 [17–30] |          |         |
| Contraceptive         |         |                  |                    |          |         |
| Ever not use          | 8895 (56.95) | 4617 (51.9) | 21 [17–26] | 844.2    | <0.001  |
| Ever use              | 6727 (43.05) | 5970 (88.7) | 19 [16–22] |          |         |
| Media exposure        |         |                  |                    |          |         |
| No                    | 11509 (73.63) | 8342 (72.5) | 19 [16–22] | 576.6    | <0.001  |
| Yes                   | 4115 (26.37) | 2245 (54.6) | 22 [17–28] |          |         |
| Ever married          |         |                  |                    |          |         |
| No                    | 4022 (25.81) | 93 (2.3)   | -                  | 3974.7   | <0.001  |
| Yes                   | 11600 (74.19) | 10494 (90.5) | 19 [15–21] |          |         |
| Spousal age gap       |         |                  |                    |          |         |
| ≤5 years              | 3326 (32.63) | 2984 (89.7) | 19 [16–22] | 129.2    | <0.001  |
| ≥5 years              | 6867 (67.37) | 6366 (92.7) | 18 [15–21] |          |         |
| Age at first marriage |         |                  |                    |          |         |
| Below age 15          | 3044 (26.24) | 2915 (95.8) | 16 [14–17] | 5582.3   | <0.001  |
| 15–17                 | 4256 (36.69) | 3890 (91.4) | 18 [16–19] |          |         |
| 18 and above          | 4300 (37.07) | 3689 (85.8) | 22 [19–25] |          |         |
| Age at first sex      |         |                  |                    |          |         |
| <15 years             | 3027 (32.38) | 2860 (94.47) | 15 [13–18] |          |         |
| 15–17 years           | 5062 (59.04) | 4576 (90.4) | 18 [16–20] |          |         |
| ≥18 years             | 7546 (48.26) | 3151 (41.75) | 22 [19–26] | 396.1    | <0.001  |
| Husband-education     |         |                  |                    |          |         |
| no education          | 4750 (46.60) | 4516 (95.1) | 18 [15–21] |          |         |
| Primary               | 3765 (36.94) | 3454 (91.7) | 18 [15–21] |          |         |
| Secondary             | 971 (9.53)  | 808 (83.2)   | 20 [16–23] |          |         |
| Higher                | 707 (6.94)  | 573 (81.1)   | 21 [17–25] |          |         |
| Husband occupation    |         |                  |                    |          |         |
| not working           | 802 (7.87)  | 740 (92.3)   | 18              | 256.1    | 0.001   |
| Agriculture employee  | 6323 (61.93) | 5930 (93.9) | 18              |          |         |
| Nonagriculture        | 3078 (30.20) | 2681 (87.1) | 19              |          |         |
| religion              |         |                  |                    |          |         |
| Orthodox              | 6762 (43.25) | 4371 (64.6) | 20              | 178.6    | <0.001  |
| Muslim                | 4881 (31.22) | 3593 (73.6) | 19              |          |         |
| Protestant            | 3662 (23.42) | 2367 (64.7) | 20              |          |         |
| Others                | 330 (2.11)  | 255 (77.1)   | 19              |          |         |
| Total                 | 15,635 (10635 (67.7) | 20 [16,24] |          |          |         |

*N=weighted value, IQR=interquartile
Parsimonious Model Selection
Cox proportional hazard model

All fourteen predictor variables that were significant at 0.2 p value in bivariable analysis were entered into the multivariable Cox model and ever married reduced from the model due to collinearity effect with age at first marriage. Then the Schoenfeld test for proportional hazard assumption of the time to first birth data was evaluated. The proportional hazard assumption violated in both global test and at each variable level due to significant correlation of time to first birth and all predictor variables (Table 4), as a result, the Cox model was excluded for this data.

Table 4: Schoenfeld residual test for proportionality assumption of the Cox model

| Predictors            | Rho  | Chi2  | df | Prob > Chi² |
|-----------------------|------|-------|----|-------------|
| Geo-regions           | 0.056| 91.18 | 1  | < 0.001     |
| Residence             | -0.078| 174.81| 1  | < 0.001     |
| Religion              | -0.061| 82.37 | 1  | < 0.001     |
| Education level       | 0.071| 107.88| 1  | < 0.001     |
| Occupation            | -0.055| 80.36 | 1  | < 0.001     |
| Wealth index          | -0.095| 235.12| 1  | < 0.001     |
| Spousal age difference| -0.108| 231.14| 1  | < 0.001     |
| Contraceptive use     | 0.193| 1009.79| 1  | < 0.001     |
| Media exposure        | 0.030| 20.33 | 1  | < 0.001     |
| Age first marriage    | 0.220| 1589.96| 1  | < 0.001     |
| Age first sex         | 0.138| 463.55| 1  | < 0.001     |
| Husband education     | -0.066| 118.00| 1  | < 0.001     |
| Husband occupation    | 0.019| 13.02 | 1  | < 0.001     |
| Global test           | 6191.37|       | 13 | < 0.001     |

<0.001 means significant at 5% significance level; proportionality assumption is violated

Then stratified Cox model also inappropriate for this data because there is no predictor variable that fulfills proportional hazard assumption to be in the model. Another alternative extended Cox (time-varying Cox model) also faces the challenge of choosing the appropriate function of survival time to include in the model. For example, if we create covariate log-survival time interaction term, this interaction term could be appropriate if the hazard ratio comparing any two levels of covariate monotonically increases (or decreases) over time. But in the case of our data, the time distribution is unimodal rather than monotonic (Fig. 4). So those parametric models are considered to the data due to these constraints.

Appropriate Parametric Survival Model Selection
Exploratory analysis
Baseline hazard plot

The shape of the baseline hazard function (Fig. 5) of time to first birth data looks closer to the hazard function of the classical shape of unimodal hazard curve models. It seems reasonable that first birth starts to happen at puberty (age 10–13 years) and increased to maximum (at the age of 18–22 years), the period at which most girls became married and sexually active. Then, it changes its direction and decreased gradually as those who did not married and sexually inactive or those who planned to delay their first birth in the later age of their life by different reasons. This theoretical concept is similar to the baseline hazard plot of time to first birth data (Fig. 5). Therefore, the shape of hazard
function indicated that time to first birth data might be modeled by Log-Logistic, Lognormal or Generalized gamma or inverse Weibull survival models. These are complex "inverted bathtub" shaped functions that might be appropriate for modeling human life over a long period of time (47).

** Appropriately transformed survival function plot against the natural log of survival time **

A more informative way of assessing whether a particular distribution for the survival times is plausible is to compare the survivor function for the data with that of a chosen model. This technique is through the plot of appropriately transformed survival function with the log of survival time and produce a plot that should give a straight line if the assumed model is appropriate (48).

On the basis of the appropriately transformed survival function plot against the natural log of survival time, the time to first birth data may suitably be explained by Log-Logistic, Lognormal or inverse Weibull survival models as their transformed survival function over log survival time is reasonably straight line (Fig. 6). The final choice of the model was made by fitting model with covariates and through likelihood ratio test for nested models, and Akaike's information criterion for none nested models, Cox-Snell residuals plot and R2 type statistic for goodness of fit of the model for the given data.

** Identifying nested distribution in generalized gamma for the data **

Since lognormal, Weibull, exponential, gamma and inverse Weibull can be nested in generalized gamma after multivariable generalized gamma model fitted, Wald test and likelihood ratio tests were applied to identify presence of nesting for this data (Table 5).

** Table 5: Identifying the nested model in generalized gamma for time to first birth data **

| Hypothesis | Coefficient (Se) | z-value | P value | 95% CI |
|------------|------------------|---------|---------|--------|
| Kappa (K)  | -0.98 (0.028)    | -38.01  | <0.001  | (-1.13,-0.88) |
| Sigma (σ)  | 0.11 (0.002)     |         |         | (0.10,0.11)  |
| HO: k = 0 lognormal | 1776.84 <0.001 | 1444.68 <0.001 | Ho rejected |
| HO: k = 1 Weibull       | 5385.27 <0.001 | Ho rejected |
| HO: k = 1, σ = 1 Exponential | 53014.06 <0.001 | Ho rejected |
| HO: k = σ Gamma From k and σ CI | | Ho rejected |
| K = -1 Inverse Weibull | 0.14 0.709 | Ho failed to reject |

Ho: assumption the model is nested in saturated generalized gamma

When k=-1 inverse Weibull is nested in the Generalized gamma distribution
Then none nested models were compared using AIC to select best-fitted model and $R^2$ type statistics applied to identify in which model variables best predict the outcome (Table-6).

The inverse Weibull is preferred parametric model for the given data with the highest log likelihood, smallest AIC and higher $R^2$ type statistics prediction of the outcome 58% using variables in the model as shown in (Table 6).

Table 6: None nested parametric survival model comparison of time to first birth data with AIC and $R^2$ type statistics

| Model        | N   | Null model(L0) | Full model(Lp) | df | AIC  | $R^2p$ | LR chi2(34) | P-value LLF |
|--------------|-----|----------------|----------------|----|------|--------|-------------|-------------|
| Exponential  | 9788| -3467.52       | -2807.93       | 35 | 5685.86 | 12.6%  | 1319.18    | < 0.0001    |
| Gompertz     | 9788| -1962.20       | 355.51         | 36 | -639.018 | 37.8%  | 4635.42    | < 0.0001    |
| Weibull      | 9788| -185.63        | 2616.31        | 36 | -5160.62 | 43.6%  | 5603.89    | < 0.0001    |
| Log normal   | 9788| -32.42         | 3841.78        | 36 | -7611.57 | 54.7%  | 7748.42    | < 0.0001    |
| Log logistic | 9788| 43.62          | 4296.98        | 36 | -8521.97 | 58.1%  | 8506.74    | < 0.0001    |
| Generalized gamma | 9788| 1387.47       | 5745.62        | 37 | -11417.23 | 59.0%  | 8716.29    | < 0.0001    |
| Inverse Weibull | 9788| 2302.55       | 6521.81        | 36 | -12970.98 | 58.0%  | 8422.65    | < 0.0001    |

Where LP is the log likelihood for the full model with p covariates and L0 is the log-likelihood for the null model, the model with no covariates.

The inverse of the inverse-Weibull (IW) data follows a Weibull distribution. Graphical demonstrations of how the inverse of inverse-Weibull is Weibull distribution in the time to first birth data (Fig. 7). So the parameter estimates of the IW distribution can be easily obtained by applying to its reciprocal data, the same standard procedures implemented in packages for the Weibull model or the Log-Logistic survival model can be fitted with the cumulative distribution function (Cdf) of IW data very well (49). Therefore in this study, the inverse Weibull model was applied to model the time to first birth data.

Shared Frailty Model

A likelihood ratio test for a variance of frailty theta = 0 yields a highly statistically significant p-value of < 0.001 for all baseline hazard function with both inverse Gaussian and gamma shared frailty distribution in the models (Table 7), suggesting that the frailty component contributes to the model and that there is a within-cluster correlation. The value of shared frailty distribution ($\theta$) is 0.028, 0.23
and 0.18 for inverse-Weibull gamma, log-logistic gamma and lognormal gamma shared frailty models respectively and 0.028, 0.84 and 0.25 for inverse-Weibull-inverse Gaussian, log-logistic-inverse Gaussian and lognormal inverse Gaussian shared frailty models respectively. The inverse Weibull gamma shared frailty model is preferred model for the give data due to its lowest AIC. The dependence within clusters (EAS) for the inverse Weibull gamma shared frailty model found to be ($\tau = 0.0244$) before adjusting for predictors and ($\tau = 0.014$) after adjusting for predictors and after addition of interaction term ($\theta = 0.025$ and $\tau = 0.012$).

Table 7: Parametric shared frailty model comparison on time to first birth data of reproductive age women in Ethiopia, 2016 EDHS

| Model                        | Log-likelihood | DF | AIC        | Variance Of $\theta$ | LR test of $\theta = 0$ |
|------------------------------|----------------|----|------------|----------------------|-------------------------|
| Lognormal gamma              | 4511.66        | 34 | -8955.31   | 0.18                 | $< 0.001$               |
| Lognormal inverse Gaussian   | 4511.62        | 34 | -8955.24   | 0.25                 | $< 0.001$               |
| Log logistic gamma           | 4881.54        | 34 | -9695.08   | 0.23                 | $< 0.001$               |
| Log logistic inverse Gaussian| 4936.02        | 34 | -9804.03   | 0.87                 | $< 0.001$               |
| Inverse Weibull gamma        | 5708.19        | 34 | -11348.37  | 0.028                | $< 0.001^a$             |
| Inverse Weibull inverse Gaussian| 5707.78      | 34 | -11347.55  | 0.028                | $< 0.001$               |

$a = \text{preferred model}$

It also interpreted as prior to adjusting for predictor variables the median increase in the hazard of early childbirth when comparing a woman at a cluster with higher risk of early childbirth to a woman at a cluster with lower risk early childbirth was 24% (MHR = 1.24, 95%, CI [1.21–1.27]). After accounting for predictor factors and interaction term the median increase in the hazard of early childbirth when comparing a woman at a cluster with higher risk of early childbirth to a woman at a cluster with lower risk of early childbirth was 16% (MHR = 1.16, 95%, CI [1.13–1.20]) (Table 8).

Table 8: Bivariable and multivariable inverse-Weibull gamma shared frailty model on predictors of time to first birth among reproductive-age women in Ethiopia, EDHS, 2016

| Variable | Null model | First birth status | Full model |
|----------|------------|--------------------|------------|
| Log-likelihood | -1036.84 |                    | 5907.45    |
| Effect size |           |                    |            |
| Region    |            |                    |            |
| Most urban |            |                    |            |
| Northern  | 474        | gave               | 1.08(1.01–1.18)** | 1.08(0.97–1.19) |
| Oromia    | 3224       | Not gave           | 1.07(0.98–1.18)* | 1.18(1.06–1.30)** |
| SNNP      | 4130       |                    | 0.98(0.90–1.18) | 1.19(1.06–1.33)*** |
| Eastern   | 2192       |                    | 1.00(0.92–1.09) | 1.16(1.05–1.28)*** |
| Residence | Urban | Rural |
|-----------|-------|-------|
|           | 1769  | 8818  |

| Education | No education | Primary | Secondary | Higher |
|-----------|--------------|---------|-----------|--------|
|           | 6785         | 2865    | 593       | 344    |

| Occupation | Not working | Agriculture | Non-agriculture |
|------------|-------------|-------------|-----------------|
|            | 5243        | 2522        | 2822            |

| Wealth index | Poorest | Poorer | Middle | Richer | Richest |
|--------------|---------|--------|--------|--------|---------|
|              | 2060    | 2122   | 2128   | 2089   | 2190    |

| Spousal age gap | < 5 years | ≥ 5 years |
|-----------------|-----------|-----------|
|                 | 2984      | 6366      |

| Contraceptive | Ever not use | Ever use |
|---------------|--------------|----------|
|               | 4617         | 5970     |

| Media exposure | No | Yes |
|----------------|----|-----|
|                | 8342 | 2245 |

| Age at first marriage | < 15 years | 15–17 years | ≥ 18 years |
|-----------------------|------------|-------------|------------|
|                       | 2915       | 3890        | 3689       |

| Age at first sex | < 15 years | 15–17 years | ≥ 18 years |
|-----------------|------------|-------------|------------|
|                 | 2,860      | 4,576       | 3,151      |

| Husband education | No Education | Primary | Secondary | Higher |
|-------------------|--------------|---------|-----------|--------|
|                   | 4516         | 3454    | 808       | 573    |

| Husband occupation | Not working | Agriculture | Non-agriculture |
|--------------------|-------------|-------------|-----------------|
|                    | 740         | 5930        | 2681            |

| Religion | Orthodox | Muslim | Protestant | Others |
|----------|----------|--------|------------|--------|
|          | 4371     | 3593   | 2367       | 255    |

| Theta | 0.05 (0.04–0.06) | 0.028 (0.027–0.04)** | 0.025 (0.016–0.039)†*** |
|-------|-------------------|-----------------------|-------------------------|
|       |                   | 0.025 (0.016–0.039)†*** |

| MHR | 1.24 (1.21–1.27) | 1.17 (1.17–1.21)*** |
|-----|------------------|----------------------|
|     |                   | 1.16 (1.13–1.20)†*** |
LR test of theta Chibar2(1) 126.23 35.40

| Variable                  | unadjusted | adjusted | Interaction model |
|---------------------------|------------|----------|-------------------|
| Log likelihood            | CHR        | AHR      | AHR               |
|                           | 5907.45    | 5802.68  |                   |
| Effect size               |            |          |                   |
|                           |            |          |                   |
| Region                    |            |          |                   |
| Most urban                | 1          | 1        | 1                 |
| Northern                  | 1.08(1.01-1.18)** | 1.05(0.95-1.16) | 1.08(0.97-1.19) |
| Oromia                    | 1.07(0.98-1.18)** | 1.18(1.06-1.30)** | 1.18(1.06-1.30)** |
| SNNP                      | 0.98(0.90-1.18) | 1.22(1.09-1.37)** | 1.19(1.06-1.33)** |
| Eastern                   | 1.00(0.92-1.09) | 1.11(1.01-1.24)* | 1.16(105-1.28)** |
| Western                   | 1.12(1.03-1.22)** | 1.35(1.22-1.49)** | 1.37(1.24-1.52)** |
| Residence                 |            |          |                   |
| Urban                     | 1          | 1        | 1                 |
| Rural                     | 0.96(0.91-1.02) | 1.03(0.93-1.14) | 1.09 (0.98-1.19) |
| Education                 |            |          |                   |
| No Educ                   | 1          | 1        | 1                 |
| Primary                   | 1.72 (1.64-1.82)** | 0.95(0.89-1.01) | 1.12 (1.05-1.19) |
| Secondary                 | 0.83 (0.76-0.87)** | 0.85(0.77-0.94)** | 0.86 (0.78-0.96)** |
| Higher                    | 0.72 (0.65-0.80)** | 0.66(0.58-0.75)** | 0.75 (0.65-0.85)** |
| Occupation                |            |          |                   |
| Not working               | 1.18 (1.13-1.24)** | 0.98(0.92-1.04) | 1.01(0.95-1.06) |
| Agriculture               | 0.98 (0.93-1.04) | 0.94(0.88-1.02) | 0.93(0.86-1.01) |
| non agriculture           | 1          | 1        | 1                 |
| Wealth index              |            |          |                   |
| Poorest                   | 1          | 1        | 1                 |
| Poorer                    | 1.03 (0.96-1.10) | 0.98(0.91-1.05) | 0.98(0.91-1.05) |
| Middle                    | 1.12 (1.05-1.21)** | 1.00(0.93-1.09) | 0.98(0.92-1.06) |
| Richer                    | 1.12 (1.05-1.21)** | 1.10(1.01-1.19)* | 1.04(0.96-1.12) |
| Richest                   | 1.12 (1.05-1.21)** | 1.08(0.97-1.15) | 1.01(0.91-1.12) |
| Spousal age difference    |            |          |                   |
| < 5 years                 | 1          | 1        | 1                 |
| ≥ 5 years                 | 1.26 (1.21-1.33)** | 1.09(1.04-1.14)** | 1.11(1.05-1.16)** |
| Contraceptive use         |            |          |                   |
| Ever not                  | 1          | 1        | 1                 |
| Ever use                  | 0.50 (0.48-0.52)** | 0.94 (0.89-0.99) | 0.91(0.86-0.97)** |
| Media exposure            |            |          |                   |
| No                        | 1          | 1        | 1                 |
| Yes                       | 1.10 (1.04-1.15)** | 1.01(0.94-1.08) | 0.99(0.94-1.06) |
| Age at first marriage     |            |          |                   |
| < 15 years                | 9.10 (8.83-9.86)** | 2.82 (2.60-3.03)** | 2.68 (2.87-3.18)** |
| 15-17 years               | 3.50 (3.30-3.64)** | 1.98 (1.85-2.13)** | 2.33 (2.08-2.63)** |
| ≥ 18 years                | 1          | 1        | 1                 |
| Age at first sex          |            |          |                   |
| < 15 years                | 1.89 (1.78-1.99)** | 13.60 (12.50-14.93)** | 27.78 (23.26-32.26)** |
| 15-17 years               | 0.68 (0.65-0.71)** | 3.23 (3.03-3.52)** | 2.60 (2.07-2.63)** |
| ≥ 18 years                | 1          | 1        | 1                 |
| Husband education         |            |          |                   |
| No _educ                  | 1.47 (1.34-1.59)** | 0.94(0.85-1.05) | 0.94(0.85-1.05) |
| primary                   | 1.45 (1.32-1.59)** | 1.00(0.91-1.11) | 1.00(0.91-1.11) |
| secondary                 | 1.28 (1.16-1.41)** | 1.03(0.93-1.14) | 1.03(0.93-1.14) |
| Higher                    | 1          | 1        | 1                 |
| Husband occupation        |            |          |                   |
| not working               | 1.14 (1.05-1.23)** | 0.98(0.91-1.06) | 0.97 (0.90-1.05) |
| agriculture               | 1.13 (1.08-1.19)** | 0.96(0.91-1.02) | 0.97 (0.92-1.03) |
| Occupation                |            |          |                   |
| Orthodox                  | 1          | 1        | 1                 |
| Region          | Muslim          | Protestant       | Others          |
|----------------|-----------------|-----------------|-----------------|
|                | 1.02 (0.97-1.08)| 0.99 (0.92-1.05)| 0.90 (0.77-1.06)|
|                | 1.07 (0.99-1.15)| 1.01 (0.92-1.10)| 1.03 (0.87-1.22)|
|                | 1.10 (1.02-1.18)**| 1.00 (0.92-1.09)| 1.05 (0.89-1.25)|

| >18 intercourse and marriage | 1 |
| <15 marriage <15 intercourse | 1.32 (0.62-2.89) |
| <15 marriage 15-17 intercourse | 0.86 (0.62-1.23) |
| 15-17 intercourse <15 marriage | 4.55 (2.13-10.02)** |
| 15-17 intercourse 15-17 marriage | 2.63 (2.01-3.45)** |

| Theta | P | 1/p |
|-------|---|-----|
|       | 10.11 (9.97-10.25) | 0.099 (0.098-0.10) |

| LR test of theta = 0 | Chibar2(1) | Prob-hibar2 |
|----------------------|-----------|------------|
|                      | 35.40     | < 0.001    |

** p value < 0.01 ** p value < 0.05 * p value < 0.25

Annex 3: Table 11: Output comparison from shared frailty models of inverse Weibull gamma frailty and log logistic frailty inverse Gaussian survival models.

| variable                 | Log-logistic inverse-Gaussian shared frailty | Log-logistic-gamma shared frailty | Inverse Weibull gamma shared frailty |
|--------------------------|---------------------------------------------|-----------------------------------|-------------------------------------|
| Log likelihood           | 4942.16                                     | 4890.75                           | 5907.45                            |
| Effect size              | TR (CI)                                     | TR (CI)                           | HR                                 |
| Region                   |                                             |                                   |                                    |
| Most urban               | 1                                           | 1                                 | 1                                  |
| Northern                 | 1.01 (0.98-1.02)                            | 1.01 (1.00-1.02)                  | 1.05 (0.95-1.16)                   |
|                         |                                             |                                   | 1.00 (0.99-1.01)                   |
| Oromia                   | 0.99 (0.95-1.01)                            | 0.99 (0.98-1.00)                  | 1.18 (1.06-1.30)**                 |
|                         |                                             |                                   | 0.98 (0.97-0.99)**                 |
| SNNP                     | 1.00 (0.99-1.02)                            | 1.00 (0.99-1.01)                  | 1.22 (1.09-1.37)**                 |
|                         |                                             |                                   | 0.98 (0.97-0.99)**                 |
| eastern                  | 0.99 (0.98-1.01)                            | 1.00 (0.98-1.01)                  | 1.11 (1.01-1.24)*                  |
|                         |                                             |                                   | 0.99 (0.98-0.99)*                  |
| western                  | 0.98 (0.96-0.99)**                          | 0.98 (0.96-0.98)**                | 1.35 (1.22-1.49)**                 |
|                         |                                             |                                   | 0.97 (0.96-0.98)**                 |
| residence                |                                             |                                   |                                    |
| urban                    | 1.00 (0.99-1.02)                            | 1.00 (0.99-1.01)                  | 1.03 (0.93-1.14)                   |
|                         |                                             |                                   | 1.00 (0.99-1.01)                   |
| rural                    | 1                                             | 1                                 | 1                                   |
| Education                |                                             |                                   |                                    |
| No education             | 1.01 (1.01-0.2)*                            | 1.01 (1.01-0.1)*                  | 0.95 (0.89-1.01)                   |
| primary                  | 1.01 (1.01-0.1)*                            | 1.01 (1.01-0.1)*                  | 1.01 (0.99-1.01)                   |
| secondary                | 1.03 (1.01-1.04)**                           | 1.03 (1.01-1.04)**                | 0.85 (0.77-0.94)**                 |
| higher                   | 1.07 (1.05-1.08)**                           | 1.08 (1.06-1.09)**                | 0.75 (0.65-0.85)**                 |
| occupation               |                                             |                                   | 1.04 (1.03-1.05)**                 |
| not working              | 1.00 (0.99-1.01)                            | 1.00 (0.99-1.01)                  | 0.98 (0.92-1.04)                   |
| agriculture              | 1.01 (1.00-1.02)                            | 1.00 (1.00-1.02)                  | 0.94 (0.88-1.02)                   |
| Non agriculture          | 1                                             | 1                                 | 1                                   |
| Wealth index             |                                             |                                   |                                    |
| poorest                  | 0.99 (0.99-1.01)                            | 0.99 (0.99-1.01)                  | 0.98 (0.91-1.05)                   |
| poorer                   | 1.00 (0.99-1.01)                            | 1.00 (0.99-1.01)                  | 1.00 (0.99-1.01)                   |
| Middle                   | 1.01 (1.00-1.01)                            | 1.00 (1.00-1.01)                  | 1.00 (0.93-1.09)                   |
| richer                   | 0.99 (0.98-0.99)*                           | 0.99 (0.98-0.99)*                 | 1.10 (1.01-1.19)*                  |
| richest                  | 1.00 (0.99-1.01)                            | 1.00 (0.99-1.01)                  | 1.08 (0.97-1.15)                   |
| 0.99 (0.98-0.99)**       |                                             |                                   | 0.99 (0.98-0.99)*                  |
| 0.99 (0.98-0.99)**       |                                             |                                   | 0.99 (0.98-0.99)**                  |
| Spousal age difference   |                                             |                                   |                                    |
| Less than 5 years        | 1                                             | 1                                 | 1                                   |
| More than 5 years        | 0.99 (0.98-0.99)**                          | 0.99 (0.98-0.99)**                | 1.09 (1.04-1.14)**                 |
| Contraceptive use        |                                             |                                   | 0.99 (0.99-0.99)**                  |
| Ever not use             | 1.00 (0.99-0.99)                            | 0.99 (0.99-0.94)                  | 1.01(1.01-1.01)                    |
| Ever use                 | 1.00 (0.99-0.99)                            | 0.99 (0.99-0.94)                  | 1.01(1.01-1.01)                    |
Multivariable analysis of Inverse Weibull gamma shared frailty model

In the inverse Weibull gamma shared frailty model, the null model, only with the cluster effect and the full model, with predictor factors were compared to visualize reduction of frailty variance on the addition of predictor variables which revealed that in the full model variance theta reduced from null model 0.05 to 0.028 (Table 8) and 0.025 in the interaction model significantly (annex 2, table 10) (table part) (Interaction involving inverse Weibull gamma shared frailty model) respectively. In this model predictor variables geographical regions, women education level, contraceptive use, spousal age difference, age at first marriage, age at first sexual intercourse, religion and age at first sexual intercourse interaction with age at first marriage, were significant predictor variables at 95% confidence level. This shows that they were significant factors for determining the time to first birth.

| Media exposure       | Ever use       | 1.00 (0.99–1.01) | 0.99* (0.99–1.01) | 0.94 (0.89–0.99)* | 1.01 (1.01–1.02)* |
|----------------------|----------------|------------------|-------------------|-------------------|-------------------|
|                      | Had no access  | 1                | 1                 | 1                 | 1                 |
|                      | Had access     | 1.00 (0.99–1.01) | 1.00 (1.00–1.01)  | 1.01 (0.94–1.08)  | 1.00 (0.99–1.01)  |
| Age at first marriage| less than 15 years | 0.85 (0.84–0.86)** | 0.84 (0.83–0.85)** | 2.82 (2.60–3.03)** | 0.90 (0.89–0.91)** |
|                      | 15 to 17 years | 0.90 (0.89–0.91)** | 0.89 (0.88–0.90)** | 1.98 (1.85–2.13)** | 0.94 (0.93–0.95)** |
|                      | 18 and above   | 1                | 1                 | 1                 | 1                 |
| Age at first sex     | < 15 years     | 0.83 (0.81–0.84)** | 0.82 (0.81–0.83)** | 13.60 (12.50–14.93)** | 0.77 (0.76–0.78)** |
|                      | 15 to 17 years | 0.91 (0.90–0.92)** | 0.91 (0.90–0.92)** | 3.23 (3.03–3.52)** | 0.89 (0.88–0.90)** |
|                      | ≥ 18 years     | 1                | 1                 | 1                 | 1                 |
| Husband education    | No education   | 1                | 1                 | 1                 | 1                 |
|                      | primary        | 1.00 (0.99–1.00) | 1.00 (0.99–1.01)  | 1.03 (0.97–1.09)  | 1.00 (0.99–1.00)  |
|                      | secondary      | 1.00 (0.99–1.01) | 1.00 (0.99–1.01)  | 1.05 (0.96–1.15)  | 1.00 (0.99–1.01)  |
|                      | higher         | 0.99 (0.97–1.01) | 1.00 (0.99–1.01)  | 1.03 (0.93–1.14)  | 0.99 (0.97–1.01)  |
| Husband occupation   | not working    | 1.00 (0.99–1.02) | 1.00 (0.99–1.01)  | 0.98 (0.91–1.06)  | 1.00 (0.99–1.02)  |
|                      | agriculture    | 1.01 (1.00–1.01) | 1.00 (1.00–1.01)  | 0.96 (0.91–1.02)  | 1.01 (1.00–1.01)  |
|                      | Non agriculture| 1                | 1                 | 1                 | 1                 |
| Religion             | orthodox       | 1                | 1                 | 1                 | 1                 |
|                      | Muslim         | 0.99 (0.98–0.99)** | 0.99 (0.98–0.99)** | 1.10 (1.03–1.19)** | 0.99 (0.98–0.99)** |
|                      | protestant     | 0.99 (0.98–0.99)** | 0.99 (0.98–0.99)** | 1.01 (0.93–1.10)  | 0.99 (0.98–0.99)** |
|                      | others         | 0.99 (0.97–1.00) | 0.98 (0.97–1.01)  | 1.06 (0.89–1.27)  | 0.99 (0.98–1.01)  |
| ln_gam/p             | -3.09 (-3.07, -2.95) | -2.82 (-2.85, -2.79) | 2.31 (-2.30, -2.33) | 2.31 (-2.30, -2.33) |
| ln_theta             | -0.42 (-0.42, -0.08) | 1.47 (-1.66, -1.28) | -3.58 (-4.00, -3.17) | -3.58 (-4.00, -3.17) |
| Gamma/p              | 0.05 (0.04–0.05) | 0.06 (0.06–0.062) | 10.11 (9.97–10.25) | 10.11 (9.97–10.25) |
| Theta                | 0.84 (0.65–1.09) | 0.23 (0.19–0.28) | 0.03 (0.03–0.04) | 0.03 (0.03–0.04) |
| LR test of theta = 0 | Chibar2(1)     | 702.10           | 599.27            | 35.40             | < 0.001           |
|                     | Prob-chibar2   | < 0.001          | < 0.001           | < 0.001           | < 0.001           |

* Significant at 95% CI, ** Significant at 99% CI
† Significant at 95% CI, †† Significant at 99% CI
MHR = median hazard ratio, † from interaction model
Annex 2: Table 10: Interaction involving inverse Weibull gamma shared frailty model (effect modification)
for Ethiopian reproductive age women.

Having the same frailty or cluster effect living in Oromia increased the hazard of early childbirth by 18% (AHR = 1.18, 95%, CI: 1.06-1.30); living in SNNP increased the hazard of early childbirth by 19% (AHR = 1.19, 95, CI: 1.06–1.30); living in Eastern pastoralist region increased the hazard of early childbirth by 16% (AHR = 1.16, 95%, CI: 1.05-1.28) and living in western semi pastoralist regions increased the hazard of early childbirth by 37% (AHR = 1.37, 95%, CI:1.24-1.52) than living in most urban regions controlling for other factors (Table 8).

With the same level of frailty and adjusting for the other factors women having secondary and higher education level have 14% (AHR = 0.86, 95% CI: 0.78–0.96) and 25% (AHR = 0.75,95% CI: 0.65–0.85) hazard reduction of first birth at early age compared to women with no education level respectively. It was also seen that from the accelerated failure time output women who had secondary education able to delay their first birth by a factor of 1.02 (ATR = 1.02, 95% CI: 1.01-1.03) and those who had higher education by a factor of 1.04 (ATR = 1.04, 95%; CI: 1.03-1.05) than those women had no any formal education at any time (table 10).

Women with richer wealth index were had 10% higher hazard of first birth at an early age compared to those women with poorest wealth index keeping other factors constant and in the same frailty level (AHR = 1.10, 95%, CI:1.01-1.19).

Women living in the same cluster and adjusted for other factors women ever using any methods of contraceptive to delay first birth reduces the hazard of first birth at an early age by 0.91 times compared to ever non-users (AHR = 0.91, 95%, CI:0.86–0.97).

Adjusting for other factors and women in the same frailty having spousal age difference greater than 5 years had 11% higher hazard of first birth at an early age compared to women having spousal age difference less than 5 years (AHR = 1.11, 95% CI:1.05-1.16).

At the same level of susceptibility and holding constant other factors women who were married 15-17 years had 2.33 (AHR = 2.33, 95%, CI:2.08-2.63) times higher hazard of first birth at early age compared to women those who were married 18 years and above respectively. It was also interpreted as time to first birth was accelerated by a factor of 0.90 (ATR = 0.90: 95% CI:0.89-91) among women
married before 15 years and by factor 0.94 (ATR = 0.94, 95%, CI:0.93–0.95) among married 15 to 17 years compared to women married 18 years and later at any time (Annex 3, Table 11).

The hazard of first birth at an early age was increased by (AHR = 23.81, 95%, CI: 22.22–25.64) times in married stratum and reduced by (AHR = 0.063, 95%, CI: 0.035–0.11) time in not married stratum among women who were started sexual intercourse earlier than 15 years than those women started sexual intercourse at the age of 18 years and later with marriage in the same level frailty level and making constant other factors. The hazard of early childbirth was higher among women who were stated intercourse 15 to 17 years in marriage by (AHR = 5.56, 95%, CI: 5.26–5.88) and it was reduced by (AHR = 0.033: 95%, CI:0.022–0.048) in those started intercourse before marriage than those who were started sexual intercourse in marriage at the age of 18 years and later (Table 9).

Table 9: crude, adjusted and marriage specific strata comparison of effect sizes to identify interaction or confounding

| Age at first sex | Crude HR  | Adjusted HR  | Married stratum  | Not married stratum  |
|------------------|----------|--------------|------------------|----------------------|
| < 15 years       | 1.89 (1.78-1.99) | 12.26 (11.26-13.33) | 23.81 (22.22-25.64) | 0.063 (0.035–0.11) |
| 15–17 years      | 0.68 (0.65-0.71) | 3.22 (3.03–3.45) | 5.56 (5.26–5.88) | 0.033 (0.022–0.048) |
| ≥ 18 years       | Reference | 1            | 1                | 1                    |
| LR test for interaction | Degree of freedom | Chi-square statistic | p-value |                      |
| Age at first marriage with age at first sexual intercourse | 4 | 184.33 | < 0.001 |                      |

The hazard of early childbirth was higher among Muslim religion followers by 10% than orthodox followers given that they were in the same cluster and control for other factors (AHR = 1.10, 95%, CI: 1.03–1.19).

For both below 15 years and 15 to 17 years age at first sexual intercourse the crude, marriage strata specific and adjusted hazard ratio were different. However, the crude hazard ratio was in between marriage strata which indicate marriage is effect modifier of age at first sexual intercourse on time to first birth data (Table 9).

In addition to main effect the interaction term revealed that those married before the age of 15 and enter into sexual intercourse at the age of 15–17 years had an increased hazard of first birth at an early age by (AHR = 4.55, 95%,CI: 2.13–10.02) than who were enter into sexual intercourse with marriage at the age of 18 and later. The hazard of an early childbirth increased by (AHR = 2.63, 95%, CI: 2.22–3.11).
CI: 2.01–3.45) times among women had sexual intercourse at marriage 15 to 17 years than who were married 18 years and later.

**Model Adequacy**

The finding of the bivariable analysis showed that region, respondents education, respondents occupation, household wealth index, spousal age difference, contraceptive use, age at first marriage, age at first sexual intercourse, media exposure, husband education, and occupation were significantly associated with time to the first birth. Residence and religion were included in the multivariable analysis due to previous research significance. However, in the multivariable analysis; region, respondent’s education, age at first sexual intercourse, age at first marriage, spousal age difference, contraceptive use, household wealth index, religion and age at first sexual intercourse and age at first marriage interaction terms are statistically significant predictors of time to first birth among reproductive-age women in Ethiopia (Table 8).

The Cox-Snell residuals versus the Nelson-Aalen cumulative hazard function were obtained by fitting the cox gamma shared frailty, inverse Weibull gamma shared frailty, log-logistic inverse Gaussian frailty and lognormal gamma shared frailty models. The Nelson Aalen cumulative hazard function against the Cox-Snell residuals has a linear pattern making a straight line through the origin of the inverse Weibull gamma shared frailty model when compared to the rest models. This suggests that the inverse Weibull gamma shared frailty model provided the best fit for the time to first birth data analysis (Fig. 8)

Some variability about the 45° line in the right-hand tail is due to reduced effective sample caused by prior gave birth and censoring.

**Discussion**

This study was set out to examine the timing of first birth among reproductive-age women in Ethiopia and modeled factors affecting it using a parametric shared frailty analysis method. The study revealed that majority of women gave their first birth at an early age and age at first marriage, age at first sexual intercourse and women education were most significant factors.

In the current study, the median age at first birth found to be 20 years. This finding is in agreement
with the finding of, Martial Island, Ghana, and Nigeria where the median age at first birth was 19.91 years in Ghana, 20 years in Nigeria to 20.2 years in Martial Island (8,31,37). This might be due to the high prevalence of early marriage and sexual intercourse activities in these countries (50,51). Early marriage compromise women’s decision role in her reproductive health and resulted in early childbirth (52). The other possible justification for this similarity might be due to the limited educational opportunity of girls in these countries as the majority of the population lived in the rural area (53), which forces them to get married at an early age, to get social and financial support (54,55).

However, our finding was much lower than the median ages (> 30 years) in most developed countries (3,56). This might be due to a higher opportunity for girls to stay in school for their adolescent age and a number of women going out to work for their economic independence (3) which help them to delay their first birth. It is also well justified with the awareness of women in developed countries about the consequences of early childbirth and having access to contraceptives to delay first birth in these countries (39). Moreover, women in developed countries have the chance to exercise their reproductive rights and make a decision regarding their reproductive health issues (39).

Women who were started sexual intercourse at an early age had higher hazards of having first birth at an early age than those who were started intercourse at a later age. This outcome is in concurrence with studies conducted in Ghana (31), Bangladeshi (24) and Swaziland (9). This might be due to the exclusion of young women from education and sociocultural miss-conception regarding female reproductive health issues and poor legal backing of women in these developing countries. This argument is supported by the United Nation (UN) report stating that still, one-half (49.8 percent) of the female youth population had either no education or limited education in developing countries (57).

Age at first marriage was also another predictor of age at first birth, as women got married early, the hazard of early motherhood at an early age was increased. This is in agreement with studies conducted in Bangladesh (30), Nigeria (37) and other many studies conducted elsewhere (3,4,7,14,19,20,22,26,31,32). It is apparent that marriage increases the frequency of fertile sexual
intercourses and as it happened in early, it leads motherhood at an early age (18). This is consistent with previous evidence that shows marriage is not planned and desire for women in developing countries rather a requirement to get an economic guarantee and social respect by keeping virginity at marriage (55). In most cases, young females are characterized by lower educational attainment, lack of adequate knowledge about the negative consequences of early childbearing, are financially dependent on their husbands and limited to no role in the decision-making process which essentially restricts their capability to postpone their childbearing to older ages (52).

In addition to main effects the interactions terms between age at first sexual intercourse and age at first marriage revealed those in married stratum in early age were positively associated with early age childbirth and those in not married stratum were negatively associated with early childbirth. It might be due to that in Ethiopia marriage provides normative legalization for childbirth. So, even sexual intercourse happened in an early age unless supported with marriage probability of childbirth is minimal in Ethiopia.

Higher spousal age difference among women was found to be associated with higher early age maternity. This finding was in agreement with findings in Nigeria (37) and Bangladesh (30). Possible reasons might be that higher spousal age difference leads to imbalanced power relations in the family and low level of inter-spouse communication which basically translate into women’s lower involvement in the family decision-making process including the decision to use contraceptives (52,55).

Women’s education and early motherhood were inversely associated in this study. This finding was consistent with study findings in Degua Tembien District, Tigray, Northern Ethiopia (32), Bangladeshi (1) and results elsewhere (3,4,7,14,19,21,22,26,31–35,41–43). In particular, ensuring those adolescent girls to receive at least a secondary level of education is the optimal way of delaying childbirth (53, 58). Possible explanations of the inverse association between educational attainment and motherhood at an early age could be due to that enrolling and retaining girls at least up to a secondary level of education probably reduce early marriage and sexual experience and increase awareness of reproductive health issues (53,58). In contrast, women at lower education level have
lack of adequate knowledge about the high-risk period of becoming pregnant, are not fully aware of family planning methods and the costs of early childbearing on their health and children as well (59). Regarding region of residence Oromia, SNNP, Eastern pastoralist and western semi-pastoralist regions significantly increased the hazard of first birth at an early age compared to most urban regions (Addis Ababa, Dire Dawa, and Harare), controlling for other factors and holding cluster effect the same. This finding was coherent with the study reported in Ethiopia (60) and Ghana (31). This might be due to fewer proportions of educated women, and access to contraceptive and reproductive health issues in rural regions (28). Furthermore, women in rural regions might have less decision making role regarding their reproductive health and timing of first birth.

One contrasting finding in this study was the richer wealth index associated with an increased hazard of first birth at an early age compared to the poorest in the full model. The possible reason may be as 78% of women in Ethiopia are rural residents (28) and in most rural areas wealth is one precondition for marriage as “macha”, which is an amalgamation of wealth from families for the new couples. So those girls from richer families got married early in their lives and became mothers in adolescent age. Ever contraceptive users able to delay their first birth than their counterparts in this study. This finding is in concurrence with findings reported in Northeast Ethiopia (39), East Asia (8) and studies elsewhere (3,7,19,31,33,37,40). It might be due to the fact that as far as the appropriate utilization of contraceptive, sexually active women may able to delay unintended pregnancies and births.

Muslim women had their first births earlier than orthodox women. This might be due to normative pressure and traditional cultures of Muslims influence women not to use a contraceptive. It is supported with 68% of Muslims were not used any form contraceptive compared to only 47% orthodoxies were not used in 2016, EDHS (28). The other justification could be the ignorance of Muslim women. It is also supported by the EDHS report that more than 90% of Muslim women were had primary and no education level (28). This finding was in concurrence with findings in Bangladesh (30) and Nigeria (20) where 90% and 50% of the population were Muslim religion followers.

The study findings should be interpreted in light of numerous limitations. First, the analysis is based on self-reported information and thus is subject to self-report bias (recall and social desirability bias).
For example, there is possibly under-reporting of births ended with death. The choice of predictors in the analysis was also limited to background characteristics. There was the possibility, that other variables not included in the analysis significantly affect time to first birth like parental education and economic status. Some variables like religion are time varying to predict the outcome since current religion only considered in the study.

These limitations notwithstanding, the findings highlight some key factors that are likely to be significant drivers of early entry into motherhood and in a far advanced age at first birth among reproductive-age women in Ethiopia. A key strength of this study is the use of a nationally representative and population-based data to model the timing of first births among reproductive-age women in Ethiopia which make the result to be generalized to the reproductive age women in Ethiopia.

Another important strength of the finding was accounting for the contextual effect which helps to design strategies for context-based interventions. In statistical analysis the possible suitable model for the data considered.

Conclusion
In this study, the median age at first birth was found to be 20 years which was at a lower age compared to the optimum age to first birth 20-29 years. Early age at first marriage, sexual intercourse, high spousal age difference, and being Muslim religion followers were predictors of first birth at an early age. On the other hand secondary and higher education levels, living in the most urban regions, contraceptive use were factors to delay first birth.

Early childbirth, which often originated from early marriage and sexual behavior, result in potential health risks for the young mother and their child, as well as the termination of education and blurred future job prospects. Therefore we recommend: the ministry of women and children affairs’ to introduce programs aiming to reduce early sexual intercourse very early, and before the commencement of the sexual activity.

Better to avoid marriage at an early age and high spousal age difference by teaching the community and enforcing legal marriage age. The Ministry of Education better to retain women to at least a
secondary education level and higher by extending the accesses to rural dominant and pastoralist regions. The Ministry of Health better to maximize utilization of contraceptives by increasing access and promoting friendly methods as well.

Researchers better to conduct researches incorporating family factors and investigate what factors may influence in Muslim religion followers to give first birth at an early age.

Better to explore factor associated with delayed first birth among urban region residents and those had secondary and higher education

List Of Abbreviations
AHR - Adjusted Hazard Ratio, AIC- Akaike Information Criterion, ATR-Adjusted Time Ratio, CSA- Central Statistics Agency, CSPro-Census Survey Program, EAs-Enumeration Areas,EDHS-Ethiopian Demographic Health Survey, GG-Generalized gamma, IW-Inverse Weibull, IQR-interquartile range, MHR- Median hazard ratio, PH-Proportional Hazard, PO- Proportional Odds, WHO-World Health Organization

Declarations

Consent for publication
=Not applicable

Availability of data and material
All data and materials related to the study can be obtained through contacting the corresponding authors.

Competing interests
The authors declare that they have no competing interests.

Adherence to national and international regulations
Not applicable

Funding
There was no specific funding for the research.

Acknowledgement
We are deeply grateful to Mr. Getahun Molla (MPH), Mr. Dessie Abebaw (MPH), Mr. Yigizie Yeshaw
Mr. Baye Dagnew (MSC) and Mr. Adugnaw Zeleke always found time to provide constructive feedback to our thoughts.

We acknowledge University of Gondar for its general support and willingness to conduct this study and measure DHS for their permission to use EDHS data.

**Authors’ contributions**

RD, FA and WS were involved in conception, design and analysis of the study, RD interpretation and drafting the manuscript. FA and WS reviewing the manuscript. All authors read and approved the final manuscript.

**References**

1. Mohammad A, Rabbi F, Kabir MH. Factors Influencing Age at First Birth of Bangladeshi Women- A Multivariate Approach. Am J Public Heal Res. 2013;1(7):191-5. https://doi.org/10.12691/ajphr-1-7-8.

2. Mathews TJ, Hamilton BE, Ph D. Delayed Childbearing: More Women Are Having Their First Child Later in Life. 2009; 1-8.

3. SIRC. The Changing Face of Motherhood. Vol. 44. 2011;1-30.

4. Temin M, Levine R. A New Agenda for Global Health. 2009;1-12

5. Campbell B, Martinelli-heckadon S, Wong S. Motherhood in Childhood. 2013;1-132.

6. Kassa GM, Arowojolu AO, Odukogbe AA, Yalew AW. Prevalence and determinants of adolescent pregnancy in Africa: a systematic review and Meta-analysis. Reprod Health. 2018 Nov; 15(1):195; 1-17 https://doi.org/10.1186/s12978-018-0640-2PMID: 30497509

7. Patton GC, Coff C, Sawyer SM, Viner RM, Haller DM, Bose K, et al. Global patterns of mortality in young people: a systematic analysis of population health data. Lancet. 2009 Sep; 374(9693):881-92. https://doi.org/10.1016/S0140-6736(09)60741-8PMID: 19748397

8. Kennedy E, Gray N, Azzopardi P, Creati M. Adolescent fertility and family planning in
East Asia and the Pacific: a review of DHS reports. Reprod Health. 2011 May; 8(1):1-12. Available from: http://www.reproductive-health-journal.com/content/8/1/11https://doi.org/10.1186/1742-4755-8-11PMID: 21545708

9. Honours SN-M. Demographic and socio-economic determinants of age at first birth in Swaziland. 2017;1-6.

10. Jeha D, Usta I, Ghulmiyyah L, Nassar A. A review of the risks and consequences of adolescent pregnancy. J Neonatal Perinatal Med. 2015 Mar;2015(8):1-8. https://doi.org/10.3233/NPM-15814038PMID:25766198

11. Al CI et. Comparative quantification of health risks global and regional burden of disease attributable to selected major risk factors. 2004;1-1200.

12. Karra M, Lee M. Human capital consequences of teenage childbearing in trends in south african teen. 2012;(March):1-5.

13. Chang Z, Lichtenstein P, D’Onofrio BM, Almqvist C, Kuja-Halkola R, Sjölander A, et al. Maternal age at childbirth and risk for ADHD in offspring: a population-based cohort study. Int J Epidemiol. 2014 Dec;43(6):1815–24. https://doi.org/10.1093/ije/dyu204PMID:25355726

14. Beguy D, Ndugwa R, Kabiru CW. Entry into motherhood among adolescent girls in two informal settlements in Nairobi, Kenya. J Biosoc Sci. 2013;45:721–42https://doi.org/10.1017/S0021932013000199PMID:23688912

15. Dupont J, Ngowa K, Kasia JM, Piso WD, Ngassam A, Noa C. Obstetrical and Perinatal Outcomes of Adolescent Pregnancies in Cameroon: A Retrospective Cohort Study at the Yaoundé General Hospital. 2015;5(February):88-93.

16. Sakai T, Sugawara Y, Watanabe I, Watanabe T, Tomata Y, Nakaya N. Age at first birth and long-term mortality for mothers: the Ohsaki cohort study. Environ Health Prev Med. 2017;22(4):1-14.https://doi.org/10.1186/s12199-017-0631-xPMID:29165118.
17. WHO U. Preventing early pregnancy and poor reproductive outcomes among adolescents in developing countries: what the evidence says. 2008;1-8

18. Central Statistical Agency [Ethiopia] and ICF International. 2012. Ethiopia Demographic and Health Survey 2011. report. Addis Ababa, Ethiopia and Calverton, Maryland, USA; 2012;1-452.

19. Booklet D. World Fertility Patterns 2015. 2015;1-30.

20. Fagbamigbe AF, Idemudia ES. Survival analysis and prognostic factors of timing of first childbirth among women in Nigeria [Internet]. BMC Pregnancy Childbirth. 2016 May; 16(102):1-12. https://doi.org/10.1186/s12884-016-0895-y PMID:27178189

21. Mohammad A, Rabbi F, Kabir M, Kabir R. What Went Wrong with the Achievement of Replacement Fertility in Bangladesh and Its Consequences on the Demographic Dividend: The Role of Proximate Determinants. Rom J Popul Stud. 2018;12(1):1-24.

22. Jacobsson B, Ladfors L, Milsom I. Advanced Maternal Age and Adverse Perinatal Outcome. Obstet Gynecol. 2004; 104(4):72733. https://doi.org/10.1097/01.AOG.0000140682.63746.be PMID:15458893

23. Valadan M, Tanha FD, Sepahi A. Pregnancy Outcomes in Women of Advanced Age. J Fam Reprod Heal. 2011;5(2):57-62.

24. Chowdhury AH, Rumana AS, Faisal A. Factors Affecting Age for First Birth: An Exploratory Analysis on Bangladeshi Women. Int J Res Stud Med Heal Sci. 2017;2(7):31-7.

25. Zare N, Nouri B, Moradi F, Parvareh M. The study of waiting time to first pregnancy in the south of Iran: A parametric frailty model approach. Int J Reprod Biomed (Yazd). 2017 Jan; 15(1):11-6. https://doi.org/10.29252/ijrm.15.1.11PMID:28280795

26. Rossier C. Abortion: An Open Secret? Abortion and Social Network Involvement in Burkina Faso. Reprod Health Matters. 2007 Nov; 15(30):230-
8. https://doi.org/10.1016/S0968-8080(07)30313-3 PMID:17938091

27. Guidelines U. Distinguishing the impact of postponement, spacing and stopping on birth intervals: fecundity. J Biosoc Sci. 2013;45:311-30. https://doi.org/10.1017/S0021932012000648 PMID:23192103.

28. Central Statistical Agency (CSA) [Ethiopia] and ICF. 2016. Ethiopia Demographic and Health Survey 2016. Addis Ababa, Ethiopia, and Rockville, Maryland, USA; 2016;1-551.

29. Mathews TJ, Hamilton BE, Ph D. Mean Age of Mothers is on the Rise: United States, 2000 – 2014. 2016;(232):1-8.

30. Mohammad.s. patterns and determinants of age at first birth in bangladesh. Nüfusbilim Derg. 2013; 35:63–77

31. Ida LA, Albert L. The Statistical Distribution and Determinants of Mother’s Age at First Birth. Am J Theor Appl Stat. 2015;4(2):41–52. https://doi.org/10.11648/j.ajtas.20150402.11.

32. Ayele BG, Gebregzabher TG, Hailu TT, Assefa A. Determinants of teenage pregnancy in Degua Tembien District, Tigray, Northern Ethiopia: A community-based case-control study. PLoS One. 2018;1-15: e0200898. https://doi.org/10.1371/journal.pone.0200898 PMID:30044850

33. Gurmu E, Etana D. Age at First Marriage and First Birth Interval in Ethiopia: Analysis of the Roles of Social and Demographic Factors. African Popul Stud. 2014;28(3):1332-44. https://doi.org/10.11564/0-0-625.

34. Yohanis A, Anteh Y. Prevalence and Factors Associated with Teenage Pregnancy, Northeast Ethiopia, 2017: A Cross-Sectional Study. Hindawi J pregnancy. 2018;2018:1-8).

35. Singh SGARD. The Effect of Early Marriages and Early Childbearing on Women’s
36. Pandey A, Nath DC. Frailty Approach to Age at First Birth in Uttar. J Math Stat Oper Res. 2015;3(1):30-5.

37. Michael O N Kunnuji. A survival analysis of the timing of onset of childbearing among young females in Nigeria: are predictors the same across regions? Reprod Health. 2018;15(173):1-9.

38. Mekonnen Y, Telake DS, Wolde E. Adolescent childbearing trends and sub-national variations in Ethiopia: a pooled analysis of data from six surveys. BMC Pregnancy Childbirth. 2018;18(276):1-13.

39. Habitu YA, Yalew A, Bisetegn TA. Prevalence and Factors Associated with Teenage Pregnancy, Northeast Ethiopia, 2017: A Cross-Sectional Study. J pregnancy. 2018;2018:1-7.

40. Brahmbhatt H, Ph D, Kågesten A, H MP, Emerson M, Decker MR, et al. Prevalence and Determinants of Adolescent Pregnancy in Urban Disadvantaged Settings Across Five Cities. J Adolesc Heal [Internet]. 2014;55(6):S48-57. Available from: http://dx.doi.org/10.1016/j.jadohealth.2014.07.023

41. Islam MM, Islam K, Hasan MS. Adolescent motherhood in Bangladesh: Trends and determinants. PLoS One. 2017 Nov; 12(11):e0188294; 1-14. https://doi.org/10.1371/journal.pone.0188294PMID:29176807.

42. Babalola S, Oyewubi O, Speizer IS, Cobb L, Akiode A, Odeku M. Factors affecting the achievement of fertility intentions in urban Nigeria: analysis of longitudinal data. BMC Public Health. 2017 Dec; 17(1):1-8. https://doi.org/10.1186/s12889-017-4934-z PMID:29228926

43. Yakubu I. Determinants of adolescent pregnancy in sub-Saharan Africa: a systematic review. Reprod Health. 2018;15(15):1-11. https://doi.org/10.1186/s12978-018-0460-
44. Patra S. Motherhood in childhood: addressing reproductive health hazards among adolescent married women in India. Reprod Health. 2016 May; 13(1):1-9. https://doi.org/10.1186/s12978-016-0171-7 PMID:27142211

45. Croft, Trevor N., Aileen M. J. Marshall, Courtney K. Allen et al. 2018. Guide to DHS Statistics. Rockville, Maryland, USA; 2018;1-645.

46. Munda M. Beyond the shared frailty model. 2014. 1-181

47. Hosmer DW. Applied survival analysis: regression modeling of time-to-event data. 2nd ed. David J. Balding, Noel A. C. Cressie, Garren M. Fitzmaurice, Iain M. Johnstone, Geert Molenberghs, David W. Scott, Adrian F. M. Smith, Ruey S. Tsay SW, editor. San Diego: A John Wiley & Sons, Inc., Publication; 411 p; https://doi.org/10.1002/9780470258019.

48. David Collett. Modelling Survival Data in Medical Research. Third edit. Francesca Dominici, Harvard School of Public Health, USA Julian J. Faraway, University of Bath, UK Martin Tanner, Northwestern University, USA Jim Zidek, University of British Columbia C, editor. London: CRC Press Taylor & Francis Group; 2015. 1-538 p.

49. Erto P. The Inverse Weibull Survival Distribution and its Proper Application. Naples, Italy; 2013:1-30.

50. Walker J. Early Marriage in Africa - Trends, Harmful Effects and Interventions. African J Reprod. 2012;16(2):231-40. PMID:22916555.

51. Adebowale SA, Fagbamigbe FA, Okareh TO, Lawal GO. Survival Analysis of Timing of First Marriage among Women of Reproductive age in Nigeria: Regional Differences. African J Reprod Heal December 2012; 2012;16(4):95-107.

52. UNICEF.2001. Early marriage: child spouses. Innocenti Digest No. 7. 2001. Vol. Innocenti. 2001:1-30
53. Mahy M. Adolescent childbearing in sub-Saharan Africa: Can increased schooling alone raise ages at first birth? Neeru Gupta. Demogr Res. 2003;8(4):93–106.

54. Merrill RM. Reproductive Epidemiology Principles and Methods. Chapman T, editor. Michael Brown; 2010. 1-386 p.

55. The United Nations Children’s Fund (UNICEF) 2005. EARLY MARRIAGE A harmful traditional practice: a statistical exploration early marriage a harmful traditional practice a statistical exploration contents. 2005:1-45.

56. OECD. Mean age of mothers at first childbirth. 2014:1-8.

57. Kring SE and S. Young and female - a double strike? 2016.

58. Ferré C. Age at First Child Does Education Delay Fertility Timing? The Case of Kenya. 2009. Report No.: 4833:1-47

59. Angeles G, Guilkey DK, Mroz TA, Street WF, Hill C. The Effects of Education and Family Planning Programs on Fertility in Indonesia. Carolina at Chapel Hill; 2003:1-77.

60. Mekonnen Y, Telake DS, Wolde E. Adolescent childbearing trends and sub-national variations in Ethiopia: a pooled analysis of data from six surveys. 2018;18(276):1-13.

61. Cox C. A Comparison of the Generalized Gamma and Exponentiated Weibull Distributions Christopher. 2015;33(21):3772–80.

62. Khan MS, Pasha GR. The Plotting of Observations for the Inverse Weibull Distribution on Probability Paper The Plotting of Observations for the Inverse Weibull Distribution on Probability Paper. 2009;1(1):11-22.

Additional Tables
Annex 2: Table 10: Interaction involving inverse Weibull gamma shared frailty model (effect modification)
| Variable          | unadjusted | adjusted | Interaction model | Effect size | CHR     | AHR     | AHR     |
|-------------------|------------|----------|------------------|-------------|---------|---------|---------|
| Log likelihood    |            |          |                  |             | 5907.45 | 5802.68 |         |
| Effect size       |            |          |                  | CHR         | AHR     | AHR     |         |
| Region            |            |          |                  |             |         |         |         |
| Most urban        | 1          | 1        | 1                |             |         |         |         |
| Northern          | 1.08(1.01-1.18)** | 1.05(0.95-1.16) | 1.08(0.97-1.16) |             |         |         |         |
| Oromia            | 1.07 (0.98-1.18)* | 1.18(1.06-1.30)** | 1.18(1.06-1.30) |             |         |         |         |
| SNNP              | 0.98 (0.90-1.18) | 1.22(1.09-1.37)** | 1.19(1.06-1.37) |             |         |         |         |
| Eastern           | 1.00 (0.92-1.09) | 1.11(1.01-1.24)* | 1.16(1.05-1.24) |             |         |         |         |
| Western           | 1.12 (1.03-1.22)** | 1.35(1.22-1.49)** | 1.37(1.24-1.49) |             |         |         |         |
| Residence         |            |          |                  | CHR         | AHR     | AHR     |         |
| Urban             | 1          | 1        | 1                |             |         |         |         |
| Rural             | 0.96 (0.91-1.02) | 1.03(0.93-1.14) | 1.09(0.96-1.14) |             |         |         |         |
| Education         |            |          |                  | CHR         | AHR     | AHR     |         |
| No Educ           | 1          | 1        | 1                |             |         |         |         |
| Primary           | 1.72 (1.64-1.82)*** | 0.95(0.89-1.01) | 1.12 (1.05-1.19) |             |         |         |         |
| Secondary         | 0.83 (0.76-0.87)*** | 0.85(0.77-0.94)*** | 0.86 (0.79-0.94) |             |         |         |         |
| Higher            | 0.72 (0.65-0.80)*** | 0.66(0.58-0.75)*** | 0.75 (0.68-0.83) |             |         |         |         |
| Occupation        |            |          |                  | CHR         | AHR     | AHR     |         |
| Not working       | 1.18 (1.13-1.24)*** | 0.98(0.92-1.04) | 1.01(0.95-1.06) |             |         |         |         |
| Agriculture       | 0.98 (0.93-1.04) | 0.94(0.88-1.02) | 0.93(0.86-0.99) |             |         |         |         |
| Non agriculture   | 1          | 1        | 1                |             |         |         |         |
| Wealth index      |            |          |                  | CHR         | AHR     | AHR     |         |
| Poorest           | 1          | 1        | 1                |             |         |         |         |
| Poorer            | 1.03 (0.96-1.10) | 0.98(0.91-1.05) | 0.98(0.91-1.05) |             |         |         |         |
| Middle            | 1.12 (1.05-1.21)*** | 1.00(0.93-1.09) | 0.98(0.92-1.09) |             |         |         |         |
| Richer            | 1.12 (1.05-1.21)*** | 1.10(1.01-1.19)*** | 1.04(0.96-1.09) |             |         |         |         |
| Richest           | 1.12 (1.05-1.21)*** | 1.08(0.97-1.15)*** | 1.01(0.91-1.05) |             |         |         |         |
| Spousal age       |            |          |                  | CHR         | AHR     | AHR     |         |
| < 5 years         | 1          | 1        | 1                |             |         |         |         |
| ≥5 years          | 1.26 (1.21-1.33)*** | 1.09(1.04-1.14)*** | 1.11(1.05-1.14) |             |         |         |         |
| Contraceptive use |            |          |                  | CHR         | AHR     | AHR     |         |
| Ever not          | 1          | 1        | 1                |             |         |         |         |
| Ever use          | 0.50 (0.48-0.52)*** | 0.94 (0.89-0.99)*** | 0.91(0.86-0.97) |             |         |         |         |
| Media exposure    |            |          |                  | CHR         | AHR     | AHR     |         |
| Yes               | 1.10 (1.04-1.15)*** | 1.01(0.94-1.08) | 0.99(0.96-1.06) |             |         |         |         |
| Age at marriage   |            |          |                  | CHR         | AHR     | AHR     |         |
| < 15 years        | 9.10 (8.83-9.86)*** | 2.82 (2.60-3.03)*** | 1.26 (0.87-1.08) |             |         |         |         |
| 15 - 17 years     | 3.50 (3.30-3.64)*** | 1.98 (1.85-2.13)*** | 2.33 (2.06-2.60) |             |         |         |         |
| ≥18 years         | 1          | 1        | 1                |             |         |         |         |
| Age at first sex  |            |          |                  | CHR         | AHR     | AHR     |         |
| < 15 years        | 1.89 (1.78-1.99)*** | 13.60 (12.50-14.93)*** | 27.78 (23.05-31.52) |             |         |         |         |
| 15 - 17 years     | 0.68 (0.65-0.71)*** | 3.23 (3.03-3.52)*** | 2.60 (2.07-3.14) |             |         |         |         |
| Variable                  | Log-logistic-gamma shared frailty | Inverse-Weibull gamma shared frailty | Log-logistic-gamma shared frailty |
|--------------------------|-----------------------------------|-------------------------------------|---------------------------------|
| Husband education        |                                   |                                     |                                 |
| ≥18 years                | 1                                 | 1                                   | 1                               |
| No _educ                 | 1.47 (1.34-1.59)***               | 0.94 (0.85-1.05)                    | 0.94 (0.85-1.05)                |
| primary                  | 1.45 (1.32-1.59)***               | 1.00 (0.91-1.11)                    | 1.00 (0.91-1.11)                |
| secondary                | 1.28 (1.16-1.41)***               | 1.03 (0.93-1.14)                    | 1.03 (0.93-1.14)                |
| Higher                   | 1                                 | 1                                   | 1                               |
| Husband occupation       |                                   |                                     |                                 |
| not working              | 1.14 (1.05-1.23)***               | 0.98 (0.91-1.06)                    | 0.97 (0.96-1.03)                |
| agriculture              | 1.13 (1.08-1.19)***               | 0.96 (0.91-1.02)                    | 0.97 (0.92-1.02)                |
| Non agriculture          | 1                                 | 1                                   | 1                               |
| Religion                 |                                   |                                     |                                 |
| orthodox                 | 1                                 | 1                                   | 1                               |
| Muslim                   | 1.02 (0.97-1.08)                  | 1.07 (0.99-1.15)                    | 1.10 (1.02-1.18)                |
| protestant               | 0.99 (0.92-1.05)                  | 1.01 (0.92-1.10)                    | 1.00 (0.92-1.09)                |
| Others                   | 0.90 (0.77-1.06)                  | 1.03 (0.87-1.22)                    | 1.05 (0.89-1.09)                |
| >18 intercourse and marriage |                                 |                                     |                                 |
| <15 marriage<15 intercourse |                                 |                                     |                                 |
| <15 marriage 15-17 intercourse |                                 |                                     |                                 |
| 15-17 intercourse <15marriage |                                 |                                     |                                 |
| 15-17 intercourse 15-17 marriage |                                 |                                     |                                 |
| Theta                    |                                   |                                     |                                 |
| P                        | 10.11 (9.97-10.25)                |                                     |                                 |
| 1/p                      | 0.099 (0.098-0.10)                |                                     |                                 |
| Theta                    | 0.028 (0.027-0.04)                |                                     |                                 |
| LR test of theta=0       | 35.40                             |                                     |                                 |
| Chibar²(1)               |                                   |                                     |                                 |
| Prob-hibar2              | < 0.001                           |                                     |                                 |

*** p value < 0.01 ** p value < 0.05  * p value <0.25

Annex 3: Table 11: Output comparison from shared frailty models of inverse Weibull gamma frailty and log logistic frailty inverse Gaussian survival models.
|                      | Northern  | Oromia   | SNPP     |
|----------------------|-----------|----------|----------|
|                      | 1.01 (0.98-1.02) | 0.99 (0.95-1.01) | 1.00 (0.99-1.01) | 1.05(0.95-1.16) | 1.18(1.06-1.30)** | 1.22(1.09-1.37)** |
|                      | 1.01 (1.00-1.02) | 0.99 (0.98-1.00) | 1.00 (0.99-1.01) | 1.11(1.01-1.24)* | 1.35(1.22-1.49)** |
|                      | 0.98 (0.96-0.99)** | 0.98 (0.96-0.98)** | 1.18(1.06-1.30)** | 1.11(1.01-1.24)* | 1.35(1.22-1.49)** |
| residence            | urban     | 1        | 1        | 1         |
|                      | rural     | 1.00 (0.99-1.02) | 1.00 (0.99-1.01) | 1.03(0.93-1.14) |
| Education            | No education | 1        | 1        | 1         |
|                      | primary   | 1.01(1.01-.02)* | 1.01(1.01-1.01)* | 0.95(0.89-1.01) |
|                      | secondary | 1.03(1.01-1.04)** | 1.03(1.01-1.04)** | 0.85 (0.77-0.94)** |
|                      | higher    | 1.07(1.05-1.08)** | 1.08(1.06-1.09)** | 0.75 (0.65-0.85)** |
| occupation           | not working | 1.00 (0.99-1.01) | 1.00 (0.99-1.01) | 0.98(0.92-1.04) |
|                      | agriculture | 1.01 (1.00-1.02) | 1.00 (1.00-1.02) | 0.94(0.88-1.02) |
|                      | Non agriculture | 1        | 1        | 1         |
| Wealth index         | poorest   | 1        | 1        | 1         |
|                      | poorer    | 1.00 (0.99-1.01) | 1.00 (0.99-1.01) | 0.98(0.91-1.05) |
|                      | Middle    | 1.01 (1.00-1.01) | 1.00 (1.00-1.01) | 1.00(0.93-1.09) |
|                      | richer    | 0.99 (0.98-0.99)* | 0.99 (0.98-0.99)* | 1.10(1.01-1.19)* |
|                      | richest   | 1.00 (0.99-1.01) | 1.00 (0.99-1.01) | 1.08(0.97-1.15) |
| Spousal age difference| Less than 5 years | 1        | 1        | 1         |
|                      | More than 5 years | 0.99 (0.98-0.99)** | 0.99 (0.98-0.99)** | 1.09(1.04-1.14)** |
| Contraceptive use    | Ever not use | 1        | 1        | 1         |
|                      | Ever use  | 1.00 (0.99-1.01) | 0.99 (0.99-0.99)* | 0.94(0.89-0.99)* |
| Media exposure       | Had no access | 1        | 1        | 1         |
|                      | Had access | 1.00(0.99-1.01) | 1.00 (1.00-1.01) | 1.01(0.94-1.08) |
| Age at first marriage| less than 15 years | 0.85 (0.84-0.86)** | 0.84 (0.83-0.85)** | 2.82(2.60-3.03)** |
|                      | 15 to 17 years | 0.90 (0.89-0.91)** | 0.89(0.88-0.90)** | 1.98(1.85-2.13)** |
|                      | 18 and above | 1        | 1        | 1         |
| Age at first sex     | < 15 years | 0.83(0.81-0.84)** | 0.82(0.81-0.83)** | 13.60(12.50-14.93)** |
|                      | 15 to 17 years | 0.91 (.90-0.92)** | 0.91 (0.90-0.92)** | 3.23(3.03-3.52)** |
|                      | ≥18 years   | 1        | 1        | 1         |
| Husband              | No education | 1        | 1        | 1         |
| Education          | Primary  | Secondary | Higher  |
|--------------------|----------|-----------|---------|
|                    | 1.00 (0.99-1.00) | 1.00 (0.99-1.01) | 1.03 (0.97-1.09) |
| Husband Occupation |          |           |         |
| not working        | 1.00 (0.99-1.02) | 1.00 (0.99-1.01) | 0.98 (0.91-1.06) |
| agriculture        | 1.01 (1.00-1.01) | 1.00 (1.00-1.01) | 0.96 (0.91-1.02) |
| Non agriculture    | 1        | 1         | 1       |
| Religion           |          |           |         |
| orthodox           | 1        | 1         | 1       |
| Muslim             | 0.99 (0.98-0.99)!* | 0.99 (0.98-0.99)** | 1.10 (1.03-1.19)** |
| protestant         | 0.99 (0.98-0.99)!* | 0.99 (0.98-0.99)** | 1.01 (0.93-1.10) |
| others             | 0.99 (0.97-1.00) | 0.98 (0.97-1.01) | 1.06 (0.89-1.27) |

| ln_gam/p           | -3.09 (-3.07, -2.95) | -2.82 (-2.85, -2.79) | 2.31 (2.30-2.33) |
| ln_theta           | -0.17 (-0.42, -0.08) | -1.47 (-1.66, -1.28) | -3.58 (-4.00, -3.17) |
| Gamma/p            | 0.05 (0.04-0.05) | 0.06 (0.06-0.062) | 10.11 (9.97-10.25) |
| Theta              | 0.84 (0.65-1.09) | 0.23 (0.19-0.28) | 0.03 (0.03-0.04) |
| LR test of theta=0 | 702.10 | 599.27 | 35.40 |
| Chibar² (1)        |            |            |         |
| Prob-hibar²        | < 0.001    | < 0.001    | < 0.001 |

! Significant beyond two decimal points
* Significant at 95% CI, ** Significant at 99% CI

Figures
Figure 1

Conceptual framework on time to first birth and its predictors among reproductive-age women adapted from different literature (24, 32, 33, 35, 37, 40, and 41)
Figure 2

Sampling procedure of time to first birth and its predictors among reproductive age women
Figure 3
Kaplan-Meier failure estimates of time to first birth data
A. Overall Kaplan-Meier failure estimate
B. Early, optimal and advanced age at first birth estimates among respondents

Figure 4
Kaplan-Meier failure estimates difference and log-rank equality of survival tests of time to first birth
A. Kaplan-Meier estimate of time to first birth by age at first marriage
B. Kaplan-Meier estimate of time to first birth by education level
Figure 5

Base line hazard estimate of time to first birth among reproductive-age women in Ethiopia
Figure 6

Transformed baseline survival functions of the inverted bathtub-shaped hazard functions over log of survival time A. log-logistic B. lognormal C. Inverse Weibull
Graphical demonstrations of inverse of inverse-Weibull is Weibull distribution for time to first birth data
Figure B

Cox-Snell residual and Nelson Aalen cumulative hazard plots

A. Inverse-Weibull gamma shared frailty
B. log-logistic inverse Gaussian shared frailty
C. lognormal gamma shared frailty
D. cox gamma shared frailty
Figure 9

Figure 9: Kaplan Meier survival difference graphs of time to first birth among different predictors A. Kaplan-Meier survival estimate over geographical regions B. Kaplan-Meier survival estimate over media exposure C. Kaplan-Meier survival estimate over contraceptive use D. Kaplan-Meier survival estimate over wealth-index E. Kaplan-Meier survival estimate over spousal age difference F. Kaplan-Meier survival estimate over age at first sexual intercourse G. Kaplan-Meier survival estimate over residence H. Kaplan-Meier survival estimate over respondents occupation
Supplementary Files
This is a list of supplementary files associated with this preprint. Click to download.

STROBEchecklist.pdf
Measuresofdependenceinsharedfrailtymodeling.pdf