An Introduction to Event History Analysis

Oxford Spring School
June 18-20, 2007

Day Three: Diagnostics, Extensions, and Other Miscellanea

Data Redux: Supreme Court Vacancies, 1789-1992

```
. stset service, id(justice) failure(retire)

                id:  justice
     failure event:  retire != 0 & retire < .
obs. time interval:  (service[_n-1], service]
 exit on or before:  failure
------------------------------------------------------------------------------
     1783  total obs.
        0  exclusions
------------------------------------------------------------------------------
     1783  obs. remaining, representing
      109  subjects
       52  failures in single failure-per-subject data
     1796  total analysis time at risk, at risk from t =         0
                             earliest observed entry t =         0
                                  last observed exit t =        37



. su justice service retire  age pension pagree

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
     justice |      1783    52.65956    29.84882          1        109
     service |      1783    11.73135    8.336239          1         37
      retire |      1783    .0291643    .1683142          0          1
         age |      1783    62.08749    9.646686         32         91
     pension |      1783    .1996635    .3998595          0          1
-------------+--------------------------------------------------------
      pagree |      1783    .6118901    .4874565          0          1
```

Nonproportionality

Figure 1: ln[ln($S(t)$)] Plot: *Pension* Variable

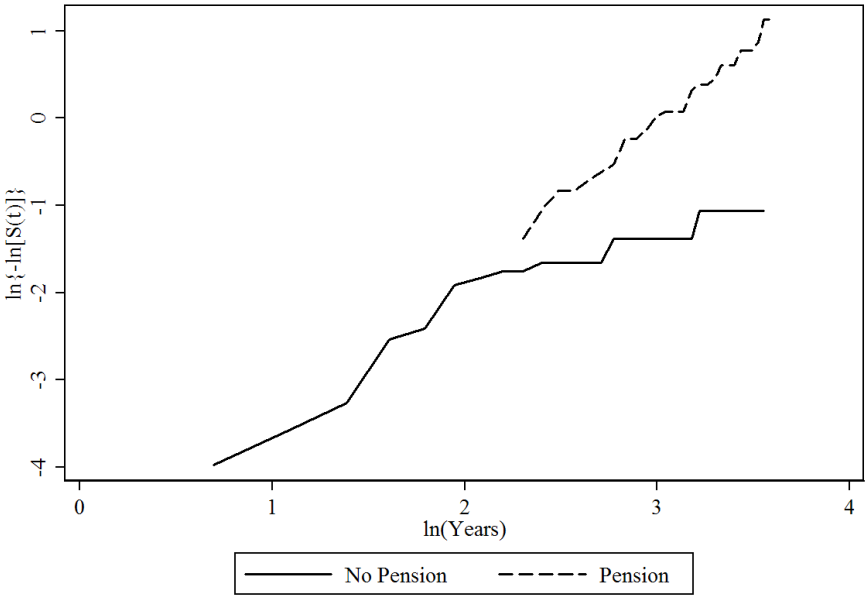
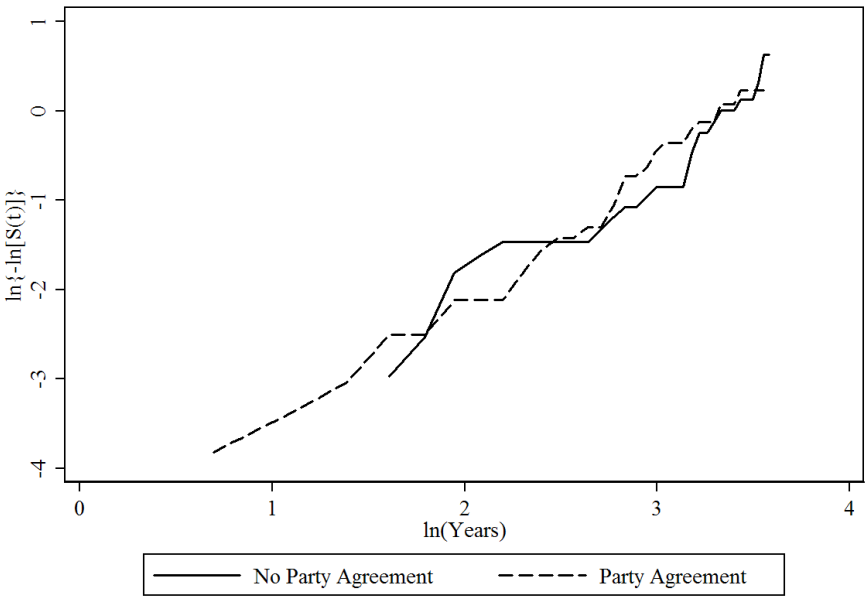


Figure 2: ln[ln($S(t)$)] Plot: *Party Agreement* Variable



```
. stcox age pension pagree, nohr efron sch(schr*) sca(scar*) mg(mgres)

Cox regression -- Efron method for ties

No. of subjects =          109                     Number of obs   =      1783
No. of failures =           52
Time at risk    =         1796
                                                   LR chi2(3)      =     40.37
Log likelihood  =   -173.87849                     Prob > chi2     =    0.0000

------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         age |   .0678159   .0271233     2.50   0.012     .0146551    .1209767
     pension |   2.042509   .5475763     3.73   0.000     .9692794    3.115739
      pagree |   .1075146     .29443     0.37   0.715    -.4695576    .6845868
------------------------------------------------------------------------------
```

Martingale Residuals

William Howard Taft (retired 1930):

```
. list justice service mgres if justice==69

      +--------------------------------+
      | justice   service        mgres |
      |--------------------------------|
1173. |      69         1            0 |
1174. |      69         2   -.03433347 |
1175. |      69         3   -.01793904 |
1176. |      69         4   -.01860524 |
1177. |      69         5   -.07749982 |
      |--------------------------------|
1178. |      69         6   -.02042447 |
1179. |      69         7   -.10997486 |
1180. |      69         8   -.02389276 |
1181. |      69         9   -.02140245 |
1182. |      69        10    .87042748 |
      +--------------------------------+
```

L.Q.C. Lamar (died 1893):

```
. list justice service mgres if justice==49

     +--------------------------------+
     | justice   service        mgres |
     |--------------------------------|
851. |      49         1            0 |
852. |      49         2   -.02881195 |
853. |      49         3   -.01505408 |
854. |      49         4   -.01561314 |
855. |      49         5   -.06503627 |
     |--------------------------------|
856. |      49         6   -.01908529 |
     +--------------------------------+
```

Figure 3: Schoenfeld Residuals for *Age*, by Supreme Court Tenure

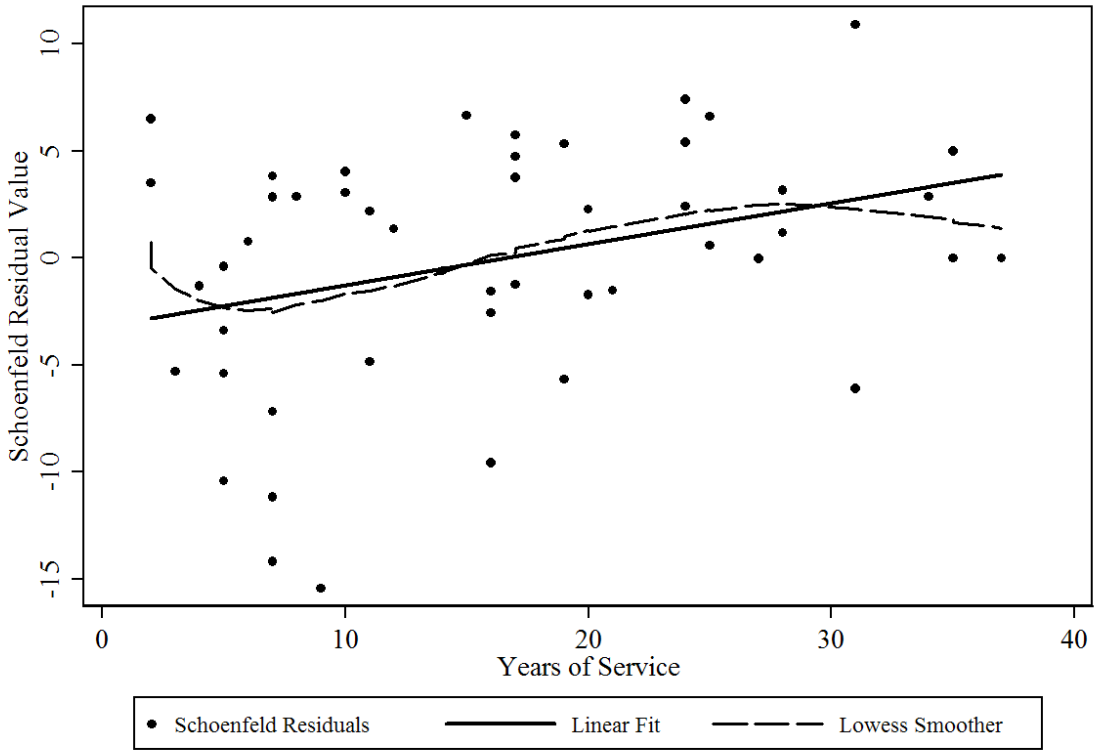


Figure 4: Schoenfeld Residuals for *Pension*, by Supreme Court Tenure

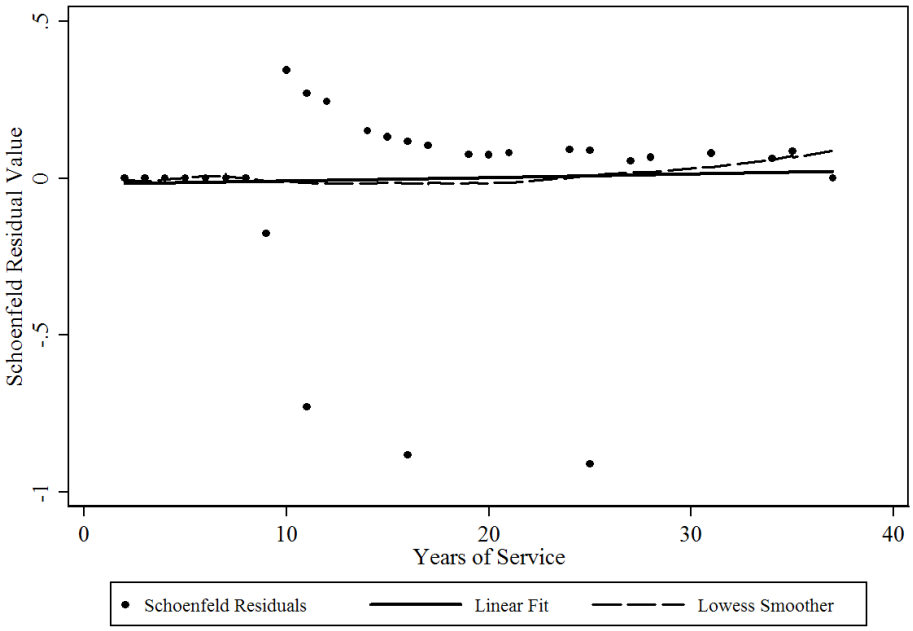
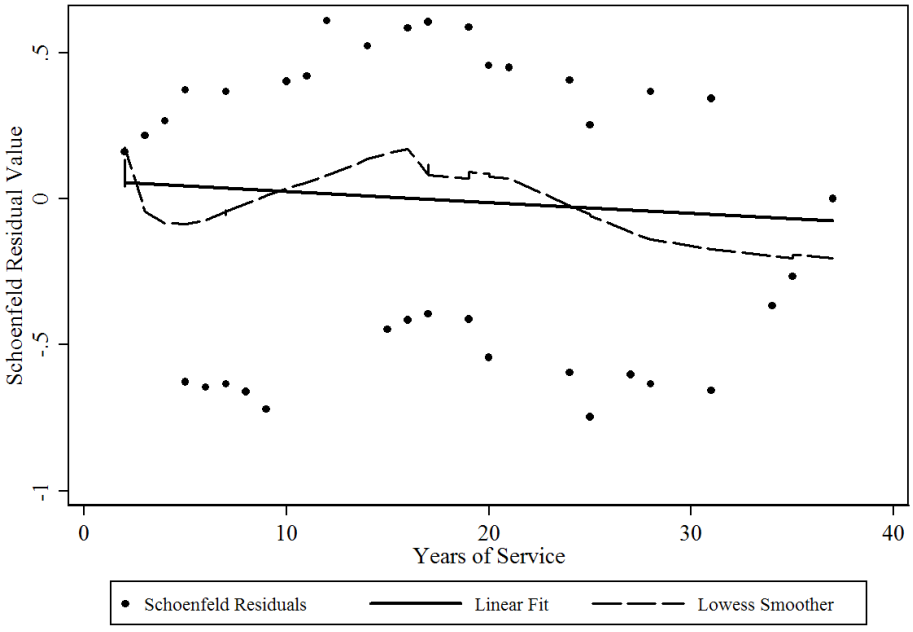


Figure 5: Schoenfeld Residuals for *Party Agreement*, by Supreme Court Tenure



Tests for Proportionality

```
. estat phtest, detail

      Test of proportional hazards assumption

      Time:  Time
      ------------------------------------------------------------
                  |       rho            chi2       df       Prob>chi2
      ------------+-----------------------------------------------
      age         |      0.34444         6.64        1         0.0100
      pension     |     -0.06250         0.20        1         0.6553
      pagree      |     -0.09512         0.51        1         0.4770
      ------------+-----------------------------------------------
      global test |                      7.02        3         0.0712
      ------------------------------------------------------------
```

(Log-)Time-by-Covariate Interactions

```
. gen lnT=ln(service)

. gen agexlnT=age*lnT

. stcox age pension pagree agexlnT, nohr efron

Cox regression -- Efron method for ties

No. of subjects =          109                     Number of obs   =      1783
No. of failures =           52
Time at risk    =         1796
                                                    LR chi2(4)      =     41.69
Log likelihood  =    -173.2178                      Prob > chi2     =    0.0000
------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         age |   .0023907   .0589481     0.04   0.968    -.1131454    .1179269
     pension |   2.039256   .5487846     3.72   0.000     .9636582    3.114854
      pagree |   .0849074   .2968391     0.29   0.775    -.4968865    .6667012
     agexlnT |   .0250956    .019777     1.27   0.204    -.0136665    .0638578
------------------------------------------------------------------------------
```

```
. nlcom _b[age] + (ln(10)*_b[agexlnT])

       _nl_1:  _b[age] + (ln(10)*_b[agexlnT])

------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |   .0601756   .0272647     2.21   0.027     .0067378    .1136134
------------------------------------------------------------------------------

. nlcom _b[age] + (ln(20)*_b[agexlnT])

       _nl_1:  _b[age] + (ln(20)*_b[agexlnT])

------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |   .0775705   .0270789     2.86   0.004     .0244968    .1306443
------------------------------------------------------------------------------


. estat phtest, detail

      Test of proportional hazards assumption

      Time:  Time
      ----------------------------------------------------------------
                  |       rho            chi2       df       Prob>chi2
      ------------+---------------------------------------------------
      age         |     -0.06453         0.21        1         0.6481
      pension     |     -0.03437         0.06        1         0.8055
      pagree      |     -0.10123         0.59        1         0.4434
      agexlnT     |      0.24114         2.13        1         0.1446
      ------------+---------------------------------------------------
      global test |                      6.11        4         0.1913
      ----------------------------------------------------------------
```

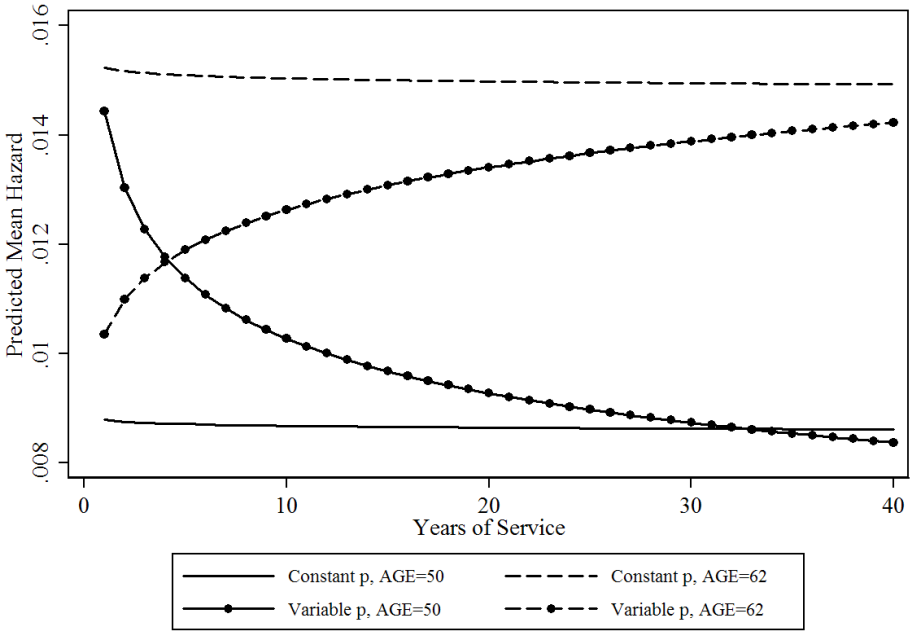
Duration Dependence

```
. streg age pension pagree, nohr dist(weib)

Weibull regression -- log relative-hazard form

No. of subjects =          109                     Number of obs   =      1783
No. of failures =           52
Time at risk    =         1796                     LR chi2(3)      =     28.36
Log likelihood  =   -77.787317                     Prob > chi2     =    0.0000
------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         age |   .0457717   .0242713     1.89   0.059    -.0017992    .0933426
     pension |    1.29297   .3893983     3.32   0.001     .5297638    2.056177
      pagree |   .0876619   .2838971     0.31   0.757    -.4687662    .6440899
       _cons |  -7.105049   1.338079    -5.31   0.000    -9.727636   -4.482462
-------------+----------------------------------------------------------------
       /ln_p |  -.0053729   .2236242    -0.02   0.981    -.4436683    .4329224
-------------+----------------------------------------------------------------
           p |   .9946415   .2224259                      .6416782    1.541757
         1/p |   1.005387   .2248289                      .6486108    1.558413
------------------------------------------------------------------------------

. streg age pension pagree, nohr dist(weib) anc(age)

Weibull regression -- log relative-hazard form

No. of subjects =          109                     Number of obs   =      1783
No. of failures =           52
Time at risk    =         1796
                                                    LR chi2(3)      =     12.40
Log likelihood  =   -76.447296                     Prob > chi2     =    0.0061
------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
_t           |
         age |  -.0478027   .0460998    -1.04   0.300    -.1381566    .0425512
     pension |    1.29184   .3927471     3.29   0.001     .5220698     2.06161
      pagree |   .0191522   .2892142     0.07   0.947    -.5476971    .5860016
       _cons |  -1.707886   2.545037    -0.67   0.502    -6.696066    3.280294
-------------+----------------------------------------------------------------
ln_p         |
         age |   .0201789   .0073804     2.73   0.006     .0057137    .0346442
       _cons |  -1.168506   .5261179    -2.22   0.026    -2.199678   -.1373342
------------------------------------------------------------------------------
```

Test whether the value of p is significantly different from 1.0 at different values of age:

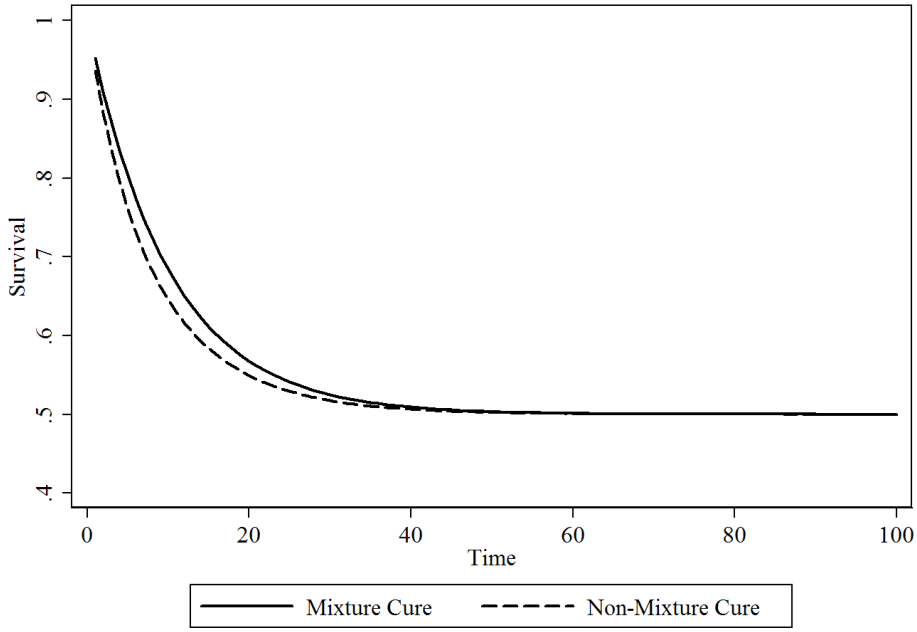
```
. nlcom exp([ln_p]_cons + ([ln_p]age)*32) - 1

------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |  -.4071299   .1907099    -2.13   0.033    -.7809145   -.0333454
------------------------------------------------------------------------------

. nlcom exp([ln_p]_cons + ([ln_p]age)*62) - 1

------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |   .0860947   .2233591     0.39   0.700    -.3516812    .5238706
------------------------------------------------------------------------------

. nlcom exp([ln_p]_cons + ([ln_p]age)*91) - 1

------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |   .9498997   .5387907     1.76   0.078    -.1061108     2.00591
------------------------------------------------------------------------------
```

Figure 6: Predicted Mean Hazards, by tenure and age



Heterogeneity: Cure Models

Figure 7: Mixture and Non-Mixture Cured-Fraction Survival Functions (Exponential Hazards with $\lambda = 0.1$ and $\pi = 0.5$)




```
. spsurv dispute contig capratio allies growth democ trade, id(dyadid) seq(duration)

Split population survival model                  Number of obs   =      20448
                                                 LR chi2(7)      =    3491.55
Log likelihood =   -243.498                      Prob > chi2     =     0.0000
------------------------------------------------------------------------------
     dispute |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
hazard       |
      contig |   1.837595   .4290062     4.28   0.000     .9967579    2.678431
    capratio |  -.7644514   .4714218    -1.62   0.105    -1.688421    .1595183
      allies |  -1.048935   .3690607    -2.84   0.004     -1.77228    -.325589
      growth |  -11.46911   2.908244    -3.94   0.000    -17.16917   -5.769059
       democ |  -.1817709   .3352441    -0.54   0.588    -.8388372    .4752954
       trade |  -84.29065   62.50562    -1.35   0.177    -206.7994    38.21811
       _cons |  -6.564065   .4501115   -14.58   0.000    -7.446268   -5.681863
-------------+----------------------------------------------------------------
cure_p       |
       _cons |  -14.70387   755.9476    -0.02   0.984    -1496.334    1466.926
------------------------------------------------------------------------------
c = Pr(never fail) = 4.113e-07; Std.Err. = .00031094; z = .00132284
Likelihood ratio test of c=0: chibar2(01)=     0.00 Prob>=chibar2 = 1.000
```

Weibull Mixture Cure Model, Logit Link

```
. cureregr contig capratio allies growth democ trade, sc(contig capratio allies
  growth democ trade) distribution(weibull) class(mix) link(logistic)

No. of subjects = 827                                 Number of obs   =      20448
                                                      LR chi2(12)     =     319.69
Log likelihood = -1819.8405                           Prob > chi2     =     0.0000
------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
cure_frac    |
      contig |  -15.82142   569.2895    -0.03   0.978    -1131.608    1099.965
    capratio |   .8653806   .1939173     4.46   0.000     .4853096    1.245451
      allies |  -14.63439   4.492417    -3.26   0.001    -23.43937   -5.829419
      growth |  -8.483389   4.323373    -1.96   0.050    -16.95704   -.0097342
       democ |   .5765627   .5447337     1.06   0.290    -.4910956    1.644221
       trade |  -539.2429   526.4039    -1.02   0.306    -1570.976    492.4898
       _cons |  -.0860498   .5041759    -0.17   0.864    -1.074217    .9021168
-------------+----------------------------------------------------------------
scale        |
      contig |   .7923751   .1991905     3.98   0.000     .4019688    1.182781
    capratio |   .0729541   .0476839     1.53   0.126    -.0205046    .1664128
      allies |  -.8146415   .1382061    -5.89   0.000    -1.085521   -.5437625
      growth |  -5.468861   1.459655    -3.75   0.000    -8.329731   -2.607991
       democ |  -.5458385   .1318536    -4.14   0.000    -.8042668   -.2874102
       trade |  -17.69049   12.81514    -1.38   0.167     -42.8077     7.42673
       _cons |  -3.802647   .2228562   -17.06   0.000    -4.239437   -3.365857
-------------+----------------------------------------------------------------
shape        |
       _cons |  -.1306664   .0473635    -2.76   0.006    -.2234972   -.0378356
------------------------------------------------------------------------------
```

Weibull Non-Mixture Cure Model, Logit Link

```
. cureregr contig capratio allies growth democ trade, sc(contig capratio allies
  growth democ trade) distribution(weibull) class(non-mix) link(logistic)

No. of subjects = 827                                 Number of obs   =      20448
                                                      LR chi2(12)     =     316.30
Log likelihood =  -1820.518                           Prob > chi2     =     0.0000
------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
cure_frac    |
      contig |  -1.453424   .4416748    -3.29   0.001     -2.31909    -.587757
    capratio |   .9643626   .1825925     5.28   0.000     .6064878    1.322237
      allies |  -15.90108   4.469876    -3.56   0.000    -24.66187   -7.140281
      growth |  -1.815384   4.311745    -0.42   0.674    -10.26625     6.63548
       democ |   .4465275   .3922274     1.14   0.255     -.322224    1.215279
       trade |   26.55957   27.15934     0.98   0.328    -26.67177     79.7909
       _cons |   -.726644   .5449239    -1.33   0.182    -1.794675    .3413873
-------------+----------------------------------------------------------------
scale        |
      contig |   .7763709   .2484559     3.12   0.002     .2894063    1.263335
    capratio |   .1838771   .0710577     2.59   0.010     .0446066    .3231477
      allies |  -3.235037   .3499214    -9.25   0.000    -3.920871   -2.549204
      growth |  -4.300142   2.227101    -1.93   0.054    -8.665178    .0648952
       democ |  -.4474085   .1834888    -2.44   0.015    -.8070399    -.087777
       trade |  -5.356716   12.67647    -0.42   0.673    -30.20213     19.4887
       _cons |  -4.273679   .4196492   -10.18   0.000    -5.096176   -3.451181
-------------+----------------------------------------------------------------
shape        |
       _cons |  -.0305103   .0563145    -0.54   0.588    -.1408848    .0798642
------------------------------------------------------------------------------
```

Figure 8: Predicted Mean Survival Probabilities, Mixture and Non-Mixture Weibull Cure Models

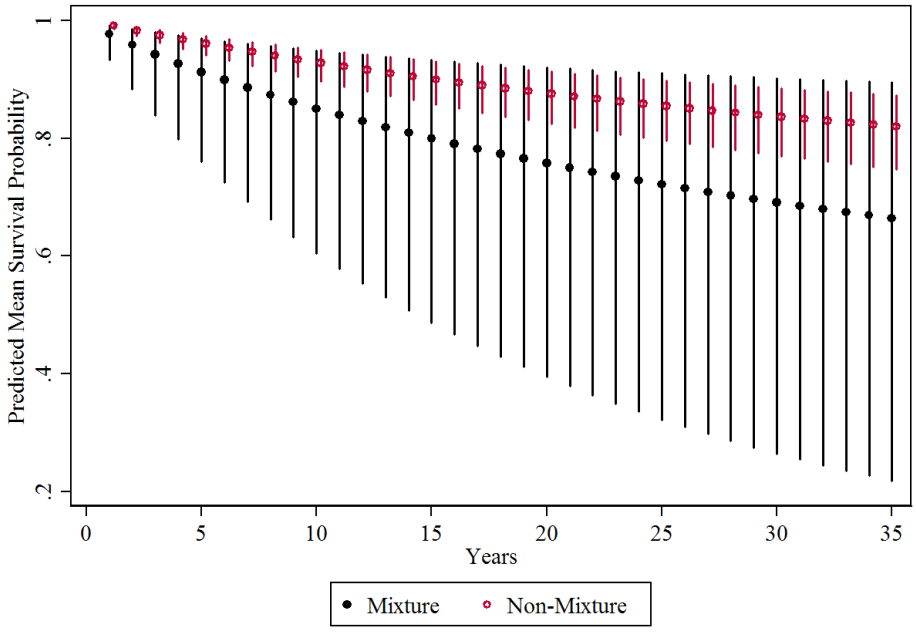
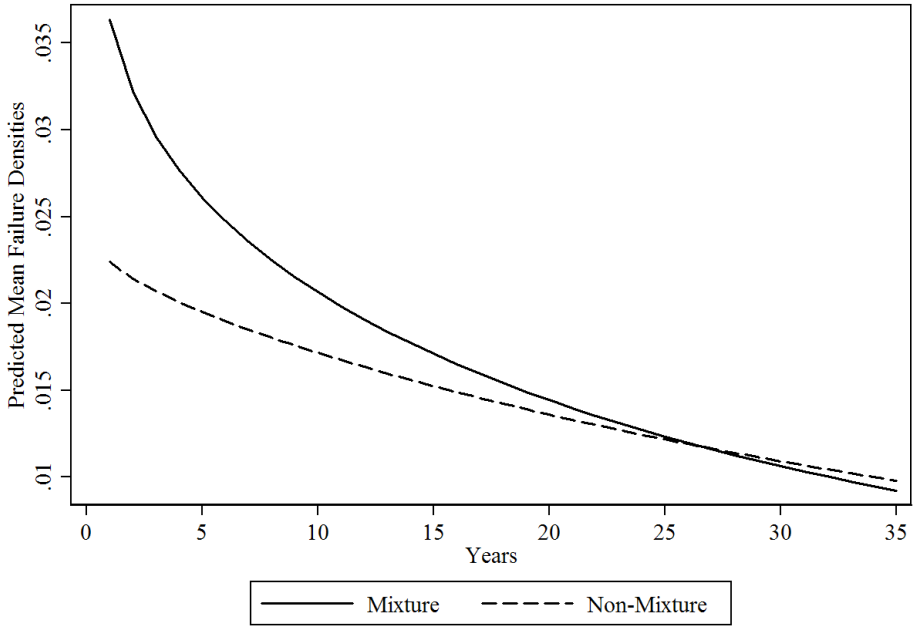


Figure 9: Predicted Mean Failure Densities, Mixture and Non-Mixture Weibull Cure Models



Cure Model Using `zip`

```
. zip dispute contig capratio allies growth democ trade, inf(contig capratio
  allies growth democ trade) robust cluster(dyadid)

Zero-inflated Poisson regression                Number of obs   =      20448
                                                Nonzero obs     =        405
                                                Zero obs        =      20043

Inflation model      = logit                    Wald chi2(6)    =      82.38
Log pseudolikelihood = -1830.467                Prob > chi2     =     0.0000
                              (Std. Err. adjusted for 827 clusters in dyadid)
------------------------------------------------------------------------------
             |               Robust
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
dispute      |
      contig |   .8638687    .200986     4.30   0.000     .4699434    1.257794
    capratio |   .0833804   .0527515     1.58   0.114    -.0200105    .1867714
      allies |  -.7433426   .1793028    -4.15   0.000     -1.09477   -.3919155
      growth |  -5.167673   1.437389    -3.60   0.000    -7.984904   -2.350442
       democ |  -.4162297    .173355    -2.40   0.016    -.7559993   -.0764602
       trade |  -16.47367    14.7979    -1.11   0.266    -45.47702    12.52969
       _cons |  -3.814973   .2295811   -16.62   0.000    -4.264944   -3.365003
-------------+----------------------------------------------------------------
inflate      |
      contig |  -3.189421   1.945931    -1.64   0.101    -7.003376    .6245331
    capratio |   .9944898   .3605983     2.76   0.006     .2877302    1.701249
      allies |  -15.86432   5.548485    -2.86   0.004    -26.73915   -4.989491
      growth |  -11.03041   5.711582    -1.93   0.053     -22.2249    .1640866
       democ |   .5670185   .8128776     0.70   0.485    -1.026192    2.160229
       trade |   15.15835   27.13517     0.56   0.576     -38.0256     68.3423
       _cons |  -.1721649   .7407517    -0.23   0.816    -1.624012    1.279682
------------------------------------------------------------------------------
```

Heterogeneity: General

A Cox Model with a Shared Gamma Frailty Term (using R)

```
> GFrail<-coxph(Surv(start, duration, dispute, type="counting")~contig+capratio
+allies+growth+democ+trade+frailty.gamma(dyadid, method=c("em")))

> summary(GFrail)
Call:
coxph(formula = Surv(start, duration, dispute, type = "counting") ~
    contig + capratio + allies + growth + democ + trade + frailty.gamma(dyadid,
        method = c("em")))

  n= 20448
                          coef   se(coef) se2     Chisq  DF  p
contig                     1.199  0.1673   0.1310  51.41   1 7.5e-13
capratio                  -0.199  0.0547   0.0495  13.29   1 2.7e-04
allies                    -0.370  0.1685   0.1252   4.82   1 2.8e-02
growth                    -3.685  1.3457   1.2991   7.50   1 6.2e-03
democ                     -0.365  0.1309   0.1108   7.78   1 5.3e-03
trade                     -3.039 12.0152  10.3084   0.06   1 8.0e-01
frailty.gamma(dyadid, met                          708.95 394 0.0e+00

         exp(coef) exp(-coef) lower .95 upper .95
contig      3.3182      0.301  2.39e+00  4.61e+00
capratio    0.8193      1.221  7.36e-01  9.12e-01
allies      0.6908      1.448  4.97e-01  9.61e-01
growth      0.0251     39.845  1.80e-03  3.51e-01
democ       0.6940      1.441  5.37e-01  8.97e-01
trade       0.0479     20.876  2.84e-12  8.09e+08

Iterations: 7 outer, 27 Newton-Raphson
     Variance of random effect= 2.42   I-likelihood = -2399.4
Degrees of freedom for terms=   0.6   0.8   0.6   0.9   0.7   0.7 394.2
Rsquare= 0.052   (max possible= 0.227 )
Likelihood ratio test= 1089  on 399 df,   p=0
Wald test            = 121  on 399 df,   p=1
```

A Parametric (Weibull) Model with Gamma-Distributed Frailties (again using R)

```
> W.GFrail<-survreg(Surv(duration, dispute)~contig+capratio+allies+growth+democ
+trade+frailty.gamma(dyadid, method=c("em")))

> print(W.GFrail)
Call:
survreg(formula = Surv(duration, dispute) ~ contig + capratio +
    allies + growth + democ + trade + frailty.gamma(dyadid, method = c("em")))

                          coef    se(coef) se2    Chisq   DF  p
(Intercept)                6.0133  0.1646  0.1438 1333.93   1 0.0e+00
contig                    -1.5687  0.1692  0.1409   85.99   1 0.0e+00
capratio                  -0.0164  0.0221  0.0198    0.55   1 4.6e-01
allies                     0.7220  0.1707  0.1386   17.90   1 2.3e-05
growth                    -0.5488  0.8454  0.8362    0.42   1 5.2e-01
democ                     -0.0431  0.0937  0.0860    0.21   1 6.5e-01
trade                     22.7762 10.4935  9.6378    4.71   1 3.0e-02
frailty.gamma(dyadid, met                          3103.90 323 0.0e+00

Scale= 0.541

Iterations: 8 outer, 41 Newton-Raphson
     Variance of random effect= 1.82   I-likelihood = -1746
Degrees of freedom for terms=   0.8  0.7  0.8  0.7  1.0  0.8  0.8 322.6  1.0
Likelihood ratio test=1525  on 327 df, p=0  n= 20448
```

Competing Events

Data: Supreme Court Vacancies, 1789–1992

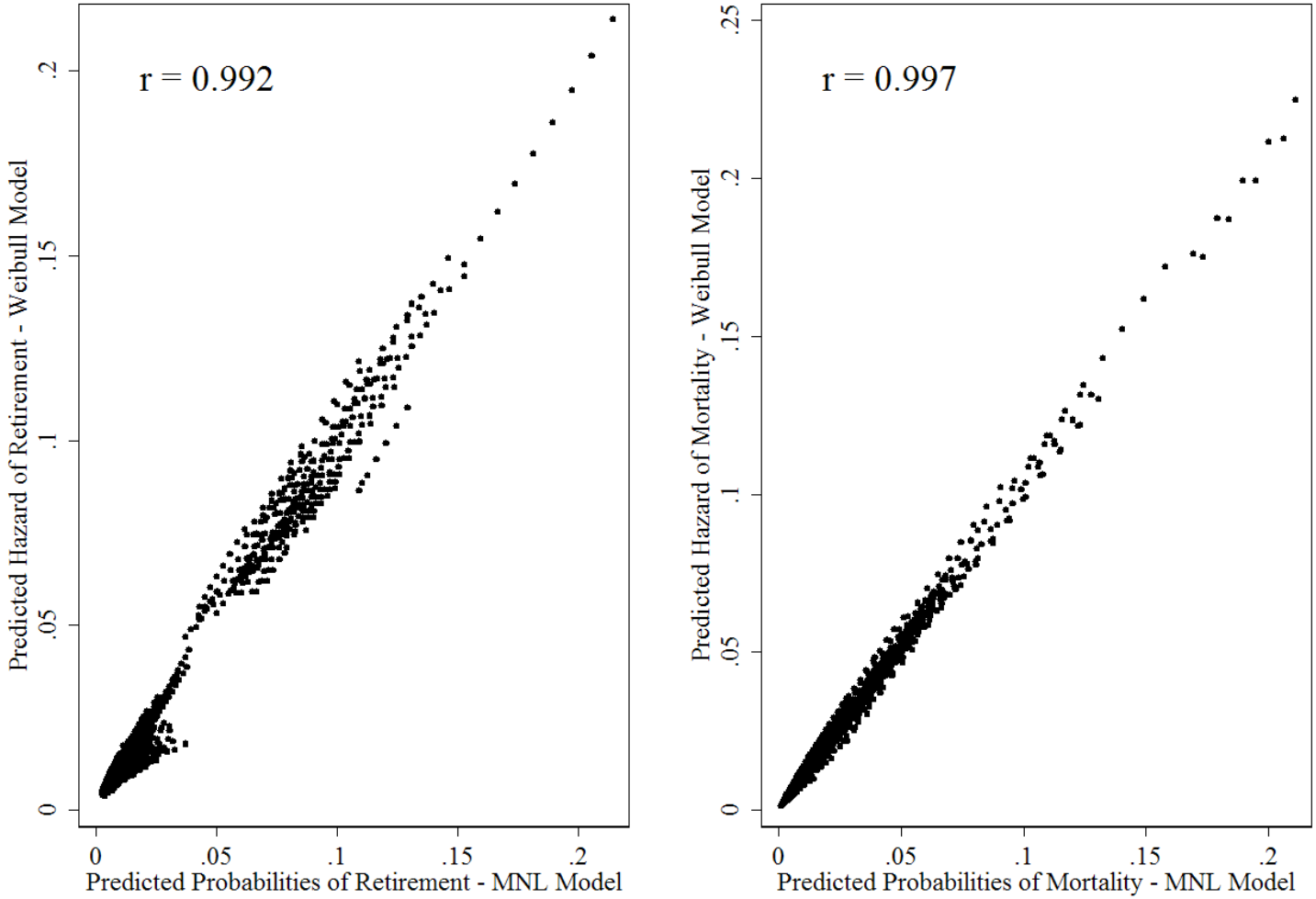
```
. stset service, id(justice) failure(retire)

                id:  justice
     failure event:  retire != 0 & retire < .
obs. time interval:  (service[_n-1], service]
 exit on or before:  failure
------------------------------------------------------------------------------
     1783  total obs.
        0  exclusions
------------------------------------------------------------------------------
     1783  obs. remaining, representing
      109  subjects
       52  failures in single failure-per-subject data
     1796  total analysis time at risk, at risk from t =         0
                             earliest observed entry t =         0
                                  last observed exit t =        37

. streg chief south age pension pagree, dist(weib) nohr

Weibull regression -- log relative-hazard form

No. of subjects =          109                     Number of obs   =      1783
No. of failures =           52
Time at risk    =         1796
                                                    LR chi2(5)      =     28.70
Log likelihood  =   -77.617401                      Prob > chi2     =    0.0000
------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       chief |  -.2474558   .4385671    -0.56   0.573    -1.107032    .6121199
       south |  -.0077937   .3311186    -0.02   0.981    -.6567741    .6411868
         age |   .0470531   .0243715     1.93   0.054    -.0007142    .0948204
     pension |   1.283057   .4023585     3.19   0.001     .4944488    2.071665
      pagree |   .0678141   .2860784     0.24   0.813    -.4928892    .6285174
       _cons |  -7.106853   1.337136    -5.31   0.000    -9.727592   -4.486114
-------------+----------------------------------------------------------------
       /ln_p |  -.0157095   .2273604    -0.07   0.945    -.4613277    .4299087
-------------+----------------------------------------------------------------
           p |   .9844132   .2238166                      .630446    1.537117
         1/p |   1.015834   .2309603                     .6505685    1.586179
------------------------------------------------------------------------------
```

```
. stset service, id(justice) failure(death)

                id:  justice
     failure event:  death != 0 & death < .
obs. time interval:  (service[_n-1], service]
 exit on or before:  failure
------------------------------------------------------------------------------
     1783  total obs.
        0  exclusions
------------------------------------------------------------------------------
     1783  obs. remaining, representing
      109  subjects
       47  failures in single failure-per-subject data
     1796  total analysis time at risk, at risk from t =         0
                             earliest observed entry t =         0
                                  last observed exit t =        37



. streg chief south age pension pagree, dist(weib) nohr

Weibull regression -- log relative-hazard form

No. of subjects =          109                     Number of obs   =      1783
No. of failures =           47
Time at risk    =         1796
                                                    LR chi2(5)      =      8.41
Log likelihood  =   -76.863351                      Prob > chi2     =    0.1349
------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       chief |   .0234548   .4078119     0.06   0.954    -.7758418    .8227514
       south |   .4152854   .3185282     1.30   0.192    -.2090184    1.039589
         age |    .041671   .0224753     1.85   0.064    -.0023798    .0857217
     pension |  -.6113548   .3965263    -1.54   0.123    -1.388532    .1658225
      pagree |   -.228433   .2977798    -0.77   0.443    -.8120707    .3552047
       _cons |  -8.269208    1.21431    -6.81   0.000    -10.64921   -5.889205
-------------+----------------------------------------------------------------
       /ln_p |   .4956265   .1715661     2.89   0.004     .1593632    .8318898
-------------+----------------------------------------------------------------
           p |   1.641526   .2816302                      1.172764    2.297657
         1/p |   .6091891   .1045162                       .435226    .8526866
------------------------------------------------------------------------------
```

Independent Competing Risks: Discrete-Time (Multinomial Logit) Approach:

```
. gen threecat=0

. replace threecat=1 if retire==1
(52 real changes made)

. replace threecat=2 if death==1
(47 real changes made)


. mlogit threecat chief south age pension pagree lnT, base(0)

Multinomial logistic regression                 Number of obs   =       1783
                                                LR chi2(12)     =      82.28
                                                Prob > chi2     =     0.0000
Log likelihood = -409.75471                     Pseudo R2       =     0.0912
------------------------------------------------------------------------------
    threecat |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
1            |
       chief |  -.2890556    .450683    -0.64   0.521    -1.172378    .5942668
       south |   .0635728    .341209     0.19   0.852    -.6051845    .7323302
         age |   .0677696   .0267422     2.53   0.011     .0153558    .1201834
     pension |   1.402186   .4236396     3.31   0.001     .5718675    2.232504
      pagree |   .0349491    .297132     0.12   0.906    -.5474189    .6173171
         lnT |  -.3031319   .2725216    -1.11   0.266    -.8372644    .2310005
       _cons |  -7.770951   1.454034    -5.34   0.000    -10.62081   -4.921096
-------------+----------------------------------------------------------------
2            |
       chief |   .0043609   .4201267     0.01   0.992    -.8190723     .827794
       south |   .4760464   .3242318     1.47   0.142    -.1594363    1.111529
         age |   .0550604   .0238218     2.31   0.021     .0083705    .1017503
     pension |  -.5593072   .4087427    -1.37   0.171    -1.360428    .2418137
      pagree |  -.2581026   .3051772    -0.85   0.398    -.8562389    .3400337
         lnT |   .5072838   .2943055     1.72   0.085    -.0695444    1.084112
       _cons |  -8.283551   1.275321    -6.50   0.000    -10.78313   -5.783969
------------------------------------------------------------------------------
(threecat==0 is the base outcome)
```

Figure 10: Predictions: MNL and Weibull Competing Risks Models



Dependent Competing Risks: Discrete-Time (Multinomial Probit) Approach:

```
. mprobit threecat chief south age pension pagree lnT, base(0)

Multinomial probit regression                     Number of obs   =       1783
                                                  Wald chi2(12)   =      75.98
Log likelihood = -410.26002                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
    threecat |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
_outcome_2   |
       chief |  -.1838577   .2741371    -0.67   0.502    -.7211565    .3534412
       south |   .0721021   .2030768     0.36   0.723     -.325921    .4701253
         age |   .0355871   .0154141     2.31   0.021     .0053761    .0657981
     pension |   .8849486   .2578744     3.43   0.001     .3795242    1.390373
      pagree |   .0053374    .183473     0.03   0.977     -.354263    .3649378
         lnT |  -.1422232   .1565439    -0.91   0.364    -.4490436    .1645971
       _cons |  -4.917864   .8311169    -5.92   0.000    -6.546823   -3.288905
-------------+----------------------------------------------------------------
_outcome_3   |
       chief |   .0194909   .2582927     0.08   0.940    -.4867536    .5257353
       south |   .3241819   .1914712     1.69   0.090    -.0510949    .6994586
         age |   .0350774   .0144876     2.42   0.015     .0066822    .0634725
     pension |   -.283333   .2508214    -1.13   0.259     -.774934    .2082679
      pagree |  -.1333901   .1832503    -0.73   0.467    -.4925541    .2257738
         lnT |   .3040445   .1672095     1.82   0.069    -.0236801    .6317691
       _cons |  -5.645491   .7842479    -7.20   0.000    -7.182589   -4.108393
------------------------------------------------------------------------------
(threecat=0 is the base outcome)
```

Figure 11: Types of Variance-Correction Models

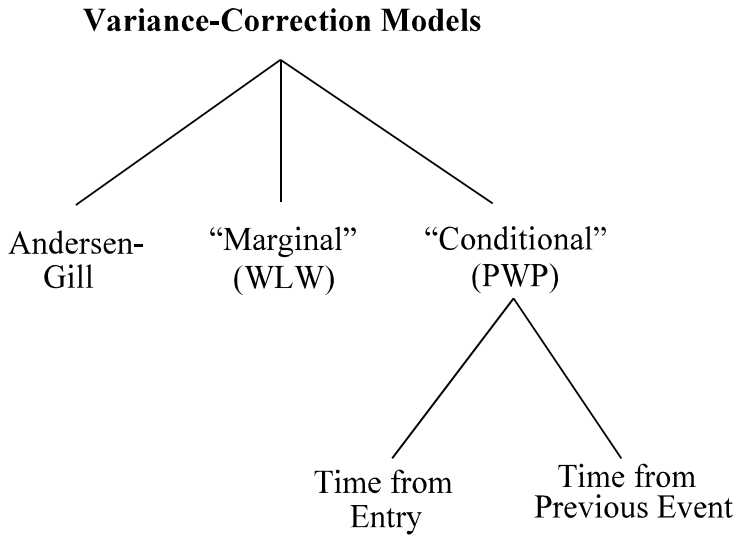


Figure 12: A Comparison of Key Characteristics of Variance-Correction Models

Model Property	Andersen-Gill (AG)	Marginal (WLW)	Conditional (PWP), Elapsed Time	Conditional (PWP), Gap Time
Risk Set for Event *k* at Time *t*	Independent Events	All Subjects that Haven't Experienced Event *k* at Time *t*	All Subjects that Have Experienced Event *k* - 1, and Haven't Experienced Event *k*, at Time *t*	
Time Scale	Duration Since Starting Observation	Duration Since Starting Observation	Duration Since Starting Observation	Duration Since Previous Event
Robust standard errors?	Yes	Yes	Yes	
Stratification by Event?	No	Yes	Yes	

First Events

```
. stcox democ growth allies contig capratio trade if eventno==0, nohr efron robust
  cluster(dyadid)

Cox regression -- Efron method for ties

No. of subjects      =        17158                 Number of obs   =     17158
No. of failures      =          205
Time at risk         =        17158
                                                    Wald chi2(6)    =     86.79
Log pseudolikelihood =   -1263.0085                 Prob > chi2     =    0.0000
                              (Std. Err. adjusted for 827 clusters in dyadid)
------------------------------------------------------------------------------
             |               Robust
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       democ |   -.423616   .1259524    -3.36   0.001    -.6704781   -.1767538
      growth |  -2.197947   1.901665    -1.16   0.248    -5.925143    1.529248
      allies |  -.4479295   .1640672    -2.73   0.006    -.7694954   -.1263637
      contig |   1.070462    .176793     6.05   0.000      .723954     1.41697
    capratio |  -.1956269   .0779756    -2.51   0.012    -.3484563   -.0427975
       trade |   -6.72787   13.91092    -0.48   0.629    -33.99278    20.53704
------------------------------------------------------------------------------
```

AG / Cox Model

```
. stcox democ growth allies contig capratio trade, nohr efron robust cluster(dyadid)

Cox regression -- Efron method for ties

No. of subjects      =        20448                 Number of obs   =     20448
No. of failures      =          405
Time at risk         =        20448
                                                    Wald chi2(6)    =     92.92
Log pseudolikelihood =   -2501.8834                 Prob > chi2     =    0.0000
                              (Std. Err. adjusted for 827 clusters in dyadid)
------------------------------------------------------------------------------
             |               Robust
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       democ |  -.4394706   .1231521    -3.57   0.000    -.6808444   -.1980969
      growth |  -3.227159   1.317689    -2.45   0.014    -5.809782   -.6445371
      allies |  -.4141413   .1704406    -2.43   0.015    -.7481988   -.0800839
      contig |   1.213475   .1782591     6.81   0.000      .864094    1.562857
    capratio |  -.2142166    .081796    -2.62   0.009    -.3745337   -.0538994
       trade |  -13.16247   13.82712    -0.95   0.341    -40.26313    13.93818
------------------------------------------------------------------------------
```

Marking Events

```
. gen eventno=.
. sort dyadid year
. quietly by dyadid : replace eventno=sum(dispute)+1
. replace eventno=eventno-1 if dispute==1
. gen altduration=1
. sort dyadid year
. quietly by dyadid: replace altduration=altduration[_n-1]+1 if altduration[_n-1]~=.
  & dispute[_n-1]==0
. gen altstart=altduration-1

. list dyadid year dispute duration eventno altduration if dyadid==2130 & year<1971

      | dyadid   year   dispute   duration   eventno   altdur~n |
      |-----------------------------------------------------------|
  461. |   2130   1951         0          1         1          1 |
  462. |   2130   1952         1          2         1          2 |
  463. |   2130   1953         0          3         2          1 |
  464. |   2130   1954         1          4         2          2 |
  465. |   2130   1956         0          5         3          1 |
      |-----------------------------------------------------------|
  466. |   2130   1957         0          6         3          2 |
           .      .          .          .         .          .
           .      .          .          .         .          .
           .      .          .          .         .          .
      |-----------------------------------------------------------|
  471. |   2130   1962         0         11         3          7 |
  472. |   2130   1963         1         12         3          8 |
  473. |   2130   1964         0         13         4          1 |
  474. |   2130   1965         0         14         4          2 |
           .      .          .          .         .          .
           .      .          .          .         .          .
           .      .          .          .         .          .

. stset altduration, failure(dispute) enter(time altstart)

     failure event:  dispute != 0 & dispute < .
obs. time interval:  (0, altduration]
 enter on or after:  time altstart
 exit on or before:  failure
------------------------------------------------------------------------------
    20448  total obs.
        0  exclusions
------------------------------------------------------------------------------
    20448  obs. remaining, representing
      405  failures in single record/single failure data
    20448  total analysis time at risk, at risk from t =         0
                             earliest observed entry t =         0
                                  last observed exit t =        35
```

PWP – Gap Time

```
. stcox democ growth allies contig capratio trade, nohr efron robust cluster(dyadid)
  strata(eventno)

Stratified Cox regr. -- Efron method for ties

No. of subjects      =        20448               Number of obs   =     20448
No. of failures      =          405
Time at risk         =        20448
                                                 Wald chi2(6)    =     79.90
Log pseudolikelihood =   -2057.3977              Prob > chi2     =    0.0000
                              (Std. Err. adjusted for 827 clusters in dyadid)
------------------------------------------------------------------------------
             |               Robust
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       democ |  -.2793135   .1028972    -2.71   0.007    -.4809883   -.0776387
      growth |  -3.464899   1.222305    -2.83   0.005    -5.860573   -1.069226
      allies |  -.3307969   .1230076    -2.69   0.007    -.5718874   -.0897065
      contig |   .9015374   .1297298     6.95   0.000     .6472717    1.155803
    capratio |  -.1687045   .0635882    -2.65   0.008     -.293335    -.044074
       trade |   -5.92099   10.72889    -0.55   0.581    -26.94923    15.10725
------------------------------------------------------------------------------
                                                      Stratified by eventno
```

PWP – Elapsed Time

```
. stcox democ growth allies contig capratio trade, nohr efron robust cluster(dyadid)
  strata(eventno)

Stratified Cox regr. -- Efron method for ties

No. of subjects      =          827               Number of obs   =     20448
No. of failures      =          405
Time at risk         =        20448
                                                 Wald chi2(6)    =     34.54
Log pseudolikelihood =   -1262.9766              Prob > chi2     =    0.0000
                              (Std. Err. adjusted for 827 clusters in dyadid)
------------------------------------------------------------------------------
             |               Robust
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       democ |   .1616935   .1025067     1.58   0.115     -.039216    .3626029
      growth |  -3.765688   1.063937    -3.54   0.000    -5.850966   -1.680409
      allies |   .1439907   .1079588     1.33   0.182    -.0676046    .3555859
      contig |   .2866263    .11086     2.59   0.010     .0693448    .5039079
    capratio |   .0593644   .0289335     2.05   0.040     .0026557    .1160731
       trade |   5.996793   6.504363     0.92   0.357    -6.751523    18.74511
------------------------------------------------------------------------------
                                                      Stratified by eventno
```

Strata-By-Covariate Interactions:

```
. gen alteventxcap=altevent*capratio

. stcox democ growth allies contig capratio trade alteventxcap, nohr efron
  robust cluster(dyadid) strata(eventno)

Stratified Cox regr. -- Efron method for ties

No. of subjects      =        20448                 Number of obs   =     20448
No. of failures      =          405
Time at risk         =        20448
                                                    Wald chi2(7)    =    101.49
Log pseudolikelihood =   -2055.1025                 Prob > chi2     =    0.0000
                              (Std. Err. adjusted for 827 clusters in dyadid)
------------------------------------------------------------------------------
             |               Robust
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       democ |  -.3022863   .0980622    -3.08   0.002    -.4944847   -.1100879
      growth |  -3.542672   1.225672    -2.89   0.004    -5.944945   -1.140399
      allies |  -.3509175   .1172335    -2.99   0.003    -.5806911    -.121144
      contig |   .9131893   .1263389     7.23   0.000     .6655696    1.160809
    capratio |  -.3609756   .1124107    -3.21   0.001    -.5812964   -.1406547
       trade |  -4.825001   10.41232    -0.46   0.643    -25.23277    15.58277
alteventxcap |   .1524646    .061653     2.47   0.013     .0316269    .2733022
------------------------------------------------------------------------------
                                                      Stratified by eventno
```

```
. xi: stcox democ growth allies contig capratio trade i.altevent*capratio, nohr
  efron robust cluster(dyadid) strata(eventno)

i.altevent        _Ialtevent_1-5      (naturally coded; _Ialtevent_1 omitted)
i.alte~t*capr~o   _IaltXcapra_#       (coded as above)

Stratified Cox regr. -- Efron method for ties

No. of subjects      =        20448               Number of obs   =     20448
No. of failures      =          405
Time at risk         =        20448
                                                  Wald chi2(10)   =         .
Log pseudolikelihood =   -2054.7298               Prob > chi2     =         .
                              (Std. Err. adjusted for 827 clusters in dyadid)
------------------------------------------------------------------------------
             |               Robust
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       democ |  -.3039187    .097843    -3.11   0.002    -.4956874     -.11215
      growth |  -3.542476   1.225773    -2.89   0.004    -5.944947   -1.140005
      allies |  -.3439247   .1194158    -2.88   0.004    -.5779754    -.109874
      contig |   .9128806   .1277827     7.14   0.000     .6624311     1.16333
    capratio |  -.2100499   .0767582    -2.74   0.006    -.3604933   -.0596065
       trade |  -4.848646   10.47485    -0.46   0.643    -25.37897    15.68168
_Ialtevent_2 |  (dropped)
_Ialtevent_3 |  (dropped)
_Ialtevent_4 |  (dropped)
_Ialtevent_5 |  (dropped)
_IaltXcapr~2 |   .1468944   .1203124     1.22   0.222    -.0889136    .3827025
_IaltXcapr~3 |   .5149924   .3156982     1.63   0.103    -.1037648     1.13375
_IaltXcapr~4 |   .3749226   .3129412     1.20   0.231    -.2384308    .9882761
_IaltXcapr~5 |   .4761326   .3180666     1.50   0.134    -.1472664    1.099532
------------------------------------------------------------------------------
                                                      Stratified by eventno
```

Tests for Constant Effects

```
. test _IaltXcapra_2 _IaltXcapra_3 _IaltXcapra_4 _IaltXcapra_5

 ( 1)  _IaltXcapra_2 = 0
 ( 2)  _IaltXcapra_3 = 0
 ( 3)  _IaltXcapra_4 = 0
 ( 4)  _IaltXcapra_5 = 0

           chi2(  4) =    7.01
         Prob > chi2 =    0.1354

. nlcom _b[capratio]+_b[_IaltXcapra_2]

       _nl_1:  _b[capratio]+_b[_IaltXcapra_2]

------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |  -.0631554   .0898826    -0.70   0.482    -.2393221    .1130112
------------------------------------------------------------------------------

. nlcom _b[capratio]+_b[_IaltXcapra_3]

       _nl_1:  _b[capratio]+_b[_IaltXcapra_3]

------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |   .3049425   .3291913     0.93   0.354    -.3402605    .9501455
------------------------------------------------------------------------------

. nlcom _b[capratio]+_b[_IaltXcapra_4]

       _nl_1:  _b[capratio]+_b[_IaltXcapra_4]

------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |   .1648728   .2974726     0.55   0.579    -.4181628    .7479083
------------------------------------------------------------------------------

. nlcom _b[capratio]+_b[_IaltXcapra_5]

       _nl_1:  _b[capratio]+_b[_IaltXcapra_5]

------------------------------------------------------------------------------
          _t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |   .2660827   .3130835     0.85   0.395    -.3475498    .8797152
------------------------------------------------------------------------------
```