

# **SURVIVAL ANALYSIS WITH SAS**

**HANDIN 2**

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# Preface

This document answers Exercise 1 and Exercise 50 of Handin 2 in the course Survival Analysis with SAS.

To see an interactive HTML version of this document, with the possibility to edit out mistakes or make comments, go to this website [afrandsen.rbind.io/bare/h2saws/](https://afrandsen.rbind.io/bare/h2saws/). It will be updated continuously if I find any mistakes myself through GitHub.

# 1 Exercise 1

One expects that the waiting time from diagnosis to death is explained by a Cox' regression model, where the explanatory variables are age, log of albumin level, log of protime and edema. Further, the level of bilirubin could be an explanatory variable, but one is in doubt whether a log transformation is necessary of this variable.

1. Shall bilirubin be included linearly or through a logarithmic transformation? Or would another transformation be more appropriate?
2. Can edema be included linearly or is it necessary to model this variable through three groups?
3. Can some variables be excluded through tests?
4. Does your model fit?

## 1.1 Introduction

In this exercise we consider the survival time of Primary biliary cholangitis (first known as Primary biliary cirrhosis<sup>1</sup>), which is an autoimmune disease of the liver. Slow, progressive destruction of the small bile ducts of the liver, causing bile and other toxins to build up in the liver results in the disease. The disease is more common in women than men. The most common symptoms are tiredness and itching, ([Wikipedia, The Free Encyclopedia, 2019b](#)).

As the disease progresses to cirrhosis, an elevated bilirubin level, a prolonged prothrombin time, and a decreased albumin level can be found. The increased bilirubin level is an ominous sign of disease progression, and liver transplantation must be considered, ([Nikolaos T. Pyrsopoulos, 2017](#)).

To examine the disease we use the dataset pbc which is obtained from ([Department of Statistics at Carnegie Mellon University, 1991](#)). Table 1.1 shows the relevant variables and the first 10 observations.

Table 1.1: The first 10 observations of the relevant subset of pbc.dat.

	futime	status	age	edema	bili	albumin	protimes
1	400	2	21464	1.0	14.5	2.60	12.2
2	4500	0	20617	0.0	1.1	4.14	10.6
3	1012	2	25594	0.5	1.4	3.48	12.0
4	1925	2	19994	0.5	1.8	2.54	10.3
5	1504	1	13918	0.0	3.4	3.53	10.9
6	2503	2	24201	0.0	0.8	3.98	11.0
7	1832	0	20284	0.0	1.0	4.09	9.7
8	2466	2	19379	0.0	0.3	4.00	11.0
9	2400	2	15526	0.0	3.2	3.08	11.0
10	51	2	25772	1.0	12.6	2.74	11.5

## 1.2 Models

We will study the following specifications of our Cox Proportional Hazard model:

- Specification of edema in our model, Section 1.2.1.

<sup>1</sup> Cirrhosis is a feature only in advanced disease.

- Functional form of bilirubin, Section 1.2.2.

Using SAS to obtain parameter estimates and test values, Section 1.3. Next visual inspection of various plots (XBeta, Deviance Residuals, Martingale Residuals, etc.) and information criteria (AIC), will be used to determine which models perform worse than others.

### 1.2.1 Edema

We need to determine if edema shall be included linearly or through three groups. This will result in two different models.

#### 1.2.1.1 Linearly

Using edema linearly as a covariate, we obtain the following Cox Proportional Hazard model

$$h(t|z) = h_0(t) \exp(\beta^T Z),$$

where  $h_0(t)$  is the baseline hazard, and  $Z$  is our vector of covariates which we will write as

$$Z = (\text{age}, \ln(\text{alb}), \ln(\text{pro}), \text{edema})^T.$$

Where we have used the given covariates from the exercise text.

#### 1.2.1.2 Grouping

Using edema in three groups as a covariate, where we use the first edema group as reference, we obtain the following Cox Proportional Hazard model

$$h(t|z) = h_0(t) \exp(\beta^T Z),$$

where  $h_0(t)$  is the baseline hazard, and  $Z$  is our vector of covariates which we will write as

$$Z = (\text{age}, \ln(\text{alb}), \ln(\text{pro}), \mathbb{1}_{\text{edema}=0.5}, \mathbb{1}_{\text{edema}=1})^T.$$

Where we have used the given covariates from the exercise text and made coded covariates that handles the grouping of edema.

### 1.2.2 Functional Form of Bilirubin

We need to determine if bilirubin shall be included linearly or through a transforming function. This will result in different models. I will test the logarithmic transform of bilirubin.

#### 1.2.2.1 Linearly

Using bilirubin linearly as a covariate, we obtain the following Cox Proportional Hazard model, assuming that edema is included linearly

$$h(t|z) = h_0(t) \exp(\beta^T Z),$$

where  $h_0(t)$  is the baseline hazard, and  $Z$  is our vector of covariates which we will write as

$$Z = (\text{age}, \ln(\text{alb}), \ln(\text{pro}), \text{edema}, \text{bili})^T.$$

### 1.2.2.2 Logarithmic Transform

Using bilirubin with a logarithmic transform as a covariate, we obtain the following Cox Proportional Hazard model, assuming that edema is included linearly

$$h(t|z) = h_0(t) \exp(\beta^T Z),$$

where  $h_0(t)$  is the baseline hazard, and  $Z$  is our vector of covariates which we will write as

$$Z = (\text{age}, \ln(\text{alb}), \ln(\text{pro}), \text{edema}, \ln(\text{bili}))^T.$$

## 1.3 Analysis in SAS

### 1.3.1 Edema

#### 1.3.1.1 Linearly

The following show the analysis for edema included linearly. The SAS code, SAS outputs and figures for the rest of the models are available in Appendix B.

```
DATA pbc;
INFILE '~/Survival Analysis/Handin_2/pbc.dat';
INPUT id futime status drug age sex ascites hepato spiders edema
      bili chol albumin copper alk_phos sgot trig platelet protime stage;
IF id < 313;
cen = 0;
IF status = 2 THEN cen = 1;
age = age / 365.25;
log_alb = log(albumin);
log_pro = log(protome);
log_bil = log(bili);
IF edema = 0 OR edema = 0.5 THEN edema_test = 0;
IF edema = 1 THEN edema_test = 1;
KEEP futime status cen age bili albumin protime log_alb log_pro log_bil edema id edema_test;
RUN;

PROC PHREG DATA = pbc ZPH PLOTS(OVERLAY) = SURVIVAL;
MODEL futime*cen(0) = age log_alb log_pro edema / RL TYPE3(ALL);
ASSESS PH / RESAMPLE;
RUN;
```

The following listing show some of the output from the above PHREG procedure.

The PHREG Procedure

#### Model Information

Data Set	WORK.PBC
Dependent Variable	futime
Censoring Variable	cen
Censoring Value(s)	0
Ties Handling	BRESLOW

Number of Observations Read	312
Number of Observations Used	312

## Summary of the Number of Event and Censored Values

Total	Event	Censored	Percent Censored
312	125	187	59.94

## Convergence Status

Convergence criterion (GCNV=1E-8) satisfied.

## Model Fit Statistics

Criterion	Without Covariates	With Covariates
-2 LOG L	1279.960	1159.869
AIC	1279.960	1167.869
SBC	1279.960	1179.182

## Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	120.0910	4	<.0001
Score	178.2996	4	<.0001
Wald	145.0707	4	<.0001

## Type 3 Tests

Effect	DF	LR Statistics	
		Chi-Square	Pr > ChiSq
age	1	6.7402	0.0094
log_alb	1	31.2793	<.0001
log_pro	1	18.8875	<.0001
edema	1	15.3399	<.0001

## The PHREG Procedure

## Type 3 Tests

Effect	DF	Score Statistics	
		Chi-Square	Pr > ChiSq
age	1	6.8929	0.0087
log_alb	1	37.0276	<.0001
log_pro	1	22.5796	<.0001
edema	1	17.7021	<.0001

## Type 3 Tests

Effect	DF	Wald Statistics		
		Chi-Square	Pr > ChiSq	
age	1	6.8590	0.0088	
log_alb	1	37.1068	<.0001	
log_pro	1	22.8438	<.0001	
edema	1	16.7701	<.0001	

### Analysis of Maximum Likelihood Estimates

Parameter	Parameter Standard			Hazard Ratio	95% Hazard Ratio	
	DF	Estimate	Error	Chi-Square	Pr > ChiSq	Confidence Limits
age	1	0.02421	0.00924	6.8590	0.0088	1.025
log_alb	1	-4.06081	0.66663	37.1068	<.0001	0.017
log_pro	1	4.11720	0.86143	22.8438	<.0001	61.387
edema	1	1.20371	0.29394	16.7701	<.0001	3.332

First of all we observe high censoring in our data, 187 observations are censored leaving us with only 125 events. We cannot remove any of our covariates from our model given the likelihood ratio test (all  $p$  values, except the one for age, are  $< 0.0001$ ).

The AIC of this model is 1167.869.

The relative risk of edema in the model is  $\hat{HR}(\text{edema}+1|\text{edema}) = 3.332$  with a 95 % confidence interval of  $C_{95}(\hat{HR}) = (1.873, 5.929)$ .

The following ZPH plots seem to fluctuate for age and log(alb), but log(pro) seems downward sloping and edema seems to stay at a level.

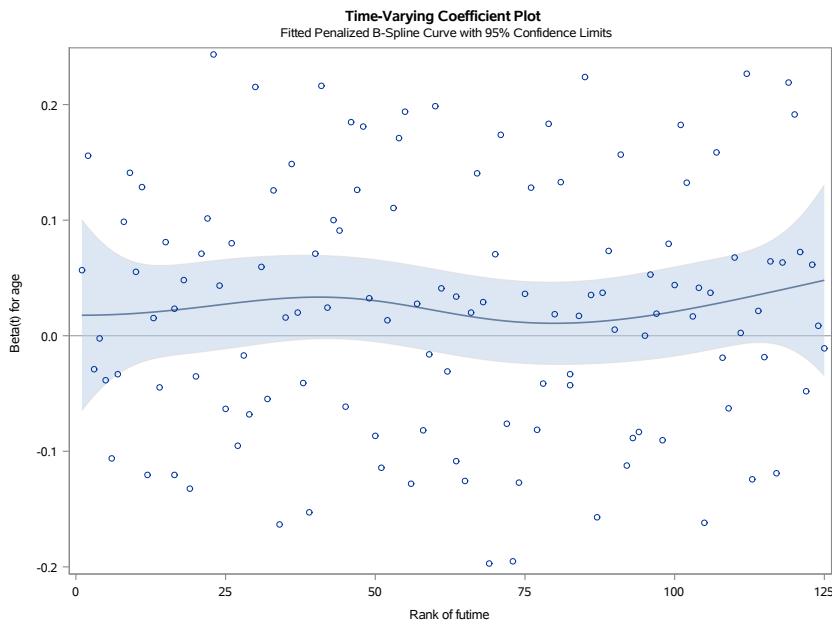


Figure 1.1: ZPH – Edema – Linearly.

The assessment of proportional hazards seems appropriate for age and log(alb), but log(pro) and edema are extreme.

In Figure 1.9 we see the product of the heavy censoring: some of the points cluster at 0.

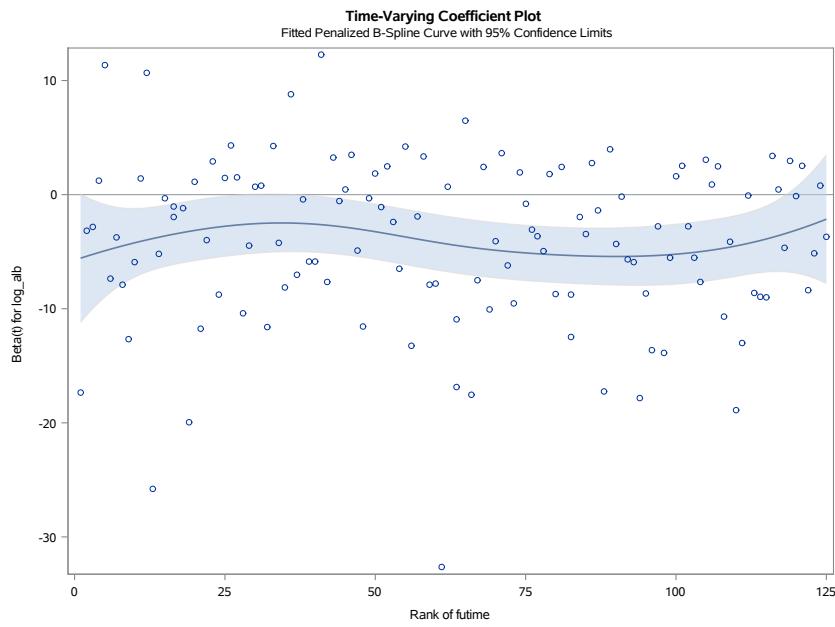


Figure 1.2: ZPH – Edema – Linearly.

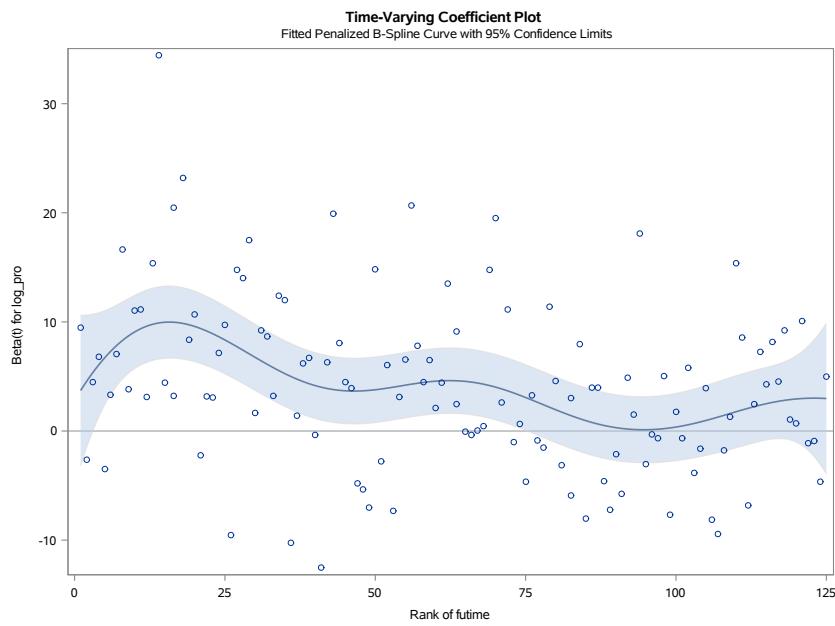


Figure 1.3: ZPH – Edema – Linearly.

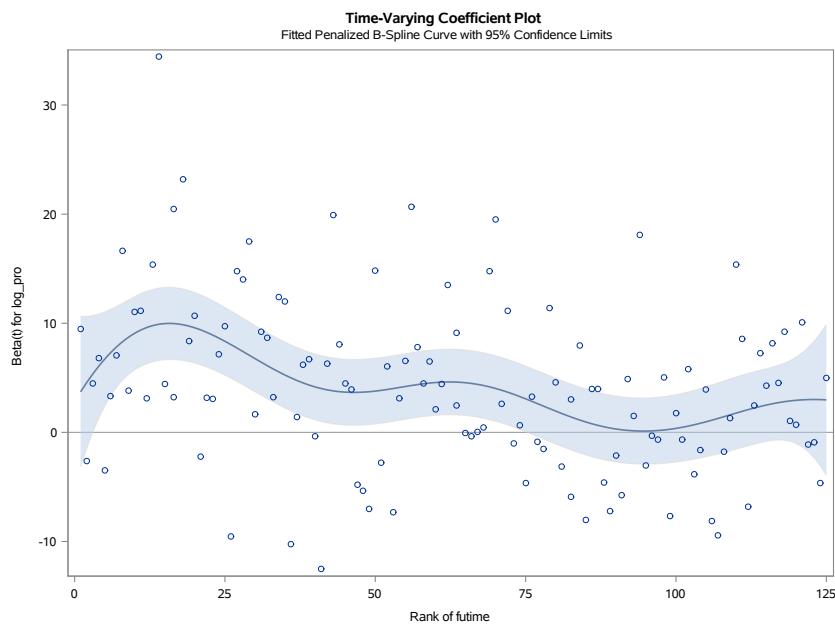


Figure 1.4: ZPH – Edema – Linearly.

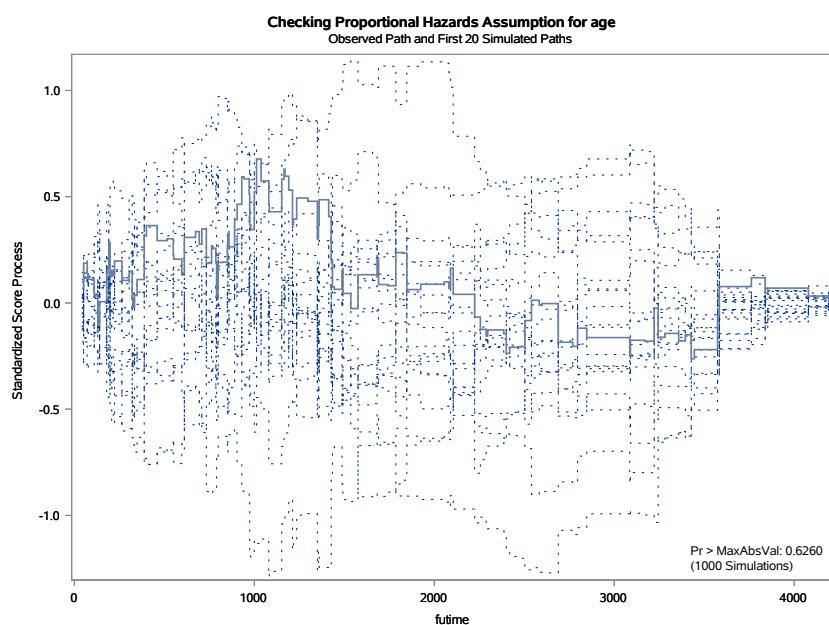


Figure 1.5: ASSESS PH – Edema – Linearly.

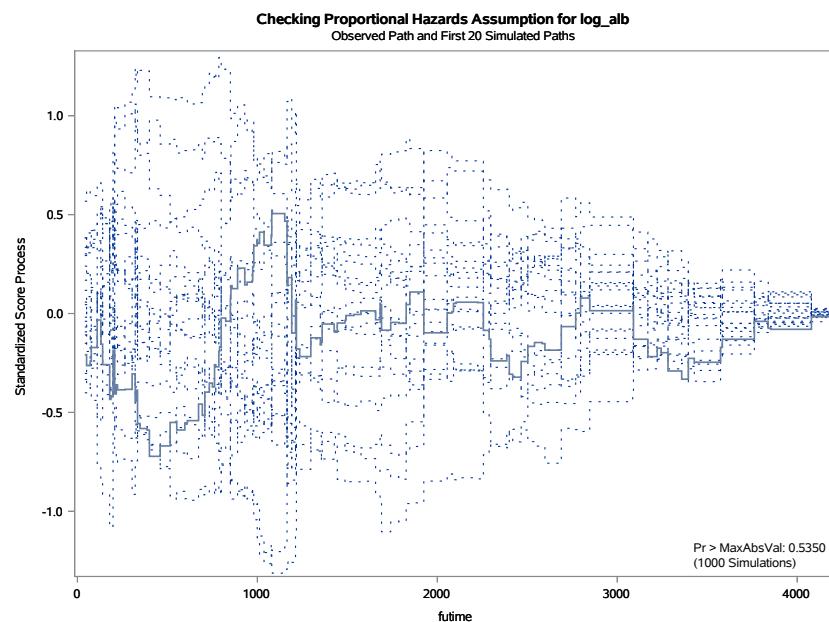


Figure 1.6: ASSESS PH – Edema – Linearly.

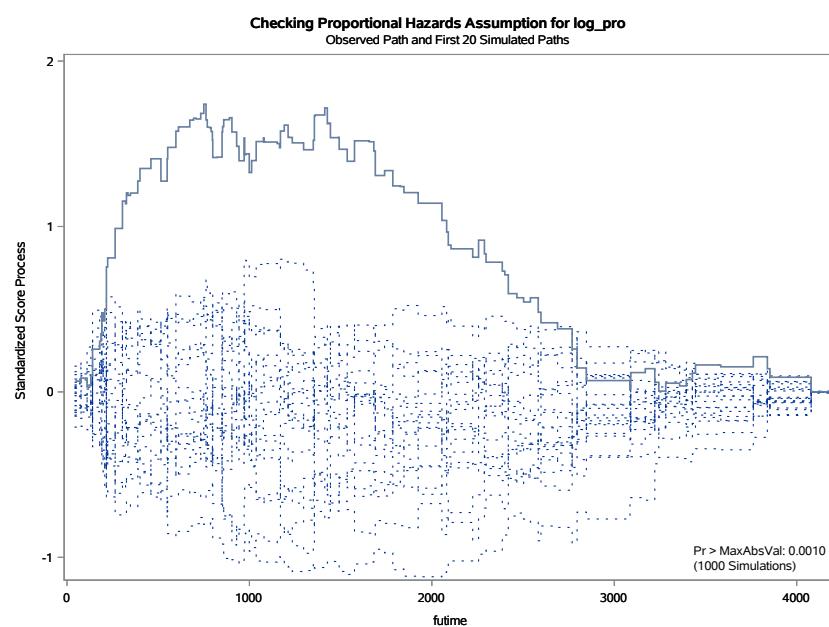


Figure 1.7: ASSESS PH – Edema – Linearly.

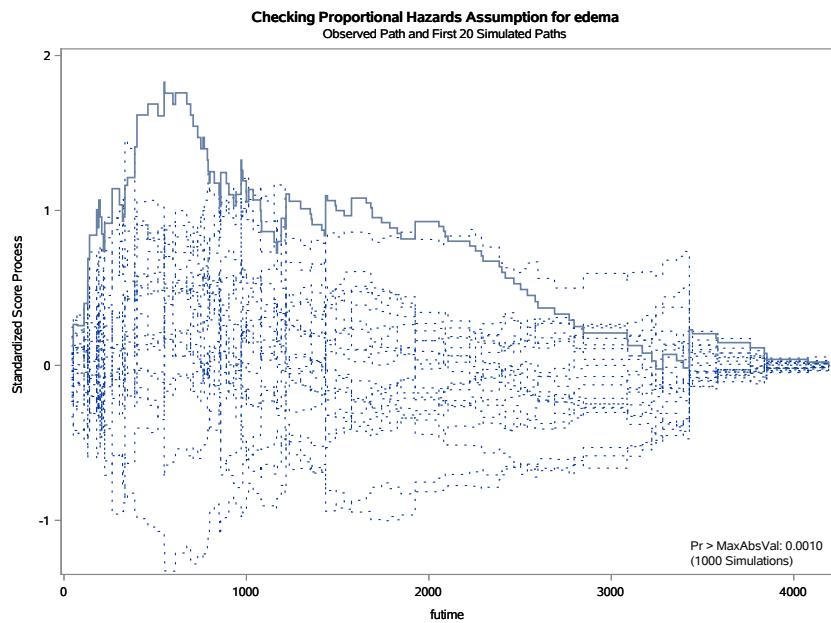


Figure 1.8: ASSESS PH – Edema – Linearly.

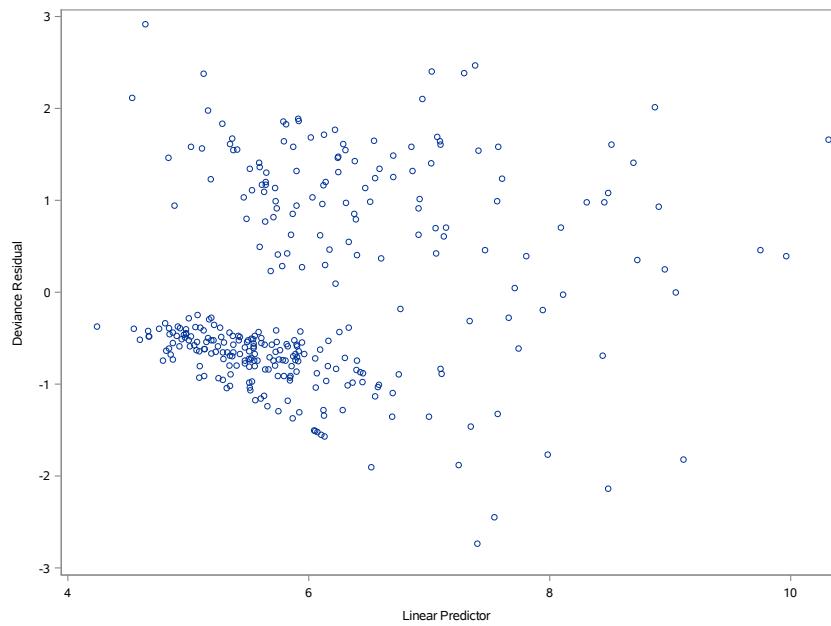


Figure 1.9: RESDEV – Edema – Linearly.

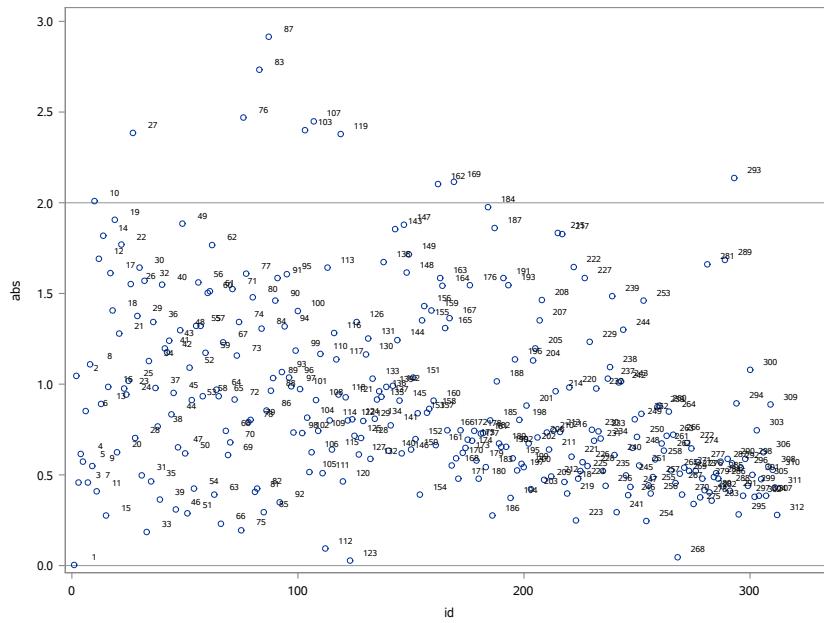


Figure 1.10: RESDEV – OBSERVATIONS – Edema – Linearly.

In Figure 1.10 we observe a great amount of possible outliers. Most noticeable are observations 87 and 83.

In Figure 1.11 we see again see the heavy censoring having an impact: some of the points cluster at 0.

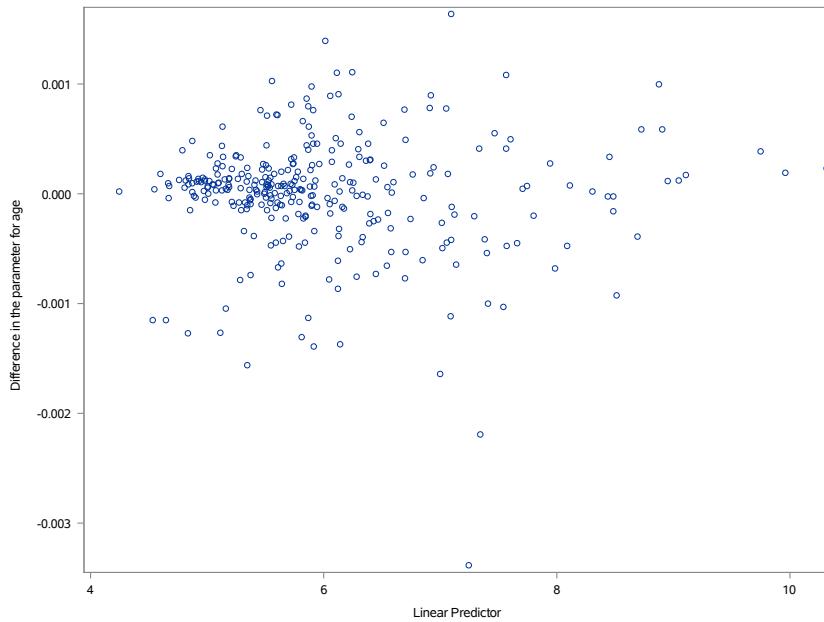


Figure 1.11: DFBETA – Edema – Linearly.

In Figure 1.12 we observe observations 147 and 253 as possible outliers.

Figure 1.13 gives the survival plot of this model.

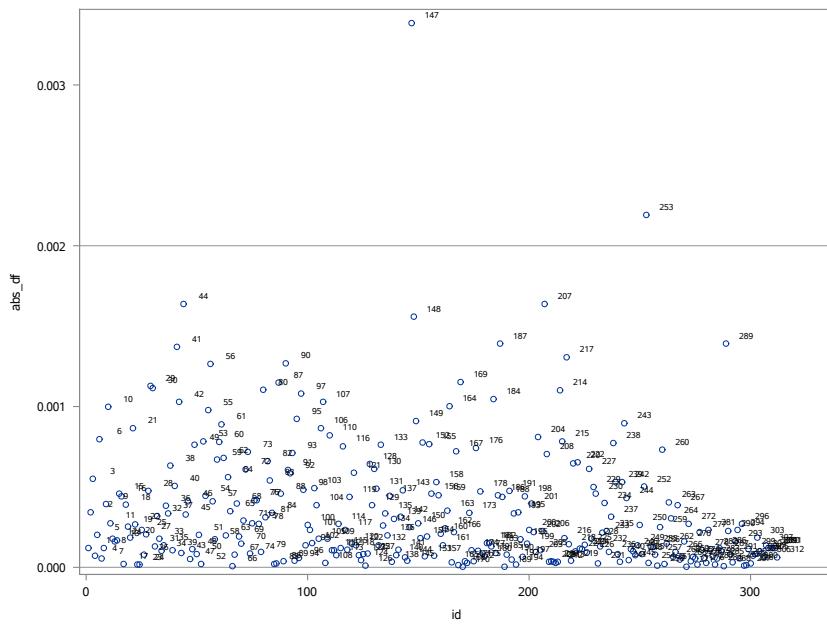


Figure 1.12: DFBETA – OBSERVATIONS – Edema – Linearly.

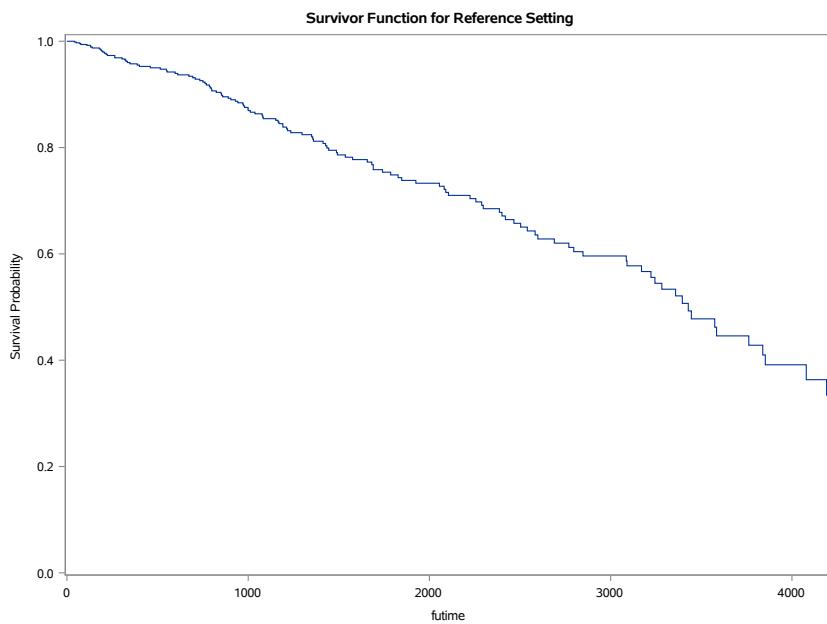


Figure 1.13: Survival Plot – Edema – Linearly.

### 1.3.1.2 Grouping

We cannot remove any of our covariates from our model given the likelihood ratio test.

The relative risk of edema in the model is  $\hat{HR}_1(\text{edema} = 1 | \text{edema} = 0) = 3.930$  with a 95 % confidence interval of  $C_{95}(\hat{HR}_1) = (2.157, 7.160)$  and  $\hat{HR}_{0.5}(\text{edema} = 0.5 | \text{edema} = 0) = 1.344$  with a 95 % confidence interval of  $C_{95}(\hat{HR}_{0.5}) = (0.789, 2.290)$ . For  $\text{edema}=0.5$  the test  $H_0 : \hat{HR}_{0.5} = 0$  suggest that  $\text{edema}=0.5$  isn't statistically significant ( $\chi^2 \approx 1.1863, p \approx 0.2761$ ).

The AIC of this model is 1167.852.

The ZPH plots, in Section B.3.1, seem to fluctuate for age and  $\log(\text{alb})$ , but  $\log(\text{pro})$ ,  $\text{edema}=0.5$  seems downward sloping and  $\text{edema}=1$  seems to stay at a level.

The assesment of proportional hazards, in Section B.3.1, seems appropriate for age and  $\log(\text{alb})$ , but  $\log(\text{pro})$ ,  $\text{edema}=0.5$  and  $\text{edema}=1$  are extreme.

In Figure B.12 we notice clusting at 0 again.

In Figure B.13 we again notice the same observations as outliers (87, 83, etc.).

Figure B.14 and Figure B.15 also seems to have the same conclusions as Figure 1.11 and Figure 1.12.

One could merge the first two groups of edema into one group since  $\hat{HR}_{0.5}$  isn't statistically significant, but then the interpretation of the parameters would be harder.

### 1.3.2 Functional Form of Bilirubin

#### 1.3.2.1 Linearly

We cannot remove any of our covariates from our model given the likelihood ratio test.

The AIC of this model is 1124.549.

The relative risk of bilirubin in the model is  $\hat{HR}(\text{bilirubin} + 1 | \text{bilirubin}) = 1.123$  with a 95 % confidence interval of  $C_{95}(\hat{HR}) = (1.091, 1.157)$ . One might see inclusion of 1 in a higher confidence level.

The ZPH plots, in Section B.3.2, seem to fluctuate for age and  $\log(\text{alb})$ , but  $\log(\text{pro})$  and  $\text{edema}$  seems downward sloping and bilirubin seems upward sloping.

The functional form assesment of the linear inclusion seem to perform bad. Figure B.16 is critical and the associated  $p$  value is  $p < 0.0001$ .

The assesment of proportional hazard for bilirubin in Figure B.26 is not good.

The deviance residual plots, Figure B.27 and Figure B.28, and DFBETA plots, Figure B.29 and Figure B.30, shows clusting and some of the same outliers as in the two previous analyzed models.

The Martingale residual plot in Figure B.31 seems to have upward sloping points suggested by the added PBSPLINE.

#### 1.3.2.2 Logarithmic transform

We cannot remove any of our covariates from our model given the likelihood ratio test.

The AIC of this model is 1090.825.

The relative risk of  $\log(\text{bilirubin})$  in the model is  $\hat{HR}(\ln(\text{bilirubin}) + 1 | \ln(\text{bilirubin})) = 2.409$  with a 95 % confidence interval of  $C_{95}(\hat{HR}_1) = (1.985, 2.923)$ .

The ZPH plots, in Section B.3.2, seem to fluctuate for age and  $\log(\text{alb})$ , but  $\log(\text{pro})$  and  $\text{edema}$  seems downward sloping and  $\log(\text{bilirubin})$  seems to be shifted a bit up, but still fluctuating.

The functional form assesment of the logarithmic inclusion seem to perform bad. Figure B.33 is better than for linear inclusion and the associated  $p$  value is  $p \approx 0.02010$ . Thus the logarithmic transform seems appropriate.

The assesment of proportional hazard for  $\log(\text{bilirubin})$  in Figure B.43 is better than for linear inclusion.

The deviance residual plots, Figure B.44 and Figure B.45, and DFBETA plots, Figure B.46 and Figure B.47, are comparable to the linear inclusion case.

The Martingale residual plot in Figure B.48 seems to have fluctuating points suggested by the added PBSPLINE.

## 1.4 Model Conclusion

The last analyzed model with both edema included linearly and log(bilirubin) seems to outperform the other models with regards to their AIC score. Table 1.2 gives a summary of all analyzed models. As noted in the introduction there seems to be time dependency on bilirubin and thus the logarithmic transformation is appropriate. The other covariates are all statistically significant as well.

Table 1.2: Summary of all models.

Extra covariates	AIC
Edema	1167.869
Edema (3)	1167.852
Edema+Bilirubin	1124.549
Edema+log(Bilirubin)	1090.825

## 2 Exercise 50 (1)

Consider the data set `melanom` which is available from `data_melanom.sas` on the course home page.

Analyze the data using an accelerated failure time model where the explanatory variables are `sex` and `dthick`; the latter is a discretized version of the tumor thickness with three values corresponding to thickness less than 2 millimeter, thickness between 2 and 5 millimeters, and thickness greater than 5 millimeter.

- `sex`, which is 0 if the patient is a woman, 1 otherwise.
- `survtime`, which is the observed survival time in days.
- `status`, which is 0 if the observation is censored, 1 otherwise.
- `invasion`, unknown factor, takes the values 0, 1, 2.
- `ici`, indicator of infectioncellinfiltrat, takes the values 0, 1, 2, 3.
- `ecells`, which is 1 if the tumor contains cells of type epithelioid, 0 otherwise.
- `ulcerat`, which is 1 if ulceration is present, 0 otherwise.
- `thick`, tumor thickness in mm.
- `age`, the age of the person.
- `logthick`, logarithm to `thick`, wrong values thus not used.
- `thick25`, which is 1 if the tumor is between 2 mm and 5 mm, 0 otherwise.
- `thick5`, which is 1 if the tumor is greater than 5 mm, 0 otherwise.

### 2.1 Introduction

In this exercise we consider the survival time of malignant melanoma, which is a type of cancer that develops from the pigment-containing cells known as melanocytes. The primary cause of melanoma is ultraviolet light (UV) exposure in those with low levels of skin pigment. The UV light may be from the sun or other sources, such as tanning devices. Those with many moles, a history of affected family members, and who have poor immune function are at greater risk, ([Wikipedia, The Free Encyclopedia, 2019a](#)).

The tumor thickness known as Breslow thickness or Breslow depth, is a significant factor in predicting how far a melanoma has advanced. In general, a thinner Breslow depth indicates a smaller chance that the tumor has spread and a better outlook for treatment success. The thicker the melanoma measures, the greater its chance of spreading, ([Skin Cancer Foundation, 2019](#)).

To examine the we use the dataset `melanom` which is obtained from the course website. Table 2.1 shows the relevant variables and the first 10 observations.

### 2.2 Models

We will study the following specifications of our Accelerated Failure Time model:

- Model with no covariates, Section 2.2.1.
- Model with `sex`, `dthick` and `sex*dthick` as covariates, Section 2.2.2
- Model with `sex` and `dthick` as covariates, Section 2.2.3

Table 2.1: The first 10 observations of melanom.sas7bdat.

sex	survtime	status	invasion	ici	ecells	ulcerat	thick	age	thick25	thick5	dthick
1	1	30	0	0	0	0	0.65	55.97	0	0	0
2	1	35	0	1	2	0	1.34	41.18	0	0	0
3	0	355	0	0	0	0	0.16	64.23	0	0	0
4	0	817	1	0	2	1	0	0.32	67.02	0	0
5	0	872	1	0	0	1	0	0.97	65.66	0	0
6	1	977	1	0	2	0	1	1.62	58.37	0	0
7	0	1156	1	1	2	0	1	1.34	56.62	0	0
8	1	1427	0	0	2	1	0	1.29	64.28	0	0
9	1	1499	0	0	1	1	0	1.29	73.36	0	0
10	0	1510	0	1	2	1	0	1.94	69.61	0	0

- Model with dthick as the only covariate, Section 2.2.4

Using SAS to obtain parameter estimates and test values for several distributions, Section 2.3. Next visual inspection of various plots (Probability Plot, Cumulative Hazard, etc.) and information criteria (AIC), will be used to determine which models perform worse than others.

### 2.2.1 Model – No Covariates

Using no covariates and assuming the usual linear model for log time, we obtain the following model for our response

$$Y_{ijk} = \ln(X_{ijk}) = \mu_{ij} + \sigma_{ij} W_{ijk},$$

where  $i = 0, 1$ ,  $j = 0, 1, 2$  and  $k = 1, \dots, n_{ij}$ . Depending upon the observation: a male or a female, and whether the tumor thickness is less than 2 millimeter, between 2 and 5 millimeters, or greater than 5 millimeter. Thus we have both different intercepts and slopes, thus we have multiple AFM's. For the lognormal distribution, which will be investigated further in Section 2.3, we have  $W_{ijk} \sim N(0, 1)$ .

### 2.2.2 Model – sex+dthick+sex\*dthick

Using sex, dthick and sex\*dthick as the only covariates and assuming the linear model for log time, we obtain the following model for our response

$$Y_{ijk} = \ln(X_{ijk}) = \mu_{ij} + \beta_j + \sigma W_{ijk},$$

where  $i = 0, 1$ ,  $j = 0, 1, 2$  and  $k = 1, \dots, n_{ij}$ . Thus with the same slope for all groups.

### 2.2.3 Model – sex+dthick

Using sex and dthick as the only covariates and assuming the linear model for log time, we obtain the following model for our response

$$Y_{ijk} = \ln(X_{ijk}) = \alpha_i + \beta_j + \sigma W_{ijk},$$

where  $i = 0, 1$ ,  $j = 0, 1, 2$  and  $k = 1, \dots, n_{ij}$ . Thus with the same slope for all groups.

### 2.2.4 Model – dthick

Using sex and dthick as the only covariates and assuming the linear model for log time, we obtain the following model for our response

$$Y_{ijk} = \ln(X_{ijk}) = \beta_j + \sigma W_{ijk},$$

where  $j = 0, 1, 2$  and  $k = 1, \dots, n_{ij}$ . Thus with the same slope for all groups.

## 2.3 Analysis in SAS

### 2.3.1 Model – No Covariates

First we test the adequacy of a given model in the univariate setting. The key tool is to find a function of the cumulative hazard rate which is linear in some function of time.

Using relevant functions we can test our fit for some different distributions (Klein and Moeschberger, 2003).

For the Exponential distribution we can plot  $\hat{H}$  against  $x$ , thus the cumulative hazard rate against the observed survival time.

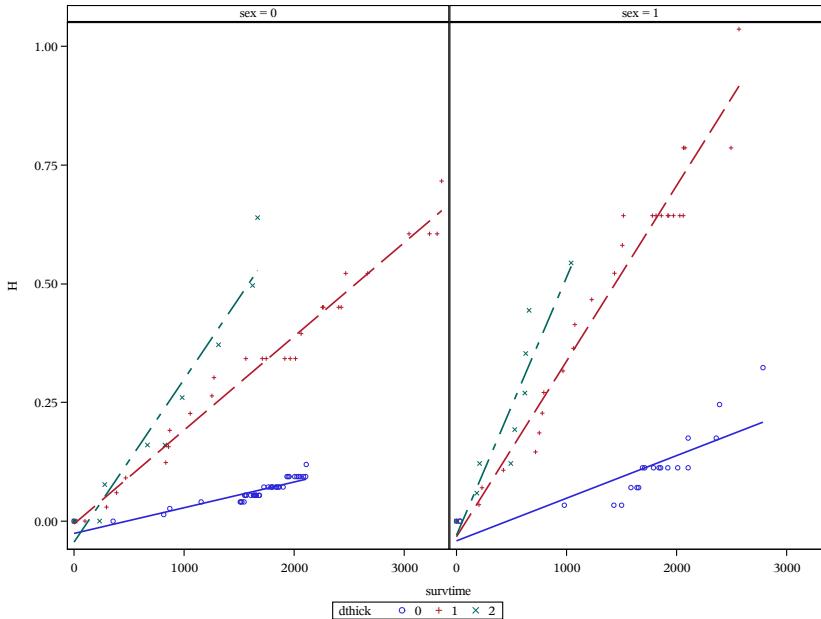


Figure 2.1: Cumulative Hazard – Exponential.

Though I have added a regression line in Figure 2.1 the linearity in group dthick=2 is arguable. Thus from a visual perspective the Exponential distribution does not look adequate for our data.

In the Weibull case we plot  $\ln(\hat{H})$  against  $\ln(x)$ .

In Figure 2.2 we see better results, because of more linearity in our data. This was also expected since the Weibull model have one extra parameter.

For the lognormal case we plot  $\Phi^{-1}(1 - \exp(-\hat{H}))$  against  $\ln(x)$ .

In Figure 2.3 we again see better results than Figure 2.1 and linearity in our data comparable to the Weibull distribution in Figure 2.2.

Lastly for the log logistic case we plot  $\ln(\exp(H) - 1)$  against  $\ln(x)$ .

The data in Figure 2.4 seems to be very linear as well for all groups.

The following show the analysis for the first model using the lognormal distribution. The SAS code, SAS outputs and figures for the rest of the models and distributions<sup>1</sup> are available in Appendix A.

```
PROC LIFEREG DATA = SUPP.melanom;
BY dthick sex;
MODEL survtime*status(0) = / DIST = LNORMAL COVB;
PPLOT;
RUN;
```

<sup>1</sup> Normal and logistic have been left out, due to abnormal AIC's.

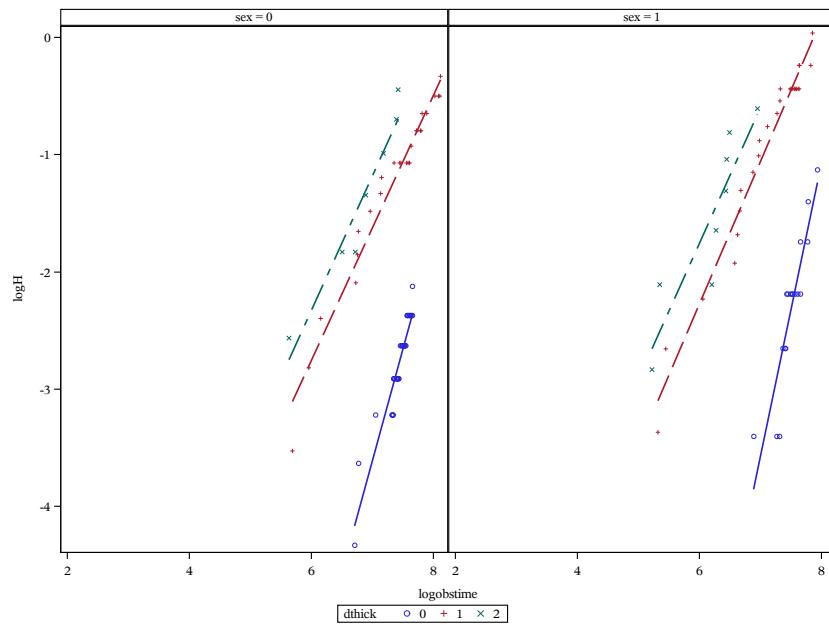


Figure 2.2: Cumulative Hazard – Weibull.

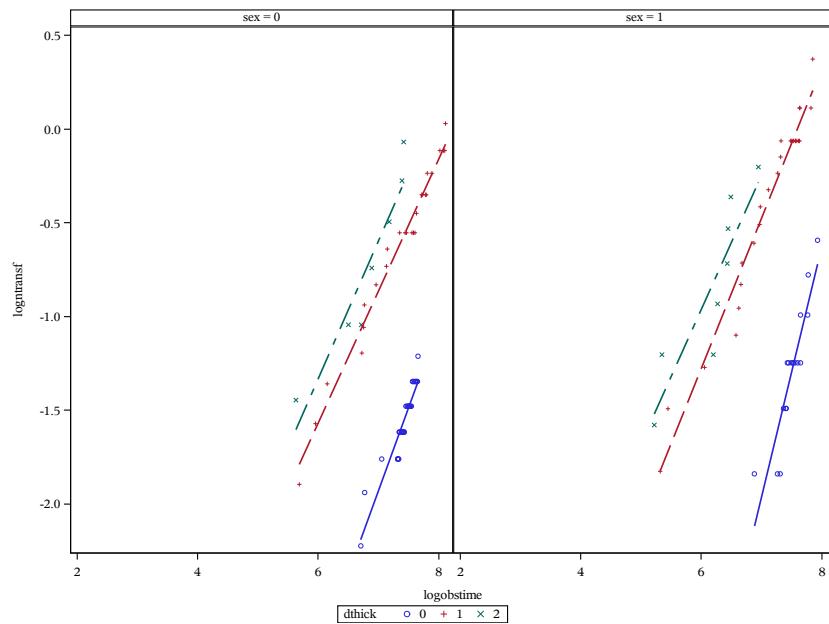


Figure 2.3: Cumulative Hazard – Lognormal.

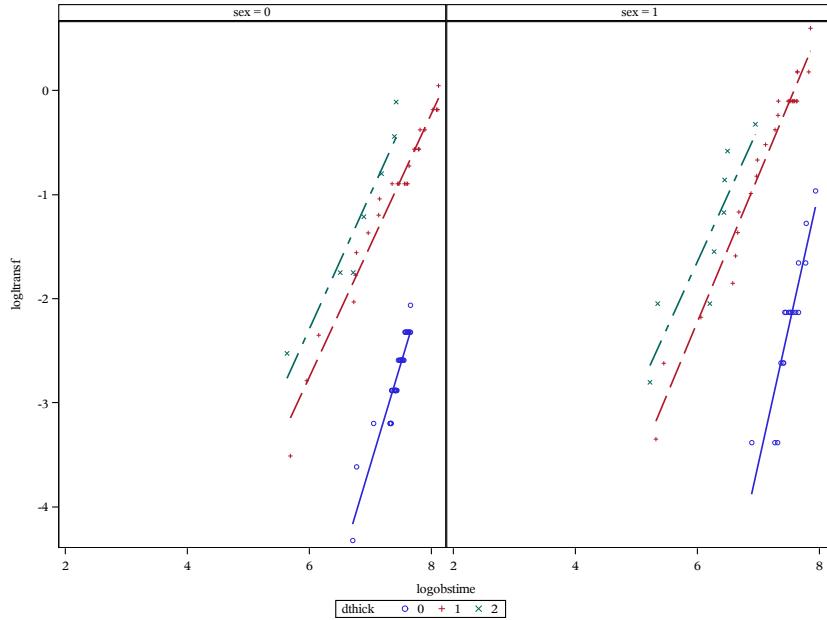


Figure 2.4: Cumulative Hazard – Log Logistic.

The following listing show some of the output from the above LIFEREG procedure.

```
----- dthick=0 sex=0 -----
```

The LIFEREG Procedure

Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	77
Noncensored Values	7
Right Censored Values	70
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	Lognormal
Log Likelihood	-26.4917833

Number of Observations Read	77
Number of Observations Used	77

Parameter Information

Parameter	Effect
Intercept	Intercept

## Fit Statistics

-2 Log Likelihood	52.984
AIC (smaller is better)	56.984
AICC (smaller is better)	57.146
BIC (smaller is better)	61.671

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	154.079
Lognormal AIC (smaller is better)	158.079
Lognormal AICC (smaller is better)	158.241
Lognormal BIC (smaller is better)	162.767

Algorithm converged.

----- dthick=0 sex=0 -----

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	9.5335	0.6414	8.2763 10.7907	220.90	<.0001
Scale	1	1.2946	0.4101	0.6959 2.4086		

## Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.411446	0.241076
Scale	0.241076	0.168163

----- dthick=0 sex=1 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	32
Noncensored Values	6
Right Censored Values	26
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	Lognormal
Log Likelihood	-15.33369667

Number of Observations Read	32
Number of Observations Used	32

## Parameter Information

Parameter	Effect
-----------	--------

Intercept	Intercept
-----------	-----------

## Fit Statistics

-2 Log Likelihood	30.667
AIC (smaller is better)	34.667
AICC (smaller is better)	35.081
BIC (smaller is better)	37.599

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	120.757
Lognormal AIC (smaller is better)	124.757
Lognormal AICC (smaller is better)	125.171
Lognormal BIC (smaller is better)	127.689

Algorithm converged.

----- dthick=0 sex=1 -----

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	95% Confidence Error	Limits	Chi-Square	Pr > ChiSq
Intercept	1	8.5494	0.3231	7.9160 9.1827	699.94	<.0001
Scale	1	0.7788	0.2500	0.4152 1.4610		

## Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.104425	0.063540
Scale	0.063540	0.062494

----- dthick=1 sex=0 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status

Censoring Value(s)	0
Number of Observations	35
Noncensored Values	15
Right Censored Values	20
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	Lognormal
Log Likelihood	-36.78640676

Number of Observations Read	35
Number of Observations Used	35

#### Parameter Information

Parameter	Effect
-----------	--------

Intercept	Intercept
-----------	-----------

#### Fit Statistics

-2 Log Likelihood	73.573
AIC (smaller is better)	77.573
AICC (smaller is better)	77.948
BIC (smaller is better)	80.684

#### Fit Statistics (Unlogged Response)

-2 Log Likelihood	285.435
Lognormal AIC (smaller is better)	289.435
Lognormal AICC (smaller is better)	289.810
Lognormal BIC (smaller is better)	292.546

Algorithm converged.

----- dthick=1 sex=0 -----

#### The LIFEREG Procedure

##### Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	8.1900	0.2889	7.6238 8.7562	803.70	<.0001
Scale	1	1.2733	0.2589	0.8548 1.8967		

#### Estimated Covariance Matrix

Intercept	Scale
Intercept	0.083459
Scale	0.038214

Scale	0.038214	0.067033
-------	----------	----------

----- dthick=1 sex=1 -----

### The LIFEREG Procedure

#### Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	29
Noncensored Values	16
Right Censored Values	13
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	Lognormal
Log Likelihood	-34.18891236

Number of Observations Read	29
Number of Observations Used	29

#### Parameter Information

Parameter	Effect
Intercept	Intercept

#### Fit Statistics

-2 Log Likelihood	68.378
AIC (smaller is better)	72.378
AICC (smaller is better)	72.839
BIC (smaller is better)	75.112

#### Fit Statistics (Unlogged Response)

-2 Log Likelihood	285.734
Lognormal AIC (smaller is better)	289.734
Lognormal AICC (smaller is better)	290.196
Lognormal BIC (smaller is better)	292.469

Algorithm converged.

----- dthick=1 sex=1 -----

### The LIFEREG Procedure

#### Analysis of Maximum Likelihood Parameter Estimates

Standard	95% Confidence	Chi-
----------	----------------	------

Parameter	DF	Estimate	Error	Limits		Square	Pr > ChiSq
Intercept	1	7.5971	0.2444	7.1181	8.0760	966.51	<.0001
Scale	1	1.1232	0.2182	0.7675	1.6438		

## Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.059716	0.019947
Scale	0.019947	0.047628

----- dthick=2 sex=0 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	15
Noncensored Values	6
Right Censored Values	9
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	Lognormal
Log Likelihood	-14.25175082

Number of Observations Read	15
Number of Observations Used	15

## Parameter Information

Parameter	Effect
Intercept	Intercept

## Fit Statistics

-2 Log Likelihood	28.504
AIC (smaller is better)	32.504
AICC (smaller is better)	33.504
BIC (smaller is better)	33.920

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	110.528
Lognormal AIC (smaller is better)	114.528
Lognormal AICC (smaller is better)	115.528
Lognormal BIC (smaller is better)	115.945

Algorithm converged.

----- dthick=2 sex=0 -----

### The LIFEREG Procedure

#### Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	7.8886	0.4341	7.0378 8.7395	330.23	<.0001
Scale	1	1.2154	0.3832	0.6552 2.2547		

#### Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.188448	0.081166
Scale	0.081166	0.146836

----- dthick=2 sex=1 -----

### The LIFEREG Procedure

#### Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	17
Noncensored Values	7
Right Censored Values	10
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	Lognormal
Log Likelihood	-20.84339775

Number of Observations Read	17
Number of Observations Used	17

#### Parameter Information

##### Parameter Effect

Intercept	Intercept
-----------	-----------

#### Fit Statistics

-2 Log Likelihood	41.687
-------------------	--------

AIC (smaller is better)	45.687
AICC (smaller is better)	46.544
BIC (smaller is better)	47.353

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	127.992
Lognormal AIC (smaller is better)	131.992
Lognormal AICC (smaller is better)	132.849
Lognormal BIC (smaller is better)	133.658

Algorithm converged.

----- dthick=2 sex=1 -----

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	8.1159	0.6506	6.8408 9.3911	155.63	<.0001
Scale	1	1.9436	0.5989	1.0625 3.5555		

## Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.423251	0.216675
Scale	0.216675	0.358691

Because we only have 205 observations with 148 censored values and a high grouping we obtain few observations in each group. We cannot remove the intercept  $\mu_{ij}$  from our model as there is a significant effect in each group ( $p < 0.0001$ ), which is as expected.

Under Estimate we can find the estimate of the intercept, base coefficient and the variance. Thus we obtain the following estimates of our model.

$$\hat{\mu} = \begin{pmatrix} 9.5335 \\ 8.5494 \\ 8.1900 \\ 7.5971 \\ 7.8886 \\ 8.1159 \end{pmatrix}, \quad \hat{\sigma} = \begin{pmatrix} 1.2946 \\ 0.7788 \\ 1.2733 \\ 1.1232 \\ 1.2154 \\ 1.9436 \end{pmatrix}.$$

The associated total AIC of the model is 319.793. The associated total -2 log likelihood is 295.793.

If we take a look at the associated plots provided by LIFEREG, we notice some issues with our model. First we take a look at the probability plot for group  $i = 0, j = 0$ . Probability plots use an inverse distribution scale so that a CDF plots as a straight line, a line representing the maximum likelihood fit from the MODEL statement and pointwise parametric confidence bands for the cumulative probabilities are also included in the plot. Thus the plotted points should approximatly fall as a straight line.

As it can be seen above in Figure 2.5 our confidence bands are quite big. This is also present in the following Probability plots for the majority of the rest of the groups. The points fall almost as a straight line, with the exception of the first point. Figure 2.6 gives the Probability plot for group  $i = 0, j = 1$ .

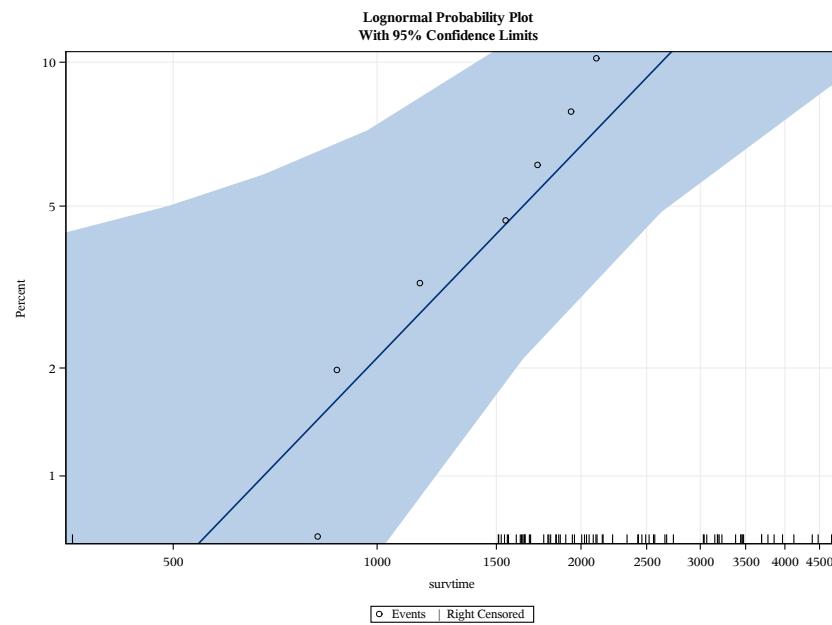


Figure 2.5: Probability Plot – BY – sex = 0, dthick = 0.

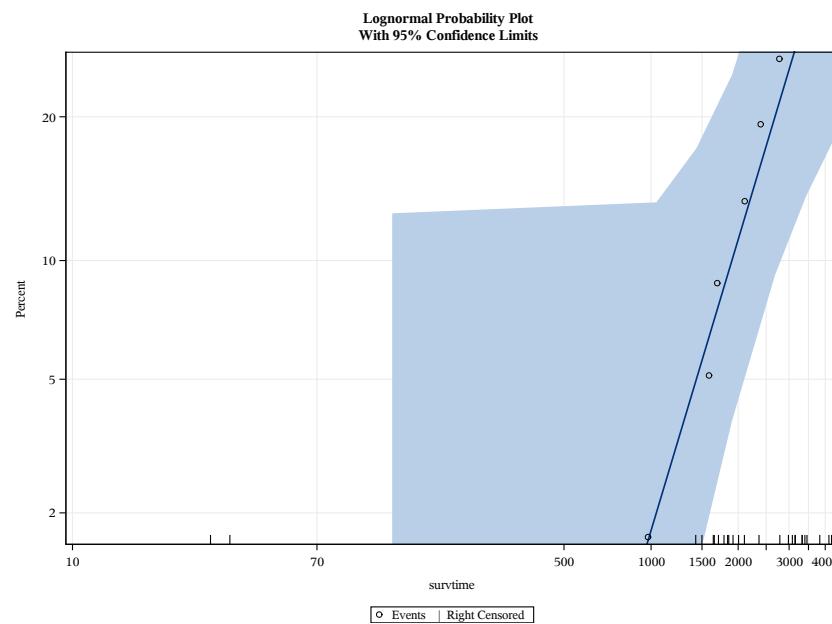


Figure 2.6: Probability Plot – BY – sex = 0, dthick = 1.

The heavy censoring is present for all of the groups. Figure 2.7 gives the Probability plot for group  $i = 0, j = 2$ . Eventhough our confidence bands are big, all of the points fall within them.

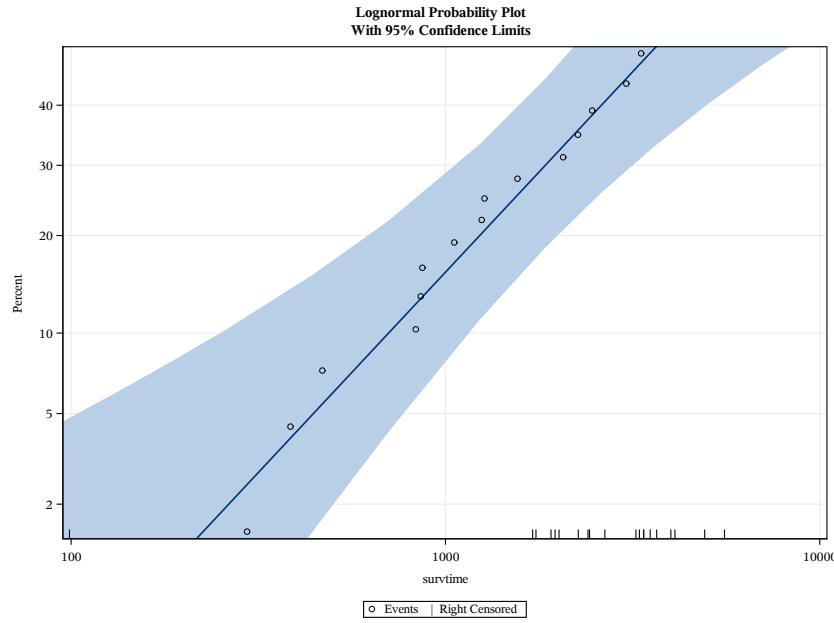


Figure 2.7: Probability Plot – BY – sex = 0, dthick = 2.

The non censored values lies pretty well. Figure 2.8 gives the Probability Plot for group  $i = 1, j = 0$ .

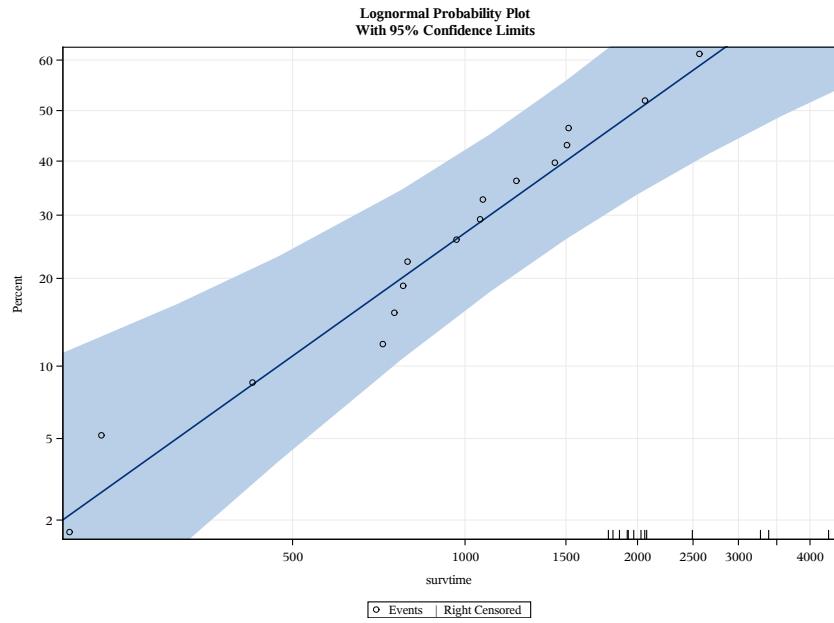


Figure 2.8: Probability Plot – BY – sex = 1, dthick = 0.

Figure 2.9 gives the Probability Plot for group  $i = 1, j = 1$ . What is noticeable as noticed earlier is the few observations in every group.

Figure 2.10 gives the Probability Plot for group  $i = 1, j = 2$ . The points does not fall as a straight line.

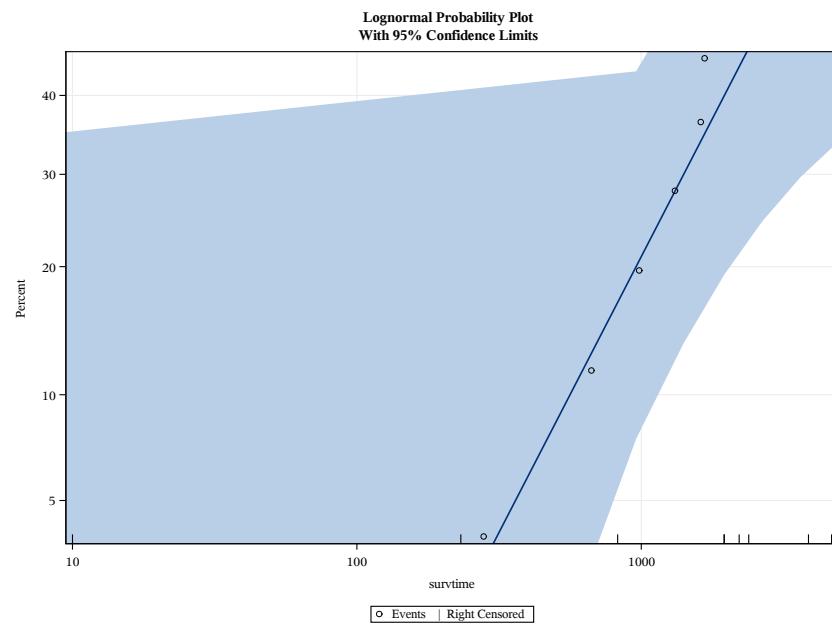


Figure 2.9: Probability Plot – BY – sex = 1, dthick = 1.

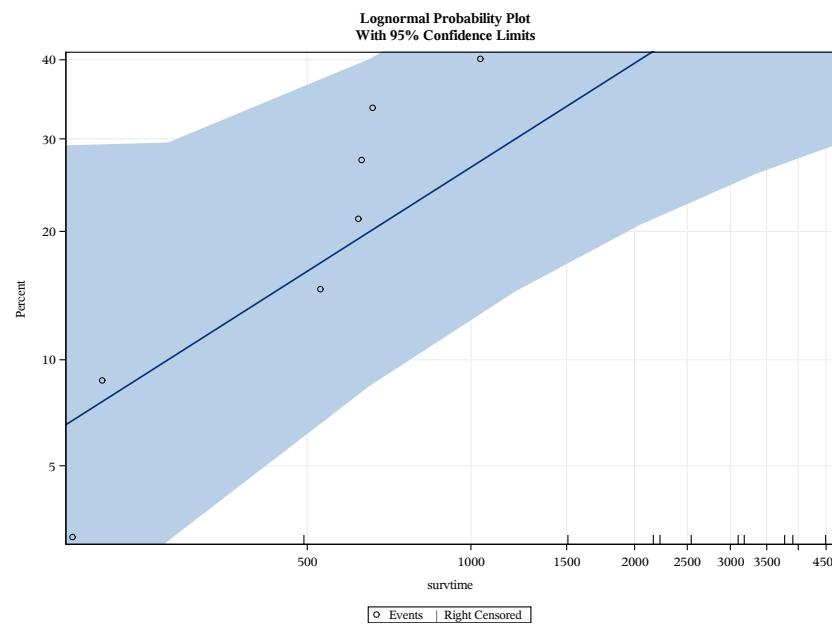


Figure 2.10: Probability Plot – BY – sex = 1, dthick = 2.

As a final conclusion the lognormal distribution seem to outperform the other distributions in this model, as it also can we seen in Table 2.3 and Section A.3.1.

### 2.3.2 Model – sex+dthick+sex\*dthick

In this model and the following we set  $i = 0$  and  $j = 0$  to be our reference group, then we can estimate the rest of the coefficients.

We obtain the following estimates of our model.

$$\hat{\mu} = \begin{pmatrix} 9.5056 \\ 9.5056 - 1.3145 \\ 9.5056 - 1.5838 \\ 9.0622 \\ 9.0622 - 1.3145 - 0.0866 \\ 9.0622 - 1.5838 + 0.2416 \end{pmatrix}, \quad \hat{\sigma} = 1.2752.$$

In the SAS output A.2.2.4 we see a significant effect of dthick ( $\chi^2 \approx 26.1773, p < 0.0001$ ). We notice that a Wald test suggests removal of both sex ( $\chi^2 \approx 2.3593, p \approx 0.1245$ ) and sex\*dthick ( $\chi^2 \approx 0.2643, p \approx 0.8762$ ).

The associated AIC of the model is 314.438. The associated -2 log Likelihood is 300.438.

To test for reduction to this model from Section 2.2.1 we use the Likelihood Ratio test. It yields

$$LR = 300.438 - 295.793 = 4.645, \quad p = 1 - \chi^2(|LR|, 5) \approx 0.46.$$

Thus we can't reject reduction to this model, and we thereby move to this model.

In Figure A.27 we notice that our points lay outside of the confidence bands, but fall in an approximatly straight line.

As a final conclusion the Weibull distribution seem to outperform the other distributions in this model with regards to the probability plot, as it can be seen in Section A.3.2. The Gamma distribution seem to be the best with regards to the AIC's, as it also can we seen in Table 2.3.

### 2.3.3 Model – sex+dthick

We obtain the following estimates of our model.

$$\hat{\alpha} = \begin{pmatrix} 9.5030 \\ 9.0703 \end{pmatrix}, \quad \hat{\beta} = \begin{pmatrix} 0 \\ -1.3581 \\ -1.4493 \end{pmatrix}, \quad \hat{\sigma} = 1.2763.$$

In the SAS output A.2.3.4 we see a significant effect of dthick ( $\chi^2 \approx 26.4328, p < 0.0001$ ). We notice that a Wald test barely suggests removal of sex ( $\chi^2 \approx 3.1687, p \approx 0.0751$ ).

The associated AIC of the model is 310.702. The associated -2 log likelihood is 300.702.

In Figure A.32 we notice that our points again lay outside of the confidence bands, but fall in an approximatly straight line.

As a final conclusion the Weibull distribution again seem to outperform the other distributions in this model with regards to the probability plot, as it can be seen in Section A.3.3. The Gamma distribution again seem to be the best with regards to the AIC's, as it also can we seen in Table 2.3.

### 2.3.4 Model – dthick

We obtain the following estimates of our model.

$$\hat{\beta} = \begin{pmatrix} 9.3787 \\ 7.9504 \\ 7.8205 \end{pmatrix}, \quad \hat{\sigma} = 1.2964.$$

In the SAS output A.2.4.4 we see a significant effect of dthick ( $\chi^2 \approx 2777.7928, p < 0.0001$ ). We also see that all dthick are statistically different from zero (0:  $\chi^2 \approx 1225.26, p < 0.0001$ ; 1:  $\chi^2 \approx 1679.19, p < 0.0001$ ; 2:  $\chi^2 \approx 792.47, p < 0.0001$ ). Thus in a comparable statistical analysis with an intercept and using  $j = 0$  as the reference, both  $j = 1$  and  $j = 2$  would be statistically different from  $j = 0$ .

The associated AIC of the model is 311.876. The associated -2 log likelihood is 303.876.

From the parameter estimates we notice that: the survival time for observations with tumors less than 2 mm in thickness is longer than for observations with tumors bigger than 2 mm in thickness, and that the survival time for observations with tumors between 2 mm and 5 mm in thickness is longer than for observations with tumors bigger than 5 mm in thickness.

In Figure A.37 we notice that our points again lay outside of the confidence bands, though closer this time, and fall in an approximatly straight line.

As a final conclusion the Weibull distribution again seem to outperform the other distributions in this model with regards to the probability plot, as it can be seen in Section A.3.4. The Gamma distribution again seem to be the best with regards to the AIC's, as it also can we seen in Table 2.3.

## 2.4 Model Conclusion

The AIC seem to favourite the sex+dthick model, while parameter removal through tests ends up in the dthick model. Table 2.2 gives the summary of the final dthick model.

Table 2.2: Summary of all distributions in final model.

Distribution	Explanatory Variables	Fitted Linear Predictor	AIC
Exponential	dthick	$9.8915_0 + 8.3298_1 + 8.3666_2 + W_{ij}$	322.423
Weibull	dthick	$9.7050_0 + 8.2816_1 + 8.3139_2 + 0.9083 \cdot W_{ij}$	323.756
Gamma	dthick	$8.5484_0 + 7.1409_1 + 6.8325_2 + 1.4307 \cdot W_{ij}$	306.630
Lognormal	dthick	$9.3787_0 + 7.9504_1 + 7.8205_2 + 1.2964 \cdot W_{ij}$	311.876
Log Logistic	dthick	$9.3316_0 + 7.9092_1 + 7.8108_2 + 0.7490 \cdot W_{ij}$	317.424

Figure 2.11 gives a visual summary of the final dthick model.

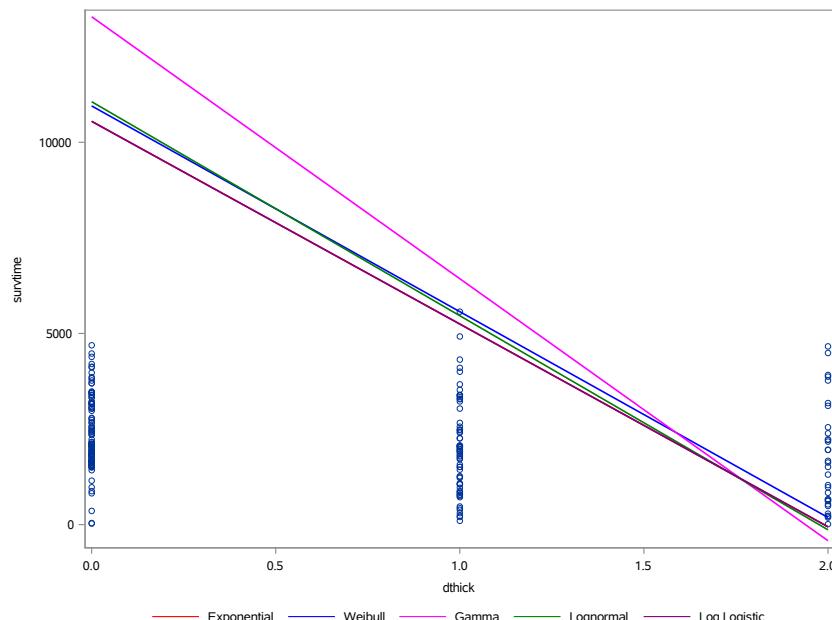


Figure 2.11: Summary of predictions in all distributions in final model.

Table 2.3: Summary of all models.

Distribution	Explanatory Variables	AIC
Exponential	No covariates	324.135
Weibull	No covariates	329.061
Gamma*	No covariates	325.260
Lognormal	No covariates	319.793
Log Logistic	No covariates	324.060
Exponential	sex+dthick+sex*dthick	324.135
Weibull	sex+dthick+sex*dthick	325.126
Gamma	sex+dthick+sex*dthick	309.885
Lognormal	sex+dthick+sex*dthick	314.438
Log Logistic	sex+dthick+sex*dthick	319.366
Exponential	sex+dthick	321.430
Weibull	sex+dthick	322.541
Gamma	sex+dthick	306.281
Lognormal	sex+dthick	310.702
Log Logistic	sex+dthick	315.860
Exponential	dthick	322.423
Weibull	dthick	323.756
Gamma	dthick	306.630
Lognormal	dthick	311.876
Log Logistic	dthick	317.424

Table 2.3 gives a summary of all models and all distributions.

For the Gamma distribution in the no covariates model SAS gave warnings regarding the negative Hessian and convergence issues.

# A SAS of Exercise 50 (1)

## A.1 SAS Code

### A.1.1 Model BY

```
LIBNAME SUPP '~/Survival Analysis/Supplementary Notes/' ;

* BY STATEMENT;

** WEIBULL BY. ;
PROC LIFEREG DATA = SUPP.melanom;
BY dthick sex;
MODEL survtime*status(0) = / DIST = WEIBULL COVB;
PPLOT;
RUN;

** EXPONENTIAL BY. ;
PROC LIFEREG DATA = SUPP.melanom;
BY dthick sex;
MODEL survtime*status(0) = / DIST = EXPONENTIAL COVB;
PPLOT;
RUN;

** GAMMA BY. ;
PROC LIFEREG DATA = SUPP.melanom;
BY dthick sex;
MODEL survtime*status(0) = / DIST = GAMMA COVB;
PPLOT;
RUN;

** LOGNORMAL BY. ;
PROC LIFEREG DATA = SUPP.melanom;
BY dthick sex;
MODEL survtime*status(0) = / DIST = LOGNORMAL COVB;
PPLOT;
RUN;

** LLOGISTIC BY. ;
PROC LIFEREG DATA = SUPP.melanom;
BY dthick sex;
MODEL survtime*status(0) = / DIST = LLOGISTIC COVB;
PPLOT;
RUN;
```

### A.1.2 Model Interaction

```

* VEKSEL.;

** EXPONENTIAL.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick sex;
MODEL survtime*status(0) = sex dthick sex*dthick / DIST = EXPONENTIAL NOINT;
PPLOT;
RUN;

** WEIBULL.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick sex;
MODEL survtime*status(0) = sex dthick sex*dthick / DIST = WEIBULL NOINT;
PPLOT;
RUN;

** GAMMA.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick sex;
MODEL survtime*status(0) = sex dthick sex*dthick / DIST = GAMMA NOINT;
PPLOT;
RUN;

** LOGNORMAL.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick sex;
MODEL survtime*status(0) = sex dthick sex*dthick / DIST = LNORMAL NOINT;
PPLOT;
RUN;

** LLOGISTIC.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick sex;
MODEL survtime*status(0) = sex dthick sex*dthick / DIST = LLOGISTIC NOINT;
PPLOT;
RUN;

```

### A.1.3 Model sex dthick

```
* SEX DTHICK.;

** EXPONENTIAL.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick sex;
MODEL survtime*status(0) = sex dthick / DIST = EXPONENTIAL NOINT;
PPLOT;
RUN;

** WEIBULL.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick sex;
MODEL survtime*status(0) = sex dthick / DIST = WEIBULL NOINT;
PPLOT;
RUN;

** GAMMA.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick sex;
MODEL survtime*status(0) = sex dthick / DIST = GAMMA NOINT;
PPLOT;
RUN;

** LOGNORMAL.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick sex;
MODEL survtime*status(0) = sex dthick / DIST = LNORMAL NOINT;
PPLOT;
RUN;

** LLOGISTIC.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick sex;
MODEL survtime*status(0) = sex dthick / DIST = LLOGISTIC NOINT;
PPLOT;
RUN;
```

### A.1.4 Model dthick

```

* DTHICK.;

** EXPONENTIAL.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick;
MODEL survtime*status(0) = dthick / DIST = EXPONENTIAL NOINT;
PPLOT;
RUN;

** WEIBULL.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick;
MODEL survtime*status(0) = dthick / DIST = WEIBULL NOINT;
PPLOT;
RUN;

** GAMMA.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick;
MODEL survtime*status(0) = dthick / DIST = GAMMA NOINT;
PPLOT;
RUN;

** LOGNORMAL.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick;
MODEL survtime*status(0) = dthick / DIST = LNORMAL NOINT;
PPLOT;
RUN;

** LLOGISTIC.;
PROC LIFEREG DATA = SUPP.melanom ORDER = DATA;
CLASS dthick;
MODEL survtime*status(0) = dthick / DIST = LLOGISTIC NOINT;
PPLOT;
RUN;

```

## A.2 SAS Output

### A.2.1 Model BY

#### A.2.1.1 Exponential

```
----- dthick=0 sex=0 -----
The LIFEREG Procedure

Model Information

Data Set           SUPP.MELANOM
Dependent Variable Log(survtime)
Censoring Variable status
Censoring Value(s) 0
Number of Observations 77
Noncensored Values 7
Right Censored Values 70
Left Censored Values 0
Interval Censored Values 0
Number of Parameters 1
Name of Distribution Exponential
Log Likelihood      -27.63950553

Number of Observations Read    77
Number of Observations Used   77

Parameter Information

Parameter Effect
Intercept Intercept

Fit Statistics

-2 Log Likelihood      55.279
AIC (smaller is better) 57.279
AICC (smaller is better) 57.332
BIC (smaller is better) 59.623

Fit Statistics (Unlogged Response)

-2 Log Likelihood      156.375
Exponential AIC (smaller is better) 158.375
Exponential AICC (smaller is better) 158.428
Exponential BIC (smaller is better) 160.718

Algorithm converged.
```

#### Analysis of Maximum Likelihood Parameter Estimates

Standard	95% Confidence	Chi-
----------	----------------	------

Parameter	DF	Estimate	Error	Limits		Square	Pr > ChiSq
Intercept	1	10.1696	0.3780	9.4288	10.9104	723.95	<.0001
Scale	0	1.0000	0.0000	1.0000	1.0000		

----- dthick=0 sex=0 -----

#### The LIFEREG Procedure

##### Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
Weibull Scale	1	26097.86	9864.062	12441.73	54743.02		
Weibull Shape	0	1.0000	0.0000	1.0000	1.0000		

----- dthick=0 sex=0 -----

#### Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	2.6484	0.1037

----- dthick=0 sex=1 -----

#### The LIFEREG Procedure

##### Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	32
Noncensored Values	6
Right Censored Values	26
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	1
Name of Distribution	Exponential
Log Likelihood	-17.49283652

Number of Observations Read	32
Number of Observations Used	32

#### Fit Statistics

-2 Log Likelihood	34.986
AIC (smaller is better)	36.986
AICC (smaller is better)	37.119
BIC (smaller is better)	38.451

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	125.076
Exponential AIC (smaller is better)	127.076
Exponential AIACC (smaller is better)	127.209
Exponential BIC (smaller is better)	128.541

Algorithm converged.

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept	1	9.4230	0.4082	8.6228	10.2231	532.75	<.0001
Scale	0	1.0000	0.0000	1.0000	1.0000		
Weibull Scale	1	12369.17	5049.691	5556.980	27532.27		
Weibull Shape	0	1.0000	0.0000	1.0000	1.0000		

----- dthick=0 sex=1 -----

## The LIFEREG Procedure

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	.	.

----- dthick=1 sex=0 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	35
Noncensored Values	15
Right Censored Values	20
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	1
Name of Distribution	Exponential
Log Likelihood	-37.84968653

Number of Observations Read	35
Number of Observations Used	35

## Fit Statistics

-2 Log Likelihood	75.699
AIC (smaller is better)	77.699
AICC (smaller is better)	77.821
BIC (smaller is better)	79.255

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	287.562
Exponential AIC (smaller is better)	289.562
Exponential AICC (smaller is better)	289.683
Exponential BIC (smaller is better)	291.117

Algorithm converged.

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	8.5854	0.2582	8.0793 9.0914	1105.63	<.0001
Scale	0	1.0000	0.0000	1.0000 1.0000		
Weibull Scale	1	5352.867	1382.104	3227.061 8879.034		
Weibull Shape	0	1.0000	0.0000	1.0000 1.0000		

----- dthick=1 sex=0 -----

## The LIFEREG Procedure

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	0.3232	0.5697

----- dthick=1 sex=1 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	29
Noncensored Values	16
Right Censored Values	13
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	1
Name of Distribution	Exponential
Log Likelihood	-35.49576534

Number of Observations Read	29
Number of Observations Used	29

## Fit Statistics

-2 Log Likelihood	70.992
AIC (smaller is better)	72.992
AICC (smaller is better)	73.140
BIC (smaller is better)	74.359

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	288.348
Exponential AIC (smaller is better)	290.348
Exponential AICC (smaller is better)	290.496
Exponential BIC (smaller is better)	291.715

Algorithm converged.

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	95% Confidence Error	Limits	Chi-Square	Pr > ChiSq
Intercept	1	8.0109	0.2500	7.5209 8.5009	1026.79	<.0001
Scale	0	1.0000	0.0000	1.0000 1.0000		
Weibull Scale	1	3013.562	753.3905	1846.204 4919.042		
Weibull Shape	0	1.0000	0.0000	1.0000 1.0000		

----- dthick=1 sex=1 -----

## The LIFEREG Procedure

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	0.8821	0.3476

----- dthick=2 sex=0 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	15
Noncensored Values	6

Right Censored Values	9
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	1
Name of Distribution	Exponential
Log Likelihood	-14.91093859

Number of Observations Read	15
Number of Observations Used	15

#### Fit Statistics

-2 Log Likelihood	29.822
AIC (smaller is better)	31.822
AICC (smaller is better)	32.130
BIC (smaller is better)	32.530

#### Fit Statistics (Unlogged Response)

-2 Log Likelihood	111.847
Exponential AIC (smaller is better)	113.847
Exponential AICC (smaller is better)	114.155
Exponential BIC (smaller is better)	114.555

Algorithm converged.

#### Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	95% Error	Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	8.3206	0.4082	7.5204 9.1207	415.39	<.0001
Scale	0	1.0000	0.0000	1.0000 1.0000		
Weibull Scale	1	4107.500	1676.880	1845.338 9142.798		
Weibull Shape	0	1.0000	0.0000	1.0000 1.0000		

----- dthick=2 sex=0 -----

#### The LIFEREG Procedure

#### Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	0.0877	0.7672

----- dthick=2 sex=1 -----

#### The LIFEREG Procedure

#### Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	17
Noncensored Values	7
Right Censored Values	10
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	1
Name of Distribution	Exponential
Log Likelihood	-22.67873152

Number of Observations Read	17
Number of Observations Used	17

#### Fit Statistics

-2 Log Likelihood	45.357
AIC (smaller is better)	47.357
AICC (smaller is better)	47.624
BIC (smaller is better)	48.191

#### Fit Statistics (Unlogged Response)

-2 Log Likelihood	131.663
Exponential AIC (smaller is better)	133.663
Exponential AICC (smaller is better)	133.929
Exponential BIC (smaller is better)	134.496

Algorithm converged.

#### Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	8.4045	0.3780	7.6637 9.1453	494.45	<.0001
Scale	0	1.0000	0.0000	1.0000 1.0000		
Weibull Scale	1	4467.000	1688.367	2129.570 9370.007		
Weibull Shape	0	1.0000	0.0000	1.0000 1.0000		

----- dthick=2 sex=1 -----

#### The LIFEREG Procedure

#### Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
-----------	------------	------------

Scale	1.1046	0.2933
-------	--------	--------

**A.2.1.2 Weibull**

```
----- dthick=0 sex=0 -----

The LIFEREG Procedure

Model Information

Data Set           SUPP.MELANOM
Dependent Variable Log(survtime)
Censoring Variable status
Censoring Value(s) 0
Number of Observations 77
Noncensored Values 7
Right Censored Values 70
Left Censored Values 0
Interval Censored Values 0
Number of Parameters 2
Name of Distribution Weibull
Log Likelihood      -27.08972224

Number of Observations Read      77
Number of Observations Used     77

Parameter Information

Parameter   Effect
Intercept   Intercept

Fit Statistics

-2 Log Likelihood      54.179
AIC (smaller is better) 58.179
AICC (smaller is better) 58.342
BIC (smaller is better) 62.867

Fit Statistics (Unlogged Response)

-2 Log Likelihood      155.275
Weibull AIC (smaller is better) 159.275
Weibull AICC (smaller is better) 159.437
Weibull BIC (smaller is better) 163.963
```

Algorithm converged.

```
----- dthick=0 sex=0 -----

The LIFEREG Procedure

Analysis of Maximum Likelihood Parameter Estimates

          Standard   95% Confidence   Chi-
Parameter   DF Estimate    Error    Limits    Square Pr > ChiSq

```

Intercept	1	9.4392	0.5770	8.3083	10.5700	267.65	<.0001
Scale	1	0.6819	0.2291	0.3529	1.3175		
Weibull Scale	1	12571.52	7253.398	4057.604	38949.88		
Weibull Shape	1	1.4665	0.4928	0.7590	2.8335		

## Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.332895	0.118282
Scale	0.118282	0.052503

----- dthick=0 sex=1 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	32
Noncensored Values	6
Right Censored Values	26
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	Weibull
Log Likelihood	-15.84057136

Number of Observations Read	32
Number of Observations Used	32

## Parameter Information

Parameter	Effect
Intercept	Intercept

## Fit Statistics

-2 Log Likelihood	31.681
AIC (smaller is better)	35.681
AICC (smaller is better)	36.095
BIC (smaller is better)	38.613

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	121.771
Weibull AIC (smaller is better)	125.771
Weibull AICC (smaller is better)	126.185

Weibull BIC (smaller is better) 128.702

Algorithm converged.

----- dthick=0 sex=1 -----

#### The LIFEREG Procedure

##### Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept	1	8.6450	0.3000	8.0570	9.2330	830.36	<.0001
Scale	1	0.4785	0.1653	0.2431	0.9419		
Weibull Scale	1	5681.601	1704.520	3155.763	10229.09		
Weibull Shape	1	2.0898	0.7221	1.0617	4.1135		

##### Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.090004	0.037644
Scale	0.037644	0.027334

----- dthick=1 sex=0 -----

#### The LIFEREG Procedure

##### Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	35
Noncensored Values	15
Right Censored Values	20
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	Weibull
Log Likelihood	-37.71626057

Number of Observations Read	35
Number of Observations Used	35

##### Parameter Information

Parameter	Effect
Intercept	Intercept

## Fit Statistics

-2 Log Likelihood	75.433
AIC (smaller is better)	79.433
AICC (smaller is better)	79.808
BIC (smaller is better)	82.543

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	287.295
Weibull AIC (smaller is better)	291.295
Weibull AICC (smaller is better)	291.670
Weibull BIC (smaller is better)	294.405

Algorithm converged.

----- dthick=1 sex=0 -----

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	8.5117	0.2621	7.9980 9.0253	1054.71	<.0001
Scale	1	0.8869	0.2009	0.5689 1.3827		
Weibull Scale	1	4972.388	1303.203	2974.921 8311.026		
Weibull Shape	1	1.1275	0.2555	0.7232 1.7578		

## Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.068690	0.025615
Scale	0.025615	0.040374

----- dthick=1 sex=1 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	29
Noncensored Values	16
Right Censored Values	13
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	Weibull
Log Likelihood	-35.17381834

Number of Observations Read	29
Number of Observations Used	29

## Parameter Information

Parameter	Effect
-----------	--------

Intercept	Intercept
-----------	-----------

## Fit Statistics

-2 Log Likelihood	70.348
AIC (smaller is better)	74.348
AICC (smaller is better)	74.809
BIC (smaller is better)	77.082

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	287.704
Weibull AIC (smaller is better)	291.704
Weibull AICC (smaller is better)	292.166
Weibull BIC (smaller is better)	294.439

Algorithm converged.

----- dthick=1 sex=1 -----

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	95% Confidence Error	Limits	Chi-Square	Pr > ChiSq
Intercept	1	7.9436	0.2196	7.5132 8.3741	1308.22	<.0001
Scale	1	0.8350	0.1802	0.5470 1.2746		
Weibull Scale	1	2817.496	618.7853	1831.978 4333.175		
Weibull Shape	1	1.1976	0.2584	0.7846 1.8280		

## Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.048234	0.012295
Scale	0.012295	0.032468

----- dthick=2 sex=0 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	15
Noncensored Values	6
Right Censored Values	9
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	Weibull
Log Likelihood	-14.87332442

Number of Observations Read	15
Number of Observations Used	15

#### Parameter Information

Parameter	Effect
-----------	--------

Intercept	Intercept
-----------	-----------

#### Fit Statistics

-2 Log Likelihood	29.747
AIC (smaller is better)	33.747
AICC (smaller is better)	34.747
BIC (smaller is better)	35.163

#### Fit Statistics (Unlogged Response)

-2 Log Likelihood	111.772
Weibull AIC (smaller is better)	115.772
Weibull AICC (smaller is better)	116.772
Weibull BIC (smaller is better)	117.188

Algorithm converged.

----- dthick=2 sex=0 -----

#### The LIFEREG Procedure

##### Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	8.2665	0.4114	7.4601 9.0728	403.74	<.0001
Scale	1	0.9090	0.3092	0.4667 1.7706		
Weibull Scale	1	3891.215	1600.865	1737.387 8715.129		
Weibull Shape	1	1.1001	0.3742	0.5648 2.1426		

## Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.169254	0.054901
Scale	0.054901	0.095606

----- dthick=2 sex=1 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	17
Noncensored Values	7
Right Censored Values	10
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	Weibull
Log Likelihood	-21.836253

Number of Observations Read	17
Number of Observations Used	17

## Parameter Information

Parameter	Effect
Intercept	Intercept

## Fit Statistics

-2 Log Likelihood	43.673
AIC (smaller is better)	47.673
AICC (smaller is better)	48.530
BIC (smaller is better)	49.339

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	129.978
Weibull AIC (smaller is better)	133.978
Weibull AICC (smaller is better)	134.835
Weibull BIC (smaller is better)	135.644

Algorithm converged.

----- dthick=2 sex=1 -----

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept	1	8.7285	0.6684	7.4184	10.0386	170.51	<.0001
Scale	1	1.4901	0.4996	0.7723	2.8748		
Weibull Scale	1	6176.570	4128.650	1666.374	22894.03		
Weibull Shape	1	0.6711	0.2250	0.3479	1.2948		

## Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.446809	0.179877
Scale	0.179877	0.249602

**A.2.1.3 Gamma**

```
----- dthick=0 sex=0 -----
The LIFEREG Procedure

Model Information

Data Set           SUPP.MELANOM
Dependent Variable Log(survtime)
Censoring Variable status
Censoring Value(s) 0
Number of Observations 77
Noncensored Values 7
Right Censored Values 70
Left Censored Values 0
Interval Censored Values 0
Number of Parameters 3
Name of Distribution Gamma
Log Likelihood      -27.20094593

Number of Observations Read      77
Number of Observations Used    77

Parameter Information

Parameter   Effect
Intercept   Intercept

Fit Statistics

-2 Log Likelihood      54.402
AIC (smaller is better) 60.402
AICC (smaller is better) 60.731
BIC (smaller is better) 67.433

Fit Statistics (Unlogged Response)

-2 Log Likelihood      155.497
Gamma AIC (smaller is better) 161.497
Gamma AICC (smaller is better) 161.826
Gamma BIC (smaller is better) 168.529

WARNING: Negative of Hessian not positive definite.
```

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept	1	9.4582	0.5691	8.3428	10.5736	276.23	<.0001
Scale	1	0.1946	0.0659	0.1002	0.3780		

```
----- dthick=0 sex=0 -----
The LIFEREG Procedure

Analysis of Maximum Likelihood Parameter Estimates

      Standard   95% Confidence   Chi-
Parameter  DF Estimate    Error    Limits     Square Pr > ChiSq
Shape       0   3.6775    0.0000   3.6775    3.6775

Estimated Covariance Matrix

      Intercept      Scale      Shape
Intercept  0.323849  0.033551    0
Scale      0.033551  0.004344    0
Shape       0           0           0

----- dthick=0 sex=1 -----
The LIFEREG Procedure

Model Information

      Data Set          SUPP.MELANOM
      Dependent Variable Log(survtime)
      Censoring Variable status
      Censoring Value(s) 0
      Number of Observations 32
      Noncensored Values 6
      Right Censored Values 26
      Left Censored Values 0
      Interval Censored Values 0
      Number of Parameters 3
      Name of Distribution Gamma
      Log Likelihood      -14.95487059

      Number of Observations Read 32
      Number of Observations Used 32

Parameter Information

      Parameter   Effect
      Intercept   Intercept

Fit Statistics

      -2 Log Likelihood      29.910
      AIC (smaller is better) 35.910
      AICC (smaller is better) 36.767
      BIC (smaller is better) 40.307
```

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	120.000
Gamma AIC (smaller is better)	126.000
Gamma AICC (smaller is better)	126.857
Gamma BIC (smaller is better)	130.397

Algorithm converged.

----- dthick=0 sex=1 -----

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	7.9988	0.7536	6.5219 9.4758	112.67	<.0001
Scale	1	1.0041	0.3188	0.5389 1.8707		
Shape	1	-2.1769	2.6030	-7.2787 2.9249		

## Estimated Covariance Matrix

	Intercept	Scale	Shape
Intercept	0.567863	0.104417	1.813478
Scale	0.104417	0.101618	0.134515
Shape	1.813478	0.134515	6.775616

----- dthick=1 sex=0 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	35
Noncensored Values	15
Right Censored Values	20
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	3
Name of Distribution	Gamma
Log Likelihood	-36.39090049

Number of Observations Read	35
Number of Observations Used	35

## Parameter Information

Parameter Effect

Intercept Intercept

## Fit Statistics

-2 Log Likelihood	72.782
AIC (smaller is better)	78.782
AICC (smaller is better)	79.556
BIC (smaller is better)	83.448

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	284.644
Gamma AIC (smaller is better)	290.644
Gamma AICC (smaller is better)	291.418
Gamma BIC (smaller is better)	295.310

Algorithm converged.

----- dthick=1 sex=0 -----

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	7.5516	0.8543	5.8772 9.2259	78.14	<.0001
Scale	1	1.4240	0.2927	0.9518 2.1305		
Shape	1	-1.3142	1.5106	-4.2750 1.6466		

## Estimated Covariance Matrix

	Intercept	Scale	Shape
Intercept	0.729779	0.109884	1.210989
Scale	0.109884	0.085680	0.120488
Shape	1.210989	0.120488	2.282034

----- dthick=1 sex=1 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	29

Noncensored Values	16
Right Censored Values	13
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	3
Name of Distribution	Gamma
Log Likelihood	-34.06830627

Number of Observations Read	29
Number of Observations Used	29

#### Parameter Information

Parameter	Effect
Intercept	Intercept

#### Fit Statistics

-2 Log Likelihood	68.137
AIC (smaller is better)	74.137
AICC (smaller is better)	75.097
BIC (smaller is better)	78.239

#### Fit Statistics (Unlogged Response)

-2 Log Likelihood	285.493
Gamma AIC (smaller is better)	291.493
Gamma AICC (smaller is better)	292.453
Gamma BIC (smaller is better)	295.595

Algorithm converged.

----- dthick=1 sex=1 -----

#### The LIFEREG Procedure

##### Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	95% Error	Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	7.3750	0.5525	6.2922 8.4578	178.21	<.0001
Scale	1	1.2151	0.2622	0.7961 1.8547		
Shape	1	-0.5277	1.0922	-2.6683 1.6129		

#### Estimated Covariance Matrix

	Intercept	Scale	Shape
Intercept	0.305204	-0.039864	0.535195
Scale	-0.039864	0.068736	-0.142320

Shape	0.535195	-0.142320	1.192794
-------	----------	-----------	----------

----- dthick=2 sex=0 -----

### The LIFEREG Procedure

#### Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	15
Noncensored Values	6
Right Censored Values	9
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	3
Name of Distribution	Gamma
Log Likelihood	-13.9700331

Number of Observations Read	15
Number of Observations Used	15

#### Parameter Information

Parameter	Effect
Intercept	Intercept

#### Fit Statistics

-2 Log Likelihood	27.940
AIC (smaller is better)	33.940
AICC (smaller is better)	36.122
BIC (smaller is better)	36.064

#### Fit Statistics (Unlogged Response)

-2 Log Likelihood	109.965
Gamma AIC (smaller is better)	115.965
Gamma AICC (smaller is better)	118.147
Gamma BIC (smaller is better)	118.089

Algorithm converged.

----- dthick=2 sex=0 -----

### The LIFEREG Procedure

#### Analysis of Maximum Likelihood Parameter Estimates

Standard	95% Confidence	Chi-
----------	----------------	------

Parameter	DF	Estimate	Error	Limits	Square	Pr > ChiSq
Intercept	1	7.2418	0.9467	5.3863	9.0974	58.51 <.0001
Scale	1	1.3211	0.4160	0.7127	2.4490	
Shape	1	-1.3544	1.6902	-4.6671	1.9583	

## Estimated Covariance Matrix

	Intercept	Scale	Shape
Intercept	0.896282	0.173345	1.418341
Scale	0.173345	0.173075	0.151023
Shape	1.418341	0.151023	2.856697

----- dthick=2 sex=1 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	17
Noncensored Values	7
Right Censored Values	10
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	3
Name of Distribution	Gamma
Log Likelihood	-18.04451077

Number of Observations Read	17
Number of Observations Used	17

## Parameter Information

Parameter	Effect
Intercept	Intercept

## Fit Statistics

-2 Log Likelihood	36.089
AIC (smaller is better)	42.089
AICC (smaller is better)	43.935
BIC (smaller is better)	44.589

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	122.394
Gamma AIC (smaller is better)	128.394

Gamma AICC (smaller is better)	130.240
Gamma BIC (smaller is better)	130.894

WARNING: The relative gradient convergence criterion of 0.0078918566 is greater than the limit of 0.0001. The convergence is questionable.

----- dthick=2 sex=1 -----

### The LIFEREG Procedure

#### Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
				Lower	Upper		
Intercept	1	5.3241	0.1849	4.9616	5.6865	828.92	<.0001
Scale	1	0.4168	0.3322	0.0874	1.9873		
Shape	1	-10.5590	7.9662	-26.1724	5.0544		

#### Estimated Covariance Matrix

	Intercept	Scale	Shape
Intercept	0.034196	0.047922	1.155276
Scale	0.047922	0.110328	2.357232
Shape	1.155276	2.357232	63.459745

**A.2.1.4 Log logistic**

```
----- dthick=0 sex=0 -----

The LIFEREG Procedure

Model Information

Data Set           SUPP.MELANOM
Dependent Variable Log(survtime)
Censoring Variable status
Censoring Value(s) 0
Number of Observations 77
Noncensored Values 7
Right Censored Values 70
Left Censored Values 0
Interval Censored Values 0
Number of Parameters 2
Name of Distribution LLogistic
Log Likelihood      -26.98241584

Number of Observations Read      77
Number of Observations Used     77

Parameter Information

Parameter   Effect
Intercept   Intercept

Fit Statistics

-2 Log Likelihood      53.965
AIC (smaller is better) 57.965
AICC (smaller is better) 58.127
BIC (smaller is better) 62.652

Fit Statistics (Unlogged Response)

-2 Log Likelihood      155.060
LLogistic AIC (smaller is better) 159.060
LLogistic AICC (smaller is better) 159.223
LLogistic BIC (smaller is better) 163.748
```

Algorithm converged.

```
----- dthick=0 sex=0 -----

The LIFEREG Procedure

Analysis of Maximum Likelihood Parameter Estimates

          Standard   95% Confidence   Chi-
Parameter   DF Estimate    Error    Limits    Square Pr > ChiSq

```

Intercept	1	9.3180	0.5547	8.2308	10.4051	282.20	<.0001
Scale	1	0.6500	0.2172	0.3377	1.2511		

## Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.307667	0.106391
Scale	0.106391	0.047159

----- dthick=0 sex=1 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	32
Noncensored Values	6
Right Censored Values	26
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	LLogistic
Log Likelihood	-15.65090834

Number of Observations Read	32
Number of Observations Used	32

## Parameter Information

Parameter	Effect
Intercept	Intercept

## Fit Statistics

-2 Log Likelihood	31.302
AIC (smaller is better)	35.302
AICC (smaller is better)	35.716
BIC (smaller is better)	38.233

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	121.392
LLogistic AIC (smaller is better)	125.392
LLogistic AICC (smaller is better)	125.805
LLogistic BIC (smaller is better)	128.323

Algorithm converged.

----- dthick=0 sex=1 -----

### The LIFEREG Procedure

#### Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	8.4965	0.2879	7.9323 9.0608	871.16	<.0001
Scale	1	0.4285	0.1469	0.2188 0.8391		

#### Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.082868	0.030407
Scale	0.030407	0.021591

----- dthick=1 sex=0 -----

### The LIFEREG Procedure

#### Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	35
Noncensored Values	15
Right Censored Values	20
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	LLogistic
Log Likelihood	-37.24994243

Number of Observations Read	35
Number of Observations Used	35

#### Parameter Information

Parameter	Effect
Intercept	Intercept

#### Fit Statistics

-2 Log Likelihood	74.500
AIC (smaller is better)	78.500

AICC (smaller is better)	78.875
BIC (smaller is better)	81.611

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	286.362
LLogistic AIC (smaller is better)	290.362
LLogistic AICC (smaller is better)	290.737
LLogistic BIC (smaller is better)	293.473

Algorithm converged.

----- dthick=1 sex=0 -----

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	8.1658	0.2689	7.6388 8.6928	922.29	<.0001
Scale	1	0.7418	0.1647	0.4801 1.1462		

## Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.072298	0.017690
Scale	0.017690	0.027119

----- dthick=1 sex=1 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	29
Noncensored Values	16
Right Censored Values	13
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	LLogistic
Log Likelihood	-34.41573453

Number of Observations Read	29
Number of Observations Used	29

## Parameter Information

Parameter Effect

Intercept Intercept

## Fit Statistics

-2 Log Likelihood	68.831
AIC (smaller is better)	72.831
AICC (smaller is better)	73.293
BIC (smaller is better)	75.566

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	286.188
LL logistic AIC (smaller is better)	290.188
LL logistic AICC (smaller is better)	290.650
LL logistic BIC (smaller is better)	292.923

Algorithm converged.

----- dthick=1 sex=1 -----

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	95% Error	Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	7.5751	0.2295	7.1254 8.0249	1089.76	<.0001
Scale	1	0.6506	0.1401	0.4266 0.9923		

## Estimated Covariance Matrix

	Intercept	Scale
Intercept	0.052656	0.008601
Scale	0.008601	0.019638

----- dthick=2 sex=0 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	15
Noncensored Values	6
Right Censored Values	9

Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	LLogistic
Log Likelihood	-14.4344073

Number of Observations Read	15
Number of Observations Used	15

## Parameter Information

Parameter Effect

Intercept Intercept

## Fit Statistics

-2 Log Likelihood	28.869
AIC (smaller is better)	32.869
AICC (smaller is better)	33.869
BIC (smaller is better)	34.285

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	110.894
LLogistic AIC (smaller is better)	114.894
LLogistic AICC (smaller is better)	115.894
LLogistic BIC (smaller is better)	116.310

Algorithm converged.

----- dthick=2 sex=0 -----

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	7.8452	0.4095	7.0425 8.6479	366.95	<.0001
Scale	1	0.7077	0.2440	0.3600 1.3911		

## Estimated Covariance Matrix

Intercept	0.167726	0.039469
Scale	0.039469	0.059547

----- dthick=2 sex=1 -----

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	17
Noncensored Values	7
Right Censored Values	10
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	2
Name of Distribution	LLogistic
Log Likelihood	-21.30076219

Number of Observations Read	17
Number of Observations Used	17

## Parameter Information

Parameter	Effect
Intercept	Intercept

## Fit Statistics

-2 Log Likelihood	42.602
AIC (smaller is better)	46.602
AICC (smaller is better)	47.459
BIC (smaller is better)	48.268

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	128.907
LLogistic AIC (smaller is better)	132.907
LLogistic AICC (smaller is better)	133.764
LLogistic BIC (smaller is better)	134.573

Algorithm converged.

----- dthick=2 sex=1 -----

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits	Chi-Square	Pr > ChiSq
Intercept	1	8.0663	0.6463	6.7996 9.3329	155.78	<.0001
Scale	1	1.2004	0.3887	0.6364 2.2643		

**Estimated Covariance Matrix**

	Intercept	Scale
Intercept	0.417677	0.115043
Scale	0.115043	0.151054

## A.2.2 Model Interaction

### A.2.2.1 Exponential

The LIFEREG Procedure

#### Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	6
Name of Distribution	Exponential
Log Likelihood	-156.067464

Number of Observations Read	205
Number of Observations Used	205

#### Class Level Information

Name	Levels	Values
dthick	3	2 1 0
sex	2	1 0

#### Fit Statistics

-2 Log Likelihood	312.135
AIC (smaller is better)	324.135
AICC (smaller is better)	324.559
BIC (smaller is better)	344.073

#### Fit Statistics (Unlogged Response)

-2 Log Likelihood	1100.869
Exponential AIC (smaller is better)	1112.869
Exponential AICC (smaller is better)	1113.293
Exponential BIC (smaller is better)	1132.807

Algorithm converged.

#### Type III Analysis of Effects

Effect	DF	Chi-Square	Wald
			Pr > ChiSq
Intercept	0	.	.

sex	1	2.0459	0.1526
dthick	2	21.8820	<.0001

## The LIFEREG Procedure

## Type III Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
dthick*sex	2	1.3225	0.5162

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard	95% Confidence		Chi-Square	Pr > ChiSq
			Error	Limits			
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
sex	1	9.4230	0.4082	8.6228	10.2231	532.75	<.0001
sex	0	10.1696	0.3780	9.4288	10.9104	723.95	<.0001
dthick	2	-1.8490	0.5563	-2.9395	-0.7586	11.05	0.0009
dthick	1	-1.5842	0.4577	-2.4814	-0.6871	11.98	0.0005
dthick	0	0.0000	.	.	.	.	.
dthick*sex	2 1	0.8305	0.7868	-0.7115	2.3726	1.11	0.2911
dthick*sex	2 0	0.0000	.	.	.	.	.
dthick*sex	1 1	0.1721	0.6623	-1.1260	1.4703	0.07	0.7949
dthick*sex	1 0	0.0000	.	.	.	.	.
dthick*sex	0 1	0.0000	.	.	.	.	.
dthick*sex	0 0	0.0000	.	.	.	.	.
Scale	0	1.0000	0.0000	1.0000	1.0000	.	.
Weibull Shape	0	1.0000	0.0000	1.0000	1.0000	.	.

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.
Scale	1.2212	0.2691

**A.2.2.2 Weibull**

```
The LIFEREG Procedure
```

```
Model Information
```

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	7
Name of Distribution	Weibull
Log Likelihood	-155.5631564

Number of Observations Read	205
Number of Observations Used	205

```
Class Level Information
```

Name	Levels	Values
dthick	3	2 1 0
sex	2	1 0

```
Fit Statistics
```

-2 Log Likelihood	311.126
AIC (smaller is better)	325.126
AICC (smaller is better)	325.695
BIC (smaller is better)	348.387

```
Fit Statistics (Unlogged Response)
```

-2 Log Likelihood	1099.861
Weibull AIC (smaller is better)	1113.861
Weibull AICC (smaller is better)	1114.429
Weibull BIC (smaller is better)	1137.122

Algorithm converged.

```
Type III Analysis of Effects
```

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
Intercept	0	.	.
sex	1	2.0883	0.1484
dthick	2	17.6303	0.0001

## The LIFEREG Procedure

## Type III Analysis of Effects

Effect	DF	Chi-Square	Wald	
			Pr > ChiSq	
dthick*sex	2	1.4431	0.4860	

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
				Lower	Upper		
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
sex	1	9.2492	0.3953	8.4745	10.0238	547.59	<.0001
sex	0	9.9089	0.4109	9.1036	10.7143	581.56	<.0001
dthick	2	-1.6547	0.5253	-2.6843	-0.6250	9.92	0.0016
dthick	1	-1.3969	0.4412	-2.2616	-0.5321	10.02	0.0015
dthick	0	0.0000	.	.	.	.	.
dthick*sex	2 1	0.7474	0.7024	-0.6294	2.1241	1.13	0.2873
dthick*sex	2 0	0.0000	.	.	.	.	.
dthick*sex	1 1	0.1117	0.5904	-1.0455	1.2689	0.04	0.8499
dthick*sex	1 0	0.0000	.	.	.	.	.
dthick*sex	0 1	0.0000	.	.	.	.	.
dthick*sex	0 0	0.0000	.	.	.	.	.
Scale	1	0.8875	0.1028	0.7073	1.1137		
Weibull Shape	1	1.1267	0.1305	0.8979	1.4138		

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.

**A.2.2.3 Gamma**

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	8
Name of Distribution	Gamma
Log Likelihood	-146.9425207

Number of Observations Read	205
Number of Observations Used	205

## Class Level Information

Name	Levels	Values
dthick	3	2 1 0
sex	2	1 0

## Fit Statistics

-2 Log Likelihood	293.885
AIC (smaller is better)	309.885
AICC (smaller is better)	310.620
BIC (smaller is better)	336.469

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	1082.619
Gamma AIC (smaller is better)	1098.619
Gamma AICC (smaller is better)	1099.354
Gamma BIC (smaller is better)	1125.203

Algorithm converged.

## Type III Analysis of Effects

Effect	DF	Chi-Square	Pr > ChiSq
Intercept	0	.	.
sex	1	2.5341	0.1114
dthick	2	43.2433	<.0001

## The LIFEREG Procedure

## Type III Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
dthick*sex	2	0.4217	0.8099

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard	95% Confidence		Chi-Square	Pr > ChiSq
			Error	Limits	.		
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
sex	1	8.4235	0.3449	7.7474	9.0995	596.34	<.0001
sex	0	8.6025	0.3371	7.9418	9.2633	651.16	<.0001
dthick	2	-1.4460	0.4285	-2.2858	-0.6061	11.39	0.0007
dthick	1	-1.2256	0.3035	-1.8204	-0.6308	16.31	<.0001
dthick	0	0.0000	.	.	.	.	.
dthick*sex	2 1	-0.3285	0.6164	-1.5366	0.8795	0.28	0.5940
dthick*sex	2 0	0.0000	.	.	.	.	.
dthick*sex	1 1	-0.2613	0.4832	-1.2084	0.6858	0.29	0.5887
dthick*sex	1 0	0.0000	.	.	.	.	.
dthick*sex	0 1	0.0000	.	.	.	.	.
dthick*sex	0 0	0.0000	.	.	.	.	.
Scale	1	1.4052	0.1499	1.1400	1.7320		
Shape	1	-1.6587	0.4760	-2.5917	-0.7257		

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.

**A.2.2.4 Lognormal**

```
The LIFEREG Procedure
```

```
Model Information
```

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	7
Name of Distribution	Lognormal
Log Likelihood	-150.2189745

Number of Observations Read	205
Number of Observations Used	205

```
Class Level Information
```

Name	Levels	Values
dthick	3	2 1 0
sex	2	1 0

```
Fit Statistics
```

-2 Log Likelihood	300.438
AIC (smaller is better)	314.438
AICC (smaller is better)	315.006
BIC (smaller is better)	337.699

```
Fit Statistics (Unlogged Response)
```

-2 Log Likelihood	1089.172
Lognormal AIC (smaller is better)	1103.172
Lognormal AICC (smaller is better)	1103.741
Lognormal BIC (smaller is better)	1126.433

Algorithm converged.

```
Type III Analysis of Effects
```

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
Intercept	0	.	.
sex	1	2.3593	0.1245
dthick	2	26.1773	<.0001

## The LIFEREG Procedure

## Type III Analysis of Effects

Effect	DF	Wald		
		Chi-Square	Pr > ChiSq	
dthick*sex	2	0.2643	0.8762	

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard		95% Confidence		Chi-Square	Pr > ChiSq
		Estimate	Error	Limits			
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
sex	1	1	9.0622	0.3575	8.3615	9.7628	642.65 <.0001
sex	0	1	9.5056	0.3171	8.8841	10.1271	898.72 <.0001
dthick	2	1	-1.5838	0.4856	-2.5355	-0.6321	10.64 0.0011
dthick	1	1	-1.3145	0.3728	-2.0452	-0.5838	12.43 0.0004
dthick	0	0	0.0000	.	.	.	.
dthick*sex	2	1	0.2416	0.6747	-1.0807	1.5639	0.13 0.7203
dthick*sex	2	0	0.0000	.	.	.	.
dthick*sex	1	1	-0.0866	0.5492	-1.1631	0.9899	0.02 0.8747
dthick*sex	1	0	0.0000	.	.	.	.
dthick*sex	0	1	0.0000	.	.	.	.
dthick*sex	0	0	0.0000	.	.	.	.
Scale	1	1	1.2752	0.1338	1.0382	1.5662	

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.

**A.2.2.5 Log logistic**

The LIFEREG Procedure

Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	7
Name of Distribution	LLogistic
Log Likelihood	-152.6828213

Number of Observations Read	205
Number of Observations Used	205

Class Level Information

Name	Levels	Values
dthick	3	2 1 0
sex	2	1 0

Fit Statistics

-2 Log Likelihood	305.366
AIC (smaller is better)	319.366
AICC (smaller is better)	319.934
BIC (smaller is better)	342.627

Fit Statistics (Unlogged Response)

-2 Log Likelihood	1094.100
LLogistic AIC (smaller is better)	1108.100
LLogistic AICC (smaller is better)	1108.668
LLogistic BIC (smaller is better)	1131.361

Algorithm converged.

Type III Analysis of Effects

Effect	DF	Chi-Square	Pr > ChiSq	Wald
Intercept	0	.	.	
sex	1	2.4295	0.1191	
dthick	2	22.6161	<.0001	

## The LIFEREG Procedure

## Type III Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
dthick*sex	2	0.4958	0.7804

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard	95% Confidence		Chi-Square	Pr > ChiSq
			Error	Limits			
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
sex	1	8.9501	0.3573	8.2498	9.6504	627.44	<.0001
sex	0	9.5085	0.3496	8.8233	10.1938	739.65	<.0001
dthick	2	-1.6459	0.5048	-2.6352	-0.6565	10.63	0.0011
dthick	1	-1.3479	0.4050	-2.1418	-0.5541	11.08	0.0009
dthick	0	0.0000	.	.	.	.	.
dthick*sex	2 1	0.4362	0.7054	-0.9462	1.8187	0.38	0.5363
dthick*sex	2 0	0.0000	.	.	.	.	.
dthick*sex	1 1	0.0104	0.5650	-1.0970	1.1178	0.00	0.9853
dthick*sex	1 0	0.0000	.	.	.	.	.
dthick*sex	0 1	0.0000	.	.	.	.	.
dthick*sex	0 0	0.0000	.	.	.	.	.
Scale	1	0.7339	0.0836	0.5870	0.9176		

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.

### A.2.3 Model sex dthick

#### A.2.3.1 Exponential

The LIFEREG Procedure

##### Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	4
Name of Distribution	Exponential
Log Likelihood	-156.7148099

Number of Observations Read	205
Number of Observations Used	205

##### Class Level Information

Name	Levels	Values
dthick	3	2 1 0
sex	2	1 0

##### Fit Statistics

-2 Log Likelihood	313.430
AIC (smaller is better)	321.430
AICC (smaller is better)	321.630
BIC (smaller is better)	334.722

##### Fit Statistics (Unlogged Response)

-2 Log Likelihood	1102.164
Exponential AIC (smaller is better)	1110.164
Exponential AICC (smaller is better)	1110.364
Exponential BIC (smaller is better)	1123.456

Algorithm converged.

##### Type III Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
Intercept	0	.	.

sex	1	3.0122	0.0826
dthick	2	21.9040	<.0001

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard	95% Confidence		Chi-Square	Pr > ChiSq
			Error	Limits			
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
sex	1	9.5823	0.3221	8.9511	10.2135	885.29	<.0001
sex	0	10.0507	0.2970	9.4686	10.6328	1145.21	<.0001
dthick	2	-1.3958	0.3992	-2.1783	-0.6133	12.22	0.0005
dthick	1	-1.5187	0.3314	-2.1683	-0.8691	21.00	<.0001
dthick	0	0.0000	.	.	.	.	.
Scale	0	1.0000	0.0000	1.0000	1.0000	.	.
Weibull Shape	0	1.0000	0.0000	1.0000	1.0000	.	.

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.
Scale	1.0616	0.3029

**A.2.3.2 Weibull**

```
The LIFEREG Procedure
```

```
Model Information
```

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	5
Name of Distribution	Weibull
Log Likelihood	-156.2704132

Number of Observations Read	205
Number of Observations Used	205

```
Class Level Information
```

Name	Levels	Values
dthick	3	2 1 0
sex	2	1 0

```
Fit Statistics
```

-2 Log Likelihood	312.541
AIC (smaller is better)	322.541
AICC (smaller is better)	322.842
BIC (smaller is better)	339.156

```
Fit Statistics (Unlogged Response)
```

-2 Log Likelihood	1101.275
Weibull AIC (smaller is better)	1111.275
Weibull AICC (smaller is better)	1111.577
Weibull BIC (smaller is better)	1127.890

Algorithm converged.

```
Type III Analysis of Effects
```

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
Intercept	0	.	.
sex	1	3.2010	0.0736
dthick	2	17.4469	0.0002

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
				Lower	Upper		
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
sex	1	1	9.3906	0.3428	8.7187	10.0625	750.34
sex	0	1	9.8267	0.3443	9.1518	10.5015	814.43
dthick	2	1	-1.2496	0.3855	-2.0052	-0.4940	10.51
dthick	1	1	-1.3670	0.3318	-2.0173	-0.7166	16.97
dthick	0	0	0.0000	.	.	.	.
Scale	1	0.8946	0.1032	0.7135	1.1216		
Weibull Shape	1	1.1178	0.1290	0.8916	1.4015		

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.

**A.2.3.3 Gamma**

## The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	6
Name of Distribution	Gamma
Log Likelihood	-147.1404642

Number of Observations Read	205
Number of Observations Used	205

## Class Level Information

Name	Levels	Values
dthick	3	2 1 0
sex	2	1 0

## Fit Statistics

-2 Log Likelihood	294.281
AIC (smaller is better)	306.281
AICC (smaller is better)	306.705
BIC (smaller is better)	326.219

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	1083.015
Gamma AIC (smaller is better)	1095.015
Gamma AICC (smaller is better)	1095.439
Gamma BIC (smaller is better)	1114.953

Algorithm converged.

## Type III Analysis of Effects

Effect	DF	Chi-Square	Pr > ChiSq
Intercept	0	.	.
sex	1	2.3238	0.1274
dthick	2	40.7558	<.0001

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
				Lower	Upper		
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
sex	1	1	8.3653	0.3071	7.7634	8.9672	741.94 <.0001
sex	0	1	8.7104	0.2957	8.1309	9.2900	867.78 <.0001
dthick	2	1	-1.5908	0.3111	-2.2006	-0.9811	26.15 <.0001
dthick	1	1	-1.3246	0.2439	-1.8026	-0.8466	29.50 <.0001
dthick	0	0	0.0000	.	.	.	.
Scale		1	1.4239	0.1477	1.1619	1.7451	
Shape		1	-1.5590	0.3959	-2.3350	-0.7831	

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.

**A.2.3.4 Lognormal**

The LIFEREG Procedure

Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	5
Name of Distribution	Lognormal
Log Likelihood	-150.3511243

Number of Observations Read	205
Number of Observations Used	205

Class Level Information

Name	Levels	Values
dthick	3	2 1 0
sex	2	1 0

Fit Statistics

-2 Log Likelihood	300.702
AIC (smaller is better)	310.702
AICC (smaller is better)	311.004
BIC (smaller is better)	327.317

Fit Statistics (Unlogged Response)

-2 Log Likelihood	1089.437
Lognormal AIC (smaller is better)	1099.437
Lognormal AICC (smaller is better)	1099.738
Lognormal BIC (smaller is better)	1116.052

Algorithm converged.

Type III Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
Intercept	0	.	.
sex	1	3.1687	0.0751
dthick	2	26.4328	<.0001

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard	95% Confidence		Chi-Square	Pr > ChiSq
			Error	Limits			
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
sex	1	1	9.0703	0.2961	8.4900	9.6506	938.50 <.0001
sex	0	1	9.5030	0.2849	8.9446	10.0615	1112.32 <.0001
dthick	2	1	-1.4493	0.3464	-2.1282	-0.7703	17.50 <.0001
dthick	1	1	-1.3581	0.2890	-1.9245	-0.7917	22.08 <.0001
dthick	0	0	0.0000	.	.	.	.
Scale	1	1.2763	0.1335	1.0397	1.5667		

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
-----------	------------	------------

Intercept	.	.
-----------	---	---

**A.2.3.5 Log logistic**

The LIFEREG Procedure

Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	5
Name of Distribution	LLogistic
Log Likelihood	-152.9302109

Number of Observations Read	205
Number of Observations Used	205

Class Level Information

Name	Levels	Values
dthick	3	2 1 0
sex	2	1 0

Fit Statistics

-2 Log Likelihood	305.860
AIC (smaller is better)	315.860
AICC (smaller is better)	316.162
BIC (smaller is better)	332.475

Fit Statistics (Unlogged Response)

-2 Log Likelihood	1094.595
LLogistic AIC (smaller is better)	1104.595
LLogistic AICC (smaller is better)	1104.896
LLogistic BIC (smaller is better)	1121.210

Algorithm converged.

Type III Analysis of Effects

Effect	DF	Chi-Square	Pr > ChiSq	Wald
Intercept	0	.	.	
sex	1	3.5789	0.0585	
dthick	2	22.7538	<.0001	

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter		DF	Standard Estimate	Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept		0	0.0000	0.0000	0.0000	0.0000	.	.
sex	1	1	9.0052	0.3021	8.4131	9.5973	888.45	<.0001
sex	0	1	9.4718	0.2989	8.8859	10.0577	1003.93	<.0001
dthick	2	1	-1.4284	0.3689	-2.1513	-0.7054	15.00	0.0001
dthick	1	1	-1.3507	0.3036	-1.9458	-0.7556	19.79	<.0001
dthick	0	0	0.0000	.	.	.	.	.
Scale		1	0.7350	0.0834	0.5884	0.9182		

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.

### A.2.4 Model dthick

#### A.2.4.1 Exponential

The LIFEREG Procedure

##### Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	3
Name of Distribution	Exponential
Log Likelihood	-158.2113372

Number of Observations Read	205
Number of Observations Used	205

##### Class Level Information

Name	Levels	Values
dthick	3	0 1 2

##### Fit Statistics

-2 Log Likelihood	316.423
AIC (smaller is better)	322.423
AICC (smaller is better)	322.542
BIC (smaller is better)	332.392

##### Fit Statistics (Unlogged Response)

-2 Log Likelihood	1105.157
Exponential AIC (smaller is better)	1111.157
Exponential AICC (smaller is better)	1111.276
Exponential BIC (smaller is better)	1121.126

Algorithm converged.

##### Type III Analysis of Effects

Effect	DF	Chi-Square	Pr > ChiSq	Wald
Intercept	0	.	.	
dthick	3	4332.8852	<.0001	

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
				Lower	Upper		
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
dthick	0 1	9.8915	0.2774	9.3479	10.4351	1271.94	<.0001
dthick	1 1	8.3298	0.1796	7.9778	8.6818	2150.94	<.0001
dthick	2 1	8.3666	0.2774	7.8230	8.9102	910.00	<.0001
Scale	0	1.0000	0.0000	1.0000	1.0000		
Weibull Shape	0	1.0000	0.0000	1.0000	1.0000		

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.
Scale	0.7752	0.3786

**A.2.4.2 Weibull**

The LIFEREG Procedure

Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	4
Name of Distribution	Weibull
Log Likelihood	-157.8781413

Number of Observations Read	205
Number of Observations Used	205

Class Level Information

Name	Levels	Values
dthick	3	0 1 2

Fit Statistics

-2 Log Likelihood	315.756
AIC (smaller is better)	323.756
AICC (smaller is better)	323.956
BIC (smaller is better)	337.048

Fit Statistics (Unlogged Response)

-2 Log Likelihood	1104.491
Weibull AIC (smaller is better)	1112.491
Weibull AICC (smaller is better)	1112.691
Weibull BIC (smaller is better)	1125.783

Algorithm converged.

Type III Analysis of Effects

Effect	DF	Chi-Square	Pr > ChiSq	Wald
Intercept	0	.	.	
dthick	3	3430.9239	<.0001	

The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
dthick	0 1	9.7050	0.3295	9.0591	10.3508	867.33	<.0001
dthick	1 1	8.2816	0.1717	7.9451	8.6181	2327.11	<.0001
dthick	2 1	8.3139	0.2585	7.8072	8.8205	1034.27	<.0001
Scale	1	0.9083	0.1048	0.7244	1.1388		
Weibull Shape	1	1.1010	0.1271	0.8781	1.3804		

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.

**A.2.4.3 Gamma**

The LIFEREG Procedure

Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	5
Name of Distribution	Gamma
Log Likelihood	-148.3148934

Number of Observations Read	205
Number of Observations Used	205

Class Level Information

Name	Levels	Values
dthick	3	0 1 2

Fit Statistics

-2 Log Likelihood	296.630
AIC (smaller is better)	306.630
AICC (smaller is better)	306.931
BIC (smaller is better)	323.245

Fit Statistics (Unlogged Response)

-2 Log Likelihood	1085.364
Gamma AIC (smaller is better)	1095.364
Gamma AICC (smaller is better)	1095.666
Gamma BIC (smaller is better)	1111.979

Algorithm converged.

Type III Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
Intercept	0	.	.
dthick	3	767.0002	<.0001

The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
dthick	0 1	8.5484	0.3131	7.9347	9.1620	745.44	<.0001
dthick	1 1	7.1409	0.3143	6.5248	7.7570	516.12	<.0001
dthick	2 1	6.8325	0.3794	6.0889	7.5762	324.26	<.0001
Scale	1	1.4307	0.1526	1.1608	1.7633		
Shape	1	-1.7025	0.5071	-2.6963	-0.7086		

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.

**A.2.4.4 Lognormal**

The LIFEREG Procedure

## Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	4
Name of Distribution	Lognormal
Log Likelihood	-151.9378754

Number of Observations Read	205
Number of Observations Used	205

## Class Level Information

Name	Levels	Values
dthick	3	2 1 0

## Fit Statistics

-2 Log Likelihood	303.876
AIC (smaller is better)	311.876
AICC (smaller is better)	312.076
BIC (smaller is better)	325.168

## Fit Statistics (Unlogged Response)

-2 Log Likelihood	1092.610
Lognormal AIC (smaller is better)	1100.610
Lognormal AICC (smaller is better)	1100.810
Lognormal BIC (smaller is better)	1113.902

Algorithm converged.

## Type III Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
Intercept	0	.	.
dthick	3	2777.7928	<.0001

## The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Estimate	Standard Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
				Lower	Upper		
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
dthick	2	1	7.8205	0.2778	7.2760	8.3650	792.47 <.0001
dthick	1	1	7.9504	0.1940	7.5701	8.3307	1679.19 <.0001
dthick	0	1	9.3787	0.2679	8.8536	9.9038	1225.26 <.0001
Scale		1	1.2964	0.1358	1.0558	1.5919	

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.

**A.2.4.5 Log logistic**

The LIFEREG Procedure

Model Information

Data Set	SUPP.MELANOM
Dependent Variable	Log(survtime)
Censoring Variable	status
Censoring Value(s)	0
Number of Observations	205
Noncensored Values	57
Right Censored Values	148
Left Censored Values	0
Interval Censored Values	0
Number of Parameters	4
Name of Distribution	LLogistic
Log Likelihood	-154.7119641

Number of Observations Read	205
Number of Observations Used	205

Class Level Information

Name	Levels	Values
dthick	3	0 1 2

Fit Statistics

-2 Log Likelihood	309.424
AIC (smaller is better)	317.424
AICC (smaller is better)	317.624
BIC (smaller is better)	330.716

Fit Statistics (Unlogged Response)

-2 Log Likelihood	1098.158
LLogistic AIC (smaller is better)	1106.158
LLogistic AICC (smaller is better)	1106.358
LLogistic BIC (smaller is better)	1119.450

Algorithm converged.

Type III Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
Intercept	0	.	.
dthick	3	3088.0718	<.0001

The LIFEREG Procedure

## Analysis of Maximum Likelihood Parameter Estimates

Parameter	DF	Standard Estimate	Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept	0	0.0000	0.0000	0.0000	0.0000	.	.
dthick	0 1	9.3316	0.2809	8.7812	9.8821	1103.97	<.0001
dthick	1 1	7.9092	0.1836	7.5494	8.2689	1856.41	<.0001
dthick	2 1	7.8108	0.2822	7.2578	8.3639	766.19	<.0001
Scale	1	0.7490	0.0851	0.5994	0.9359		

## Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Intercept	.	.

### A.3 SAS Plots

#### A.3.1 Model BY

##### A.3.1.1 Exponential

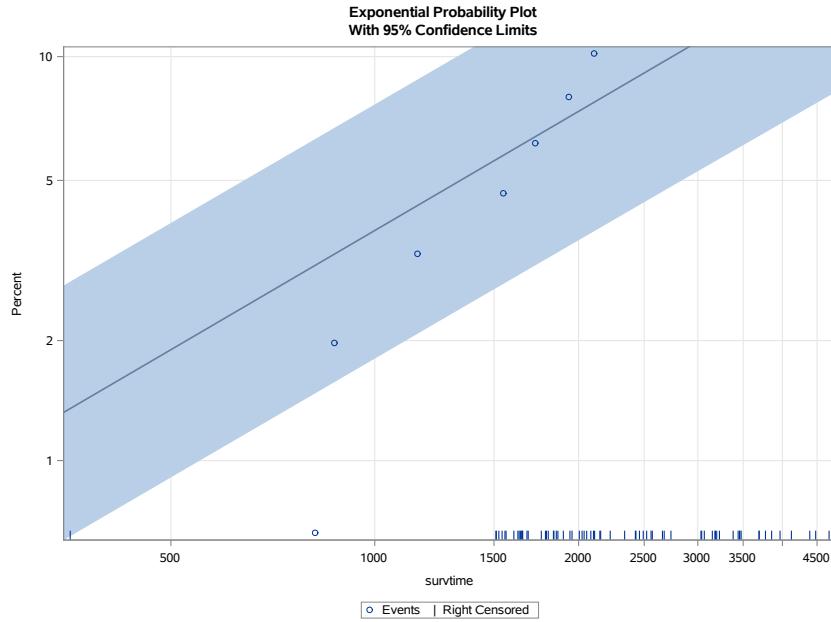


Figure A.1: Probability Plot – BY – sex = 0, dthick = 0.

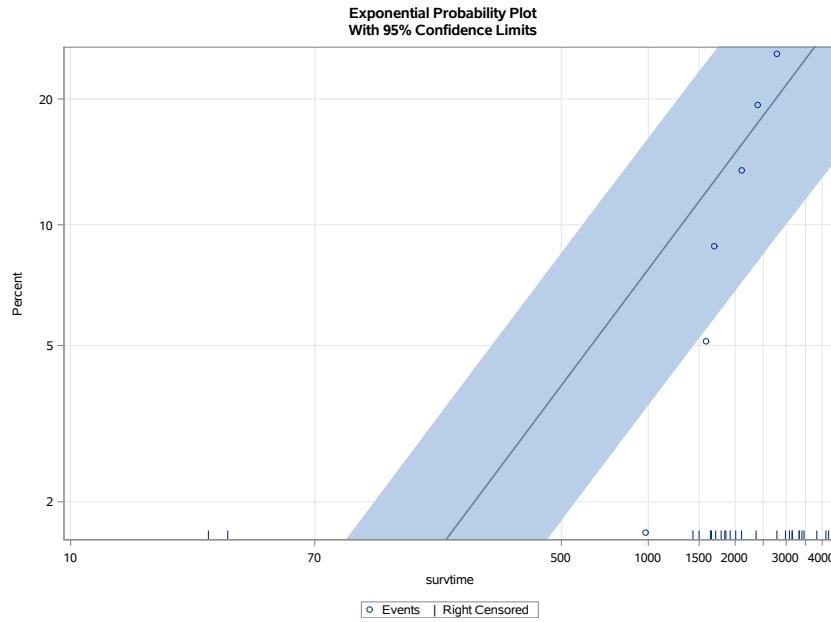


Figure A.2: Probability Plot – BY – sex = 0, dthick = 1.

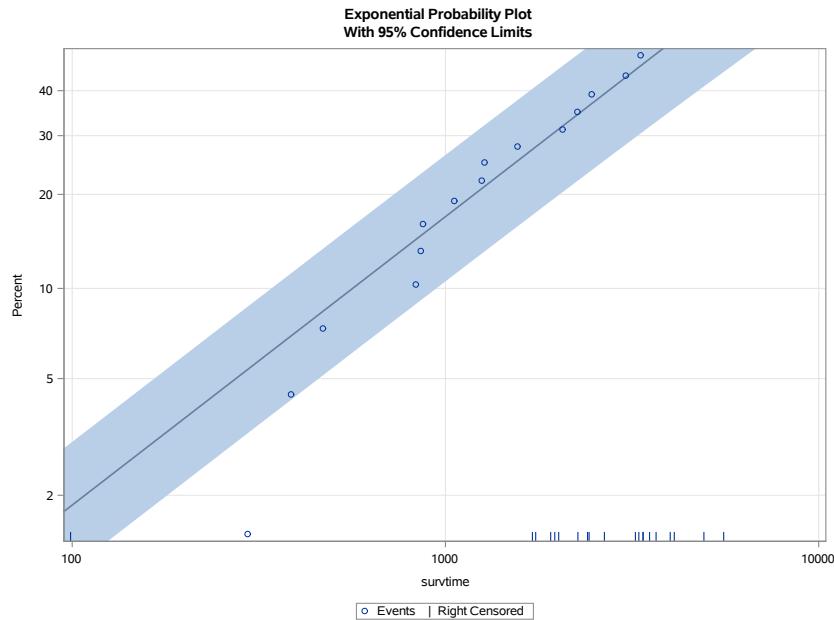


Figure A.3: Probability Plot – BY – sex = 0, dthick = 2.

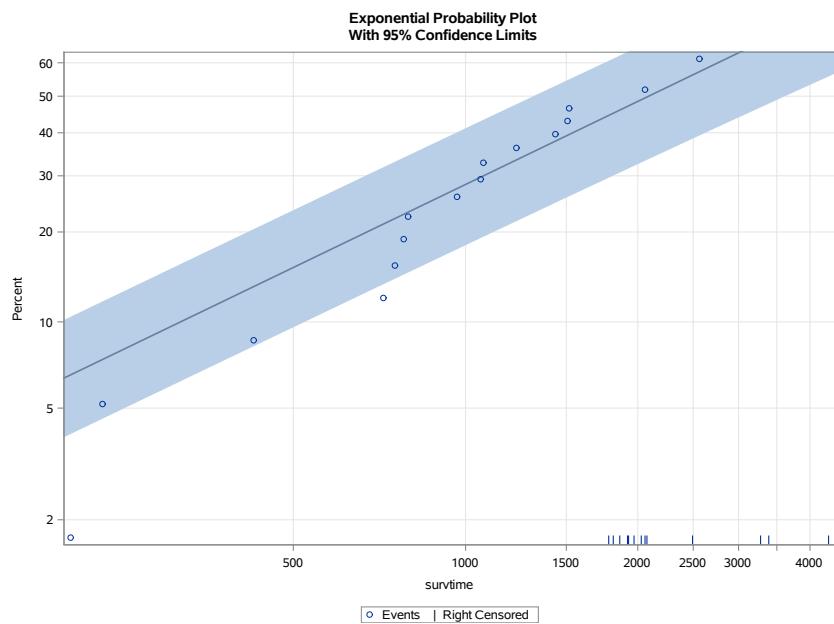


Figure A.4: Probability Plot – BY – sex = 1, dthick = 0.

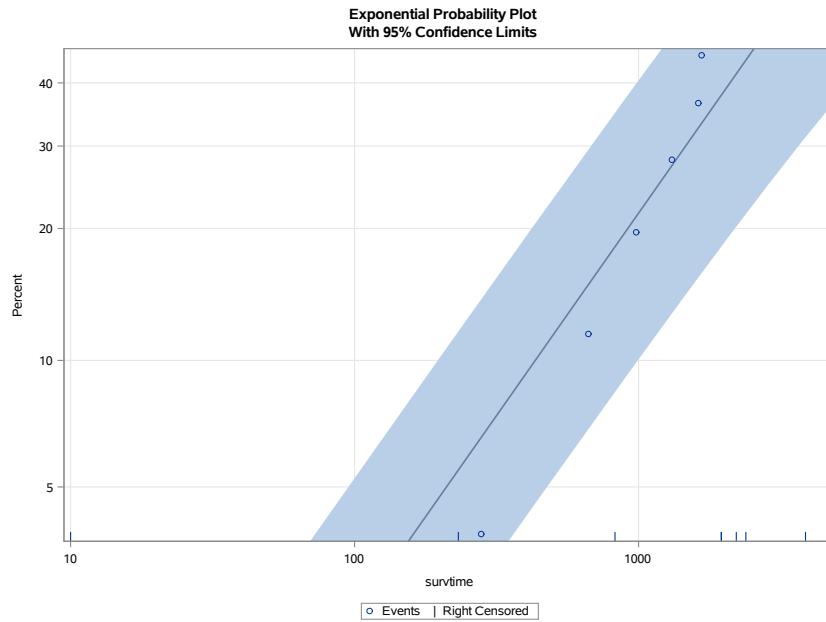


Figure A.5: Probability Plot – BY – sex = 1, dthick = 1.

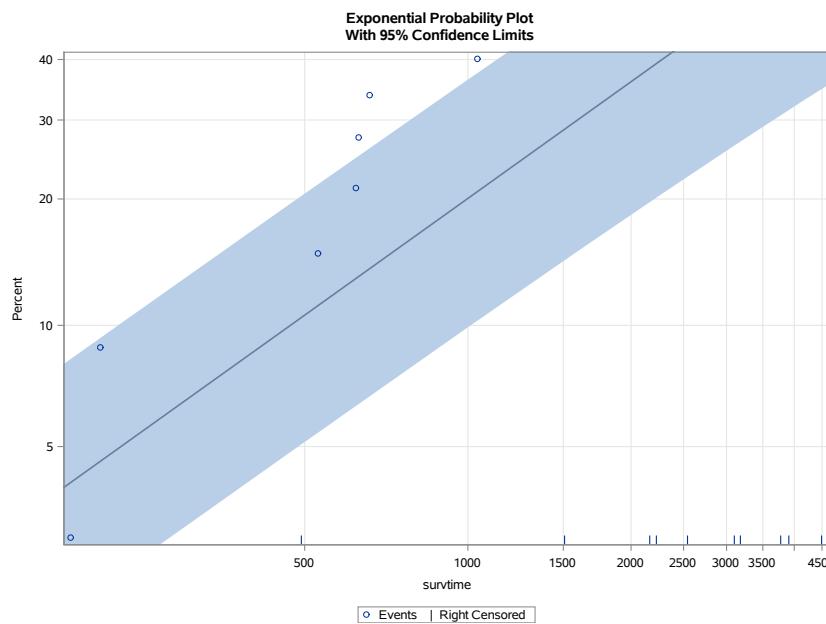


Figure A.6: Probability Plot – BY – sex = 1, dthick = 2.

### A.3.1.2 Weibull

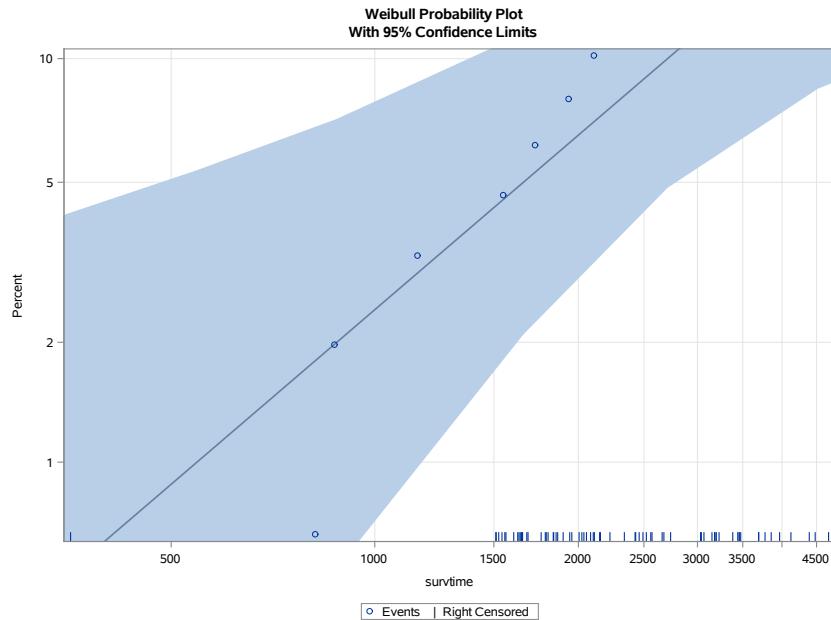


Figure A.7: Probability Plot – BY – sex = 0, dthick = 0.

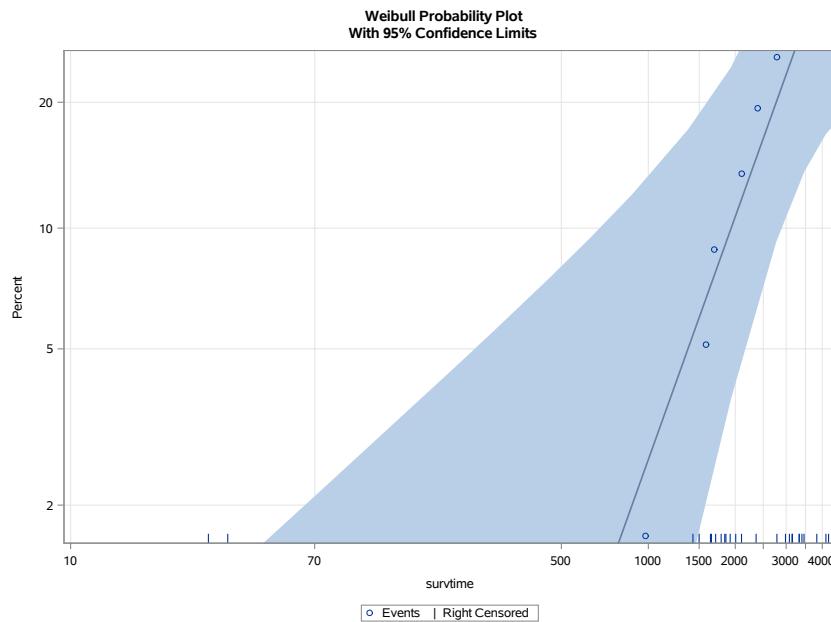


Figure A.8: Probability Plot – BY – sex = 0, dthick = 1.

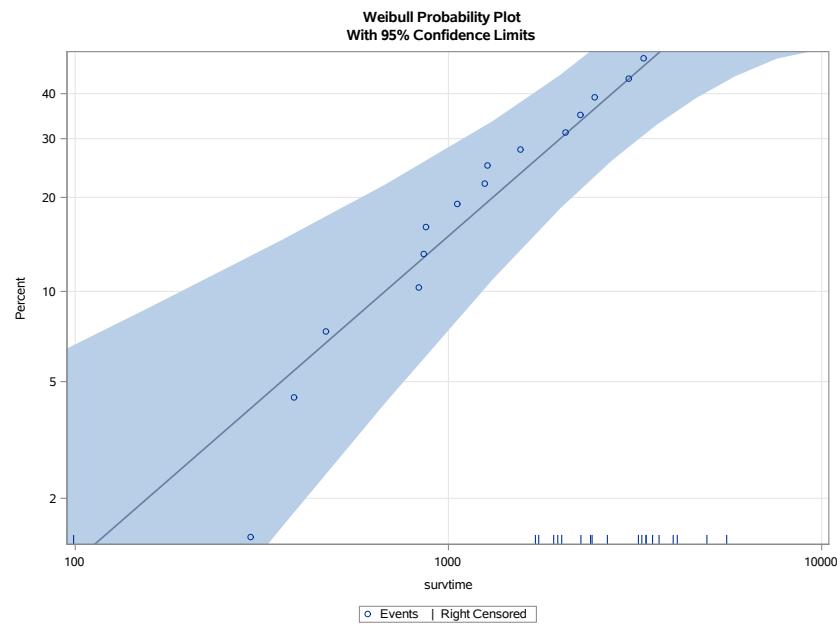


Figure A.9: Probability Plot – BY – sex = 0, dthick = 2.

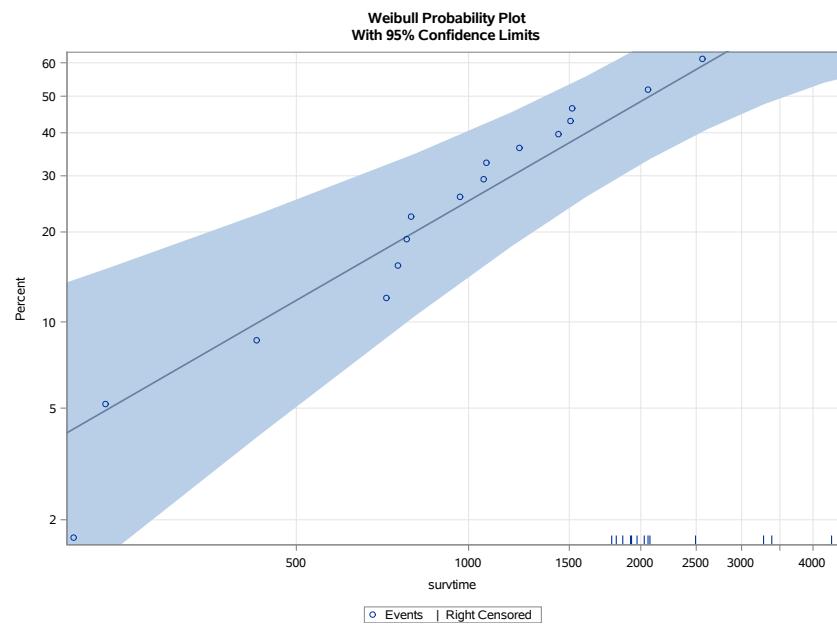


Figure A.10: Probability Plot – BY – sex = 1, dthick = 0.

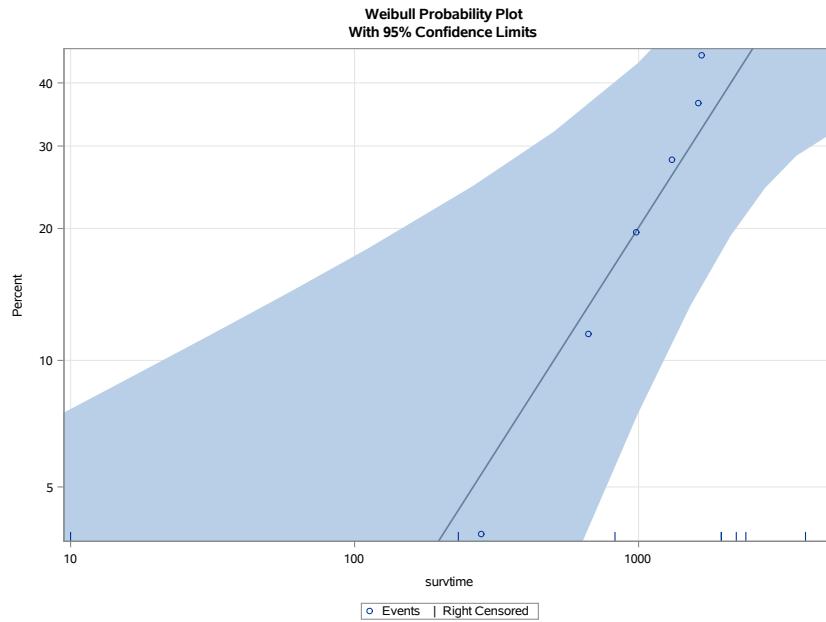


Figure A.11: Probability Plot – BY – sex = 1, dthick = 1.

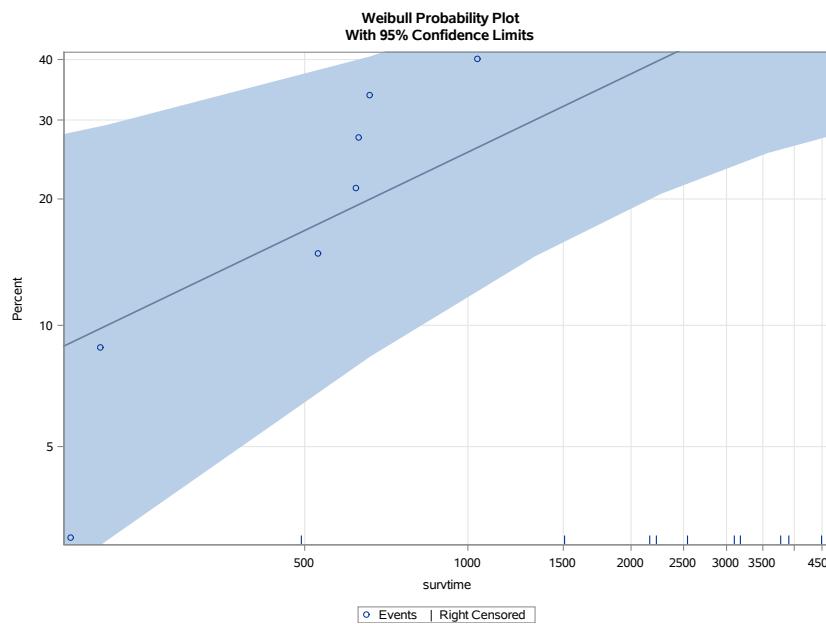


Figure A.12: Probability Plot – BY – sex = 1, dthick = 2.

### A.3.1.3 Gamma

No plot possible for first group.

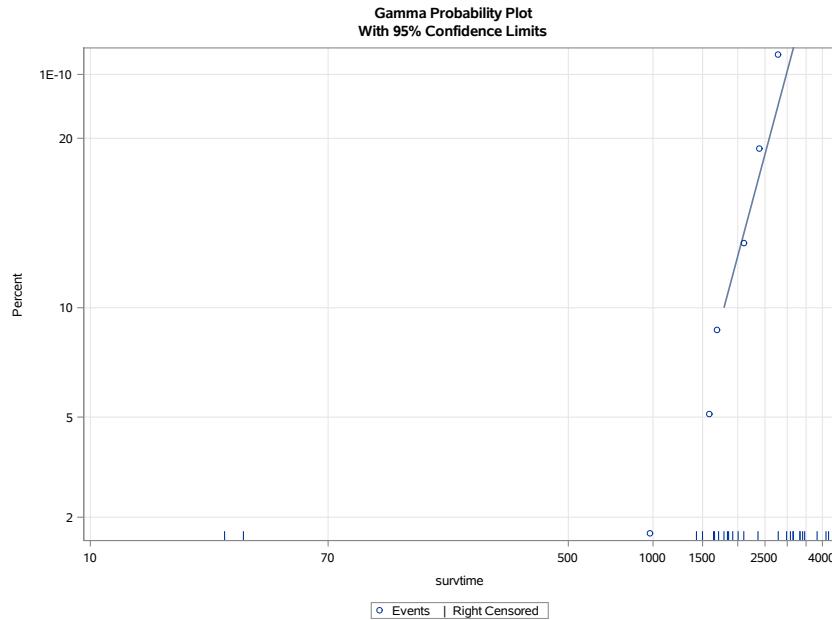


Figure A.13: Probability Plot – BY – sex = 0, dthick = 1.

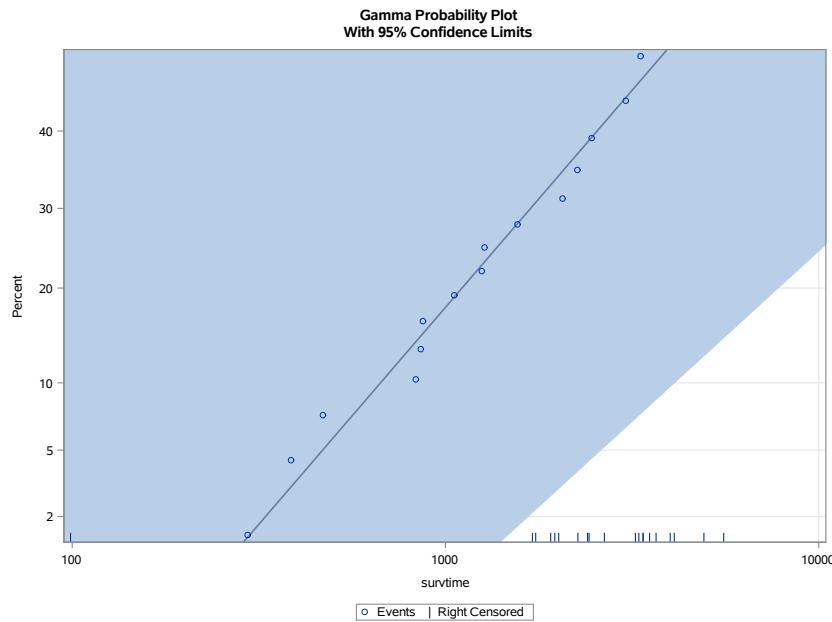


Figure A.14: Probability Plot – BY – sex = 0, dthick = 2.

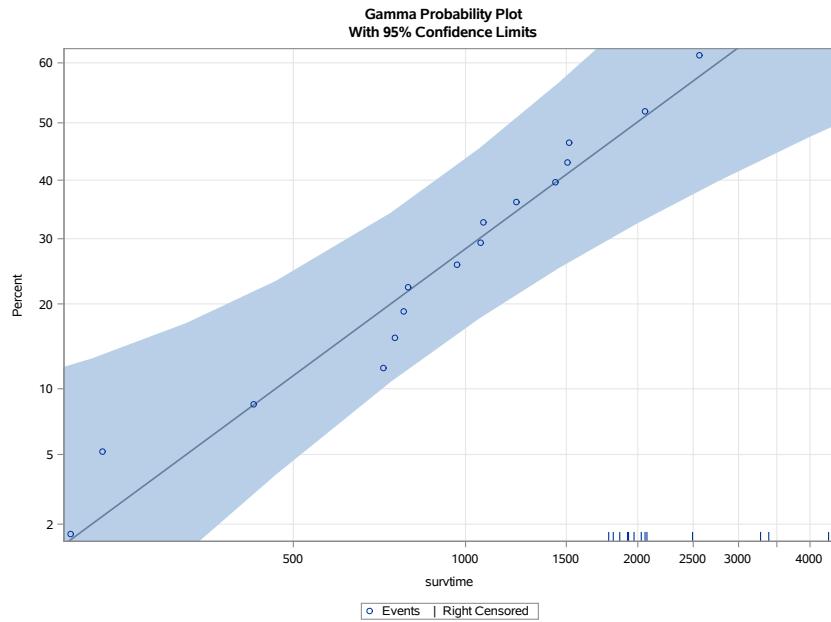


Figure A.15: Probability Plot – BY – sex = 1, dthick = 0.

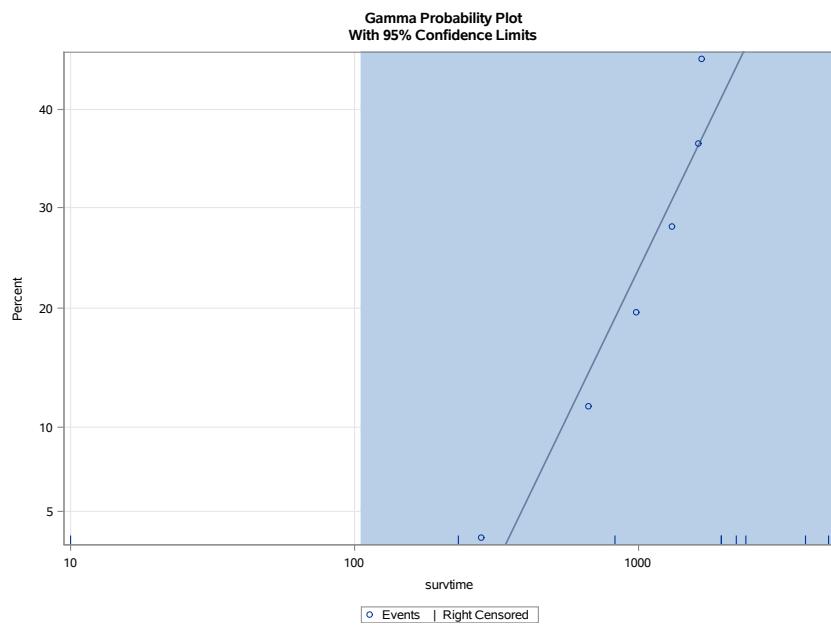


Figure A.16: Probability Plot – BY – sex = 1, dthick = 1.

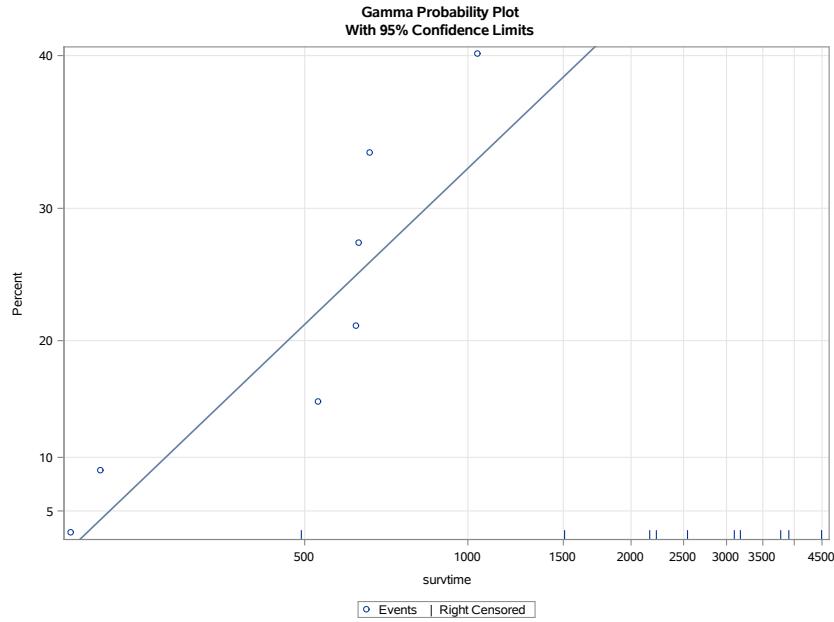


Figure A.17: Probability Plot – BY – sex = 1, dthick = 2.

#### A.3.1.4 Log logistic

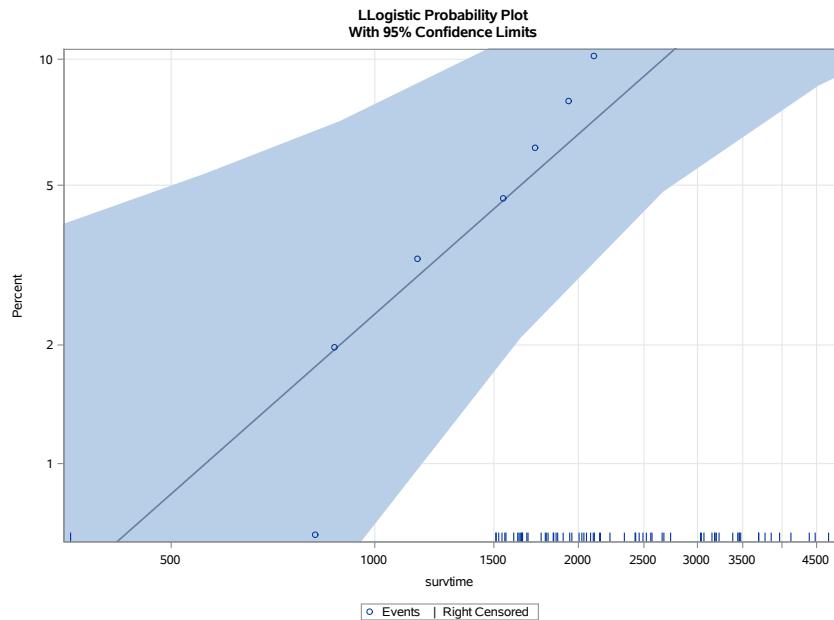


Figure A.18: Probability Plot – BY – sex = 0, dthick = 0.

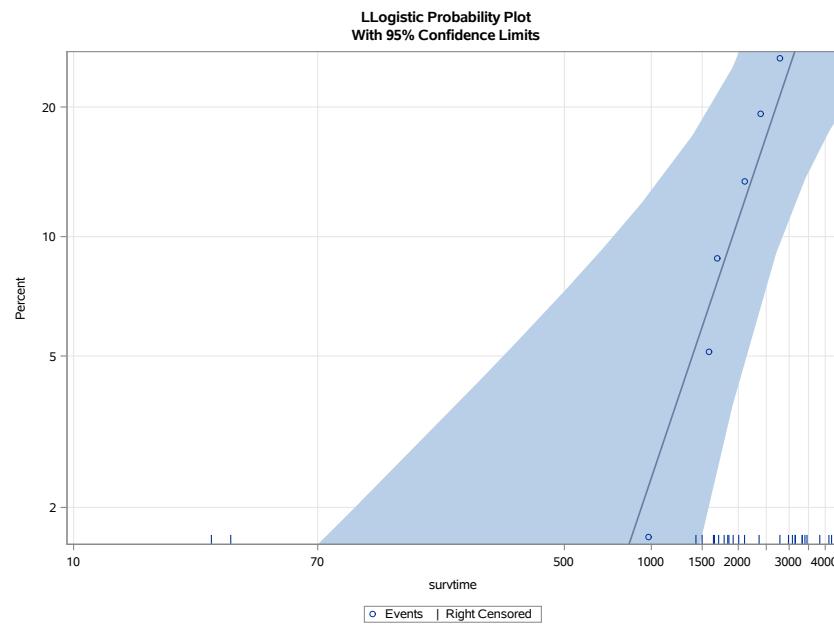


Figure A.19: Probability Plot – BY – sex = 0, dthick = 1.

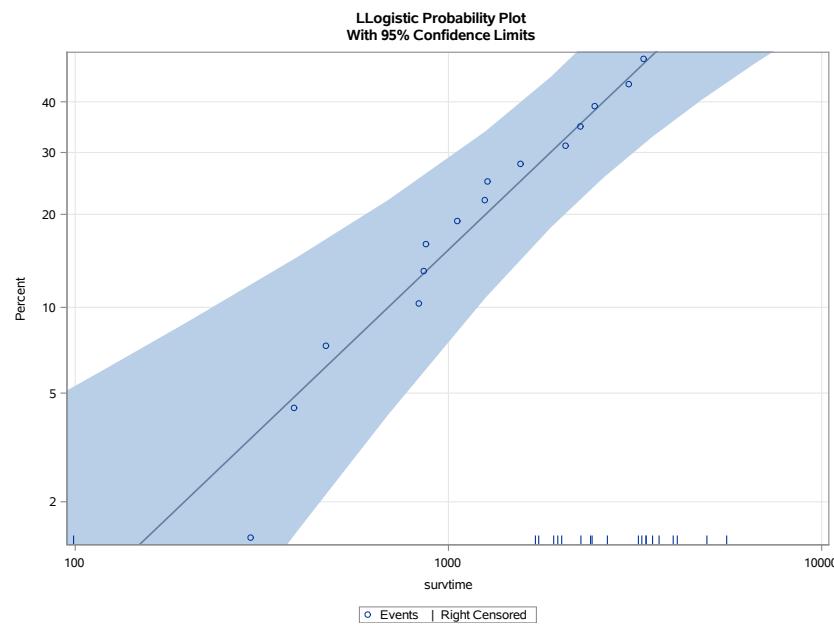


Figure A.20: Probability Plot – BY – sex = 0, dthick = 2.

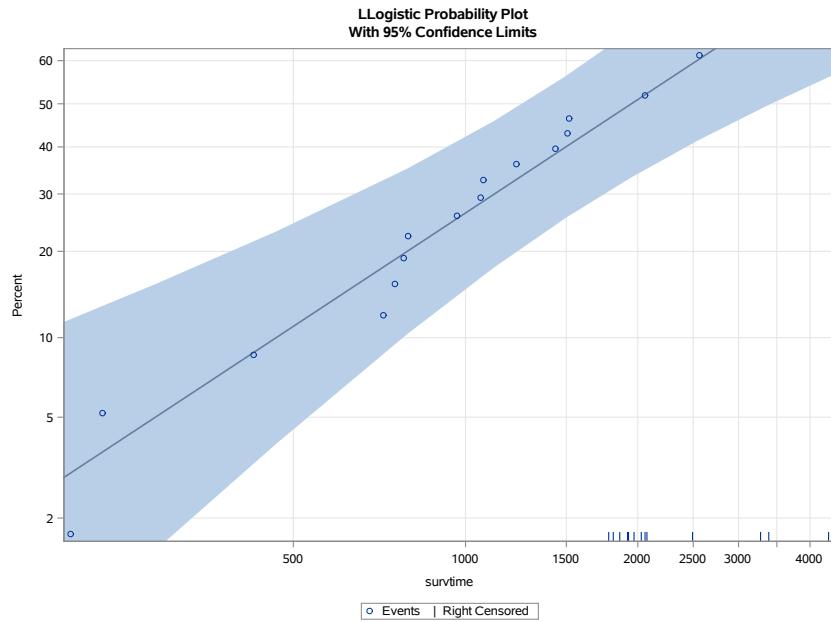


Figure A.21: Probability Plot – BY – sex = 1, dthick = 0.

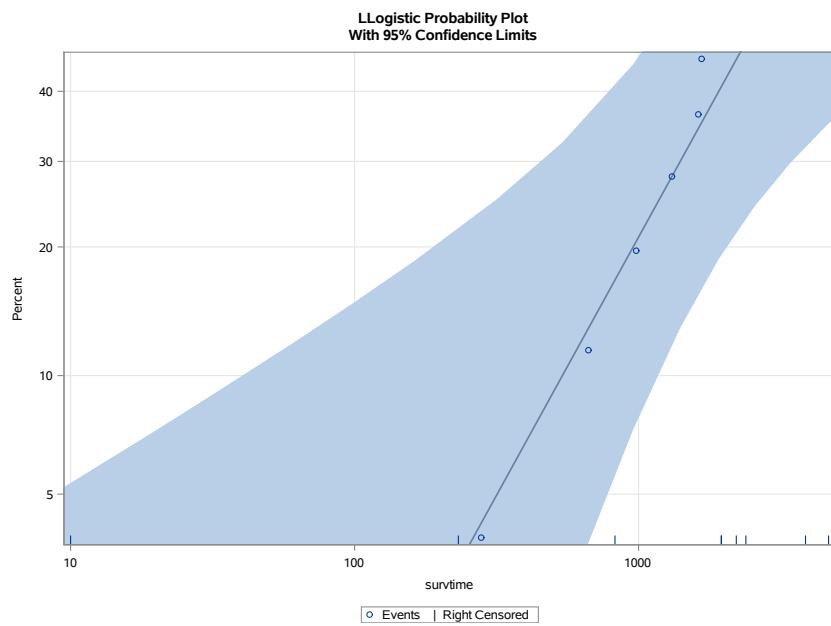


Figure A.22: Probability Plot – BY – sex = 1, dthick = 1.

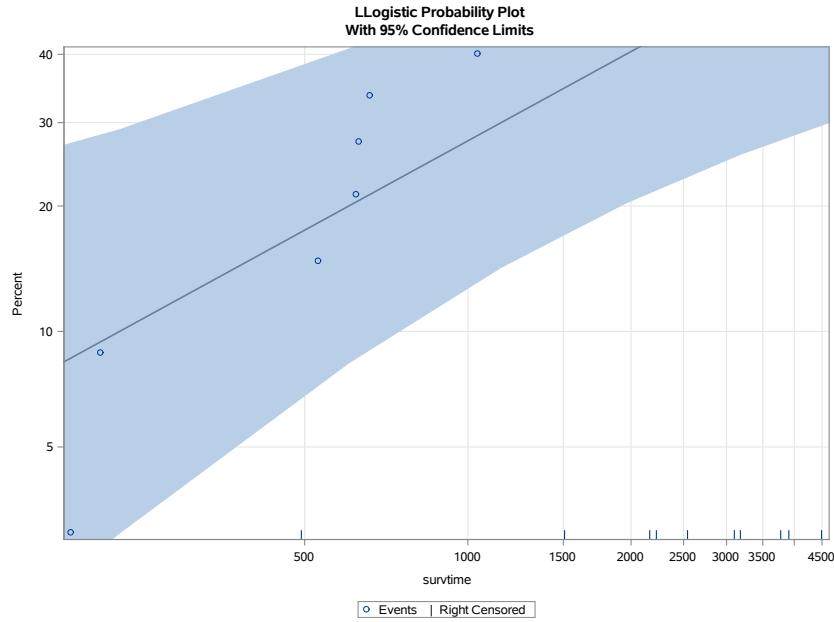


Figure A.23: Probability Plot – BY – sex = 1, dthick = 2.

### A.3.2 Model Interaction

#### A.3.2.1 Exponential

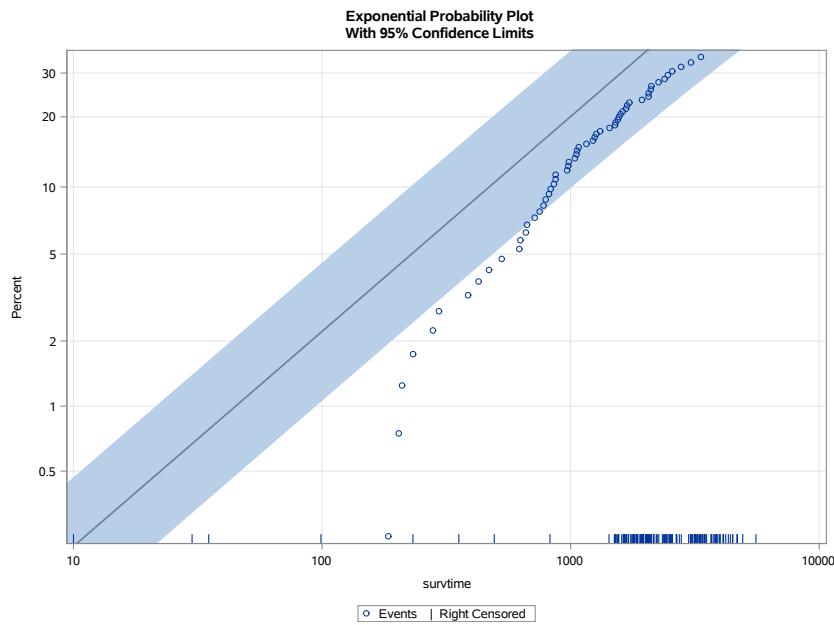


Figure A.24: Probability Plot – Interaction.

### A.3.2.2 Weibull

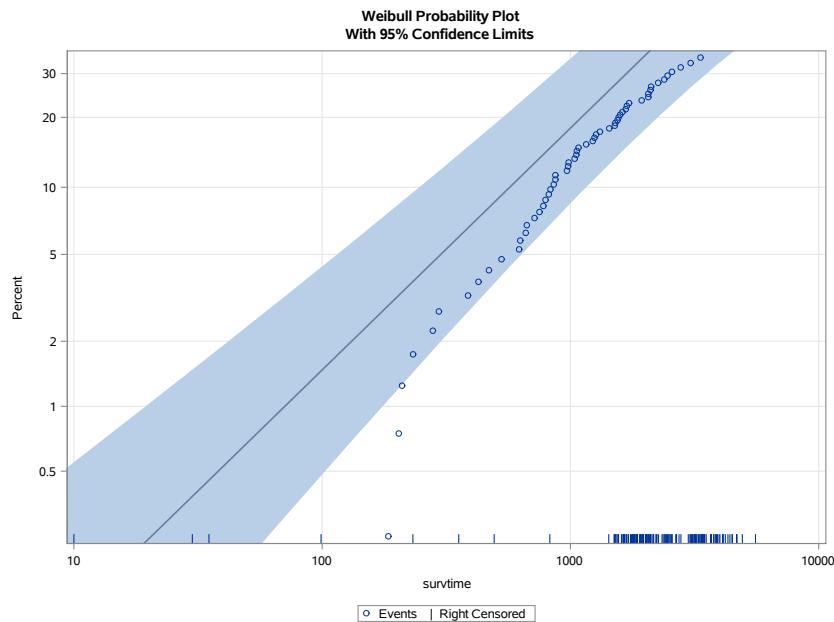


Figure A.25: Probability Plot – Interaction.

### A.3.2.3 Gamma

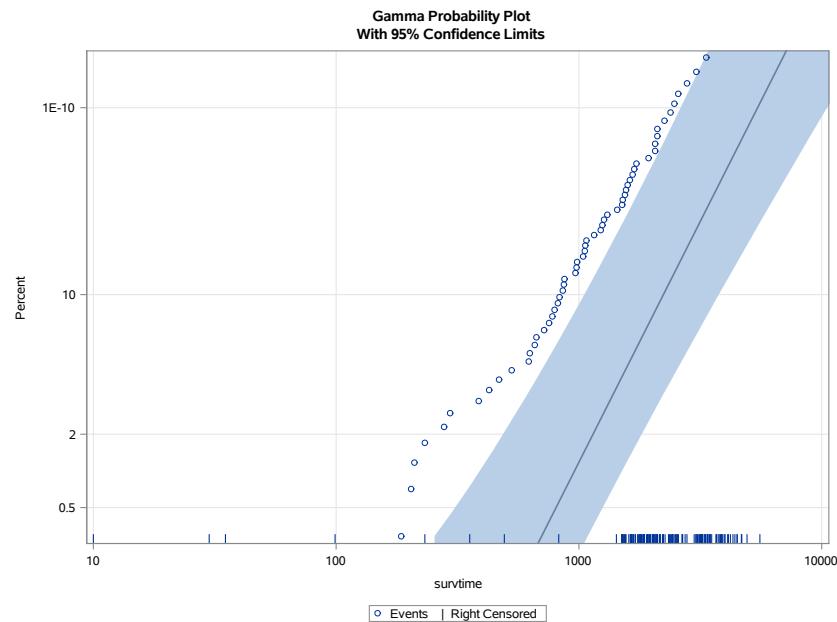


Figure A.26: Probability Plot – Interaction.

#### A.3.2.4 Lognormal

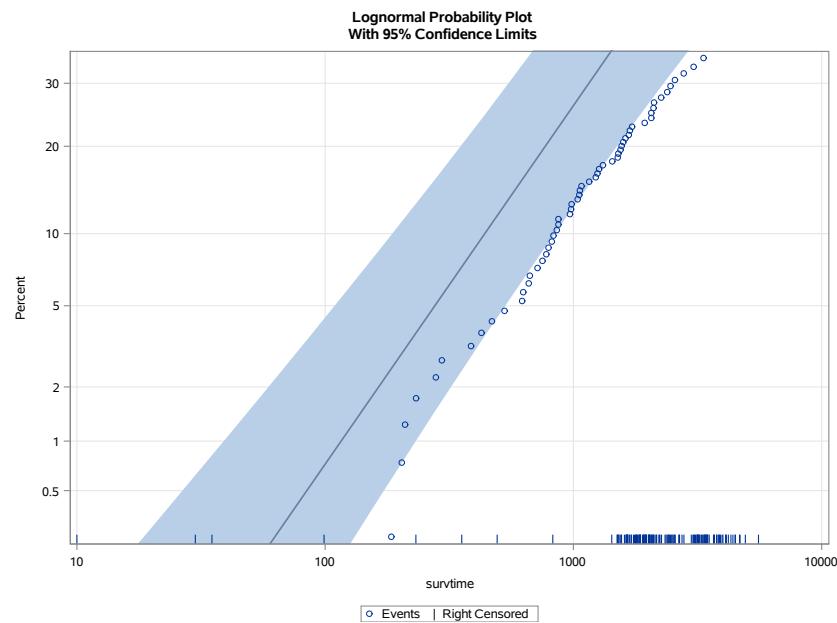


Figure A.27: Probability Plot – Interaction.

### A.3.2.5 Log logistic

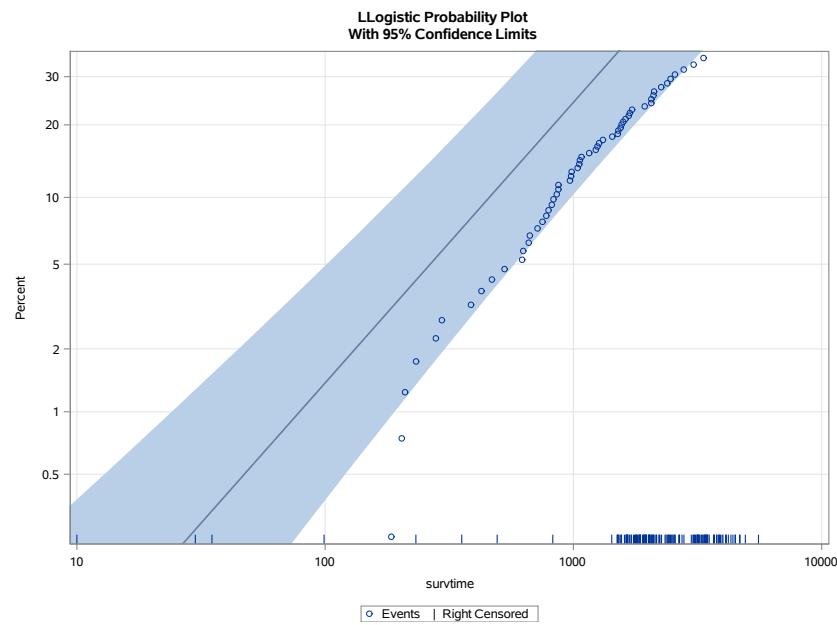


Figure A.28: Probability Plot – Interaction.

### A.3.3 Model sex dthick

#### A.3.3.1 Exponential

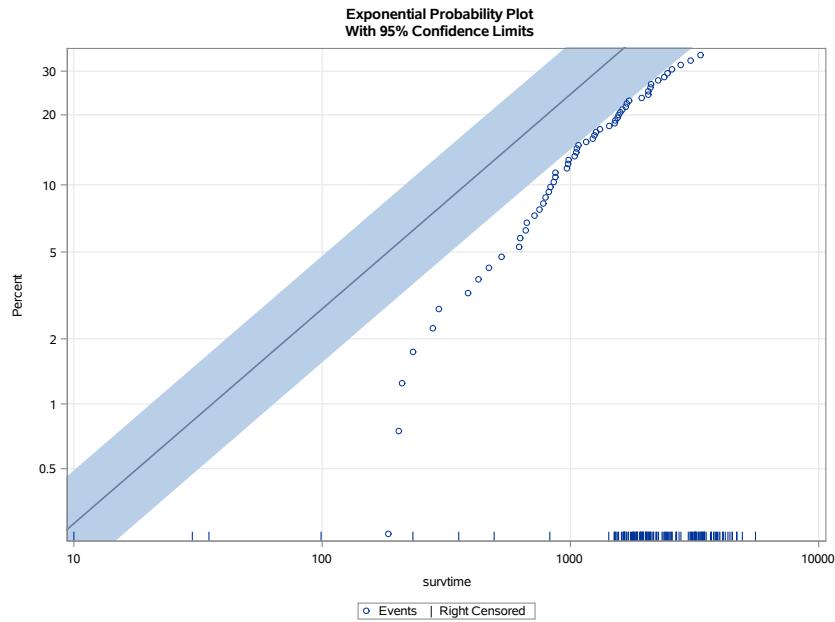


Figure A.29: Probability Plot – dthick sex.

#### A.3.3.2 Weibull

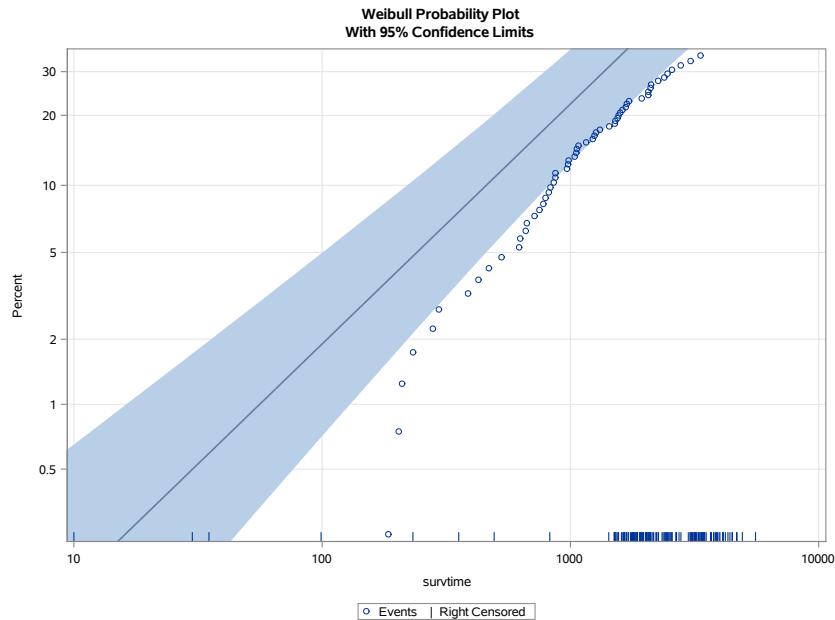


Figure A.30: Probability Plot – dthick sex.

### A.3.3.3 Gamma

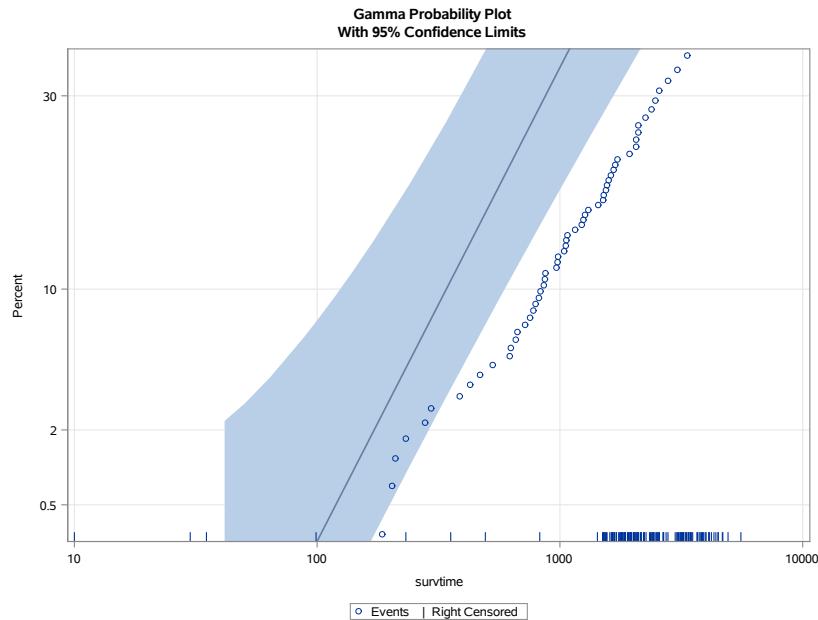


Figure A.31: Probability Plot – dthick sex.

#### A.3.3.4 Lognormal

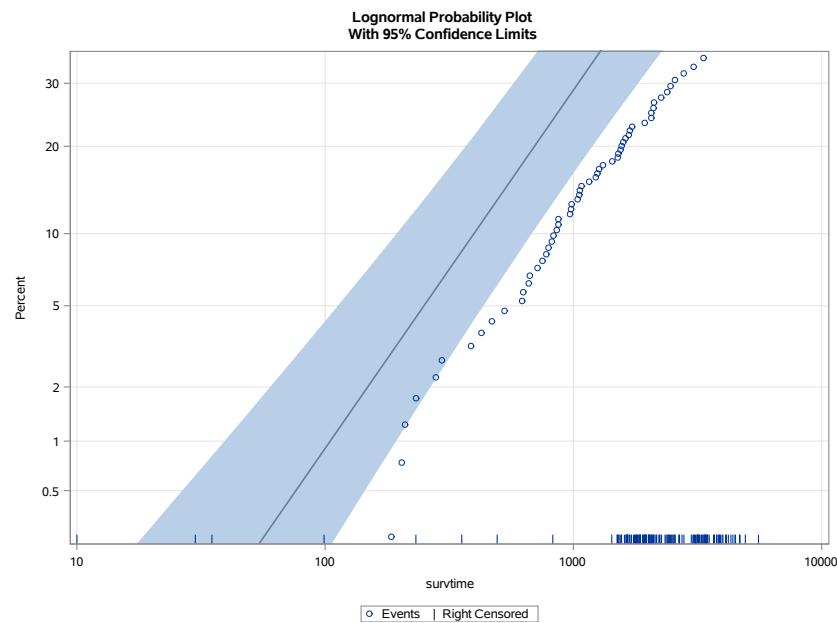


Figure A.32: Probability Plot – dthick sex.

### A.3.3.5 Log logistic

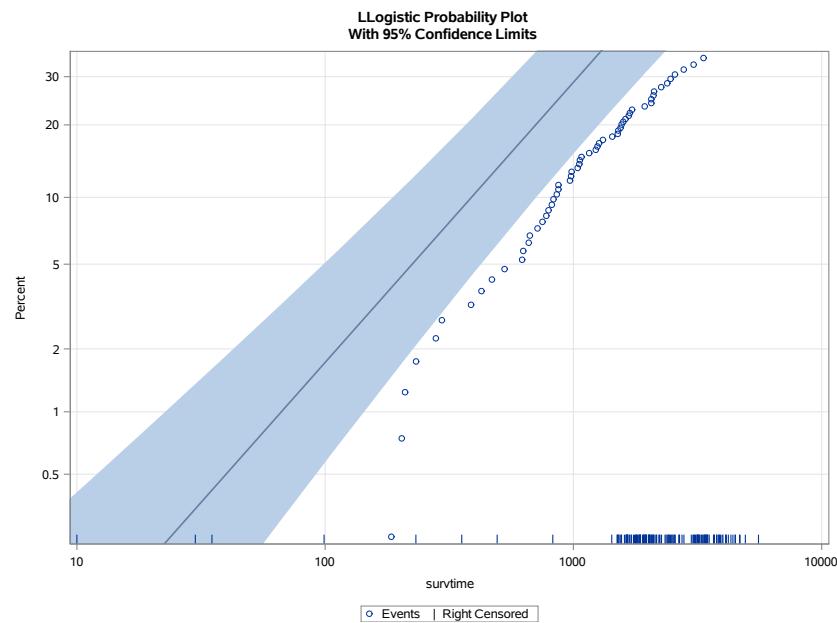


Figure A.33: Probability Plot – dthick sex.

### A.3.4 Model dthick

#### A.3.4.1 Exponential

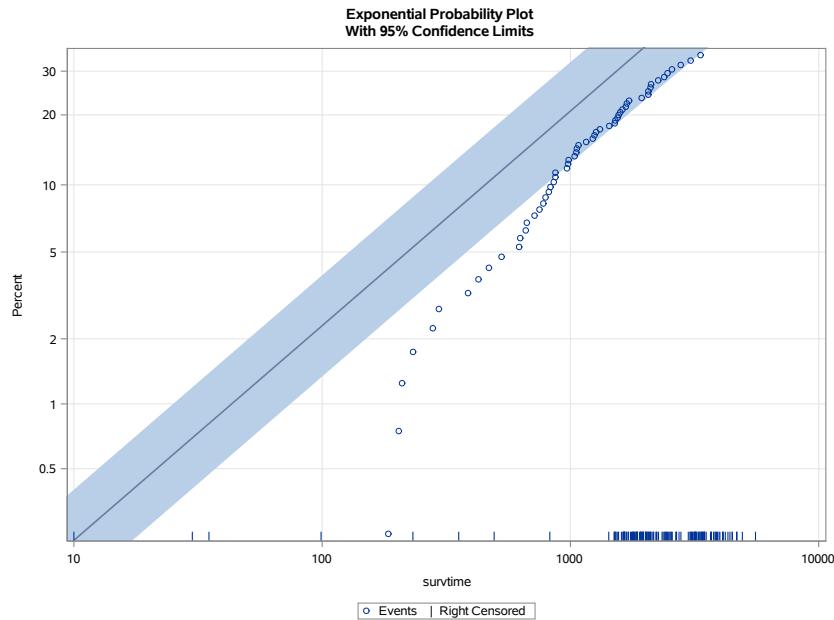


Figure A.34: Probability Plot – dthick.

### A.3.4.2 Weibull

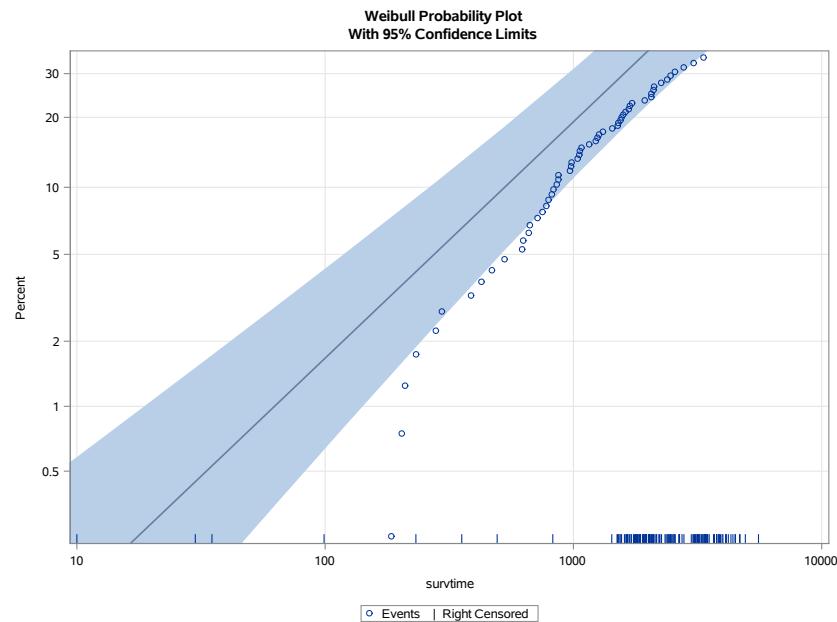


Figure A.35: Probability Plot – dthick.

### A.3.4.3 Gamma

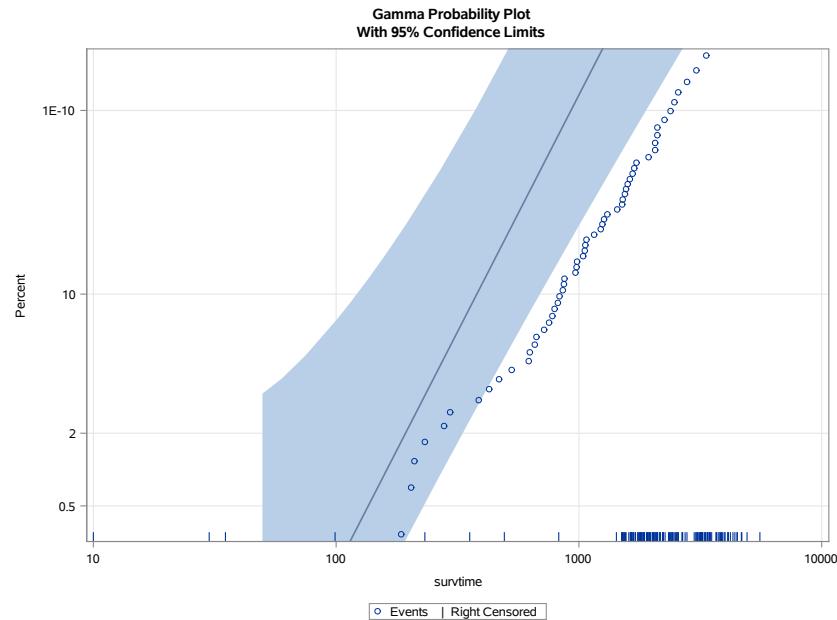


Figure A.36: Probability Plot – dthick.

#### A.3.4.4 Lognormal

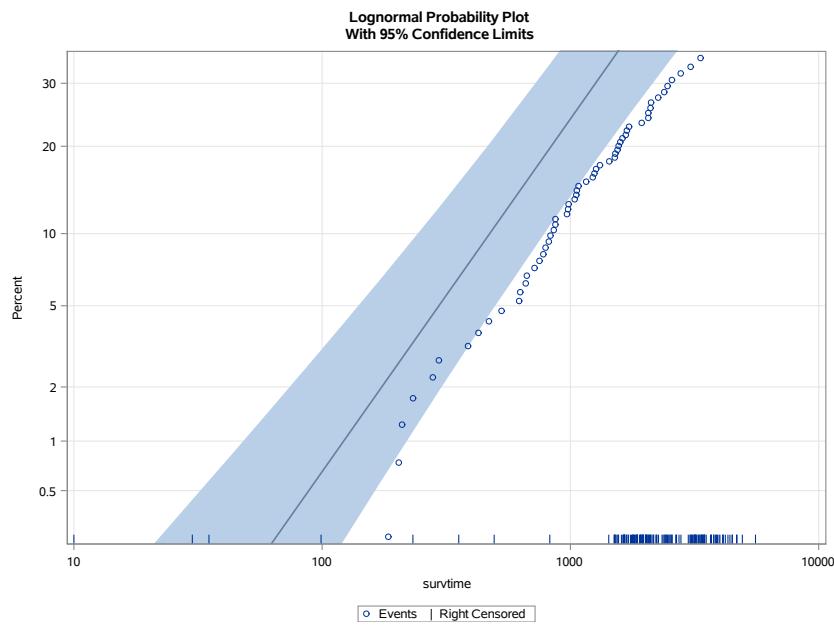


Figure A.37: Probability Plot – dthick.

#### A.3.4.5 Log logistic

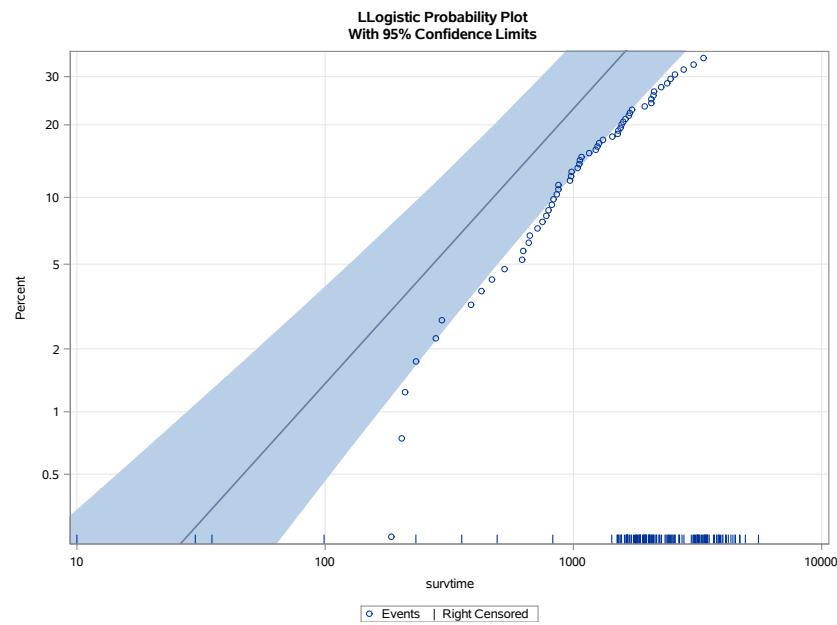


Figure A.38: Probability Plot – dthick.

## B SAS of Exercise 1

### B.1 SAS Code

#### B.1.1 Edema

##### B.1.1.1 Grouping

```
PROC PHREG DATA = pbc ZPH PLOTS(OVERLAY) = SURVIVAL;
CLASS edema(REF = '0');
MODEL futime*cen(0) = age log_alb log_pro edema / RL TYPE3(ALL);
ASSESS PH / RESAMPLE;
RUN;
```

#### B.1.2 Bilirubin

##### B.1.2.1 Linearly

```
PROC PHREG DATA = pbc ZPH PLOTS(OVERLAY) = SURVIVAL;
MODEL futime*cen(0) = age log_alb log_pro edema bili / RL TYPE3(ALL);
ASSESS PH VAR = (bili) / RESAMPLE;
RUN;
```

##### B.1.2.2 Logarithmic Transform

```
PROC PHREG DATA = pbc ZPH PLOTS(OVERLAY) = SURVIVAL;
MODEL futime*cen(0) = age log_alb log_pro edema log_bil/ RL TYPE3(ALL);
ASSESS PH VAR = (log_bil) / RESAMPLE;
RUN;
```

## B.2 SAS Output

### B.2.1 Edema

#### B.2.1.1 Grouping

```
The PHREG Procedure

Model Information

Data Set                  WORK.PBC
Dependent Variable        futime
Censoring Variable       cen
Censoring Value(s)       0
Ties Handling            BRESLOW

Number of Observations Read      312
Number of Observations Used     312

Class Level Information

Design
Class    Value    Variables
edema   0         0         0
          0.5       1         0
          1         0         1

Summary of the Number of Event and Censored Values

Percent
Total    Event    Censored    Censored
312      125       187        59.94

Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Without           With
Criterion Covariates Covariates
-2 LOG L       1279.960    1157.852
AIC            1279.960    1167.852
SBC            1279.960    1181.994

Testing Global Null Hypothesis: BETA=0

Test           Chi-Square      DF      Pr > ChiSq
Likelihood Ratio      122.1076      5      <.0001
```

Score	207.4383	5	<.0001
Wald	152.5728	5	<.0001

## The PHREG Procedure

## Type 3 Tests

Effect	DF	LR Statistics	
		Chi-Square	Pr > ChiSq
age	1	7.7146	0.0055
log_alb	1	29.4846	<.0001
log_pro	1	18.6016	<.0001
edema	2	17.3564	0.0002

## Type 3 Tests

Effect	DF	Score Statistics	
		Chi-Square	Pr > ChiSq
age	1	7.8672	0.0050
log_alb	1	34.5077	<.0001
log_pro	1	22.5170	<.0001
edema	2	22.0722	<.0001

## Type 3 Tests

Effect	DF	Wald Statistics	
		Chi-Square	Pr > ChiSq
age	1	7.8200	0.0052
log_alb	1	34.6076	<.0001
log_pro	1	22.6580	<.0001
edema	2	20.0062	<.0001

## Analysis of Maximum Likelihood Estimates

Parameter	DF	Parameter Estimate	Standard Error			Chi-Square	Pr > ChiSq	Hazard Ratio	95% Confidence Limits	Hazard Ratio Label
			Chi-Square	Pr > ChiSq	Hazard Ratio					
age	1	0.02637	0.00943	7.8200	0.0052	1.027	1.008	1.046		
log_alb	1	-3.95486	0.67227	34.6076	<.0001	0.019	0.005	0.072		
log_pro	1	4.08911	0.85905	22.6580	<.0001	59.686	11.083	321.439		
edema	0.5	1	0.29593	0.27170	1.1863	0.2761	1.344	0.789	2.290	edema 0.5
edema	1	1	1.36858	0.30612	19.9871	<.0001	3.930	2.157	7.160	edema 1

## B.2.2 Bilirubin

### B.2.2.1 Linearly

The PHREG Procedure

#### Model Information

Data Set	WORK.PBC
Dependent Variable	futime
Censoring Variable	cen
Censoring Value(s)	0
Ties Handling	BRESLOW

Number of Observations Read	312
Number of Observations Used	312

#### Summary of the Number of Event and Censored Values

Total	Event	Censored	Percent Censored
312	125	187	59.94

#### Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

#### Model Fit Statistics

Criterion	Without Covariates	With Covariates
-2 LOG L	1279.960	1114.549
AIC	1279.960	1124.549
SBC	1279.960	1138.690

#### Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	165.4109	5	<.0001
Score	288.8856	5	<.0001
Wald	186.3233	5	<.0001

#### Type 3 Tests

Effect	DF	LR Statistics	
		Chi-Square	Pr > ChiSq
age	1	12.2728	0.0005
log_alb	1	24.8553	<.0001
log_pro	1	12.0370	0.0005

edema	1	6.2285	0.0126
bili	1	45.3199	<.0001

## The PHREG Procedure

## Type 3 Tests

Effect	DF	Score Statistics	
		Chi-Square	Pr > ChiSq
age	1	12.6412	0.0004
log_alb	1	28.9186	<.0001
log_pro	1	13.6135	0.0002
edema	1	6.6726	0.0098
bili	1	66.9252	<.0001

## Type 3 Tests

Effect	DF	Wald Statistics	
		Chi-Square	Pr > ChiSq
age	1	12.5547	0.0004
log_alb	1	28.9537	<.0001
log_pro	1	13.8481	0.0002
edema	1	6.5578	0.0104
bili	1	59.2310	<.0001

## Analysis of Maximum Likelihood Estimates

Parameter	DF	Parameter Estimate	Standard		Hazard Ratio	95% Hazard Ratio		
			Error	Chi-Square		Confidence Limits		
age	1	0.03287	0.00928	12.5547	0.0004	1.033	1.015	1.052
log_alb	1	-3.79843	0.70591	28.9537	<.0001	0.022	0.006	0.089
log_pro	1	3.37937	0.90811	13.8481	0.0002	29.352	4.951	174.031
edema	1	0.79174	0.30918	6.5578	0.0104	2.207	1.204	4.046
bili	1	0.11634	0.01512	59.2310	<.0001	1.123	1.091	1.157

### B.2.2.2 Logarithmic Transform

The PHREG Procedure

#### Model Information

Data Set	WORK.PBC
Dependent Variable	futime
Censoring Variable	cen
Censoring Value(s)	0
Ties Handling	BRESLOW

Number of Observations Read	312
Number of Observations Used	312

#### Summary of the Number of Event and Censored Values

Total	Event	Censored	Percent Censored
312	125	187	59.94

#### Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

#### Model Fit Statistics

Criterion	Without Covariates	With Covariates
-2 LOG L	1279.960	1080.825
AIC	1279.960	1090.825
SBC	1279.960	1104.966

#### Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	199.1349	5	<.0001
Score	269.3073	5	<.0001
Wald	198.2020	5	<.0001

#### Type 3 Tests

Effect	DF	LR Statistics	
		Chi-Square	Pr > ChiSq
age	1	14.2555	0.0002
log_alb	1	15.8896	<.0001
log_pro	1	7.8749	0.0050
edema	1	6.5176	0.0107
log_bil	1	79.0438	<.0001

## The PHREG Procedure

## Type 3 Tests

Effect	DF	Score Statistics	
		Chi-Square	Pr > ChiSq
age	1	14.9346	0.0001
log_alb	1	17.6316	<.0001
log_pro	1	8.5099	0.0035
edema	1	7.0129	0.0081
log_bil	1	84.5418	<.0001

## Type 3 Tests

Effect	DF	Wald Statistics	
		Chi-Square	Pr > ChiSq
age	1	14.7565	0.0001
log_alb	1	17.7818	<.0001
log_pro	1	8.6764	0.0032
edema	1	6.8814	0.0087
log_bil	1	79.2980	<.0001

## Analysis of Maximum Likelihood Estimates

Parameter	DF	Parameter Estimate	Standard Error		Chi-Square	Pr > ChiSq	Hazard Ratio	95% Hazard Ratio	
			Error	Chi-Square			Ratio	Confidence Limits	
age	1	0.03327	0.00866	14.7565	0.0001		1.034	1.016	1.052
log_alb	1	-3.05332	0.72408	17.7818	<.0001		0.047	0.011	0.195
log_pro	1	3.01567	1.02380	8.6764	0.0032		20.403	2.743	151.756
edema	1	0.78470	0.29913	6.8814	0.0087		2.192	1.219	3.939
log_bil	1	0.87921	0.09873	79.2980	<.0001		2.409	1.985	2.923

## B.3 SAS Plots

### B.3.1 Edema

#### B.3.1.1 Grouping

ZPH:

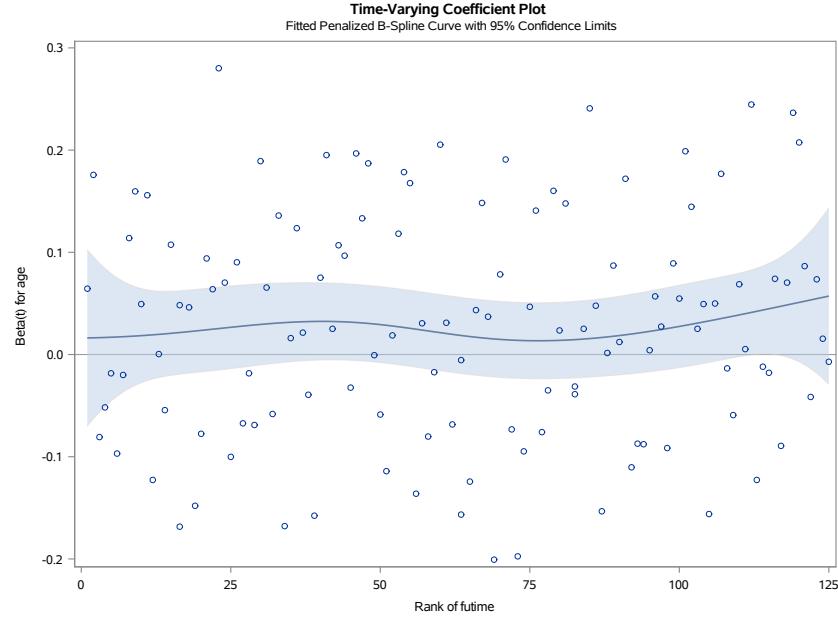


Figure B.1: ZPH – Edema – Grouping.

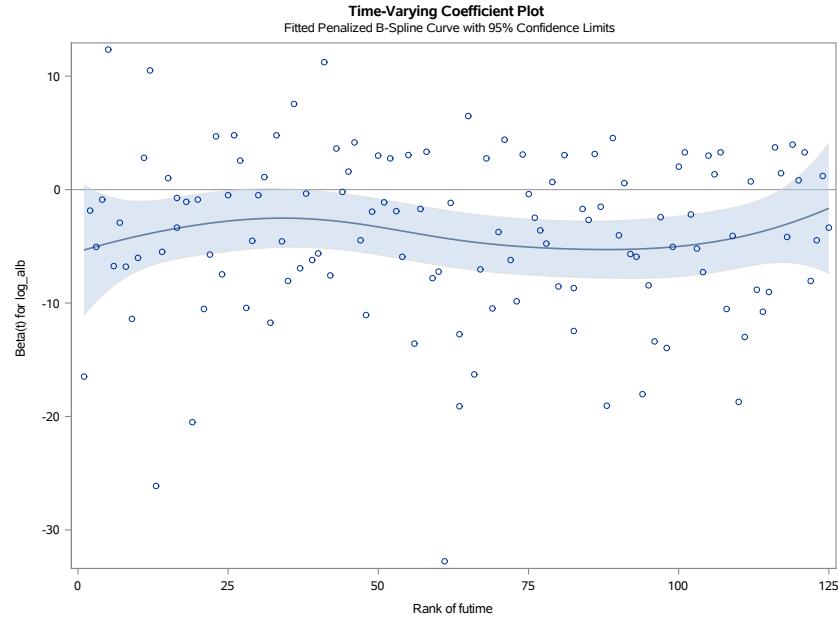


Figure B.2: ZPH – Edema – Grouping.

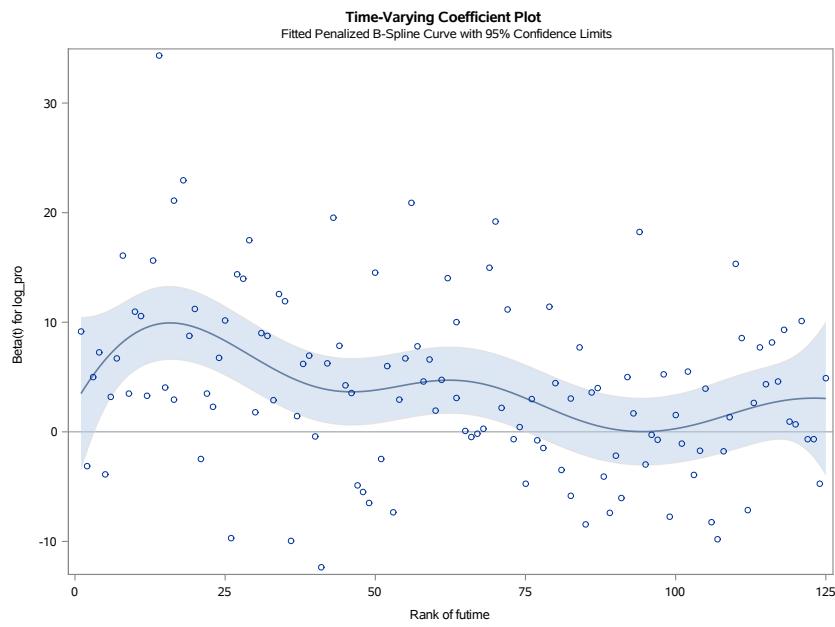


Figure B.3: ZPH – Edema – Grouping.

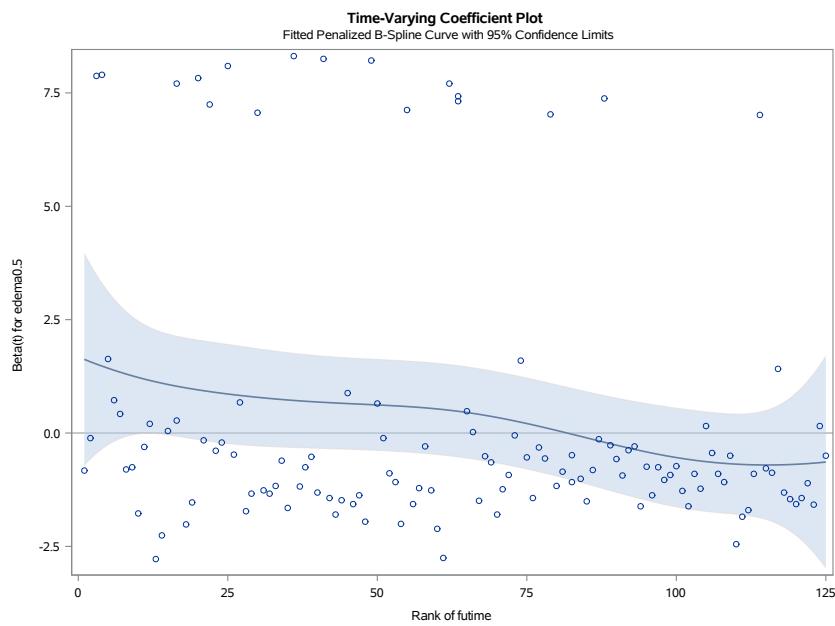


Figure B.4: ZPH – Edema – Grouping.

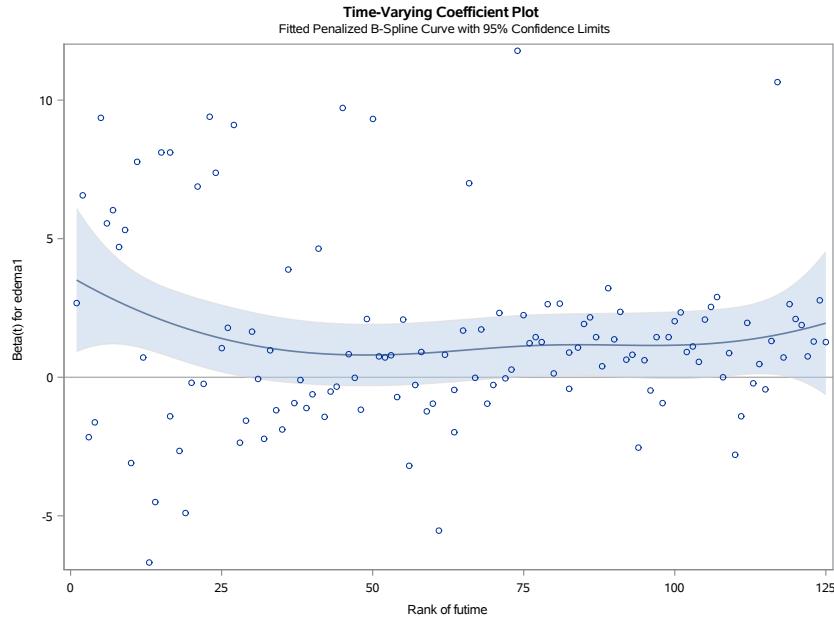


Figure B.5: ZPH – Edema – Grouping.

PH:

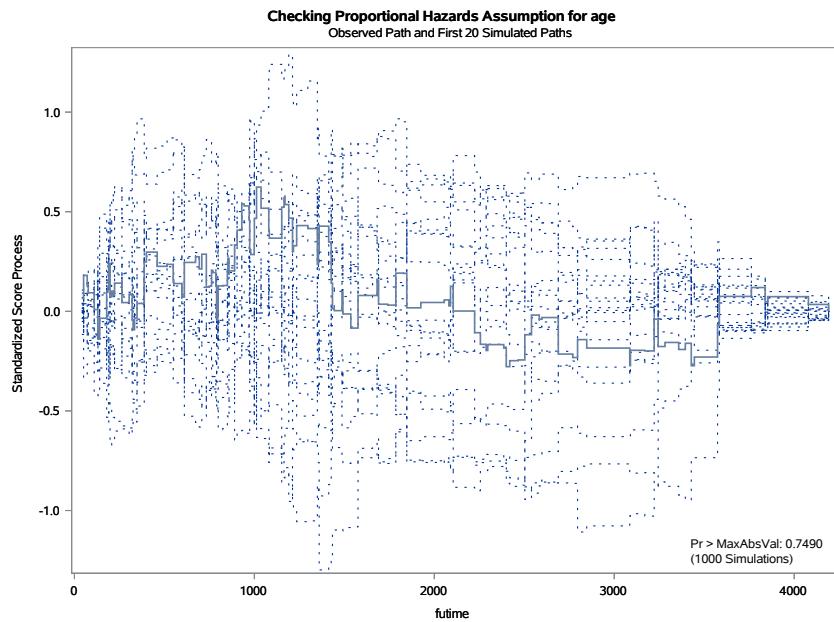


Figure B.6: ASSESS PH – Edema – Grouping.

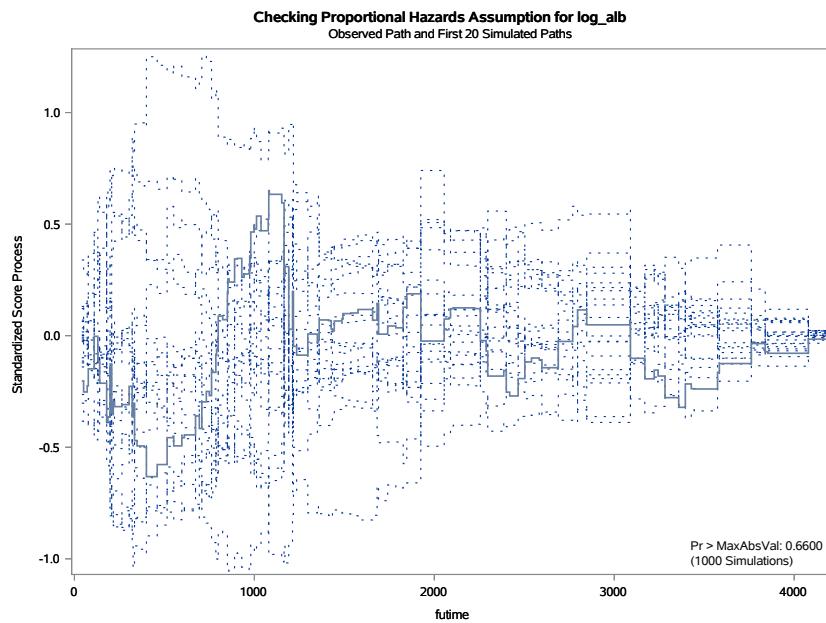


Figure B.7: ASSESS PH – Edema – Grouping.

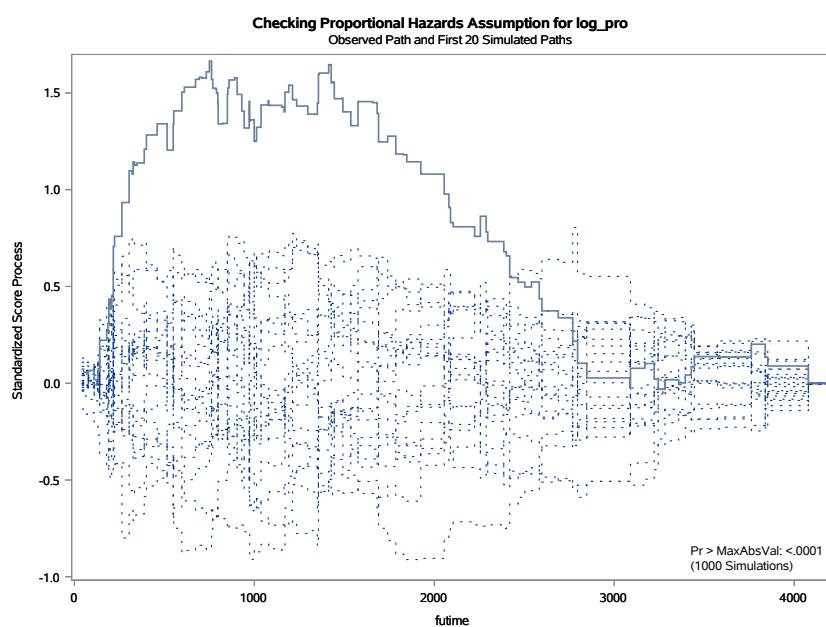


Figure B.8: ASSESS PH – Edema – Grouping.

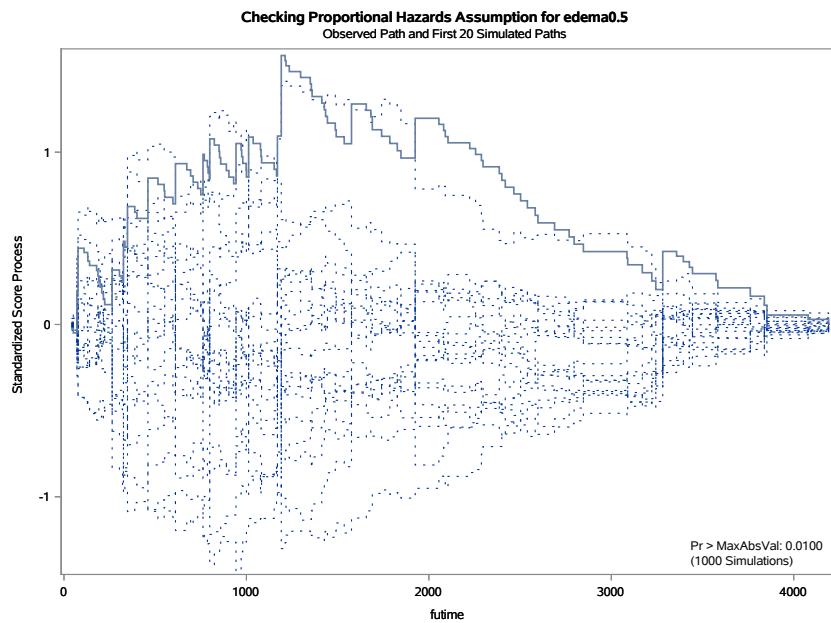


Figure B.9: ASSESS PH – Edema – Grouping.

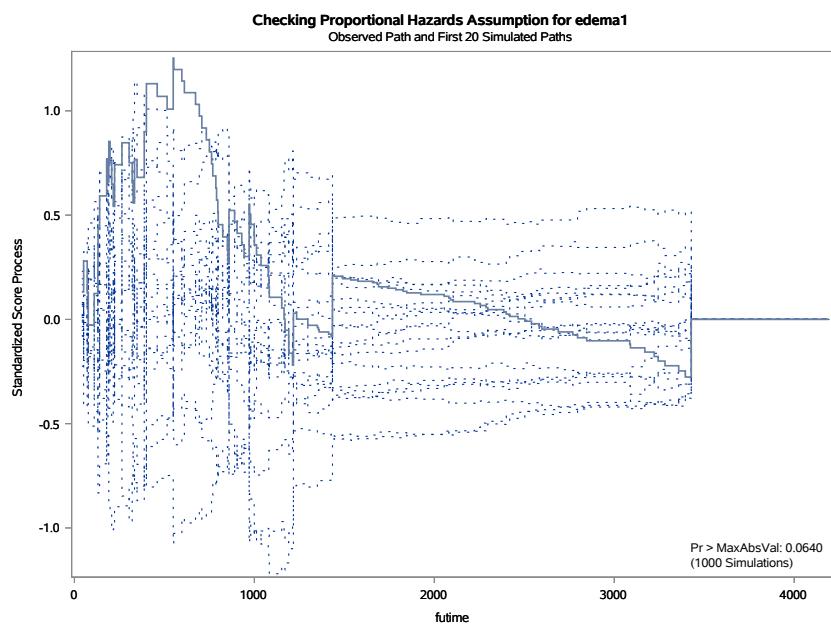


Figure B.10: ASSESS PH – Edema – Grouping.

SURV:

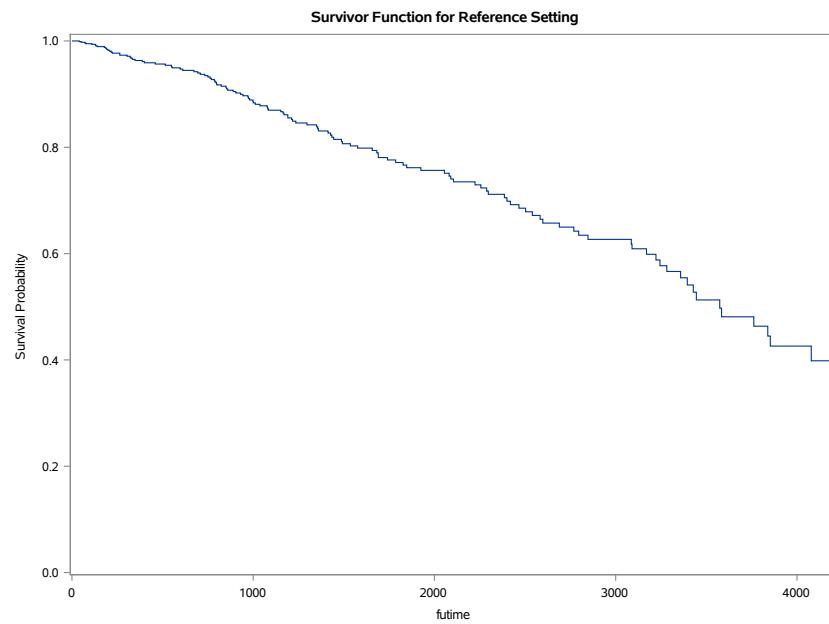


Figure B.11: Survival Plot – Edema – Grouping.

RESDEV:

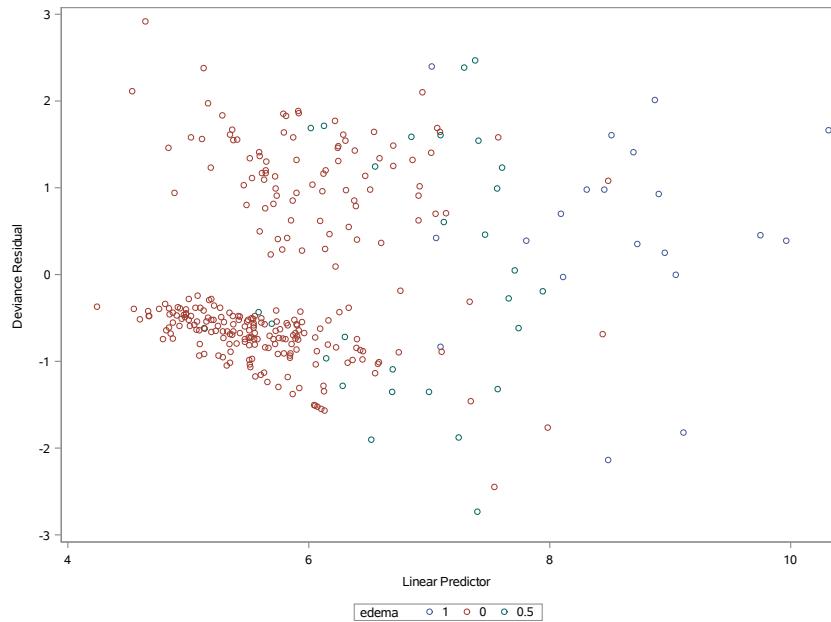


Figure B.12: RESDEV – Edema – Grouping.

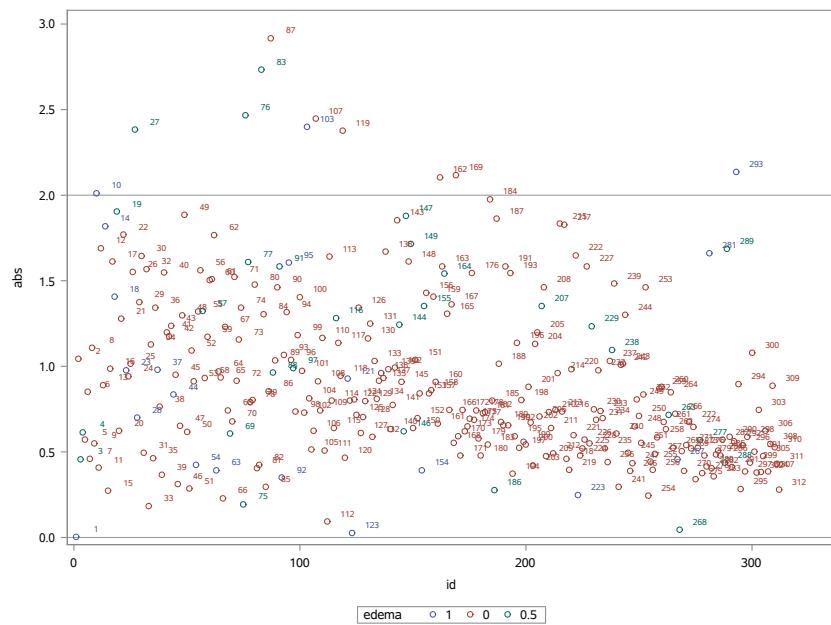


Figure B.13: RESDEV – OBSERVATIONS – Edema – Grouping.

DFBETA:

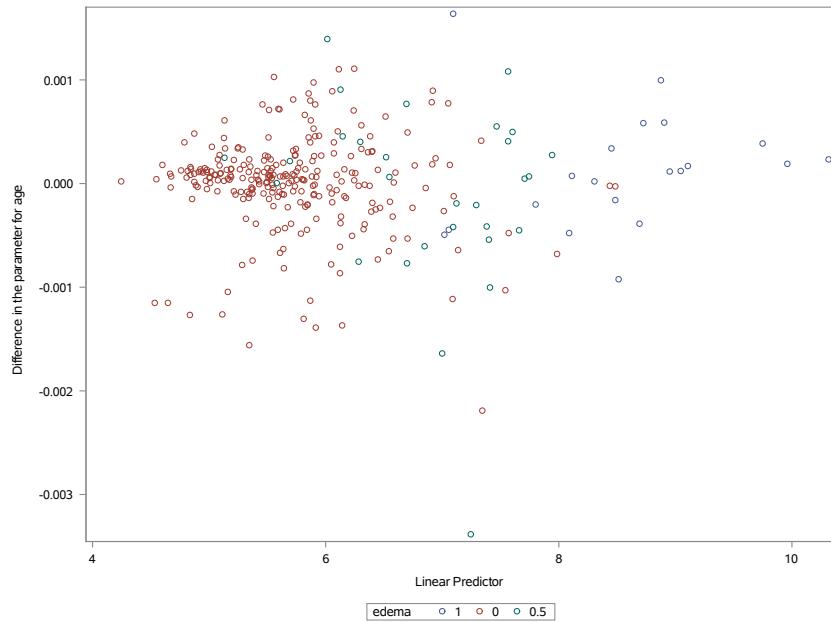


Figure B.14: DFBETA – Edema – Grouping.

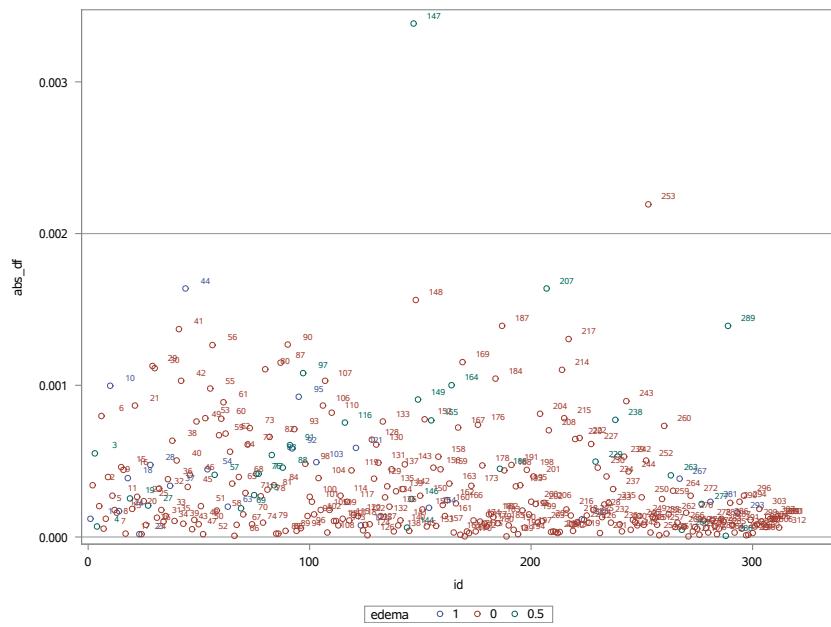


Figure B.15: DFBETA – OBSERVATIONS – Edema – Grouping.

### B.3.2 Bilirubin

#### B.3.2.1 Linearly

VAR:

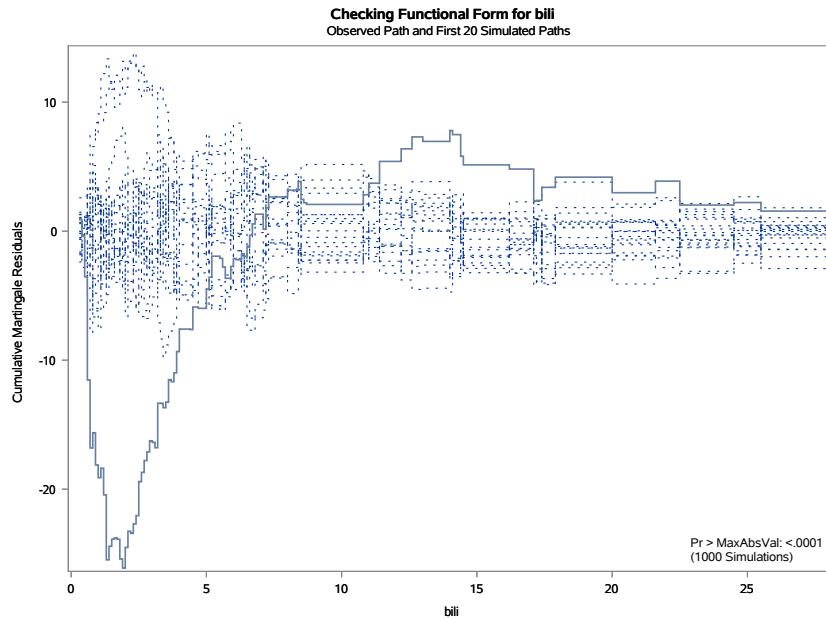


Figure B.16: Functional Form – Bilirubin – Linear.

ZPH:

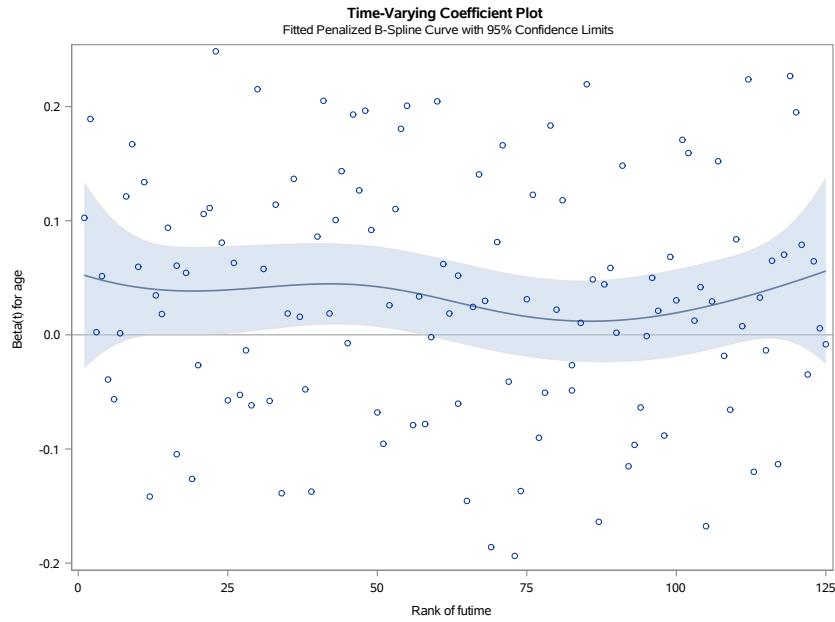


Figure B.17: ZPH – Bilirubin – Linear.

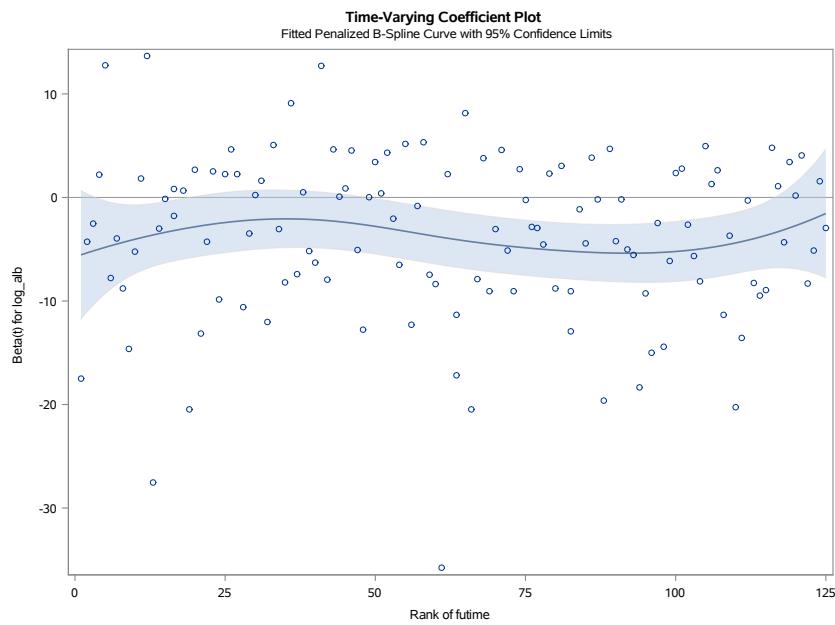


Figure B.18: ZPH – Bilirubin – Linear.

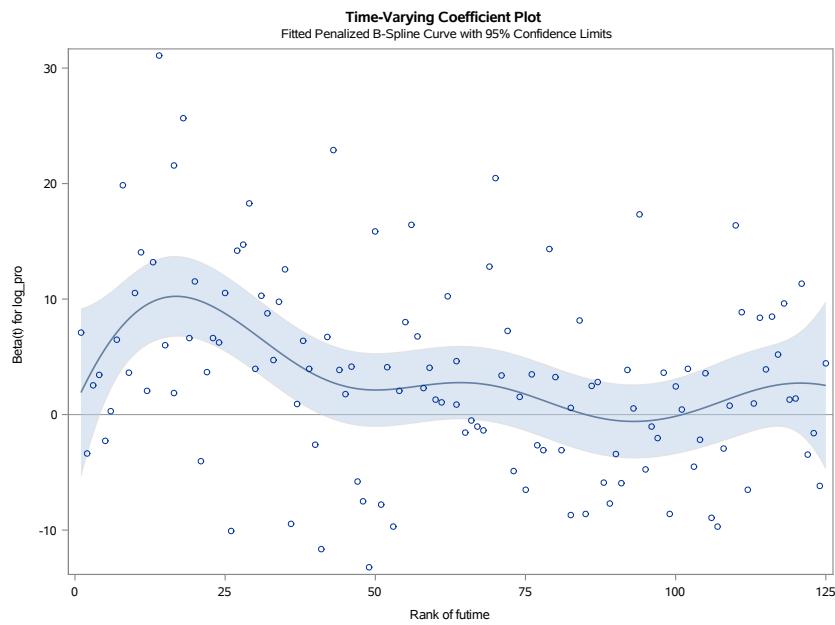


Figure B.19: ZPH – Bilirubin – Linear.

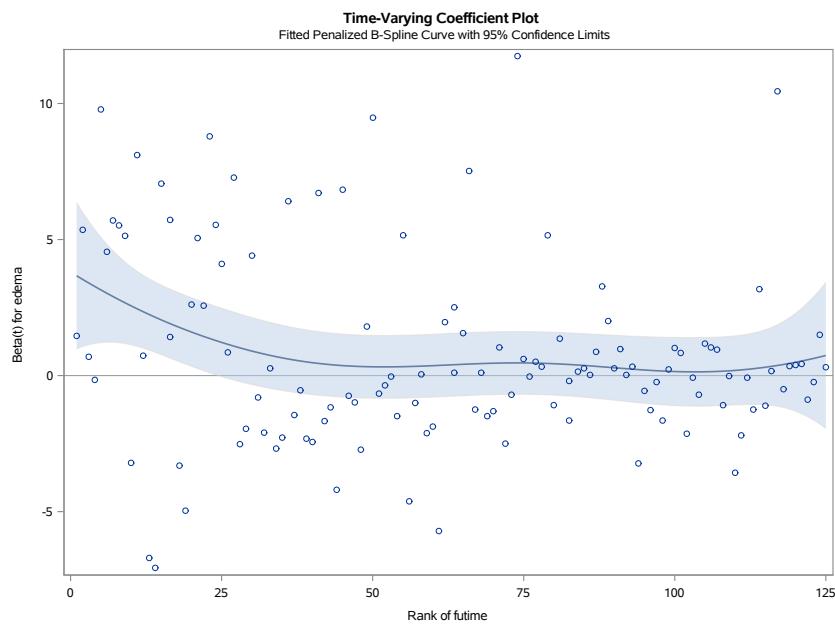


Figure B.20: ZPH – Bilirubin – Linear.

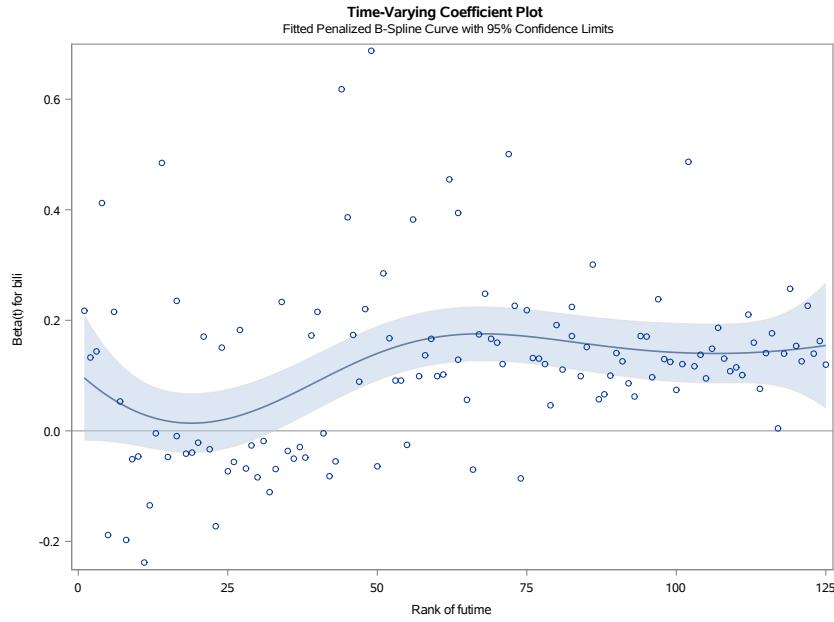


Figure B.21: ZPH – Bilirubin – Linear.

PH:

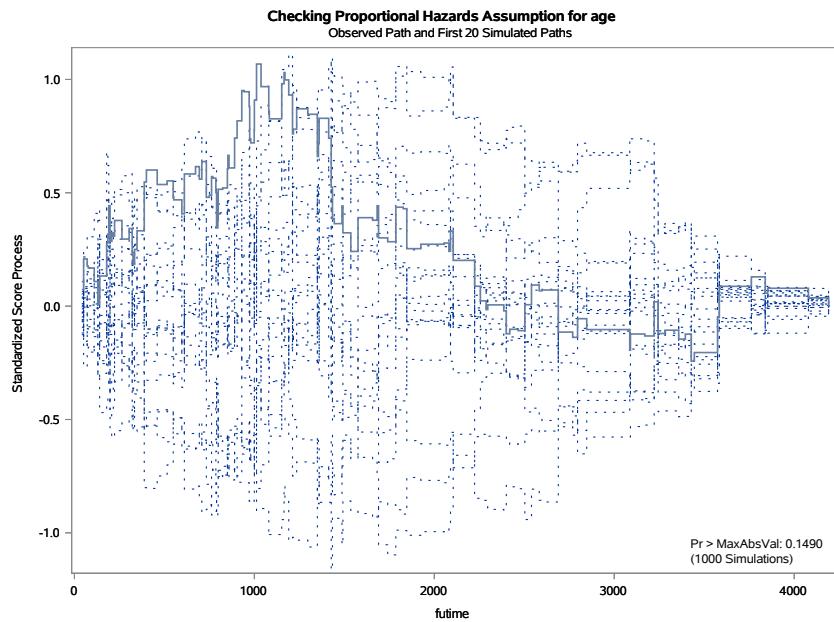


Figure B.22: ZPH – Bilirubin – Linear.

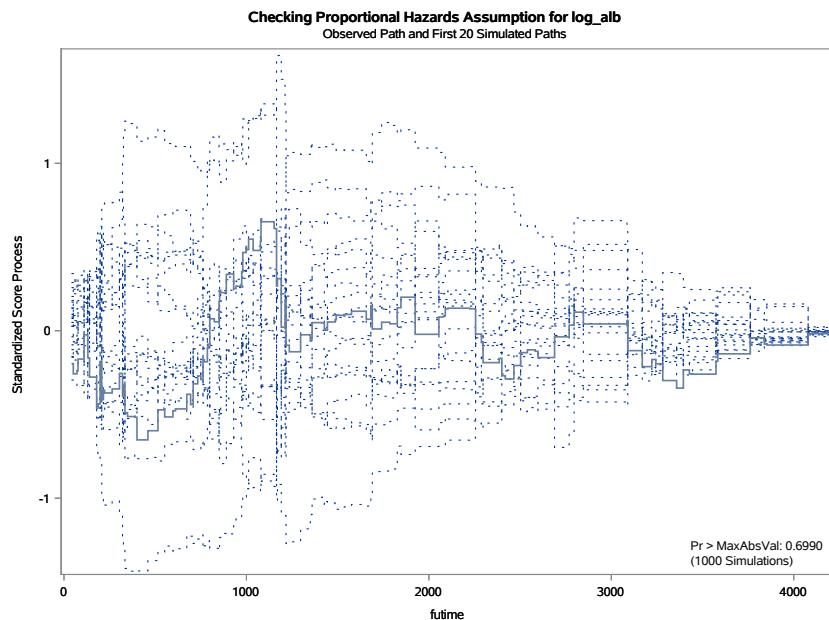


Figure B.23: ASSESS PH – Bilirubin – Linear.

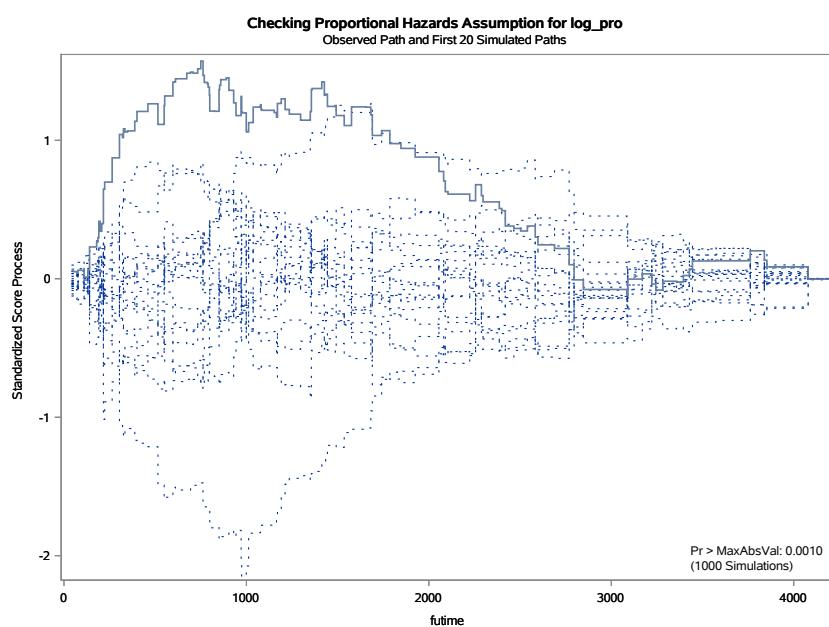


Figure B.24: ASSESS PH – Bilirubin – Linear.

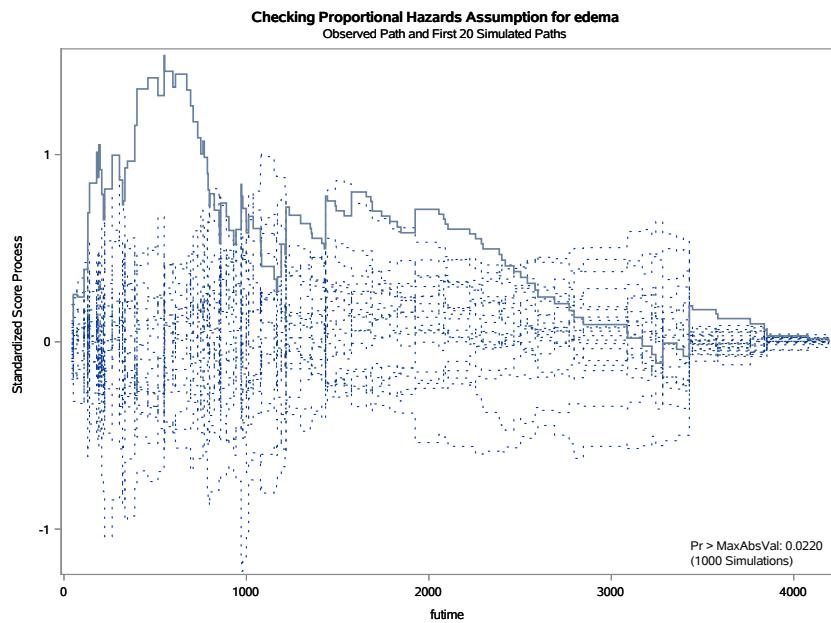


Figure B.25: ASSESS PH – Bilirubin – Linear.

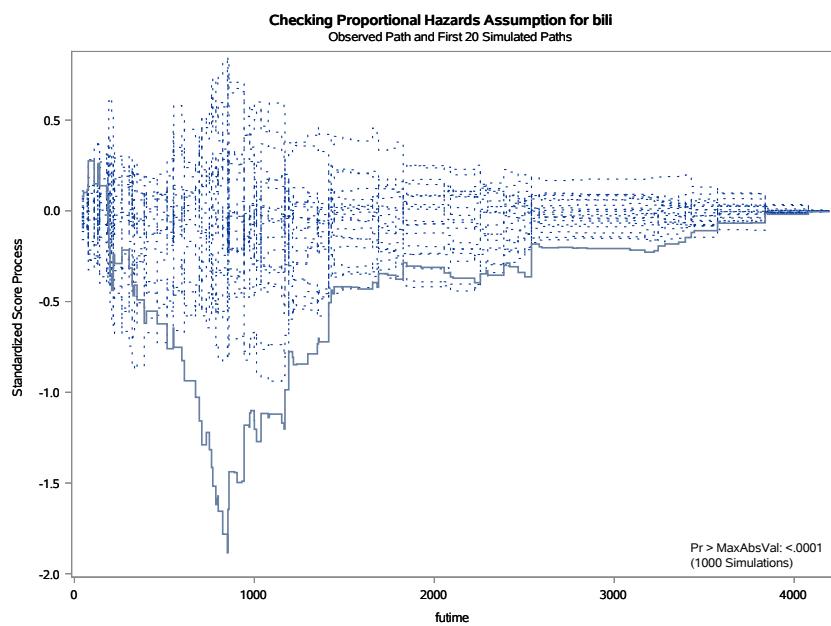


Figure B.26: ASSESS PH – Bilirubin – Linear.

RESDEV:

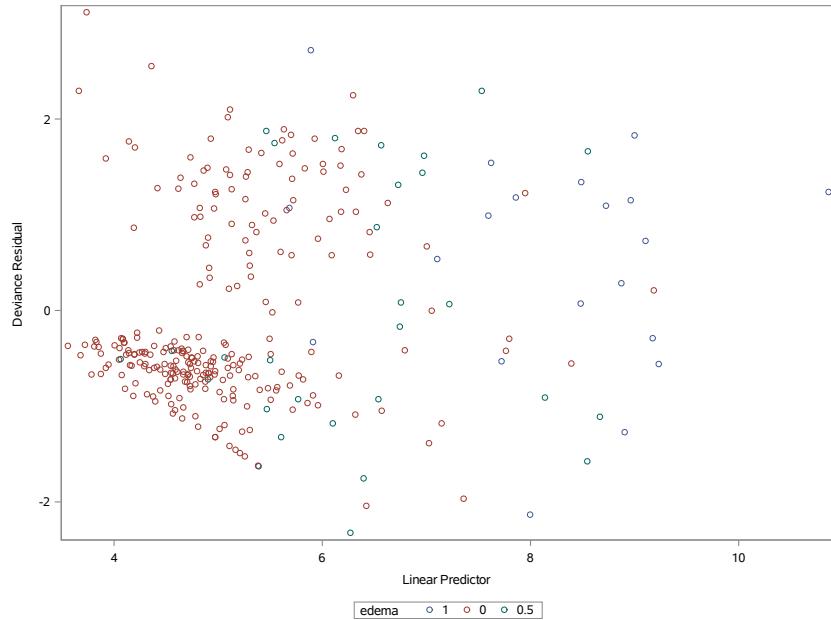


Figure B.27: RESDEV – Bilirubin – Linear.



Figure B.28: RESDEV – OBSERVATIONS – Bilirubin – Linear.

DFBETA:

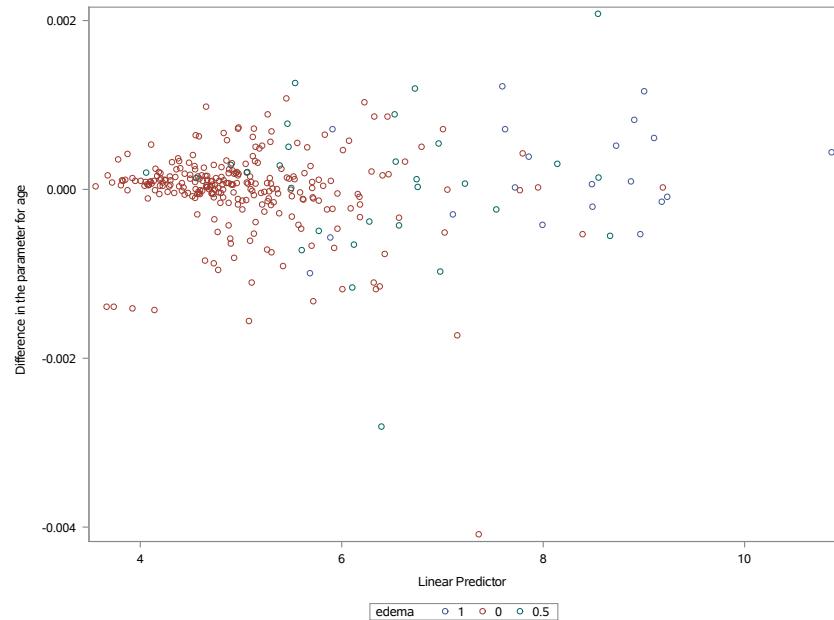


Figure B.29: DFBETA – Bilirubin – Linear.

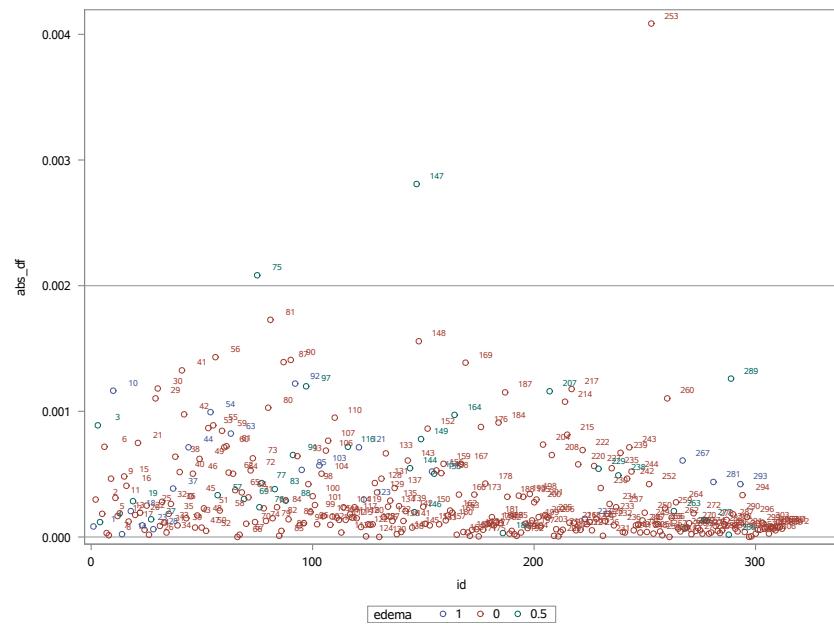


Figure B.30: DFBETA – OBSERVATIONS – Bilirubin – Linear.

MART:

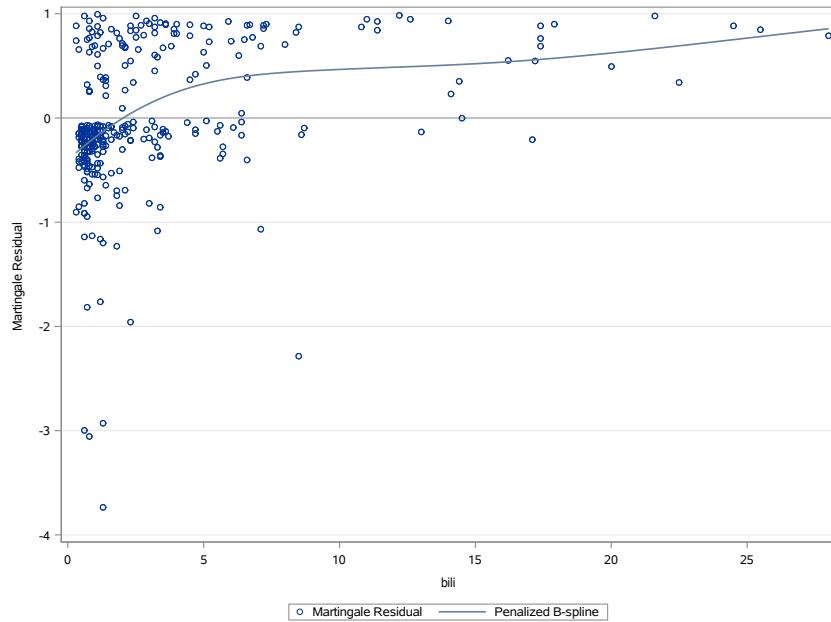


Figure B.31: MARTINGALE RESIDUALS – Bilirubin – Linear.

SURV:

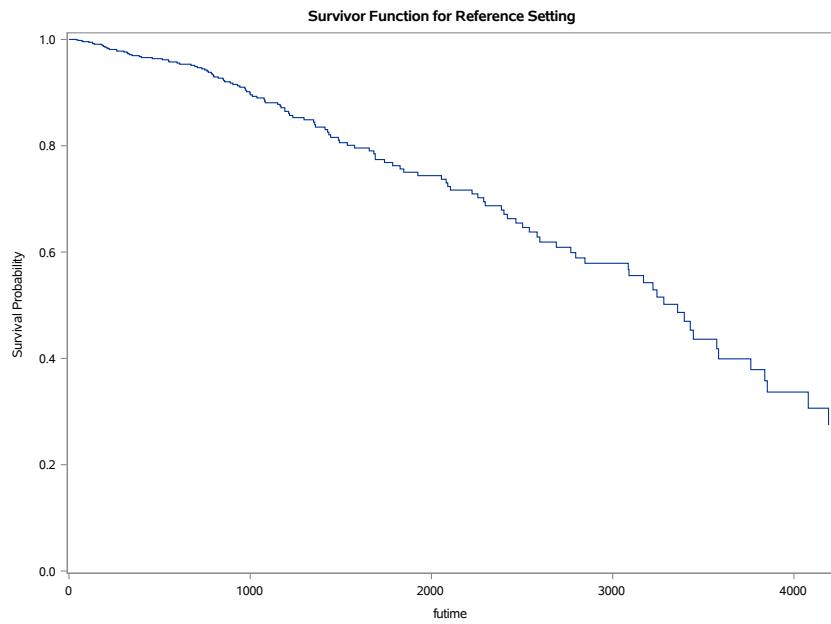


Figure B.32: Survival Plot – Bilirubin – Linear.

### B.3.2.2 Logarithmic Transform

VAR:

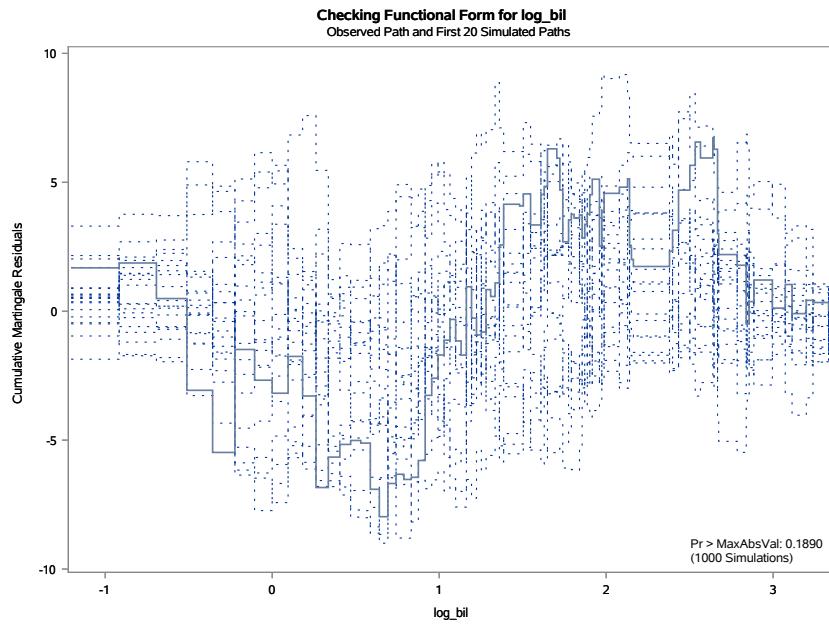


Figure B.33: Functional Form – Bilirubin – Log.

ZPH:

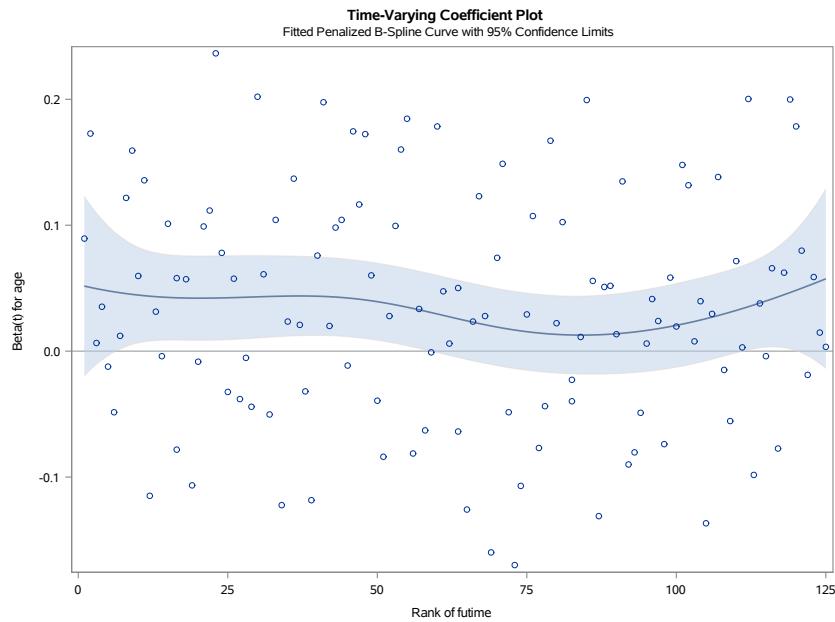


Figure B.34: ZPH – Bilirubin – Log.

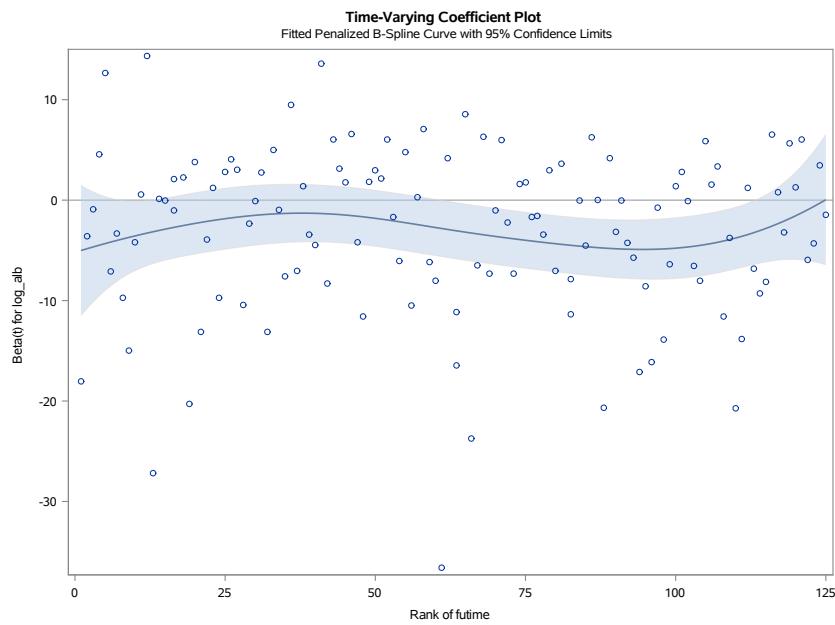


Figure B.35: ZPH – Bilirubin – Log.

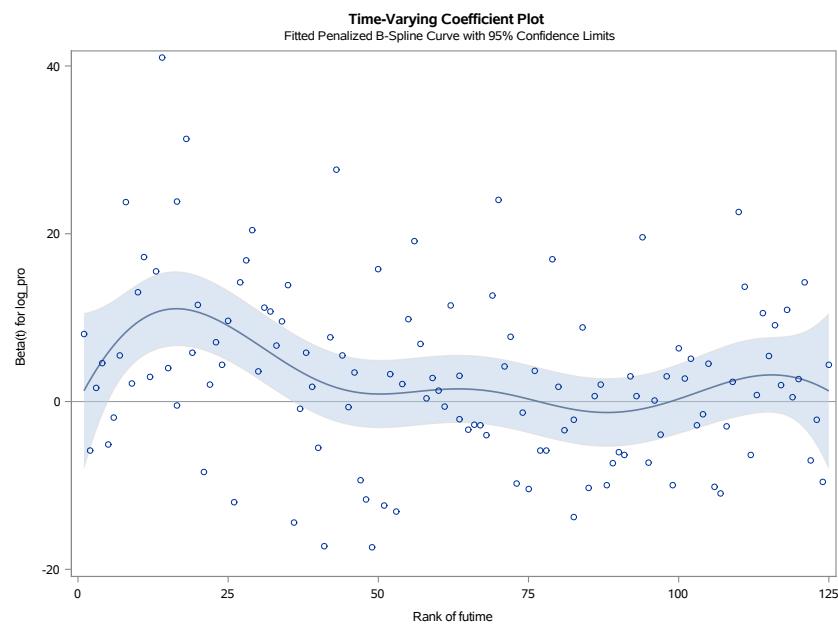


Figure B.36: ZPH – Bilirubin – Log.

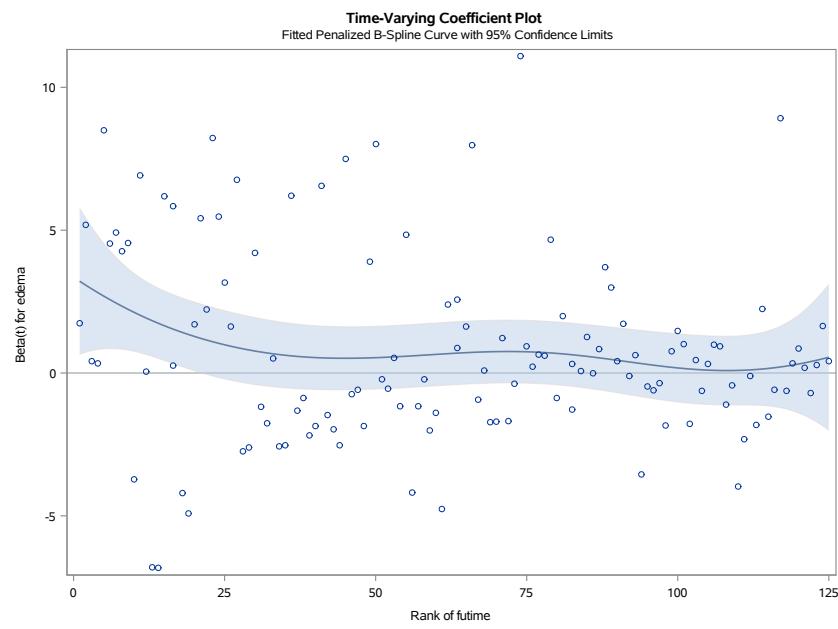


Figure B.37: ZPH – Bilirubin – Log.

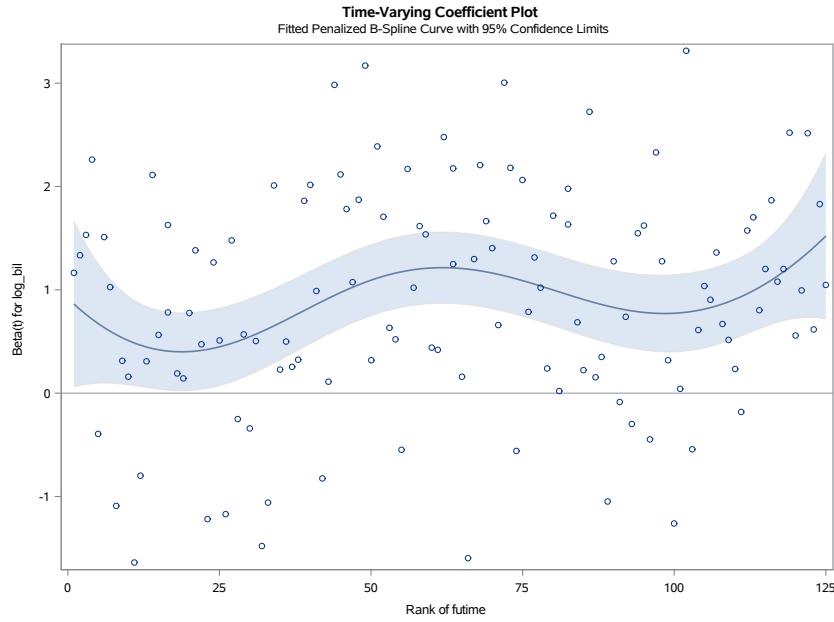


Figure B.38: ZPH – Bilirubin – Log.

PH:

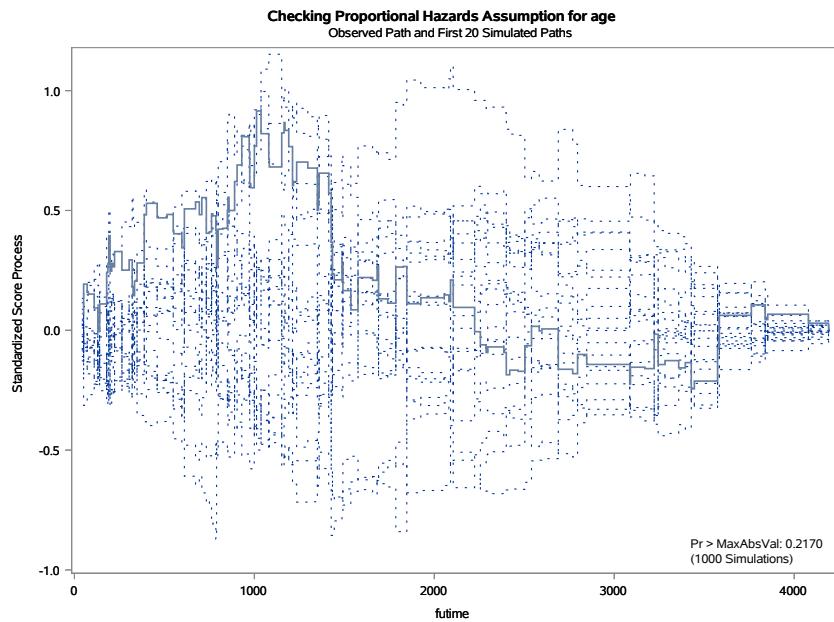


Figure B.39: ASSESS PH – Bilirubin – Log.

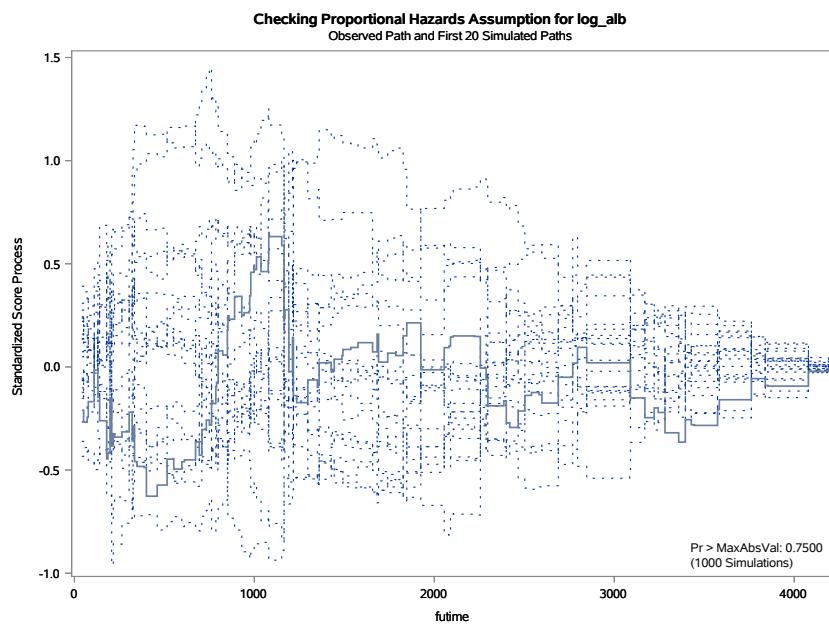


Figure B.40: ASSESS PH – Bilirubin – Log.

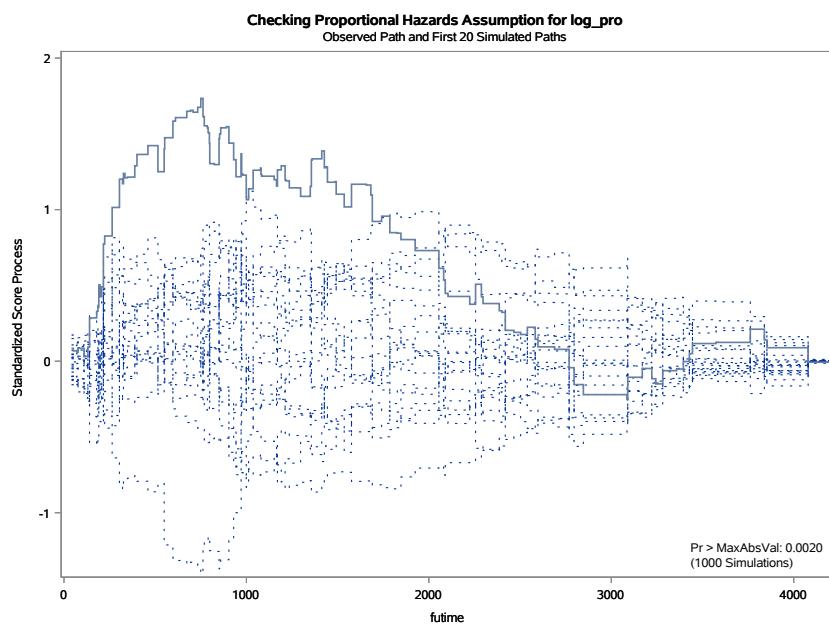


Figure B.41: ASSESS PH – Bilirubin – Log.

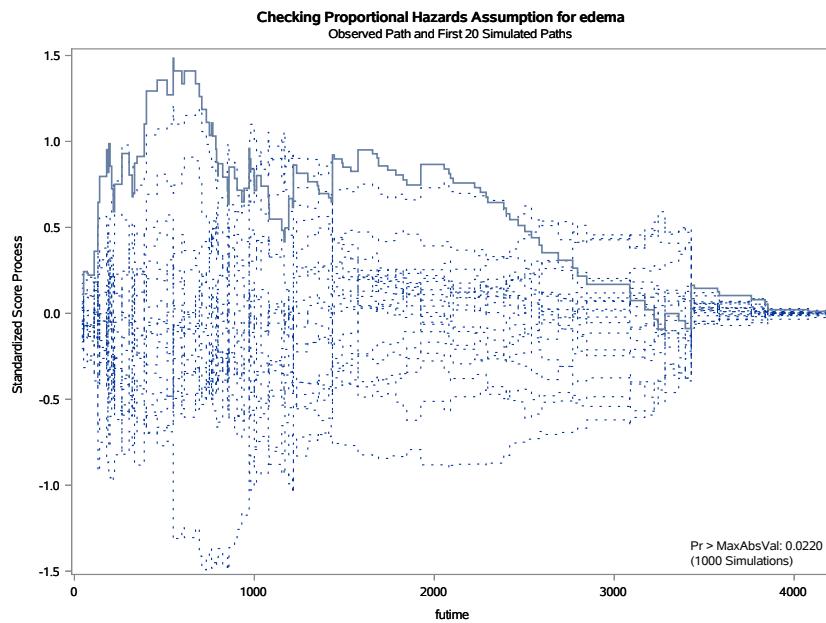


Figure B.42: ASSESS PH – Bilirubin – Log.

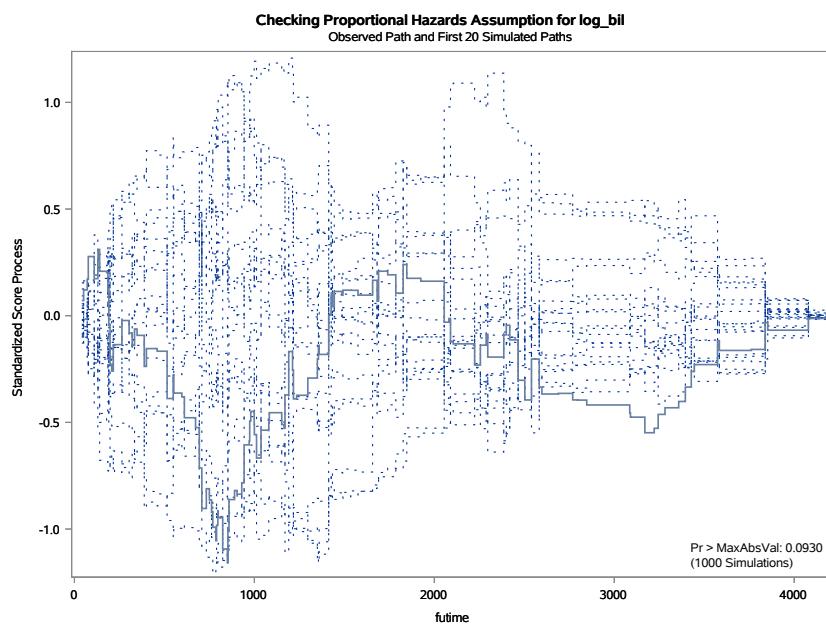


Figure B.43: ASSESS PH – Bilirubin – Log.

RESDEV:

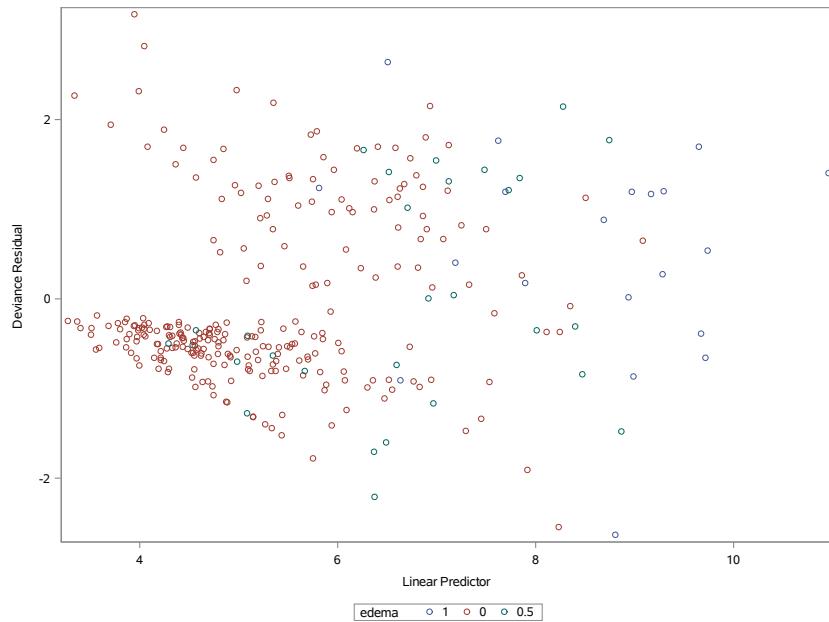


Figure B.44: DFBETA – Bilirubin – Log.

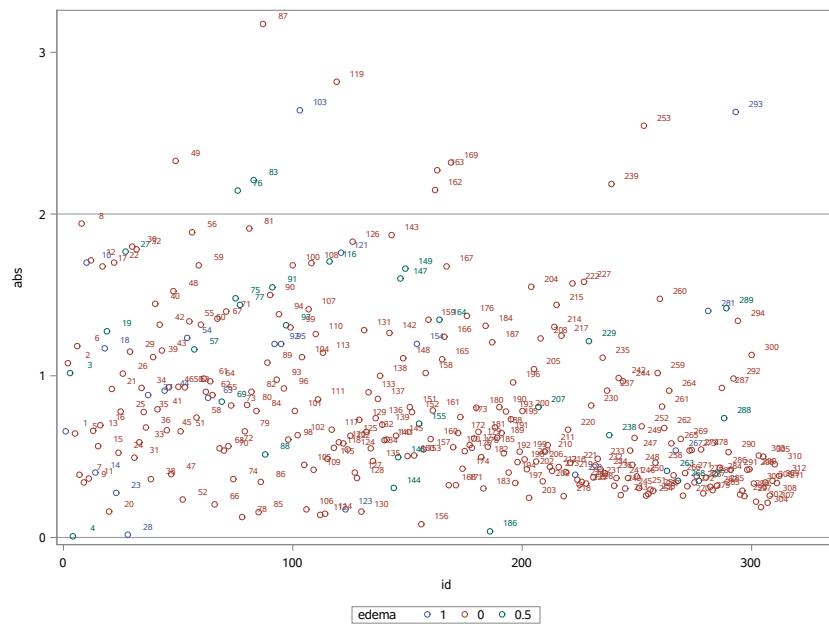


Figure B.45: DFBETA – OBSERVATIONS – Bilirubin – Log.

DFBETA:

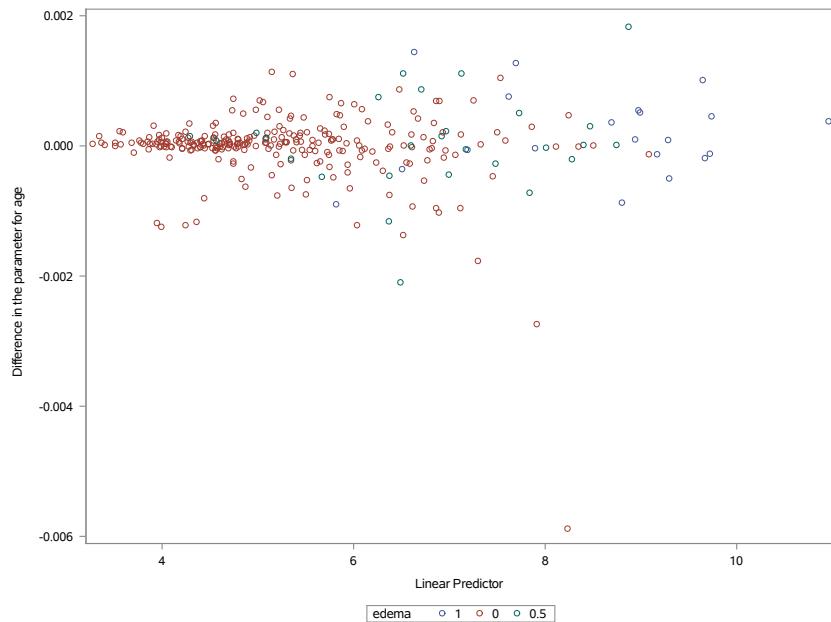


Figure B.46: DFBETA – Bilirubin – Log.

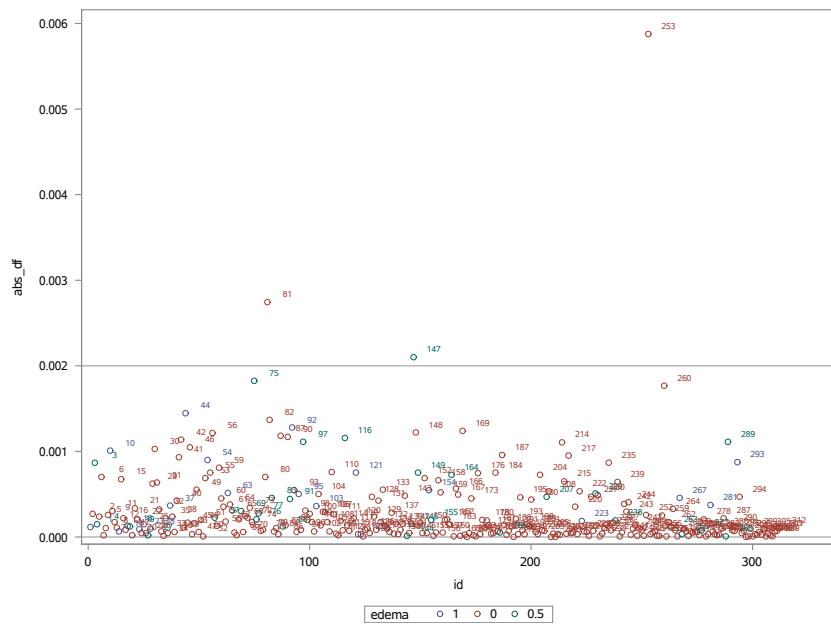


Figure B.47: DFBETA – OBSERVATIONS – Bilirubin – Log.

MART:

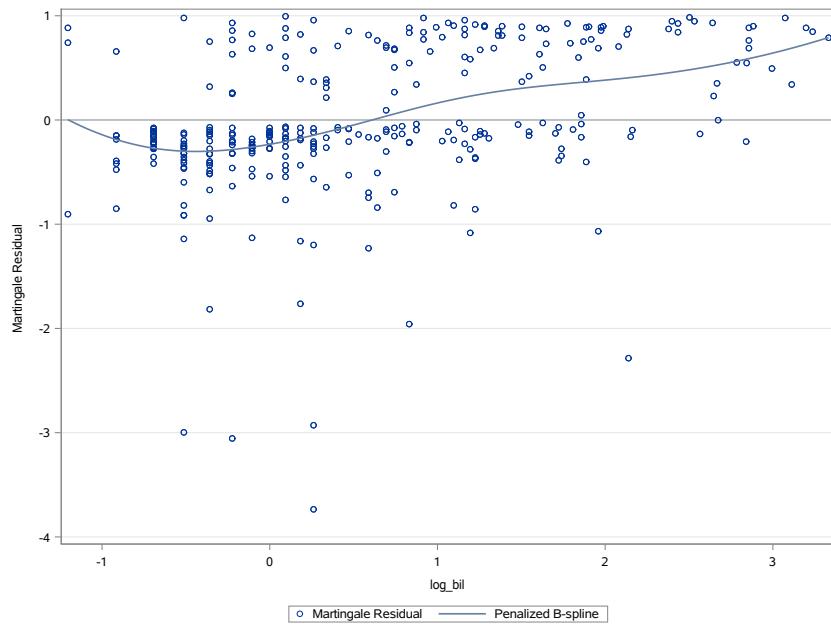


Figure B.48: MARTINGALE RESIDUALS – Bilirubin – Log.

SURV:

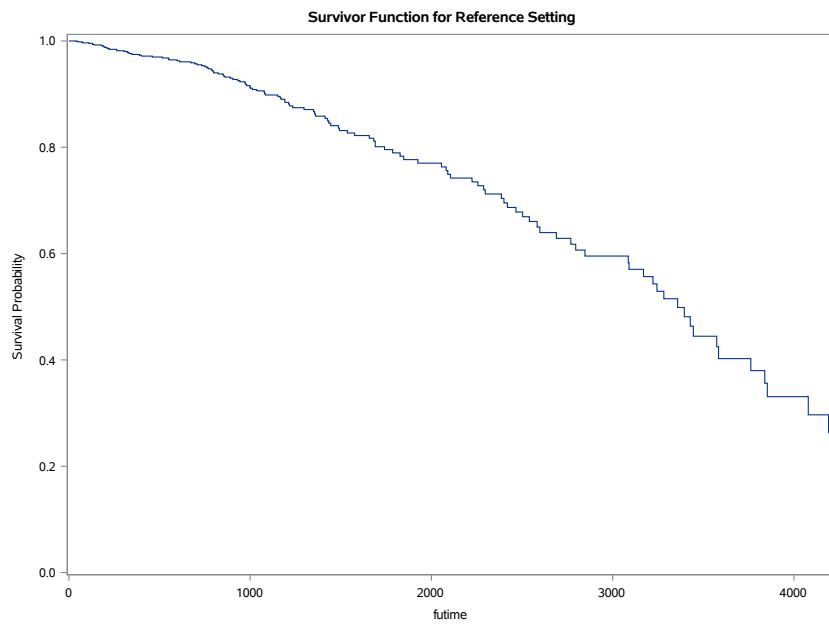


Figure B.49: Survival Plot – Bilirubin – Log.

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