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COMPARISON BETWEEN COX AND WEIBULL SURVIVAL MODELS IN ESTIMATING THE DETERMINANTS OF DIVORCE IN RIVERS STATE, NIGERIA

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ABSTRACT: *This study examined the comparison between Cox and Weibull survival models in estimating the determinants of divorce in Rivers State, Nigeria. Data consisting of demographic, socio-economic and treatment related variables were collected from Judiciary High court for a period of 10 years for the analysis. The factors estimated were age at marriage of husband and wife, presence of children, duration of marriage, employment status of husband and wife, educational level of husband and wife, number of counselling sessions and court sittings attended. Cox proportional Hazard (Semi-parametric) and Weibull (Parametric) regression models were compared for a better fit in estimating the determinants of the risk of divorce among couples, using the Akaike Information Criterion (AIC). The result showed that Cox proportional hazards regression model performed better than Weibull regression model with a difference of 44.5 AIC value lower than that of the Weibull model. Hence, Cox PH model revealed that, of all the factors, the estimated employment status of husband, presence of children and duration of marriage had significant effect on the risk of divorce. Specifically, employment status of husband and duration of marriage reduced the risk of statutory marriage divorce by 3% and 41% respectively, while presence of children in statutory marriage increased the risk of divorce by 72%. The study thereby recommended among others that the husband, who is the head of the family, should strive, struggle, engage and explore legitimate and genuine jobs or businesses to be able to provide the immediate needs of his family, because the marriage of a jobless and idle husband is always at the risk of divorce.*

KEYWORDS: Cox model, Weibull model, Divorce, Statutory marriage, Survival analysis, Nigeria**.**

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INTRODUCTION

Marriage is a sanctioned union between a man and a woman, which is legally and socially recognized and governed by laws, norms, conventions, beliefs, and attitudes that specify each partner's rights and responsibilities and grant status to offspring (if any) (Rodriguez & Lotha, 2023). Marriage is universal in many societies and cultures because it serves as a structure for many fundamental social and personal functions, including the regulation and gratification of sexual desires, the division of labour between partners, the production and consumption of economic goods, and the satiation of individual needs for status, affection, and companionship. Procreation, child care, education, and socialization are arguably its most important functions. Ensuring the partners' rights against one another and defining the rights and relationships of the children within a community are the primary legal functions of marriage. Traditionally, the act of marriage bestowed upon the child a legitimate status that granted him or her access to the rights of inheritance and other benefits established by the customs of the community.

Black's Law Dictionary (2021) defines divorce as the termination of a marriage by a court decree, releasing the parties from their marital obligations. It is a formal dissolution of marriage that takes place through the legal system. Compared to a separation, it is more permanent. If one gets a divorce, it means the marriage is officially over. On the grounds of divorce in Nigeria, marriage must be at least two (2) years old, else the persons involved would have to go through another process called annulment (Jegede, 2020). Before filing for divorce, couples are advised to attend counseling sessions in the hopes of getting back together. They are legally entitled to a divorce if it does not work out.

Nigerian divorce laws vary depending on the type of marriage. In customary court, a divorce of the customary marriage can happen as fast as two months or less, especially if there are actually no contentions. A High Court statutory marriage divorce cannot be granted in less than six months, unless both parties have mutually decided to end their union amicably. In reality, it could take more than two years to conclude a highly contentious divorce case. More recent studies have shown that the number of divorces is increasing (Michael, 2020), but not many Mathematicians or Statisticians in Nigeria have been able to model factors that could be responsible for this rise in divorce rate. A recent study showed that the North-East and South-South regions of Nigeria had the greatest rates of marital dissolution among ever married populations in Nigeria, with a crude rate of 29.5 per 1000 marriages (Ntoimo & Akokuwebe, 2022). This information triggered this research on divorce; to compare between Cox and Weibull survival models in estimating the determinants of divorce in Rivers State, Nigeria.

Survival analysis is a branch of statistics that deals with analyzing the expected duration of time until a specific event occurs, such as death in biological organisms or failure in mechanical systems (Pocock & Ware, 2013). This field is also known as reliability theory, reliability analysis, or reliability engineering in engineering, duration analysis or duration modeling in economics, and event history analysis in sociology (Hosmer et al., 2013). It is a tool used mostly for clinical trials in the medical field to study the duration of time before a specific event of interest (mostly death) occurs (Klein & Moeschberger, 2010). But recently, it is being applied in engineering, finance, economics, social sciences and many other fields; where the event of interest need not be death, but could be failure of a machine, discharge from hospital after a surgery, divorce from a marriage (as in the case of this study),

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infections, suicide, graduation, and time till malfunctioning of a device, among others (Emmert-Streipt, 2019).

The alarming rate of divorce worldwide has severe consequences on children's well-being and societal stability. Research indicates that divorce can irreparably harm millions of children globally (Patrick & Aaron, 2012). The breakdown of family structures and parent-child relationships leads to numerous negative outcomes, including emotional distress, behavioral problems, decreased academic performance, and social competency issues.

Studies have shown that children from divorced families often experience difficulties in forming healthy relationships, trusting marriage, and adjusting to change (Oluwakemi et al., 2023). They are also more likely to engage in early virginity loss, substance abuse, and delinquency. Furthermore, divorce can lead to increased poverty, economic instability, reduced productivity, and social participation (Michele, 2018; Taylor, 2017). In Nigeria, divorce rates are rising, with severe societal implications, including stigmatization, emotional instability, and increased health problems (Maunde, Salihu & Usman, 2019; Lauren, 2015). Despite this growing concern, there is a lack of research on the underlying factors contributing to the rising divorce rate in Nigeria.

This study aims to fill this knowledge gap by investigating the determinants of divorce in Rivers State, Nigeria, using survival analysis. Specifically, it seeks to compare Cox and Weibull survival models in estimating the factors influencing divorce rates in the region.

METHODOLOGY

Divorce petitions in Nigeria can only be filed in High and Customary courts for Statutory and Customary marriages, respectively. Hence, the data used in this study were secondary data set from Rivers State High court. The dataset consists of 111 cases reported by couples who filed for a divorce between 2010 and 2020.

Categorization and Coding of Variables

The variables were grouped into three categories, namely: demographic variables, socioeconomic variables and treatment variables. The demographic variables include the age at marriage of husband and wife, the presence of children and the duration of marriage. The age at marriage of husband and wife is divided into eight age groups (limits) as shown in Table 1 below.

The presence of children in the marriage was presented as either yes (if the Couples have children or no (if the couples have no children). Hence, we assigned 0 to “no children” and 1 to “the presence of children”.

Duration of marriage is divided into four groups as shown in Table 1. It is measured in years; as the difference between the year of marriage and the year divorce was granted.

The socio-economic variables include the educational level of the husband and wife and their employment status. The education level of the couples is divided into four groups as shown in Table 1 below.

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The employment status of the couples is also divided into three groups. The treatment variable includes the number of attendance of counseling sessions and court sittings.

Variables and Coding

Table 1 shows the selected demographic, socio-economic and treatment variables and the codes assigned to each group of these variables.

Table 1: Description and Coding of Variables

Variables	Description/Coding
Demographic Factors	
Age at marriage of Wife and Husband	Less or equal to 24 years = 1 between the ages of 25 and 29 years = 2 between the ages of 30 and 34 years = 3 between the ages of 35 and 39 years = 4 between the ages of 40 and 44 years = 5 between the ages of 45 and 49 years = 6 between the ages of 50 and 54 years = 7 Greater or equal to 55 = 8
Presence of Children	Children Absent = 0 Children Present = 1
Duration of Marriage	Less or equal to 1 year - Very Short = 1 Between 2 – 5 years - Short = 2 Between 6 – 10 years - Medium = 3 Above 10 years - Long = 4
Socio-Economic Variables	
Educational level of husband and Wife	None or Primary School level = 1 Secondary School or OND level = 2 BSc or HND level = 3 Postgraduate level = 4
Employment Status of Husband and Wife	Unemployed = 1 Business = 2 Civil Servant/Professional Career = 3
Treatment Variables	None = 0 Once = 1 Twice = 2
Number of Counseling Sessions attended	Three or more = 3
Number of Court Sittings attended	1 - 2 times = 1 3 - 4 times = 2 5 - 6 times = 3 7 times or more = 4

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The Survival Function

Let t_i the individual survival time, be a non-negative random variable T, and let $f_i(t)$ be the probability density function and $F_i(t)$ be the cumulative distribution function (cdf). Then; the lifetime distribution function is

$F_i(t) = \Pr\,(T < t_i)$.

The probability density function is

$$f_i(t) = \frac{d}{dt} F_i(t) \quad (1)$$

The survival function $S_i(t)$ is defined as the compliment of the distribution function and is given by

$$S_i(t) = \Pr(T \geq t_i) = 1 - F_i(t) = \int_t^{\infty} f_i(t)dt \quad (2)$$

Survival functions are non-increasing because they get smaller as time t grows. Since no one has yet reached the event, the survival function at time t = 0 is 1, indicating that the likelihood of surviving past time 0 is one at the beginning of the study.

The Hazard Function

The hazard function h(t_0) is the probability of occurrence of an event (e.g divorce) within a short interval δt, given that the individual (marriage) was alive (was not dissolved) at the beginning of the interval $(t_0,\ t_0 + \delta t)$ (Kalbfleisch & Prentice, 2023)

$$h(t_0) = \lim_{\delta t \to 0} \frac{1}{\delta t} \Pr(divorce\ in\ interval[t_0, t_0 + \delta t) | not\ divorced\ at\ time\ t_0) \quad (3)$$

The survivor function and the hazard function are connected in the following ways:$h(t_0) = \lim_{\delta t \to 0} \frac{1}{\delta t} \Pr(divorce\ in\ interval[t_0, t_0 + \delta t) | not\ divorced\ at\ time\ t_0)$

$= \lim_{\delta t \to 0} \frac{1}{\delta t} \frac{F(t_0 + \delta t) - F(t_0)}{S(t_0)}$

$= \frac{1}{S(t_0)} \lim_{\delta t \to 0} \frac{1}{\delta t} \frac{F(t_0 + \delta t) - F(t_0)}{S(t_0)}$

$= \frac{1}{S(t_0)} \frac{d}{dt} F(t_0)$

$= \frac{f(t_0)}{S(t_0)}$

So we have h(t) $= f(t)/S(t)$ (4)

The hazard rate varies between individuals depending on their covariates.

Equation (4) expresses the significant link between h(t), f(t), and S(t). This indicates that survival, density, and hazard are not mutually exclusive (Frank & Matthias, 2019).

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Hazard Ratio

The Hazard Ratio (HR), is a statistical measure that compares the hazard rate between two or more groups (Kemp, 2023), often in the context of time-to-event data, such as in the studies of survival or time until a specific event (divorce) occurs. The hazard rate represents the risk of an event happening at a particular point in time (Reid et al., 2020). The hazard ratio provides insight into how the hazard rate of two groups (e.g., presence of children in the marriage and absence of children) compared over time. A hazard ratio of 1 implies that the two groups have equal hazard rates, meaning there is no difference in the risk of the event (divorce) between the groups. A hazard ratio less than 1 suggests that the first group has a lower risk, while a hazard ratio greater than 1 indicates that the first group has a higher risk of experiencing the event. The hazard ratio is often expressed as;

$$\text{HR} = \frac{h_1(t)}{h_0(t)}$$

Where;

$h_1(t)$ is the hazard rate in group 1 (study group) at time t

$h_0(t)$ is the hazard rate in group 2 (control group) at time t

Kaplan-Meier Estimator of the Survival Function

A basic task in any analysis of survival data is to estimate the survival function. The most basic, popular, and significant nonparametric estimator of the survival function is the Kaplan Meier (KM) estimator (Kleinbaum & Klein, 2017). Another name for it is the product-limit estimator. Non-parametric techniques do not make any particular distributional assumptions. The Kaplan-Meier curve, which is a visual depiction of this function, typically indicates the likelihood of an event, such as a divorce, at a specific time interval (Ruben, 2019). An important advantage of the Kaplan-Meier curve is that the method can take into account "censored data.

The Kaplan - Meier estimator $\hat{S}(t)$ is given by

$$\hat{S}(\text{t}) = \prod_{i:t_i \leq t}\left(1 - \frac{d(t_i)}{n(t_i)}\right)$$

where t_i is the survival time i.e the duration of divorce petition at point i, d_i is the number of divorces up to time t_i and n_i is the number of marriages at risk prior to t_i. The survival function is based upon the probability that a divorce petition survives at the end of a time interval, on the condition that the petition has been filed at the start of the time interval. Hence, the survival function is a product of these probabilities.

Log Rank Test

The log rank test is a popular test to test the null hypothesis of no difference in survival between two or more independent groups (Lisa, 2016). The test compares the entire survival experience between groups and can be thought of as a test of whether the survival curves are identical (overlapping) or not.

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Model Specification

In line with the objectives of this study, two models were used in the study, namely: Cox Proportional Hazard regression model and Weibull regression model.

The Cox Proportional Hazard Regression Model

A semi-parametric model, the Cox proportional hazard model is primarily used to evaluate the correlation between predictor variables and survival time, including age, gender, and treatment type (Kabtamu & Sharma, 2014). The following is a possible expression for the Cox proportional hazard regression model:

$$h(t) = h_o(t)\exp(b_1x_1 + b_2x_2 + b_3x_3 + \cdots + b_px_p)$$

Where h(t) is the expected hazard at time t, h_o(t) is the baseline hazard Function and represent the hazard when all the predictors (or independent variables) $x_1, x_2, x_3, \ldots x_p$ are equal to zero. Notice that predicted hazard (ie h(t)), or the rate of suffering the event of interest in the next instant, is the product of the baseline hazard ($(h_o(t))$) and the exponential function of the linear combination of the prediction. Thus, the predictors have a multiplicative or proportional effect on the predicted hazard. The purpose of the model is to evaluate simultaneously the effect of several factors on survival. In other words, it allows us to examine how specified factors influence the rate of a particular event happening (eg divorce) at a particular point in time. The Schoenfeld residuals was used to test for the Cox proportional hazards assumption. Schoenfeld residuals is defined as the observed values minus the expected values of the covariates (factors) at each event time (Steffensmeier and Jones, 2004).

The Weibull Regression Model

The Weibull regression model is one of the most popular forms of parametric regression model that provides estimate of baseline hazard function, as well as coefficients for factors (Zhangheng 2016). For lifetime data, the Weibull distribution offers a great deal of flexibility. It is the exponential distribution in a more generalized version. A Weibull distribution with scale parameter λ and shape parameter α has the following distribution function:

$$F(t) = 1 - e^{(-\lambda t^{\alpha})}$$

By setting α=1, the Weibull model reduces to an exponential model.

The probability density function of the Weibull distribution is given by

$$f(t) = \lambda\sigma t^{\sigma-1}e^{(-\lambda t^{\sigma})}$$

The survival function is $S(t) = e^{(-\lambda t^{\sigma})}$

The hazard function is $h(t) = \lambda\sigma t^{\sigma-1}$

Where λ and σ are positive constant terms, representing the scale and shape parameter of the distribution respectively. When $\sigma < 1$, it indicates that the hazard rate decreases over time, a

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value of σ = 1 indicates that the hazard rate is constant over time and a value of $\sigma > 1$ indicates that the hazard rate increases over time.

It follows that

$$S(t) = e^{(-\lambda t^{\sigma})}$$

So $\log(-\log[\hat{S}(t)]) = \log\lambda + \sigma \log t$

We plot

$\log(-\log[\hat{S}(t)])$ against log t

Plotting a straight line gradient σ intercept logλ will roughly represent a Weibull lifetime distribution.

RESULTS

Kaplan-Meier Estimate of Survival Time

Figure 1 illustrates the probability of (marriage at risk) surviving against time in months. Time is represented by the horizontal axis (x axis) in months, while the vertical axis (y axis) displays the likelihood of survival or the percentage of marriages that survive. The lines represent the survival curves and the vertical drop in the curve indicates an event; which implies a divorce occurred. The vertical tick marks on the curve means censored data, which implies that the event did not occur; meaning that there was no divorce. The graph shows a steady decrease in the survival rate of statutory marriages within the first 35 months and only about 10% of the marriages survived beyond 100 months. On average, the survival time of statutory marriage was 20.6 months. The minimum survival time was 1 month, meaning that the month the case was filed at the court was the same month the couples divorced, while the maximum survival time was 106.8 months.

Survival Function of Marriage

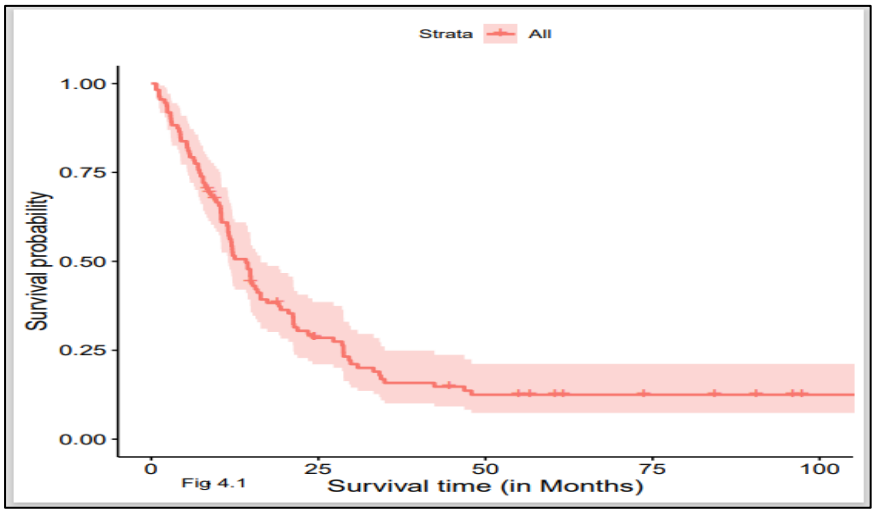

Figure 1: Survival Function of Marriage

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Table 2 shows the results of the Log rank test, which was used to test the null hypothesis of no difference in the survival between the independent groups (Bland & Altman, 2004). Meaning that, there is no difference between populations in the probability of divorce at any point in time. The table displays the chi-square and p-values of the factors of the three different categories. The result shows that duration of marriage (P = 0.001), employment status of husband (P = 0.01) and educational level of husband (P = 0.02) are statistically significant. This means that there is a significant difference in the survival times of the different groups of these determinants.

Table 2: Log Rank Test Result

Factors	Chi-Square	P - Value
Demographics Variables		
Age at marriage of husband	12.3	0.09
Age at marriage of wife	4.7	0.4
Presence of children	0.8	0.4
Duration of marriage	15.4	0.001
Socio-Economic Variables		
Educational level of husband	9.9	0.02
Educational level of wife	1.3	0.3
Employment Status of husband	8.5	0.01
Employment Status of wife	1.3	0.7
Treatment Variables		
No. of Counselling session	1.7	0.4
No. of Court sittings	1.1	0.8

Proportional Hazard Assumptions Test Results

Using a statistical test based on scaled Shoenfeld residuals, the proportional hazard (PH) assumptions were verified. The notion of proportional hazard is reinforced by the non-significant correlation between time and residuals (Kleinbaum & Klein, 2017) . Table 3 shows the Chi-square and p-values for each of the factors.

Table 3: Proportional Hazards Assumption Test Results

Factors	Chi-Square	p-Values
Age at marriage of husband	3.37e-02	0.854
Age at marriage of wife	5.29e-01	0.467
Presence of children	1.26e+00	0.262
Duration of marriage	2.92e+00	0.325
Educational level of husband	2.27e-02	0.496

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Educational level of wife	5.60e-01	0.880
Employment Status of husband	9.69e-01	0.454
Employment Status of wife	4.63e-01	0.991
No. of Counseling session	1.25e-04	0.498
No. of Court sittings	4.60e-01	0.088
Global	1.37e+01	0.185

The Cox Proportional Hazards and Weibull Regression Models Result

A mathematical technique for assessing how well a model matches the data it was created from is the Akaike Information Criterion (AIC) (Bevans, 2020). AIC was used to compare Cox proportional hazard and Weibull models; to determine which one is the better fit for the data. Table 3 shows that the AIC value for Cox ph model (735.33) is lower than the AIC value for Weibull model (779.83). This implies that the Cox ph model is a better fit for statutory marriage data and produces better estimates compared to the Weibull model. Hence, the Cox PH model provides a more parsimonious explanation of the data while still capturing the underlying relationships between the determinants and the hazard rate.

Table 3: Comparing Cox Proportional Hazards and Weibull Models

	COX PH			**WEIBULL**		
Factors	**Coef**	**HR (95% C.I)**	**p-Value**	**Coef**	**HR (95% C.I)**	**p-Value**
Age at marriage of Husband	0.122	1.129 (0.896 – 1.424)	0.304	0.131	1.140 (0.902 – 1.440)	0.273
Age at marriage of Wife	- 0.037	0.963 (0.696 – 1.334)	0.822	-0.028	0.973 (0.705 – 1.343)	0.867
Presence of children	0.540	1.716 (1.012 – 2.909)	0.045	0.591	1.805 (1.069 – 3.047)	0.027
Employment Status of husband	- 0.482	0.618 (0.417 – 0.916)	0.028	-0.490	0.613 (0.413 – 0.908)	0.030
Employment status of Wife	- 0.153	0.858 (0.576 – 2.279)	0.453	-0.176	0.839 (0.566 – 1.245)	0.383
Educational level of husband	0.215	1.240 (0.687 – 2.238)	0.476	0.422	1.525 (0.854 – 2.723)	0.154
Educational level of wife	0.139	1.149 (0.698 – 1.893)	0.584	0.143	1.154 (0.688 – 1.937)	0.588
No. Counseling session	- 0.182	0.833 (0.679 – 1.022)	0.080	-0.157	0.855 (0.696 – 1.050)	0.135
No. of Court Sittings	- 0.056	0.946 (0.697 – 1.283)	0.719	-0.061	0.941 (0.691 – 1.282)	0.700
Duration of Marriage	- 0.521	0.594 (0.447 – 0.789)	0.000	-0.604	0.547 (0.413 – 0.725)	0.000
AIC	735.33			779.83		
Overall p-value	0.029			0.004		

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DISCUSSION

Evaluating Cox proportional hazards (PH) and Weibull regression models using Akaike Information Criterion (AIC) showed that Cox PH (AIC = 735.33) model was a better fit compared to Weibull model (AIC = 779.83). Hence, Cox PH regression model results were considered in this study. The application of Cox PH model on statutory marriage data revealed that age at marriage of husband (P = 0.304) and wife (P = 0.822), educational level of husband (P = 0.476) and wife (P = 0.584) and employment status of wife (P = 0.453) do not affect the risk of divorce. This implies that these factors neither increased nor decreased the rate of divorce among couples in Rivers State because their p-values were all greater than 0.05 significant level. Likewise, the number of counseling sessions (P = 0.080) and court sittings (P = 0.719 attended did not also have any impact on the risk of divorce among couples in Rivers State. Rather, presence of children (P = 0.045), employment status of husband (P = 0.028) and duration of marriage (P = 0.000) were the determinants of divorce of statutory marriage among couples in Rivers State. Specifically, employment status of husband and duration of marriage decreased the risk of divorce by 38% and 41% respectively. This implies that the husband who is the head of the family needs a good job or business to keep his marriage intact, because with a good job or business the husband can provide for his family and take good care of his wife and children.

Also, the number of years couples have been married was found to be a strong reducing factor of divorce of statutory marriage. This could be due to the fact that, as couples stay married longer, they tend to develop stronger bonds and deeper emotional connections over time (Cherry, 2024). They may also learn to navigate challenges more effectively, develop better communication skills and have greater commitment to making the relationship work, thereby reducing the risk of divorce by resolving their marital issues.

Ironically, presence of children was found to be an increasing factor of the risk of divorce of statutory marriage. This could be due to couples facing challenges in balancing parenting responsibilities (Amato, 2018). It could also be due to the inheritance associated with the court rulings, knowing that they have certain protections or assets in place in the event of a divorce (Xu et al, 2015).

CONCLUSION

Based on the findings from the results of the analysis, Cox PH model fits the data better because it is more flexible than the Weibull model. Cox PH model does not assume a specific baseline hazard function, allowing it to flexibly adapt to various hazard shapes. Unlike the Weibull model which assumes a specific parametric form of hazard function and imposes a parametric structure on the data.

The results from the Cox PH Model revealed the factors that increase or decrease the risk of divorce in Rivers State. Conversely, marrying too young, or age at marriage of husband and wife; had no effect on the risk of divorce among couples in Rivers State as presumed. This could be as a result of economic factors, where economic independence and stability could play a larger role in marital success than age at marriage. Couples with stable income and financial security may be less likely to divorce regardless of their age at marriage.

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This research recommends that couples should prioritize the welfare of their children; they should consider the negative effect of divorce in their lives and strive to resolve any marital issues that are not life threatening, in order to avoid divorce.

The research also recommends that the judiciary should keep proper records of divorce cases handled in their various courts to help researchers get enough data for their research and studies, which was the limitation of this research work.

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