Model Building for the Cox Proportional Hazards Model with the SAS® System

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ABSTRACT

To fit a Cox proportional hazards model, the SAS procedure proc phreg can be used. For variable selection, the 'forward', 'backward' or 'stepwise' options are available. These are useful if the explanatory variables are dichotomous. However, factors with $n>2$ main effects cannot be readily included. In a data step, indicator variables have to be created for each factor. The automatic selection options should not be used if such factors need to be included in the model. A 'manual' model selection involves comparing the values of the -2 Log Likelihood statistics of many nested models on multiple outputs. It is, however, more efficient to use macros which provide the relevant information in a condensed way. Macros facilitating model selection for the Cox proportional hazard model using the -2 Log Likelihood statistic will be presented. In particular, these macros could be used where multi-level variables are involved. The use of these macros will be illustrated by the application on a set of patients with colorectal cancer and liver metastases.

1. Introduction

The Cox proportional hazards model\(^1\) is widely used in medical and pharmaceutical research to evaluate survival or 'time-to-event' data. The model assumes that the hazard function $\lambda_i(t;x)$ for an individual $i$ with covariate vector $x$ can be written as

$$\lambda_i(t;x) = \lambda_0(t) \exp(\beta_1 x_1 + \ldots + \beta_n x_n)$$

Here, $\lambda_0(t)$ is the 'baseline hazard', and $\beta_1 \ldots \beta_n$ are unknown regression coefficients. To fit a Cox proportional hazards model, PROC PHREG in SAS/STAT® may be used.

2. Variable Selection

Several methods for model building have been described in literature\(^2-4\). In PROC PHREG, the options 'backward', 'forward', 'stepwise' and 'score' are provided for model building. Unfortunately, multi-level factors cannot be fit directly by PROC PHREG. In a data-step, indicator variables need to be created first. The most common method of coding an indicator variable is the method using a reference level, but other methods are also possible\(^5\).

If multi-level factors are to be considered in the model, the selection options as specified in PROC PHREG can not be used. They may pick one of the indicator variables for the model, but leave out some other indicator variables specified for the same factor. Instead, the -2 Log Likelihood statistic may be used for variable selection. Collett\(^6\) suggests the following strategy:

1. The first step is to fit models that contain each of the variables one at a time. The values of -2 Log Likelihood for these models are then compared with that for the null model to determine which variables on their own significantly reduce the value of this statistic.
2. The variables which appear to be important from Step 1 are then fitted together. Only those whose exclusion from the model lead to a significant increase in the value of -2 Log Likelihood are retained in the model.
3. Any variable that was not under consideration in Step 2 is now added to the model, one at a time. Any variable that significantly reduces the value of -2 Log Likelihood is retained in the model.
4. A final check is made to ensure that no term in the model can be omitted without significantly increasing the value of -2 Log Likelihood, and that no term not included significantly reduces the value of -2 Log Likelihood.
The value of the -2 Log Likelihood statistic is provided on the standard PROC PHREG output. Whereas it is quite easy to determine the decrease in -2 Log Likelihood in Step 1 (it requires a PROC PHREG for each of the variables under consideration), the application of the next steps is more tedious. Moreover, output on multiple pages needs to be compared.

3. Macros

Three macros to facilitate model building using the -2 Log Likelihood statistic were written:
1) %COXUNI, to provide multiple univariate analyses.
2) %COXMULT, to provide with the effect of removing variables from a specified model.
3) %COXADD, to provide with the effect of adding variables to a specified model.

These three macros facilitate Step 1, 2 and 3 as described previously. A detailed description of the macros %COXUNI and %COXMULT can be found in appendix A and B. The macro %COXADD was not displayed; it resembles the macro %COXUNI. In %COXADD, a base model can be specified. Furthermore, the Wald statistics and the estimates are not contained in the output dataset. Basically, the macros are set up as follows:
- Determine number of variables
- Calculate -2 Log Likelihood for the basic model
- Calculate -2 Log Likelihood for the model including/excluding variable for each variable
- If appropriate, calculate estimates and variances of the estimates in the relevant model in the two previous steps using COVOUT as an option in the PHREG procedure
- Calculate the differences in -2 Log Likelihood, determine degrees of freedom of the chi-square distribution and calculate p-value
- Calculate Wald-Statistics, p-values, risk-ratios and confidence intervals

4. Example

From the ‘UICC TNM Field Study Liver Metastasis’ (unpublished), 622 patients with colorectal cancer and liver metastases were extracted. They were observed between 0 and 48.23 months; for 259 patients (42%) the time to death was censored. The median survival time was 21.87 months.

For eleven covariates of interest (see below), indicator variables were calculated in a data step before the analyses. The reference levels were indicated below by the italic levels of the factors. As this analysis is for illustratory purposes only, interactions were not considered.
- Primary tumor: \textit{rectum}, colon
- Age: ≤53 years, 54-60 years, 61-67 years, > 67 years
- Therapy: none, regional chemotherapy, other
- Number of Lobes invaded: 1, 2
- Sex: males, females
- Number of LM: 1, 2-5, 5-25, > 25
- Diameter: ≤2 cm, 3-4 cm, 5-6 cm, > 6 cm
- Diagnosis: metachronous, synchronous
- Locoregional tumor: no, yes
- TNM of primary tumor: local, regional, distant
- Recetion: none, R0, R12
In a first step, the effect of fitting each of the variables alone was calculated. The SAS code (using the macro %COXUNI) was as follows:

```sas
%coxuni(data=typeltnm, by=type, time=survtime, censor=censor(0),
  var=<primtum> <a 2 a 3 a 4> <th 1 th 2> <lob2> <s 1>
  <lm 1 lm 2 lm 3> <dia2 dia3 dia4> <a 2 a 3 a 4>
  <tnm tnm2> <res0 res1>,
  out=coxuni);
```

Table 1.1: Using %COXUNI.

By using the option 'nonotes' before the macro call, the relevant information about the models used by %COXUNI is easily located in the LOG-window:

The following sets of variables were analysed

**MODEL COVARIATES**

1 primtum
2 a 2 a 3 a 4
3 th 1 th 2
4 lob2
5 s 1
6 lm 1 lm 2 lm 3
7 loc1
8 tnm tnm2
9 res0 res1

Table 1.2: Excerpt from LOG-window.

The value of -2 LLR, the p-value of the Likelihood Ratio (refer to Table 1.3 below), indicated that the covariates Primary Tumor (model 1) and Sex (model 5) do not relevantly decrease the value of the -2 Log Likelihood statistic.

Table 1.3: Excerpt from output dataset of %COXUNI.

Thus, a model was fitted using all covariates except the two factors mentioned above. The effect of removing each of the variables from the model was evaluated using %COXMULT. The syntax is given in Table 2 below.

```sas
%cpxmult(data=typeltnm, by=type, time=survtime, censor=censor(0),
  var=<a 2 a 3 a 4> <th 1 th 2> <lob2> <lm 1 lm 2 lm 3>
  <dia2 dia3 dia4> <a 2 a 3 a 4> <loc1> <tnm tnm2> <res0 res1>,
  out=coxmult);
```

Table 2: Using %COXMULT

Removal of the factor Locoregional Tumor did not significantly change the value of the -2 Log Likelihood statistic. Thus, this factor was removed, and a new model using the remaining
factors was fitted. None of the remaining covariates could be removed from the model without significantly increasing the -2 Log Likelihood statistic.

As a last step, it was checked whether adding one of the variables left out of the model would significantly decrease the -2 Log Likelihood of the model. To do so, %COXADD was used:

```sas
%coxadd(data=type1tnm, by=type, time=survtime, censor=censor(0),
  base=a_2 a_3 a_4 th_1 th_2 lob2 lm_1 lm_2 lm_3 dia2 dia3 dia4
  art1 tmnl tnml2 res0 res1,
  var=<s_1> <loc1> <primtum>,
  out=coxadd1);
```

Table 3.1: Using %COXADD

It was found (table 3.2, below) that none of the covariates significantly decreased the -2 Log Likelihood Statistic. The final model (without interactions) thus contains all variables, except sex, locoregional tumor and primary tumor.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>TYPE</th>
<th>LNBASE</th>
<th>LNLIKE</th>
<th>DF</th>
<th>LIKERAT</th>
<th>P_LLRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>3954.31</td>
<td>3952.11</td>
<td>1</td>
<td>2.20286</td>
<td>0.13776</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>3954.31</td>
<td>3953.79</td>
<td>1</td>
<td>0.51873</td>
<td>0.47224</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3954.31</td>
<td>3953.81</td>
<td>1</td>
<td>0.50518</td>
<td>0.47723</td>
</tr>
</tbody>
</table>

Table 3.2: Output dataset of %COXADD

5. Final Remarks

These macros may be a convenient tool for the building of a Cox' proportional hazards model. As it uses PROC PHREG, it may also be used to build logistic models. The macros are easily adapted to use the Akaike's information criterion, e.g. by substracting a multitude of the degrees of freedom from the Likelihood ratio before calculating the p-value.

The three macros may be obtained by sending a diskette to the following address:
Richard Vonk, Parexel GmbH, Europa-Center, Eingang Breitscheidplatz, 10789 Berlin, Germany

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References:

Note: SAS and SAS/STAT are registered trademark of SAS Institute, Cary, NC, USA
Appendix A: %COXUNI

%macro coxuni(data=, time=, censor=, var=, strata=, by=, out=coxuni, alpha=0.05);

/*
SAS MACRO TO PROVIDE WITH MULTIPLE UNIVARIATE COX PH REGRESSION ANALYSES:
EFFECT OF FITTING THE VARIABLES ALONE
AUTHOR: R. Vonk
DATE OF THIS VERSION: 05.05.95
*/

* GENERAL RULES:
- This macro performs multiple univariate PH regression analyses on the variables mentioned in 'var', sorted by the 'by' variables, and stratified by 'strata'. Confidence intervals for the risk-ratio (calculated using the normal distribution) have length 100*(1-alpha)%. No time-dependent variables can be included.

* INPUT PARAMETERS:
- DATA dataset to be analysed, including parameters for 'VAR', 'BY', 'STRATA' and 'TIME' and 'CENSOR'
- BY by-variables
- STRATA stratification variables
- VAR variables in order of analysis. Variable to be included into one analysis should be surrounded by brackets, e.g., var=<sex> [age1 age2]
  Note: only <, [ and > or ] can be used!
- TIME time to event (see PHREG procedure)
- CENSOR censoring variable (see PHREG procedure)
- ALPHA length of confidence interval will be 100*(1-alpha) (default=0.05)
- OUT name of output dataset containing analysis results (default=coxuni).

* IN_BUFFER_ THE LAST DATASET WILL BE PRESERVED

** data BUFFER;
  set _LAST_;
run;

* IN_MACDAT_ THE DATASET TO BE ANALYSED WILL BE KEPT

** data macdat;
set &data;
  _rvl_ = 0; ** DUMMY VARIABLE;
run;

proc sort; by _rvl_ &by; run;

* FIND LOG-LIKELIHOOD OF MODEL WITHOUT COVARIATES

** data estim0; delete; run;
proc phreg outest= estim0 data= macdat noprint;
model &time
  %IF %LENGTH(&censor) > 0 %THEN &censor = rvl;
  %IF %LENGTH(&by) > 0 %THEN &by;
  %IF %LENGTH(&strata) > 0 %THEN strata &strata;
run;
data _estim0_;  
  set _estim0_ (rename={_LNLIKE_=_LNBASE_});  
  _r1l_=0;  
  keep &by _LNBASE_ _r1_;  
run;  

/* DETERMINE NUMBER OF VARIABLES AND NUMBER OF VARIABLE GROUPS TO BE ANALYSED */  
%LET numvars=1;  
%LET VAR_1=%SCAN(%SCAN(&VAR, 1,<[],1,>));  
%DO %WHILE(%LENGTH(%SCAN(&VAR, &numvars + 1,<[])) >0);  
  %LET numvars=%EVAL(&numvars+1);  
  %LET VAR_%numvars=%SCAN(%SCAN(&VAR, &numvars,<[]),1,>));  
%END;  
%PUT THE FOLLOWING SETS OF VARIABLES WERE ANALYSED;  
%PUT MODEL COVARIATES;  
%DO RVCOUNT=1 %TO &numvars;  
  %PUT &rvcount &&var_&rvcount;  
%END;  

/* DELETE_ALL TO AVOID UNEXPECTED RESULTS IN CASE OF FAILURE */  
data _all_; delete; run;  

/* PROVIDE WITH ESTIMATES AND STATISTICS FOR ALL VARIABLES */  
%DO RVCOUNT=1 %TO &numvars;  
  %* AGAIN, SAFETY FIRST  
  data _estim_l _estim_cov _trestim_trcov _all1_;  
  delete;  
  run;  

/* COX PROPORTIONAL HAZARDS REGRESSION MODEL */  
proc phreg outest=_estim1_ data=macdat covqut nolprint;  
  model &time - - - -  
  %IF %LENGTH(&censor) > 0 %THEN *&censor;  
  %LET &var_rvcount _r1 alpha=alpha;  
  by _r1_l &by;  
  %IF %LENGTH(&strata) > 0 %THEN strata &strata;;  
run;  

/* SEPARATE ESTIMATES AND COVARIANCE MATRIX */  
data _estim (drop=ties_type_lnlike)  
  _cov (rename={_name_=var});  
  set _estim1;  
  if _name_='ESTIMATE' then output _estim;  
  else output _cov;  
run;  
proc sort data=_estim_; by _r1_l &by;run;  

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proc transpose data=_estim_ out=_trestim_;  
   by _rvl_ &by_;  
run;  
proc sort data=_cov_ by &by _lnlike_ _var_;run;  
  
proc transpose data=_cov_ out=_trcov_;  
   by _rvl_ &by _LNLIKE_ _var_;  
   id _TYPE_;  
run;  
data _trcov_;  
   set _trcov_;  
   if _var_=_Name_; ** THEN, COVARIANCE IS VARIANCE OF ESTIMATE;  
run;  
proc sort data=_trestim; by &by _name_; run;  
proc sort data=_trcov_; by &by _name_; run;  

%*  
%* CALCULATION OF WALD STATISTIC AND RISK-RATIO  
%*  
data all1;  
   merge _trestim _trcov_;  
   by &by _name_;  
   *** WALD STATISTIC;  
   waldchi=(estimate*estimate)/cov;  
   pwald=1-probchi(waldchi,1);  
   *** STANDARD ERROR OF ESTIMATE;  
   stderr=sqrt(cov);  
   *** RISK RATIO;  
   riskrat=exp(estimate);  
   risklow=exp(estimate-probit((1-(&alpha/2)))*stderr);  
   riskupp=exp(estimate+probit((1-(&alpha/2)))*stderr);  
   *** MODEL NUMBER;  
   model=&rvcount;  
   *** LENGTH OF CONFIDENCE INTERVAL;  
   cilength=(100-(100*&alpha));  
   drop _name_ cov;  
run;  

%*  
%* ADD RESULTS TO PREVIOUS ONES  
%*  
data all;  
   set all _all1_;  
run;  
%END;  

%*  
%* MERGE WITH LIKELIHOOD OF MODEL WITHOUT COVARIATES  
%*  
proc sort data=all; by _rvl_ &by; run;  
proc sort data=_estim0_; by _rvl_ &by; run;  
data all;  
   merge all _estim0_;  
   by _rvl_ &by;  
run;
/* FIND DEGREES OF FREEDOM FOR ALL MODELS */
proc sort; by &by model; run;
proc univariate noprint;
  var estimate;
  by &by model;
  output out=_degree_ N=DF;
run;
data _all_
  merge _all_ _degree_
  by &by model;
run;

/* CALCULATE DIFFERENCE IN LLR AND CORRESPONDING P-VALUE */
data _all_
  set _all_
  ml_base=-2*LNBASE;
  likerat=ml_base-(-2*NLIKE);
  pll=1-probchi(likerat, df);
run;

/* LABEL VARIABLES AND PROVIDE WITH OUTPUT DATASET */
data &out
  set all
  lnbased=-2*lnbase;
  _nl_=-2*lnlike;
  label estimate='Estimate' stderr='StdErr of Estimate'
    likerat='Log Likelihood Ratio (LLR)' pll='P-value (LLR)'
    DF='DF (LLR)'
    waldchi='Wald Chi-Square' pwald='P-value (WALD)'
    riskrat='Risk Ratio' risklow='Lower Limit Risk Ratio CI'
    riskupp='Upper Limit Risk Ratio CI'
    cilen='Length CI'
    model='Model'
    _lnlike=-2 Log Likelihood (Model)'
    _lnbase=-2 Log Likelihood (Without Cov.)';
  keep estimate stderr likerat pll DF waldchi pwald
    riskrat risklow riskupp cilen model _var_
    lnbased &by;
run;

/* CLEAN UP AFTERWARDS */
proc datasets nolist;
  delete MACDAT ALL DEGREE ESTIM1 ESTIM _COV_
    TRESTIM TCOV ALL1 ESTIMO_
    (MEMTYPE=DATA);
run;

/* RETURN THE LAST DATASET AS BEFORE THE MACRO */
data BUFFER
  set BUFFER;
rundemend coxuni;
Appendix B: %COXMULT

%macro coxmult(data=, time=, censor=, var=, strata=, by=, out=coxuni, alpha=0.05);
/*
SAS MACRO TO PROVIDE WITH MULTIPLE COX PH REGRESSION
ANALYSES: EFFECTS OF REMOVING VARIABLES FROM MODEL
AUTHOR: R. Vonk
DATE OF THIS VERSION: 05.05.95

* GENERAL RULES:
- This macro performs proportional hazards analyses on the
  variables listed in 'var', sorted by the 'by' variables,
  and stratified by 'strata'. Confidence intervals for the risk-ratio
  (calculated using the normal distribution) have length 100*(1-alpha)%. No
time-dependent variables can be included.
Likelihoods will be given for removal of the respective variables
from a full model (containing all variables), as well as a p-value
for the increase in the -2 Log Likelihood statistic.

* INPUT PARAMETERS:
  - DATA dataset to be analysed, including parameters for 'VAR', 'BY',
    'STRATA' and 'TIME' and 'CENSOR'
  - BY by-variables
  - STRATA stratification variables
  - VAR variables in order of analysis. Variable to be included into
    one analysis should be surrounded by brackets, e.g.,
    var=<sex> [age1 age2]
    Note: only <, [ and > ] can be used!
  - TIME time to event (refer to PHREG procedure)
  - CENSOR censoring variable (refer to PHREG procedure)
  - ALPHA length of confidence interval will be 100*(1-alpha)
  - OUT name of output dataset containing analysis results
    (default=coxmult).
*/

%* IN BUFFER THE LAST DATASET WILL BE PRESERVED
%
data BUFFER;
set _LAST_
run;

%* IN MACDAT THE DATASET TO BE ANALYSED WILL BE KEPT
%
data macdat;
set &data;
_rvl_=0; ** DUMMY VARIABLE;
run;
proc sort; by _rvl_ &by; run;

%* DETERMINE NUMBER OF VARIABLES AND NUMBER OF VARIABLE
%* GROUPS TO BE ANALYSED
%LET numvars=1;
%LET VAR_1=%SCAN(%SCAN(&VAR, 1,<[],1,>));
%DO %WHILE(%LENGTH(%SCAN(&VAR, &numvars + 1,<[])) >0);
   %LET numvars=%EVAL(&numvars+1);
   %LET VAR_&numvars=%SCAN(%SCAN(&VAR, &numvars,<[],1,>));
%END;

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%PUT THE FOLLOWING SETS OF VARIABLES WERE ANALYSED;
%PUT MODEL COVARIATES;
%DO RVCOUNT=1 %TO &numvars;
  %PUT &rvcount &&var &rvcount;
%END;

** DELETE DATASETS TO AVOID UNEXPECTED RESULTS IN CASE OF FAILURE **

data _estim0 _estim_cov _trestim_trcov_
   _alll _all2 _all_;
delete;
run;

** PROVIDE WITH ESTIMATES AND STATISTICS FOR ALL VARIABLES **

proc phreg outest=_estim0 data= macdat covout noprint;
 model &time
   %IF %LENGTH(&censor) > 0 %THEN *&censor;
   %DO COUNT=1 %TO &numvars;
      &&var &count
   %END;
   by _rvt _by;
   %IF %LENGTH(&strata) > 0 %THEN strata &strata;
run;

** SEPARATE ESTIMATES AND COVARIANCE MATRIX **

data _estim (drop= _ties _type _lnlike_)
   _cov (rename=( name _var _));
set _estim0 ;
   if name='ESTIMATE' then output _estim ;
   else output _cov ;
run;

proc sort data=_estim ; by _rvt _by;run;
proc transpose data=_estim out= _estim ;
   by _rvt _by;
run;
proc sort data= _cov ; by _by _lnlike _var ;run;
proc transpose data= _cov out= _trcov ;
   by _rvt _by _LNIK _var ;
   id _TYPE _;
run;

data _trcov ;
set _trcov ;
   if _var= Name ; ** THEN, COVARIANCE IS VARIANCE OF ESTIMATE;
run;

proc sort data=_estim ; by _by _name ; run;
proc sort data=_trcov ; by _by _name ; run;
**CALCULATION OF WALD STATISTIC AND RISK-RATIO**

```sas
data all1 (rename=(LNLIKE=_LNFULL_));
  merge trestim _trcov_; by &by_name;
  *** WALD STATISTIC;
 waldchi=(estimate*estimate)/cov;
pwald=1-probchi(waldchi,1);
  *** STANDARD ERROR OF ESTIMATE;
  stderr=sqrt(cov);
  *** RISK RATIO;
  riskrat=exp(estimate);
risklow=exp(estimate-probit((1-(&alpha/2)))*stderr);
riskupp=exp(estimate+probit((1-(&alpha/2)))*stderr);
  ** LENGTH OF CONFIDENCE INTERVAL;
cilength=(100-(100*(&alpha)));
length p $100;
  *** MODEL NUMBER;
%DO nr=l %TO &numvars;
  _p_="||upcase("&var &nr")|| ";
  if index(_p_, "|compress(_var_)|" )>0 then model=&nr;
%END;
drop _p_ name cov;
run;
%DO RVCOUNT=l %TO &numvars;
  data estim1;
delete;
run;

**COX PROPORTIONAL HAZARDS REGRESSION MODEL**

```sas
  proc phreg outest=_estim1 data=macdat noprint;
    model &time =
    %IF %LENGTH(&censor) > 0 %THEN * &censor =
    %DO COUNT=l %TO &numvars;
      %IF NOT(&COUNT=&RVCOUNT) %THEN 
      &var &count;
    %END;
    by _rv1 &by;
    %IF %LENGTH(&strata) > 0 %THEN strata &strata;
run;
  data _estim1;
    set _estim1 (keep=&by _rv1 _LNLIKE_);
    model=&rvcount;
run;

**ADD RESULTS TO PREVIOUS ONES**

```sas
  data _all2;
    set _all2 _estim1_;
run;
%END;

**MERGE WITH LIKELIHOOD OF FULL MODEL**

```sas
  proc sort data=_all2_ by _rv1 &by model; run;
  proc sort data=all1_ by _rv1 &by model; run;
```
data _all_;  
  merge _all1_ _all2_;  
  by _rv1_ &by model;  
run;

%* FIND DEGREES OF FREEDOM FOR ALL MODELS %*

proc univariate noprint;  
  var estimate;  
  by &by model;  
  output out= _degree_ N=DF;  
run;

data _all_;  
  merge _all_ _degree_;  
  by &by model;  
run;

%* CALCULATE DIFFERENCE IN LLR AND CORRESPONDING P-VALUE %*

data _all_;  
  set _all_;  
  ml_full=-2*_LNFULL_;  
  likerat=(-2*_NLIKE_)-ml_full;  
  p_Ilr=l-probchi(likerat, df);  
run;

%* LABEL VARIABLES AND PROVIDE WITH OUTPUT DATASET %*

data &out;  
  set all  
  _lnfull=-2*_lnfull_;  
  _lnlike=-2*_lnlike_;  
  label estimate='Estimate', stderr='StdErr of Estimate',  
  likerat='Log Likelihood Ratio (LLR)', p_llr='P-value (LLR)',  
  DF='DF (LLR)',  
  waldchi='Wald Chi-Square', pwald='P-value (WALD)',  
  riskrat='Risk Ratio', risklow='Lower Limit Risk Ratio CI',  
  riskupp='Upper Limit Risk Ratio CI', cilength='Length CI',  
  model='Model', var_='Covariate',  
  _lnlike='-2 Log Likelihood (Excl. covariate)',  
  _lnfull='-2 Log Likelihood (Full Model)';  
  keep estimate stderr likerat p_llr DF waldchi pwald riskrat  
  risklow riskupp cilength model _var_ _lnlike _lnfull &by;  
run;

%* CLEAN UP AFTERWARDS %*

proc datasets nolist;  
  delete MACDAT ALL -TRESTIM TRCOV (MEMTYPE=DATA);  
run;

%* RETURN THE _LAST_ DATASET AS BEFORE THE MACRO %*

data _BUFFER_;  
  set _BUFFER_;  
run;  
%mend coxmult;