Statistical and Econometric Methods for Transportation Data Analysis

Chapter 3 – Linear Regression

Example 3.9
Continuous Censored Data - Tobit Model

You are given vehicle accident data from 337 rural interstate road sections in the state of Indiana for a 5-year period (1995 to 1999). The use of accidents per vehicle-miles traveled has an intuitive appeal in highway safety – providing a standardized measure of the relative safety of roadway segments that is more easily interpreted than the number of accidents per some time period. Because accident rates on specific highway segments are assessed over some finite time period, there is the likelihood that many highway segments will have no accidents reported during the analysis period. Thus, modeling accident rates by standard OLS would result in biased and inconsistent parameter estimates. The solution to this is to consider accident rates as a censored dependent variable (censored at zero) and apply a tobit model. For the accident-rate considered, the data will be left-censored with a clustering at zero (zero accidents per 100-million vehicle miles traveled) because accidents may not be observed on all roadway segments during the period of observation. For model estimation, the accident rate (number of accidents per 100-million VMT) was calculated as:

$$Accident\ Rate_i = \frac{\sum_{Year=1}^{5} Accidents_{Year,i}}{\left[\sum_{Year=1}^{5} AADT_{Year,i} \times L_i \times 365\right] \Big/ 100{,}000{,}000}$$

where $Accident\ Rate_i$ is the number of accidents per 100-million VMT on roadway segment i, $Year$ denotes the year (1995 to 1999), $Accidents_{Year,i}$ is the number of accidents, $AADT_{Year,i}$ the average annual daily traffic, L_i the length of roadway segment i. The model's overall fit can be measured with Maddala's R^2:

$$R^2 = 1 - \exp(-LRT / N)$$

where N is the number of observations, and $LRT=2[LL(\beta)–LL(0)]$ is the likelihood ratio statistic.

Your task is to estimate a model of accident rates using tobit regression. Your solution to this problem should include:

1. The results of your best model specification.

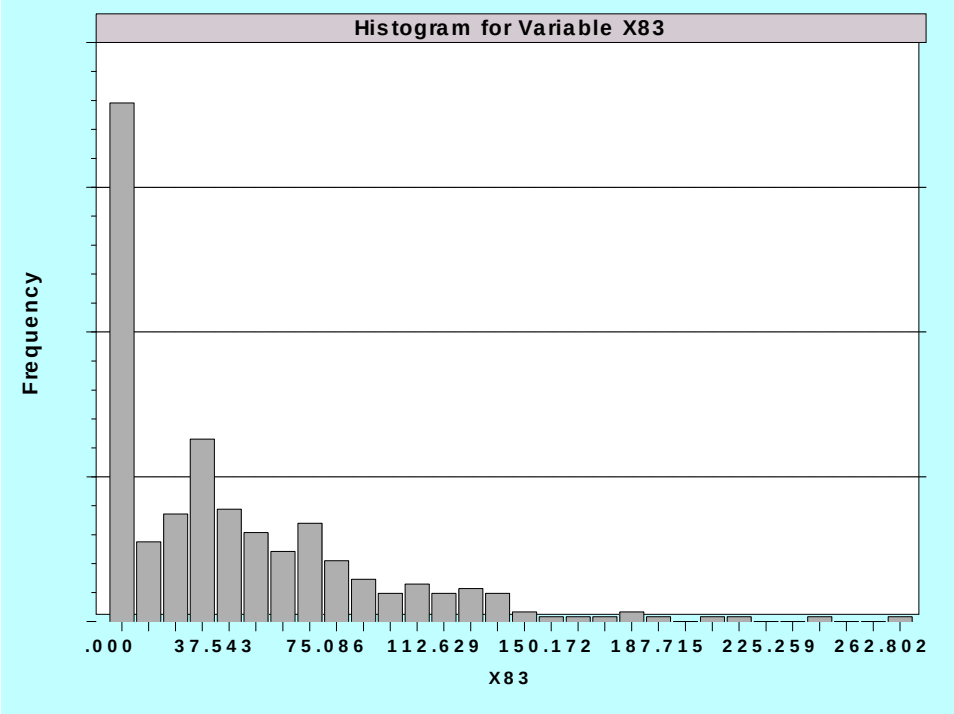
2. A discussion of the logical process that led you to the selection of your final specification. (e.g. Discuss the theory behind the inclusion of your selected variables). Include t-statistics and justify the sign of your variables.

Variables available for your specification are (file Ex3-9.txt) :

Variable	Explanation
x1	ID
x2	Number of observations for each interstate
x3	Number of single vehicle accidents per 100-million VMT
x4	Interstate (64: I-64, 65: I-65, 70: I-70, 74: I-74, and 164: I-164)
x5	Average Friction in the road section over the 5-year period (measured at 40MPH)
x6	Minimum Friction reading in the road section over the 5-year period
x7	Maximum Friction reading in the road section over the 5-year period
x8	Standard Deviation of the Friction readings in the road section over the 5-year period
x9	Age of the pavement in 1999
x10	Average IRI in the road section over the 5-year period
x11	Minimum IRI reading in the road section over the 5-year period
x12	Maximum IRI reading in the road section over the 5-year period
x13	Standard Deviation of the IRI readings in the road section over the 5-year period
x14	Average Rutting (in inches) in the road section over the 5-year period
x15	Minimum Rut (in inches) reading in the road section over the 5-year period
x16	Maximum Rut (in inches) reading in the road section over the 5-year period
x17	Standard Deviation of the Rut (in inches) readings in the road section over the 5-year period
x18	Average PCR in the road section over the 5-year period
x19	Minimum PCR in the road section over the 5-year period
x20	Maximum PCR in the road section over the 5-year period
x21	Standard Deviation of the PCR in the road section over the 5-year period
x22	Average PQI in the road section over the 5-year period
x23	Summation of AADT over the 5 years
x24	Section length (in miles)
x25	Total number of ramps in the opposite direction
x26	Total number of ramps in the viewing direction
x27	Number of lanes
x28	Pavement surface type (1: asphalt, 0: concrete)
x29	Median configuration (1: depressed, 2: depressed with bumps, 3: berms, 4: flush, 5: sloped, and 6: rock wall)
x30	Median surface (0: concrete, 1: asphalt, 2: grass, 3: paved, 4: grass with trees, 5: grass with bushes, 6: trees, and 7: rock)
x31	Median width (in feet)
x32	Presence of median barrier (1: present, 0: absent)
x33	Median barrier type (1: wbeam, 2: concrete, 3: brifen, 4: cable, 5: box-beam, 6: rock wall)
x34	Median barrier location (0: left, 1: middle left, 2: middle, 3: middle right, 4: right)
x35	Presence of interior shoulder (1: present, 0 absent)
x36	Interior shoulder width (in feet)
x37	Interior shoulder surface (0: concrete, 1: asphalt)
x38	Interior rumble strips (1: present, 0: absent)
x39	Outside shoulder width (in feet)
x40	Outside shoulder surface (0: concrete, 1: asphalt)
x41	Outside rumble strips (1: present, 0: absent)
x42	Outside barrier type (1: wbeam, 2: concrete, 3: brifen, 4: cable, 5: box-beam, 6: rock wall)

x43	Outside barrier location (1: less than 15 feet, 2: greater than 15 feet)
x44	Average AADT over the 5 years
x45	Average AADT of trucks over the 5 years
x46	Percentage of single unit trucks (average daily)
x47	Percentage of combination trucks (average daily)
x48	Speed limit of the road section
x49	State speed limit
x50	Number of bridges in the road section
x51	Horizontal curve 1 type (1: inside, 2: outside)
x52	Length of horizontal curve 1
x53	Radius of horizontal curve 1
x54	Horizontal curve 2 type (1: inside, 2: outside)
x55	Length of horizontal curve 2
x56	Radius of horizontal curve 2
x57	Horizontal curve 3 type (1: inside, 2: outside)
x58	Length of horizontal curve 3
x59	Radius of horizontal curve 3
x60	Horizontal curve 4 type (1: inside, 2: outside)
x61	Length of horizontal curve 4
x62	Radius of horizontal curve 4
x63	Horizontal curve 5 type (1: inside, 2: outside)
x64	Length of horizontal curve 5
x65	Radius of horizontal curve 5
x66	Average radius per horizontal curve in the road section
x67	Number of horizontal curves in the road section
x68	Length of vertical curve 1
x69	Vertical curve 1 type (1: crest, 2: sag)
x70	K parameter for vertical curve 1
x71	Length of vertical curve 2
x72	Vertical curve 2 type (1: crest, 2: sag)
x73	K parameter for vertical curve 2
x74	Length of vertical curve 3
x75	Vertical curve 3 type (1: crest, 2: sag)
x76	K parameter for vertical curve 3
x77	Number of vertical curves in the road section
x78	Pavement surface change in the road section (1: change, 0: no change)
x79	Changes in vertical profile (1: change, 0: no change)
x80	Number of bridges per mile
x81	Number of horizontal curves per mile
x82	Number of vertical curves per mile
x83	Number of Accidents per 100-million VMT

```
--> RESET
--> read;nvar=83;nobs=337;file=D:Ex3-9.TXT$
--> skip
--> histogram;rhs=x83$
```




```
--> create;if(x38=1&x41=1)rumblstr=1$
--> create;if(x26>0)ramp=1$
--> create;if(x38=1&x41=1)rumblstr=1$
--> create;if(x26>0)ramp=1$
--> tobit;lhs=x83;rhs=one,x32,x6,x12,x16,x18,ramp,x39,x47,x50
    ;marginal effects$

 ************************************************************************
 * NOTE: Deleted      8 observations with missing data. N is now    329 *
 ************************************************************************

Normal exit from iterations. Exit status=0.

+---------------------------------------------+
| Limited Dependent Variable Model - CENSORED |
| Maximum Likelihood Estimates                |
| Model estimated: Nov 10, 2010 at 09:44:50AM.|
| Dependent variable                  X83     |
| Weighting variable                 None     |
| Number of observations              329     |
| Iterations completed                  6     |
| Log likelihood function       -1298.850     |
| Threshold values for the model:             |
| Lower=     .0000     Upper=+infinity        |
| LM test [df] for tobit=     21.168[ 10]     |
| ANOVA  based fit measure =     .187353      |
| DECOMP based fit measure =     .204418      |
+---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Primary Index Equation for Model					
Constant	67.2956685	88.5463578	.760	.4473	
X32	-123.528829	15.8944130	-7.772	.0000	.15805471
X6	-1.56553606	.53937372	-2.903	.0037	30.5592705
X12	.16192574	.12362880	1.310	.1903	101.386018
X16	9.33598386	29.7236801	.314	.7535	.21806837
X18	.79781145	.90663051	.880	.3789	94.4201460
RAMP	30.8421934	8.42597294	3.660	.0003	.17021277
X39	-5.75386157	2.25809145	-2.548	.0108	11.2983066
X47	-35.7374539	27.6789876	-1.291	.1967	.23107196
X50	-6.18365987	4.41955008	-1.399	.1618	.34042553
Disturbance standard deviation					
Sigma	54.0516387	2.62217276	20.613	.0000	

Partial derivatives of expected val. with respect to the vector of characteristics.
They are computed at the means of the Xs.
Observations used for means are All Obs.
Conditional Mean at Sample Point 35.3801
Scale Factor for Marginal Effects .6687

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	45.0032188	59.3544926	.758	.4483	
X32	-82.6085103	9.49254349	-8.702	.0000	.15805471
X6	-1.04693457	.36040609	-2.905	.0037	30.5592705
X12	.10828601	.08259238	1.311	.1898	101.386018
X16	6.24333384	19.8774926	.314	.7535	.21806837
X18	.53352740	.60535146	.881	.3781	94.4201460
RAMP	20.6253687	5.66169987	3.643	.0003	.17021277
X39	-3.84782999	1.50841794	-2.551	.0107	11.2983066
X47	-23.8990190	18.4803827	-1.293	.1959	.23107196
X50	-4.13525275	2.95394518	-1.400	.1615	.34042553
Sigma	.000000	.....(Fixed Parameter).....			

With Random Paramters (see Chapter 16):

```
--> tobit;lhs=x83;rhs=one,x32,x6,x12,x16,x18,ramp,x39,x47,x50
    ;rpm;pts=200;halton
    ;fcn=x32(n)$
+-----------------------------------------------------+
| OLS Starting values for random parameters model     |
| Ordinary    least squares regression                |
| Model was estimated Nov 10, 2010 at 09:44:50AM      |
| LHS=X83      Mean                 =   42.13068      |
|              Standard deviation   =   47.68223      |
| WTS=none     Number of observs.   =        329      |
| Model size   Parameters           =         10      |
|              Degrees of freedom   =        319      |
| Residuals    Sum of squares       =   598786.6      |
|              Standard error of e  =   43.32521      |
| Fit          R-squared            =   .1970563      |
|              Adjusted R-squared   =   .1744027      |
| Model test   F[  9,   319] (prob) =   8.70 (.0000)  |
| Diagnostic   Log likelihood       =  -1701.667      |
|              Restricted(b=0)      =  -1737.770      |
|              Chi-sq [  9]  (prob) =  72.21 (.0000)  |
| Info criter. LogAmemiya Prd. Crt. =   7.567412      |
|              Akaike Info. Criter. =   7.567393      |
+-----------------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 Constant      100.811773     66.0926175     1.525   .1272
 X6            -.98811938      .38712311    -2.552   .0107    30.5592705
 X12            .07364387      .09179010      .802   .4224    101.386018
 X16           3.60567884     22.3421459      .161   .8718     .21806837
 X18            .10795692      .66272420      .163   .8706    94.4201460
 RAMP          23.3676259     6.53211971     3.577   .0003     .17021277
 X39          -3.47679430     1.47889203    -2.351   .0187    11.2983066
 X47          -13.8628122     20.3557843     -.681   .4959     .23107196
 X50          -3.94485022     2.93460531    -1.344   .1789     .34042553
 X32          -44.7964161     7.36136187    -6.085   .0000     .15805471

Normal exit from iterations. Exit status=0.
+---------------------------------------------+
| Random Coefficients  Tobit    Model         |
| Maximum Likelihood Estimates                |
| Model estimated: Nov 10, 2010 at 09:45:32AM.|
| Dependent variable                  X83     |
| Weighting variable                 None     |
| Number of observations              337     |
| Iterations completed                 23     |
| Log likelihood function       -1293.256     |
| Sample is  1 pds and     337 individuals.   |
| Missing data: Skipped        8 individuals. |
| TOBIT (censored) regression model           |
| (Lower) censoring  limit is     .00         |
| Simulation based on 200 Halton draws        |
+---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Nonrandom parameters				
Constant	96.0801252	57.3498022	1.675	.0939	
X6	-1.84762264	.33746849	-5.475	.0000	30.5592705
X12	.20862415	.08479648	2.460	.0139	101.386018
X16	5.66105038	18.8205540	.301	.7636	.21806837
X18	.71420105	.59636375	1.198	.2311	94.4201460
RAMP	32.2730332	5.32003298	6.066	.0000	.17021277
X39	-7.32638069	1.57636793	-4.648	.0000	11.2983066
X47	-29.9633733	15.8914149	-1.886	.0594	.23107196
X50	-5.97285462	3.19924852	-1.867	.0619	.34042553
	Means for random parameters				
X32	-301.937993	50.1580519	-6.020	.0000	.15805471
	Scale parameters for dists. of random parameters				
X32	150.616895	29.1109333	5.174	.0000	
	Variance parameter given is sigma				
Std.Dev.	52.4137073	1.03155116	50.811	.0000	

Implied standard deviations of random parameters

Matrix S.D_Beta has 1 rows and 1 columns.

	1
1	150.61689