

Modelling Determinants of Time to Age at First Marriage Among Nigeria Women: Stratified-Extended Cox Model

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ABSTRACT

The time to age at first marriage is the duration of time between birth until the age at which women began to live with their first partner. This study seeks to apply the Stratified-Extended Cox model (SE-Cox) which addresses the limitations of Cox proportional Hazard model and combines the features of both Stratified Cox and Extended Cox in a single model. The data on age at first marriage of women aged 15-49 from the Nigeria Demographic and Health Survey conducted in 2018 was used. It was observed that Highest educational qualification level, religion, birth cohort and age at first sex violates the Cox proportional hazard assumptions. The Highest educational qualification and religion are assumed to be strata while birth cohort and age at first sex are assumed to be time-varying covariates. The study showed that region, location of residence, wealth index, respondent age at first sex and birth cohort are significant factors that affects the age at first marriage.

Keywords: Stratified-Extended Cox, strata, time-varying covariates, proportional assumption, age at first marriage

Introduction

Time to age at first marriage for women is the duration of time from birth until the age a woman married for the first time (Budu *et al.*, 2021), to some, it is the length of time up to a new chapter of life (Liang *et al.*, 2021). The time at which marriage is initiated has a significant effect on the quality of life of the woman, thereby shifting her focus to family life and motherhood, rather than exploration of the world, continuation of

education, economic empowerment and social networks (Mensch, *et al.*, 1998, Singh and Samara, 1996). An increasing age at first marriage is viewed to have a significant relationship with a woman's market work (Spierings, *et al.*, 2010), equitable toward gender (Al-Nsour, *et al.*, 2009) and serves as a prerequisite for women's empowerment (Lee-Rife, 2010). Age at first marriage has a major effect on the duration of exposure to the impact of pregnancy and the

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number of children women can have over their lifetime (Demographic and Health Survey, 2012, Akhtarul and Abdur, 2020). WHO, 2023 reports that adolescent birth rate for girls between ages 10 to 14 years as at 2022 was estimated at 1.5 per 1000 women with sub-Saharan Africa countries reporting a higher rate of 4.6. Early marriage largely affects sub-Saharan African, about 40% of women aged 20-24 worldwide who were married before the age of 18 live in Sub Saharan Africa (Elengemoke, *et al.*, 2021). Nigeria being one of the most populous nations in Africa with large diversity in culture and ethnicity is faced with early age at marriage particularly in the Northern region (Adamu, *et al.*, 2003, Akpan, 2003).

Most studies on age at first marriage in Nigeria conducted used logistic regression and Cox proportional hazard models to analysis the determinants of time to age at first marriage (Adebowale, *et al.*, 2012, Adeniyi, *et al.*, 2013, Efobi, *et al.*, 2021, Adeniyi *et al.*, 2023). But those models have their own limitations. For instance, categorizing the continuous time variable in logistic regression is not a good practice since the cutoffs tend to be arbitrary and part of the information is lost (Ranganathan, *et al.*, 2017), a Cox proportional hazard model require that the the hazard ratio is assumed to remain constant throughout the follow-up for different strata and in-dependency assumption of the predictors (Hougaard, 2012, Crowther, *et at.*, 2014, Deo, *et al.*, 2021).

To overcome this situation, we used the Stratified extended Cox (SE Cox) that deals with non-proportionality hazard problem in Cox model, this model combines stratified Cox and extended Cox (Ratnaningsih, *et al.*, 2019). In many practical studies, time independent and time-dependent covariates which violates the proportional hazard assumptions often occur in a data set, assuming that all covariates which violates this assumption is time-varying may not be appropriate. Therefore, the combination of both Cox Stratified and extended Cox in a single model will address all the

peculiarities of such data set better than using both models separately. The aim of this study is to analysis the factors that influence the time to age at first marriage among Nigeria women using a methodology that address all the peculiarities of data in a single model. This study will help to identify relevant solutions for women marriage-related problems in Nigeria.

Materials and Methods

The study used dataset on age at first marriage of women aged 15-49 years from the 2018 Nigeria Demographic and Health Survey (2018); a nationally representative data.

Variable description

The dependent variable is time to age at first marriage measured in years. The factors considered are religion (Islam and Christianity), highest educational qualification (no education, primary, secondary, higher), birth cohort (less than 20, 20-29, 30-39, 40-49), wealth index (poor, middle, rich), geo-political zone (North central, North east, North west, South east, South south, South west), location of residence (urban, rural) and age at first sex. The first categories of the categorical variables are the reference categories.

Stratified-Extended Cox Model

The Cox proportional hazard model (Cox, 1972) is popularly used to model time to event data because of flexibility to give reasonably good estimates of the regression coefficient and hazard ratios for a wide variety of data even when the form of the baseline hazard is not specified. This model assumes a constant and independent risk for all subjects with respect to time. In many practical applications, some of the covariates do not follow the assumptions of the Cox Model. In order to overcome the violation of the Cox model assumptions, modifications of the Cox model have been proposed by many researchers. The stratified Cox model (Cox, 1972, Mehrotra, *et al.*, 2012) is a modification of the Cox model that allows for control by stratifying predictors that does not

satisfy the Cox model assumption. Predictors that are assumed to satisfy the assumptions are included in the model, but the predictors being stratified are not included. The stratified Cox model produced the same parameter estimates in the strata but the baseline hazards in the strata are different. The extended Cox model is an extension of the Cox model which allows the inclusion of time-dependent covariates (variable whose values changes with time) or the multiplication of independent covariates with respect to time in the model. Although the baseline hazards are the same, the estimates of the parameters are not the same over time.

In many cases, both time independent and time-dependent covariates often occurred together in a set of data and some covariates are better stratified than assumed to be time-dependent. The use of both stratified and extended Cox model separately in this scenario is inappropriate, hence a Stratified-Extended Cox Model will give better estimates and save time.

The Stratified-Extended Cox Model (SE Cox) proposed by Ratnaningsih, *et al.*, 2019 deals with non-proportionality problem in Cox model caused by two types of covariates: time-independent and time-dependent covariates. The SE Cox model assumes that there are m covariates with u time-independent covariates and v time-dependent covariates. From the u time-independent covariates, there are k covariates that fulfills the proportional hazard assumption denoted as x_1, x_2, \dots, x_k and z time-independent which violates the proportional hazard assumption with l strata which are excluded from the SE Cox model, meanwhile the time-independent covariates that fulfills the proportional hazard assumptions are included in the model. The v time-dependent covariates denoted as $y_1(t), y_2(t), \dots, y_v(t)$ are included in the model. The SE Cox model is given as

$$h_s(t, x, y) = h_{0s}(t) \exp\left(\sum_{i=1}^k \beta_i x_i + \sum_{j=1}^v \theta_j y_j(t)\right) \quad (1)$$

where:

$h_{0s}(t)$ is the baseline hazard in each stratum

β_i is the coefficient of the i^{th} time-independent covariate that fulfills the cox proportional assumption

x_i is the i^{th} time-independent covariate that fulfills the cox proportional assumption

θ_j is the coefficient the j^{th} time-dependent covariate that violates the cox proportional assumption

$y_j(t)$ the j^{th} time-dependent covariate that violates the cox proportional assumption

Parameter Estimation of the SE Cox model

The parameter estimate is based on likelihood. The maximum likelihood partial function is expressed by L_p . Only j individuals who experience the event of interest contributes to the partial likelihood while $n - j$ individuals who did not experience the event of interest are censored. The likelihood of each observed individual states that the possibility of the event at time t depends on when $T_j \geq t$. The possibility of the i^{th} individual who experience a j event, (P_{ij}) depends on a set of individuals who may experience an event at the t time, called the risk set denoted as $R(t_j)$. The risk possibility of the i^{th} individual at t_j time is defined as:

$$P_{i(t_j)} = \frac{\exp(\sum_{i=1}^k \beta_i x_i + \sum_{j=1}^v \theta_j y_j(t))}{\sum_{j \in R(t_i)} \exp(\sum_{i=1}^k \beta_i x_i + \sum_{j=1}^v \theta_j y_j(t))} \quad (2)$$

The function of the partial likelihood of the SE Cox model as the l -strata is given as:

$$L_l(\gamma) = \prod_{i=1}^{n_l} P_{i(t_j)} = \prod_{i=1}^{n_l} \frac{\exp(\sum_{i=1}^k \beta_i x_i + \sum_{j=1}^v \theta_j y_j(t))}{\sum_{j \in R(t_i)} \exp(\sum_{i=1}^k \beta_i x_i + \sum_{j=1}^v \theta_j y_j(t))} \quad (3)$$

Likelihood function of all the l -strata is given as follows:

$$L_p(\beta) = \prod_{l=1}^z L_l = \prod_{l=1}^z \prod_{i=1}^{n_l} P_{i(t_j)}$$

$$= \prod_{l=1}^z \prod_{i=1}^{n_l} \frac{\exp(\sum_{i=1}^k \beta_i x_i + \sum_{j=1}^v \theta_j y_j(t))}{\sum_{j \in R(t)} \exp(\sum_{i=1}^k \beta_i x_i + \sum_{j=1}^v \theta_j y_j(t))} \quad (4)$$

The estimates of the parameter of the SE Cox can be obtained by maximizing the partial likelihood function in (4) and taking the partial derivative with respect to each of the parameter of the model.

Result

Application to data on age at first Marriage

The SE Cox model is applied to data on age at first marriage among Nigeria women aged 15-49 years. Table 1 shows the frequency distribution of the socio-demographic characteristics of a total of 34764 women with 88.9% uncensored (women who have married) and 11.1% censored (unmarried women) observations.

In the first leg of the analysis, the assumption of the Cox model was tested on the covariates, the Cox proportional hazard analysis yields 4 covariates (highest educational qualification, religion, birth cohort and age at first sex) that fulfill the assumptions of Cox Model, the result is presented in Table 2.

Highest educational level and religion cannot be assumed to vary with time but rather seen as different groups (strata) the women belong while birth cohort and age at first sex are assumed to vary with time. The log-log survival plots of the four covariates are presented in Fig 1 and 2.

Table 3 presents the Loglik, AIC and BIC for Cox model, Cox with time varying covariates and SE Cox model. The SE Cox model produced the least Loglik, AIC and BIC with -240555.3, 481134.6 and 481236.1 which indicates that the SE Cox model is best for the data. Table 4 show the estimates of the hazard of the SE Cox model.

From Table 4, at 5% level of significance, only poor category of the wealth index was not significant in predicting the age at first marriage among the women, all other covariates are

statistically significant. Women from North east and North west are 1.2 and 1.5 times more likely to marry early than women from the North central while the hazard for marrying early decreases for women from the three southern regions compared to women from the North central. Rural dweller women are 1.04 times more likely to experience early marriage that their counterpart in the urban areas while the risk of earl marriage among rich women decreases compare to women with middle wealth index.

For the time varying covariates, the hazard of marrying early decreases by 0.0017 as the time increases for women whose birth cohort is 20-29, 30-39 and 40-49 years compared to women whose birth cohort is less than 20 years. Also, age at first marriage decreases by 0.0001 as age at first sex increases.

From Table 5, it was observed that the age at which Muslim women marries across the different educational qualifications is lower than Christian women, which implies that Muslim women have short survival time to marriage compared to Christian women.

Table 1: Socio-demographic characteristics of the women.

Covariates	Category	N (%)	Censoring status	
			Not Censored	Censored
Region	North Central	6449 (18.6)	5668	781
	North East	6417 (18.5)	6018	399
	North West	8481 (24.4)	8379	102
	South East	4481 (12.9)	3636	845
	South south	4195 (12.0)	3222	973
	South West	4741 (13.6)	3968	773
Location	Urban	13428 (38.6)	11431	1997
	Rural	21336 (61.4)	19460	1876
Highest Educational Qualification	No Education	13404 (38.6)	13219	185
	Primary	5702 (16.4)	5397	305
	Secondary	11933 (34.3)	9498	2435
	Higher	3723 (10.7)	2777	948
Religion	Christianity	17127 (49.3)	13749	3378
	Islam	17637 (50.7)	17142	495
Wealth Index	Poor	14054 (40.4)	6424	856
	Middle	7280 (20.9)	13295	759
	Rich	13430 (38.6)	11172	2258
Birth Cohort	<20 years	2936 (8.4)	1858	1078
	20-29 years	12758 (36.7)	10643	2115
	30-39 years	11219 (32.3)	10693	526
	40-49 years	7851 (22.6)	7697	154
Total			30891 (88.9%)	3873 (11.1%)

Table 2: Test of Proportional Hazard Assumption

Covariates	Categories	Rho	Chisq	p-value
Region	North central			
	North east	-0.016	7.59	0.0059
	North west	-0.0188	10.54	0.0012
	South east	0.0187	10.8	0.001
	South south	-0.0083	2.14	0.1433
	South west	0.0406	49.93	<0.0001
Location of residence	Urban			
	Rural	0.0048	2.16	0.1418
Highest Educational level	No education			
	Primary	-0.0124	4.74	0.0294
	Secondary	0.0452	63.41	<0.0001
	Higher	0.071	157.03	<0.0001
Religion	Islam			
	Christianity	-0.0175	8.93	0.0028
Wealth status	Poor			
	Middle	0.0012	0.05	0.8278
	Rich	0.0128	5.02	0.0251
Birth cohort	< 20 years			
	20-29 years	-0.0309	29.68	<0.0001
	30-39 years	-0.0325	33.16	<0.0001
	40-49 years	-0.0501	83.38	<0.0001
Age at first sex		0.237	3465.29	<0.0001
Global Test			5956.7	<0.0001

4805

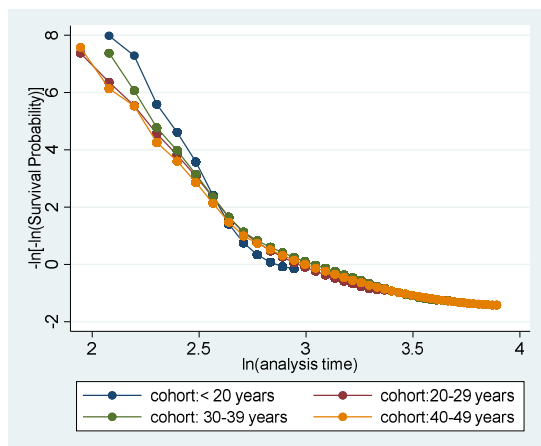
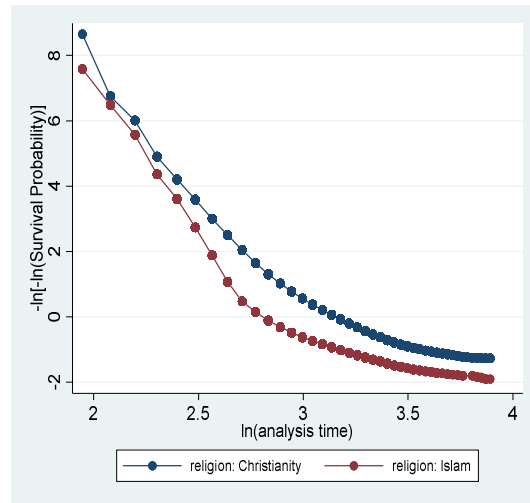
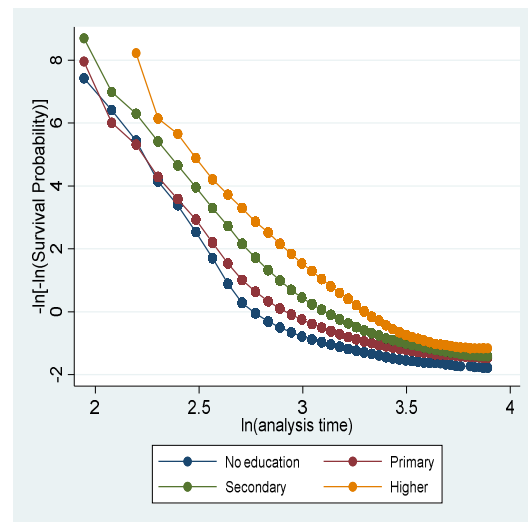


Fig 1: Log-log survival plot for the time dependent covariate



Religion



Highest Educational Qualification

Fig 2: Log-log survival plot for the time-independent covariates

Table 3: Loglik, AIC and BIC for the models

Models	Loglik	AIC	BIC
Cox	-290090.4	580212.8	580348.1
Cox with time varying covariates	-291552.3	583136.5	583271.8
SE Cox	-240555.3	481134.6	481236.1

Table 4: Parameter Estimates of the SE Cox model

Factor	Covariates	Haz. Rat.	Std. Err.	p-value	95% Conf. Int.	
Region	North central					
	North east	1.2193	0.0238	<0.001	1.1735	1.2669
	North west	1.4503	0.0281	<0.001	1.3962	1.5064
	South east	0.8380	0.0198	<0.001	0.7999	0.8777
	South south	0.7523	0.0180	<0.001	0.7177	0.7886
Location of residence	Urban					
	Rural	1.0455	0.0150	0.001	1.0165	1.0753
Wealth status	Middle					
	Poor	1.0302	0.0170	0.071	0.9974	1.0641
Time Varying Covariate	Rich	0.9256	0.0160	<0.001	0.8948	0.9575
	< 20 years					
Birth cohort	20-29 years	0.9922	0.0017	<0.001	0.9890	0.9955
	30-39 years	0.9849	0.0017	<0.001	0.9816	0.9881
	40-49 years	0.9825	0.0017	<0.001	0.9792	0.9858
Age at first sex		0.9965	0.0001	<0.001	0.9964	0.9967

Table 5: Survival time of the Strata combination

Strata combination	Survival Time		
	25%	50%	75%
No Education and Christianity	15	18	22
No Education and Islam	14	15	17
Primary and Christianity	16	19	23
Primary and Islam	14	16	19
Secondary and Christianity	18	22	26
Secondary and Islam	16	19	22
Higher and Christianity	23	27	31
Higher and Islam	19	22	26

Discussion

Several study on the factors that affects age at first marriage have shown that region, location of residence, wealth index and age at first sex are significant factors that affect the age first marriage. Women from the North east and North west are found to marry earlier than those in the other region of the country. This result coincides with the findings of Adebowale *et al.*, 2012, Adeniyi *et al.*, 2013 and Adeniyi *et al.*, 2023. Women from the South south was found to marry at a later age than other regions. The possible reason for early marriage in the North is the need to ensure the preservation of virginity of women and, that women do not become pregnant out of wedlock.

However, late marriages in the southern region of the country could arise due to marriage requirements such of bride and the huge financial challenges on the men

Early marriage was also found in the rural location of the country. This result coincides with a study conducted in Ethiopia by Mobolaji *et al.*, 2020. A possible explanation for early marriage could be inadequate social amenities for proper enlightenment on the risk of early marriage, poverty and strict adherence to traditions. Similar finding from a study in Albania reveal that parents in rural areas encourage their daughters to marry early in order to get potential husbands before they migrate to the cities, and to avoid the threat of kidnapping on the way to school (Ikamari, 2005).

The result of the study shows that the wealth status significantly affects age at first marriage of the women, the better the wealth status of the women, the later the age at first marriage. This result is consistent with the findings of Sasu, 2022 and the two studies conducted in Ethiopia by Kebede, *et al.*, 2007 and Mitiku, *et al.*, 2018 that women in Nigeria in the low wealth quintiles marries at younger age compared to women on the higher wealth quintiles. The reason for early marriage among the poor might be justified in other to raise income for their family.

From the time varying covariates, it was observed that the birth cohort the women belong have a significant effect on the age at first marriage. This is evident in the hazard as the risk of early marriage increases as the birth cohort increases. This implies that women in the earlier cohort (that is, women age 40-49 years, 30-39 year) are exposed to early marriage than women in the late cohort. This is also evidenced in the work of Adeniyi, *et al.* 2023.

One finding of interest is the adverse significant effect of the age at first sex on age at first marriage, this indicates that increase in age at first sex will lead to decrease in age at first marriage. This is consistent with the findings of Adebowale *et al.*, 2012 and inconsistent with the findings of Miller and Heaton, 1991 which found that early initiation of sexual activity was associated with a relatively slow pace of marriage initiation.

Conclusion

The study employed the SE Cox model which combines Cox stratified and extended Cox model features on the analysis of age at first marriage among Nigeria women. It was observed that four covariates did not meet the Cox proportional hazard assumption. From the four covariates, highest educational qualification and religion were assumed to be strata while birth cohort and age at first sex were assumed to be time varying. The SE Cox model presents a better goodness of fit to the data than the Cox and the Extended Cox model.

The study revealed that women from the Northern part of Nigeria marry earlier than their counterpart from other regions of the country. The onset of age at first sexual intercourse was found to increase the age at which women enters marriage while women in the late birth cohort delays marriage to a later age which might be the result of civilization and modern-day socialization. To this end, education of the girl-child should be of utmost priority in order to increase their self-esteem and become active in the decision making of their individual community.

Conflict of Interest

The authors declare no conflict of interest.

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