

Manual for *OLStraj*

A SAS Macro for Estimating and Visualizing Individual Growth Curves

Madeline M. Carrig, R. J. Wirth, and Patrick J. Curran

University of North Carolina at Chapel Hill

## Introduction

Because of the time-consuming and complicated nature of the programming work involved, it can be challenging for applied users of growth curve technology to compute and graphically display estimates of individual growth trajectories. To capitalize on the estimation of individual trajectories in our own work, we have developed a SAS-based macro that estimates and plots ordinary least squares (OLS)-estimated individual growth trajectories across a variety of experimental settings. The *OLStraj* macro graphically depicts ordinary least squares (OLS)-estimated individual trajectories, describes interindividual variability in OLS-estimated growth parameters, and identifies possible outlier observations. In our own work, we have found the macro to be highly useful as both a data-screening and post-hoc diagnostic device. Given the time invested in developing this program, combined with the power of OLS trajectory estimation techniques when used in our own applied research, we thought it would be of some use to share this program publicly.

The analytical developments underlying the *OLStraj* macro are outlined in Carrig, Wirth, & Curran (2002). The macro itself may be found at [www.unc.edu/~curran/OLStraj.htm](http://www.unc.edu/~curran/OLStraj.htm), or obtained from the program's author at [carrig@email.unc.edu](mailto:carrig@email.unc.edu). In this brief manual, we (a) outline the features of the *OLStraj* macro, (b) provide instructions for downloading and storing the *OLStraj* macro, (c) provide step-by-step instructions for running the *OLStraj* macro, and (d) present a detailed example of the macro's application to an empirical data set (see also Carrig et al.).

### Features of *OLStraj*

Upon invocation, the macro *OLStraj* performs the following procedures:

1. Listwise deletion. If specified by the user, *OLStraj* will delete any observation in the user's data set having a missing value for one or more of the repeated measures variables. Alternatively, OLS estimates can be computed using all available information for each case (i.e., partially missing data).
2. Creation of subsample. *OLStraj* allows the user to specify that a subset of observations be evaluated. (This feature is particularly useful for larger data sets, when a closer examination of a subsample of trajectories is desired.)
3. OLS case-by-case regressions. *OLStraj* next uses the ordinary-least-squares fitting function to estimate a regression model for each case in the sample (or subsample). The user specifies whether a linear, a quadratic, or both linear and quadratic case-by-case regressions should be performed.
4. Creation of group-level plots. If specified by the user, *OLStraj* produces two group-level plots using high-resolution graphics. The first plot displays overlaid simple-joined (non-interpolated) trajectories for all cases in the sample (or subsample). The second plot displays overlaid OLS-estimated trajectories for all cases in the sample (or subsample). If the user specifies a quadratic functional form of growth for OLS case-by-case regressions, the OLS-estimated trajectories displayed on this plot will be quadratic in functional form. Otherwise, the OLS-estimated trajectories displayed on the plot will be linear in functional form.
5. Creation of individual-level plots. If desired by the user, *OLStraj* produces a set of multiple individual-level plots using high-resolution graphics. These individual graphs plot the

value of each individual's repeated measures against time (as coded by the user). Linear and/or quadratic OLS-estimated trajectories are superimposed on the observed repeated measures.

6. Creation of histograms and box plots. If specified by the user, *OLStraj* produces a set of three group-level histograms and one multi-variable group-level box-and-whisker plot using high-resolution graphics.

The group-level histograms display frequency counts for ranges of values of the estimated intercepts, slopes, and (if quadratic regressions are specified by the user) quadratic terms resulting from OLS case-by-case regressions. *OLStraj* automatically computes eighteen data ranges of equal width, which extend from the minimum to the maximum value of the parameter of interest; some of these data ranges may be empty, and this will be reflected on the histograms produced. The box-and-whisker plot provides a visual display of descriptive summary statistics for estimated intercepts, slopes, and (if quadratic regressions are specified) quadratic terms. The type of box-and-whisker plot displayed by *OLStraj* corresponds to the schematic box-and-whisker plot detailed in Tukey (1977). Box plots for estimated parameters are presented side-by-side; each plot displays the mean, quartiles, and minimum and maximum observations for an individual-level estimated parameter. Observations located outside lower and upper "fences" are labeled with the value of the ID variable for that case.

7. Creation of output data set. If desired by the user, *OLStraj* creates an output data set that contains parameter estimates and r-squared values from the OLS case-by-case regressions. This data set can be submitted to other SAS procedures or exported for use in other statistical or graphics programs.

### Downloading and Storing the *OLStraj* Macro

The *OLStraj* macro was written using the SAS macro language, and incorporates both procedures included in SAS/Base and SAS/STAT software and high-resolution graphics provided by SAS/GRAPH software. The macro is embedded and invoked within a larger SAS program file. To download the program file that contains the *OLStraj* macro, complete the following three steps: (a) use your web browser to open [www.unc.edu/~curran/OLStraj.htm](http://www.unc.edu/~curran/OLStraj.htm), (b) use your mouse to click on the link entitled OLStraj macro, and (c) use the File/Save As command (or equivalent) of your web browser to save the *OLStraj* program file on your local machine. The file should be assigned the extension ".sas". The rest of this program documentation assumes that the program file containing the *OLStraj* macro has been saved with the filename *OLStraj.sas*.

Users more familiar with the SAS System may alternatively elect to store the *OLStraj* macro in a user-defined macro library. This may be accomplished using the SASAUTOS system option. If needed, detailed instructions for utilizing the SASAUTOS autocall library feature are readily available in SAS System Help documentation.

## Running *OLStraj*

The four basic steps that must be completed to tailor and run the *OLStraj.sas* program for any given data set are outlined below:

**STEP 1.** Start the SAS system, select the program editor window, and use the File/Open command to open your copy of the *OLStraj* program file (*OLStraj.sas*) into the program editor window.

**STEP 2.** Where indicated in the program file, create a SAS data set named INITIAL that contains the data to be analyzed.

### *IMPORTANT:*

- INITIAL should contain one observation (record) per sampled unit of analysis. For example, if you have collected five repeated measures of reading ability on a sample of 300 children, the data set INITIAL should contain 300 observations and at least 5 variables (one for each repeated measure of reading ability).
- The user must also create a variable containing an identification (ID) code for each of the sampled units, if one does not already exist. To create an ID variable that contains observation number, simply insert the code:

```
ID = _N_;
```

### *NOTE:*

The *OLStraj* macro may be used to analyze a user-defined or randomly-selected subsample. To do so, add the appropriate *subsetting if* or random number generation function statements to the data step(s) that produce(s) INITIAL. (Please refer to your SAS documentation for further assistance with SAS data step commands.)

*Example 1:* The user wishes to use *OLStraj* to analyze a subsample of observations stored on the data set *mydata.indtraj*, which was created during a prior run of the *OLStraj* macro. In particular, the user wishes to graphically display individual trajectories for observations having extreme (say, top 5%) values of OLS-estimated slope. Use the code:

```
proc sort data = mydata.indtraj out = INITIAL;  
  by linear;  
run;  
  
data initial;  
  set initial nobs = numobs;  
  if _N_ >= (.95 * numobs);  
run;
```

*Example 2:* The user wishes to use *OLStraj* to analyze a randomly-selected subsample of 10% of the observations stored on the data set *mydata.repmeas*. Use the code:

```

data INITIAL;
  set mydata.repmeas;
  rand_no = ranuni(123);
run;

proc sort data = initial;
  by rand_no;
run;

data initial;
  set initial nobs = numobs;
  if _N_ <= (.10 * numobs);
run;

```

**STEP 3.** Assign values to each of the macro variables (parameters) located in the “Macro variables input section,” as follows:

- a) **Assign a value to the macro variable IDVARNAME. IDVARNAME specifies the name of the ID variable on the data set INITIAL.**

*Example:* The ID variable stored on data set INITIAL is named “kid\_id.” Use the code:

```
IDVARNAME = kid_id;
```

- b) **Assign a value to the macro variable VARLIST. VARLIST specifies the names of the repeated measures stored on INITIAL.**

*IMPORTANT:*

The repeated measures must be listed *in chronological order*.

*Example:* The repeated measures stored on data set INITIAL are named “read\_a,” “read\_b,” “read\_c,” “read\_d,” and “read\_e.” Read\_a was collected in the year 1990, read\_b was collected in 1993, read\_c was collected in 1995, read\_d was collected in 1998, and read\_e was collected in 2000. Use the code:

```
VARLIST = read_a read_b read_c read_d read_e;
```

- c) **Assign a value to the macro variable TIMEPTS. TIMEPTS specifies the coding of time for the repeated measures stored on INITIAL.**

*IMPORTANT:*

The coding of time must be specified *in chronological order* (and accordingly, must correspond to the ordering of the repeated measures in VARLIST). If the number of elements in TIMEPTS does not equal the number of elements (variables) in VARLIST, the program will terminate.

*Example 1:* The repeated measures stored on data set INITIAL are named “read\_a,” “read\_b,” “read\_c,” “read\_d,” and “read\_e.” Read\_a was collected in the year 1990, read\_b was collected in 1993, read\_c was collected in 1995, read\_d was collected in 1998, and read\_e was collected in 2000. The user wishes intercept values to reflect initial status. Use the code:

```
TIMEPTS = 0 3 5 8 10;
```

*Example 2:* The repeated measures stored on data set INITIAL are named “read\_a,” “read\_b,” “read\_c,” “read\_d,” and “read\_e.” Read\_a was collected in the year 1990, read\_b was collected in 1993, read\_c was collected in 1995, read\_d was collected in 1998, and read\_e was collected in 2000. The user wishes intercept values to reflect status at the middle of the study window. Use the code:

```
TIMEPTS = -5 -2 0 3 5;
```

**d) Assign the appropriate value (“y” or “n”) to the macro variable INCLMISS to indicate whether or not listwise deletion is desired.**

*Option 1:* The user wishes to include cases with partially missing data in his or her analysis. Use the code:

```
INCLMISS = y;
```

*Option 2:* The user wishes to delete all cases without complete data prior to analysis. Use the code:

```
INCLMISS = n;
```

**e) Assign the appropriate value (“grp,” “ind,” or “both”) to the macro variable LEVEL to indicate whether group-level plots, sampling unit-level plots, or both are desired.**

*NOTE:*

LEVEL = both is the default. In other words, if LEVEL is left blank or is otherwise not specified with one of the allowable values, the program will produce both group- and individual-level plots.

*Option 1:* The user wishes to produce plots at the group level only. Use the code:

```
LEVEL = grp;
```

This code produces two group-level plots of overlaid individual trajectories, the first of which displays simple-joined trajectories (i.e., trajectories for which no smoothing or interpolation has been performed) and the second of which displays OLS-estimated trajectories. The functional form of the trajectories estimated for the second plot is specified

using the macro variable REGTYPE (see below). If REGTYPE = both is specified, three group-level plots are produced (the first displaying simple-joined trajectories, the second displaying OLS-estimated linear trajectories, and the third displaying OLS-estimated quadratic trajectories).

*Option 2:* The user wishes to produce plots at the sampling unit, or individual, level only. Use the code:

```
LEVEL = ind;
```

This code produces a set of individual plots (one for each observation in INITIAL), with each plot displaying superimposed simple-joined and OLS-estimated trajectories. If REGTYPE = lin is specified, individual-level plots will be produced that display superimposed simple-joined and OLS-estimated linear trajectories. If REGTYPE = quad is specified, the individual-level plots produced will display superimposed simple-joined and OLS-estimated quadratic trajectories. Finally, if the user has specified REGTYPE = both, individual-level plots will be produced that display superimposed simple-joined, OLS-estimated linear, and OLS-estimated quadratic trajectories.

*Option 3:* The user wishes *OLStraj* to produce both group- and individual-level plots. Use the code:

```
LEVEL = both;
```

f) **Assign the appropriate value (“lin,” “quad,” or “both”) to the macro variable REGTYPE to indicate whether linear, quadratic, or both linear and quadratic trajectories are estimated.**

*NOTE:*

REGTYPE = both is the default. In other words, if REGTYPE is left blank or is otherwise not specified with one of the allowable values, the program will estimate both linear and quadratic individual trajectories.

*Option 1:* The user wishes to estimate linear individual trajectories. Use the code:

```
REGTYPE = lin;
```

When this code is used, if the user has specified LEVEL = grp or LEVEL = both, an OLS-estimated linear group-level trajectory plot will be produced. If the user has specified LEVEL = ind or LEVEL = both, individual-level plots will be produced that display superimposed simple-joined and OLS-estimated linear trajectories.

*Option 2:* The user wishes to estimate quadratic individual trajectories. Use the code:

```
REGTYPE = quad;
```

When this code is used, if the user has specified LEVEL = grp or LEVEL = both, an OLS-estimated quadratic group-level trajectory plot will be produced. If the user has specified LEVEL = ind or LEVEL = both, individual-level plots will be produced that display superimposed simple-joined and OLS-estimated quadratic trajectories.

*Option 3:* The user wishes to estimate both linear and quadratic individual trajectories. Use the code:

REGTYPE = both;

When this code is used, if the user has specified LEVEL = grp or LEVEL = both, separate OLS-estimated linear and quadratic group-level trajectory plots will be produced. If the user has specified LEVEL = ind or LEVEL = both, individual-level plots will be produced that display superimposed simple-joined, OLS-estimated linear, and OLS-estimated quadratic trajectories.

**g) Assign a value to the macro variable NUMPLOT. NUMPLOT specifies the number of observations in the data set INITIAL to be plotted.**

*NOTE:*

The program selects observations for plotting in the order in which they appear in the data set INITIAL.

*Example 1:* The user wishes to produce group- and/or individual-level plots for the first 75 observations in data set INITIAL. Use the code:

NUMPLOT = 75;

*Example 2:* The user wishes to produce group- and/or individual-level plots for all observations in data set INITIAL. Use the code:

NUMPLOT = ;

**h) Assign the appropriate value (“y” or “n”) to the macro variable HIST to indicate whether or not histograms and box-and-whisker plots of estimates of intercept, linear, and (if REGTYPE = quad or REGTYPE = both) quadratic terms from OLS case-by-case regressions are desired. (See “Features of *OLStraj*,” above, for further details.)**

*NOTE:*

HIST = n is the default. In other words, if HIST is left blank or is otherwise not specified with one of the allowable values, the program will not produce histograms or box-and-whisker plots.

*Option 1:* The user wishes to produce histograms and box-and-whisker plots. Use the code:



HIST = y;

*Option 2:* The user does not wish to produce histograms and box-and-whisker plots. Use the code:

HIST = n;

- i) **Assign a value to the macro variable OUTDS. OUTDS specifies the name of the output data set that stores (a) estimates of intercept, linear, and (if REGTYPE = quad or REGTYPE = both) quadratic terms and (b) squared correlation coefficients (r-squared values) resulting from OLS case-by-case regressions.**

*NOTE:*

The production of an output data set can be invaluable for the identification of possible outliers. For example, the user can execute SAS PROC UNIVARIATE on the OUTDS data set to quickly identify observations that possess extreme values on the OLS-estimate variables *Intercept*, *Linear*, and/or *Quad*.

The data dictionary for the output data set is as follows:

<i>Variable Name</i>	<i>Description</i>
(name specified in macro variable IDVARNAME (e.g., <i>kid id</i> ))	ID variable from data set INITIAL
Intercept	OLS estimate of intercept
Linear	OLS estimate of slope
Quad	OLS estimate of quadratic term; present on data set only if REGTYPE = quad or REGTYPE = both
Rsquared	Squared correlation coefficient

*Example 1:* The user wishes to save program output in the work data set *indtraj* (which will be deleted when the user exits from the SAS system). Use the code:

OUTDS = indtraj;

*Example 2:* The user wishes to save program output in the permanent data set *mydata.indtraj* (where *mydata* is the name of a user-defined library and *indtraj* is the permanent data set that will be created by the program and become a member of *mydata*). Use the code:

OUTDS = mydata.indtraj;

*Example 3:* The user does not wish to produce an output data set. Use the code:

OUTDS = ;

**STEP 4.** Save your changes to the program code (if desired) and submit the program.

## Empirical Example

The following empirical example has also been presented in Carrig, Wirth, and Curran (2002). The raw data utilized in the SAS code detailed below is available at [www.curran.edu/~curran/OLStraj.htm](http://www.curran.edu/~curran/OLStraj.htm).

A subset of 221 individuals was selected from the National Longitudinal Survey of Labor Marketing Experience in Youth (NLSY), a study initiated in 1979 by the U.S. Department of Labor. The repeated measure used in the current example, the antisocial behavior subtest of the Behavior Problems Index (BPI), was drawn from a larger battery of instruments administered to NLSY mothers and children. The antisocial behavior subtest of the BPI is one of six subtests developed by Zill and Peterson (Baker, Keck, Mott, & Quinlan, 1993). Six 3-point (not true=0, sometimes true=1, often true=2) Likert-type items make up the subscale. For the present example, responses were summed to compute an overall measure of antisocial behavior; scores could range from 0 to 12. The overall measure of antisocial behavior was computed at each of the four time periods (1986, 1988, 1990, and 1992, denoted as Time 1, Time 2, Time 3, and Time 4, respectively). The resulting variables constructed for Time 1 through Time 4 were named Anti1, Anti2, Anti3, and Anti4, respectively. The individuals selected for the present example had complete data for all repeated measures. See Curran and Bollen (2001) for further details.

### An Unconditional Latent Trajectory Model

To examine the fixed and random components of growth in antisocial behavior, we used PROC CALIS (SAS Institute, 1990) to estimate an unconditional linear LTM for the repeated measures of antisocial behavior collected at Times 1, 2, 3, and 4 (Figure 1). Two latent factors were estimated: the first defined the intercept of the developmental trajectory of antisocial behavior (with all factor loadings fixed to 1.0) and the second defined the linear slope of the trajectory (with factor loadings set to 0, 1, 2, and 3 to define an annual metric of time). The model estimated is presented in Figure 1. Means were estimated for both the intercept and slope factors, with these values representing the model-implied mean developmental trajectory pooled over all individuals. Variances were also estimated for the intercept and slope factors, representing the degree of individual variability in trajectories around the group mean values. The covariance between the two factors represented the covariation between initial level and rate of change. Finally, residual variances were estimated for each repeated measure, and represent the variability in the time-specific measures not accounted for by the underlying random trajectories. It was assumed that measurement error remained constant over time and that residual variances were uncorrelated.

The initial model fit the data well according to the chi-square test of omnibus model fit,  $\chi^2(8) = 5.56, p = .70$ . Numerous fit indices also suggested exemplary model fit to the data, CFI = 1.0, NNFI = 1.0, IFI = 1.0, and 1-RMSEA = 1.0. The estimated means of the latent factors suggested that the model-implied mean trajectory for the sample was characterized by a significant mean BPI score of 1.55 at the first time period ( $p < .001$ ), and a significantly increasing slope of .18 units per year during the study window ( $p < .001$ ). Further, significant variance estimates for both the intercept ( $\hat{\psi} = .97, p < .001$ ) and slope ( $\hat{\psi} = .10, p = .03$ ) factors indicated substantial interindividual variability in both initial level and rate of change in antisocial behavior. Finally, the estimated correlation between the intercept and slope factors

( $r = .49, p = .04$ ) suggested a significant and positive association between antisocial behavior at Time 1 and the rate of change in antisocial behavior over time. Again, note that the  $\hat{\mu}_\alpha$ ,  $\hat{\mu}_\beta$ ,  $\hat{\psi}_\alpha$ ,  $\hat{\psi}_\beta$ , and  $\hat{\psi}_{\alpha\beta}$  resulting from the unconditional LTM represent summary statistics for the latent growth factors, and were estimated without direct observation of individual trajectories.

### Application of the *OLStraj* Macro

Selected output from the *OLStraj* macro is displayed in Figures 2 through 8. Our initial step was to use *OLStraj* to estimate and plot individual trajectories for each observation in the sample. We first requested plots that superimpose estimated *linear* trajectories on the observed repeated measures for an evaluation of individual fit to the data. These plots reveal that for many children in the sample, a linear functional form appears to represent change in antisocial behavior quite well (see Figure 2 for selected plots). This finding is consistent with the excellent fit of the unconditional linear LTM to the antisocial behavior data. We next requested that *OLStraj* add estimated *quadratic* trajectories to the individual trajectory plots. As shown in Figure 3, which presents a subset of the relevant output, it appears that for other children a quadratic functional form of growth better accounts for change in antisocial behavior than a linear function. This finding suggests that if theoretically reasonable, it may be beneficial to fit a quadratic LTM to the observed data and evaluate the significance of improvement in model fit.

The *OLStraj* macro was then employed to visually examine all 221 OLS-estimated individual trajectories simultaneously. The graphs provided by the macro are (a) a plot of overlaid simple trajectories and (b) a plot of overlaid OLS-estimated trajectories. As can be seen in the overlaid OLS-estimated trajectories plot (included as Figure 4), consistent with findings from the unconditional linear LTM, substantial variability in both initial level and rate of change in antisocial behavior appears to exist within the sample. From examination of the plot, it is clear that a sizable number of negative linear slopes, positive linear slopes, and possibly a number of linear slopes very close to zero exist in the sample. Potentially outlying or otherwise problematic observations (e.g., observations with negative OLS-estimated intercepts, which are theoretically impossible) can clearly be discerned from the plot and may be identified for further evaluation.

From Figure 4, it is apparent that when a large number of individuals is incorporated into a single plot, certain individual trajectories become difficult to discern. Accordingly, we next used the macro to visually examine OLS-estimated individual trajectories for a small subset ( $n = 25$ ) of the total sample ( $N = 221$ ; Figure 5). Figure 5 reveals more clearly that a positive rate of change in antisocial behavior over time does not hold for all individuals. In fact, a number of the individuals ( $n = 6$  of 25) in the subset actually appear to experience decreasing trajectories of antisocial behavior.

Distributional characteristics were further explored using the *OLStraj* macro's histogram and box-and-whisker plot option. Examination of a histogram analyzing all  $N = 221$  individual slopes (Figure 6) indicates that the distribution of OLS-estimated latent slopes is centered close to zero ( $M = .18$ ), has a slight positive skew, and represents a relatively poor approximation to the normal distribution. As shown in Figure 7, the box-and-whisker plot demonstrates that extreme values for estimated growth parameters exist, suggesting the possible presence of influential outliers. One of the extreme slopes identified and labeled on the box-and-whisker plot was estimated by *OLStraj* for ID number 69. As shown in Figure 8, the pattern of observed and OLS-estimated antisocial behavior scores for ID 69 is indeed unusual. This observation warrants further attention (e.g., this observation might be checked for keypunch errors, or if

proven to exert an undue influence on model results, considered for removal from the sample on this basis). Because evaluation of outliers is beyond the scope of this paper, we do not address this further here.

### SAS Code for the Empirical Example

- The SAS code used to fit the unconditional linear LTM is as follows:

#### Error!

```
PROC CALIS data = antidata ucov aug;
  LINEQS
    Anti1 = 1f1 + 0f2 + e1,
    Anti2 = 1f1 + 1f2 + e2,
    Anti3 = 1f1 + 2f2 + e3,
    Anti4 = 1f1 + 3f2 + e4,
    f1 = a11 intercept + d1,
    f2 = a12 intercept + d2;
  STD
    e1-e4 = th th th th,
    d1-d2 = ph11 ph22;
  COV
    d1 d2 = ph21;
RUN;.
```

- The base *OLStraj* program code used to produce the empirical example is as follows:**Error!**

```
dm 'out;clear;log;clear;pgm;recall;';
options nocenter linesize=100 nodate nonumber nomprint nosymbolgen;

*****
** PROGRAM NAME:   OLStraj.sas                               **
** AUTHOR:        Madeline Carrig                          **
** LAST MODIFIED: October 3, 2002                          **
** FOR FULL DOCUMENTATION: Visit http://www.unc.edu/~curran/OLStraj.htm **
*****;

filename antidata "C:\WINDOWS\Desktop\anti.dat";

data INITIAL;
  infile antidata;

  * Inputting data in free format;
  input anti1 anti2 anti3 anti4 gen homecog id;
run;

*****
** Macro variables input section                             **
*****;

%let idvarname = id;
%let varlist = anti1 anti2 anti3 anti4;
%let timepts = 0 1 2 3;
%let inclmiss = n;
%let level = both;
%let regtype = lin;
%let numplot = ;
```

```
%let hist = y;
%let outds = ;
*****
** END of user input section
*****;
```

- Modifications made to the base *OLStraj* code to complete the empirical example were as follows:

1. To add estimated quadratic trajectories to the individual trajectory plots, we changed

```
%let regtype = lin;
```

to

```
%let regtype = both;
```

2. To use the macro to visually examine OLS-estimated individual trajectories for a small subset ( $n = 25$ ) of the total sample ( $N = 221$ ), we changed

```
%let numplot = ;
```

to

```
%let numplot = 25;
```

## References

- Baker, P. C., Keck, C. K., Mott, F. L., & Quinlan, S. V. (1993). *NLSY Child Handbook: A guide to the 1986-1990 National Longitudinal Survey of Youth Child Data*. Columbus, OH: Center for Human Resource Research.
- Carrig, M. M., Wirth, R. J., & Curran, P. J. (2002). *A SAS Macro for Estimating and Visualizing Individual Growth Curves*. Manuscript submitted for publication.
- Curran, P. J. & Bollen, K. A. (2001). The best of both worlds: Combining autoregressive and latent curve models. In L. M. Collins & A. G. Sayer (Eds.). *New methods for the analysis of change* (pp. 105–136). Washington, DC: American Psychological Association.
- SAS Institute. (1990). *SAS/STAT user's guide: Vol. 1*. Cary, NC: Author.
- Tukey, J. W. (1977). *Exploratory data analysis*. Reading, MA: Addison-Wesley Publishing Company.

Figures

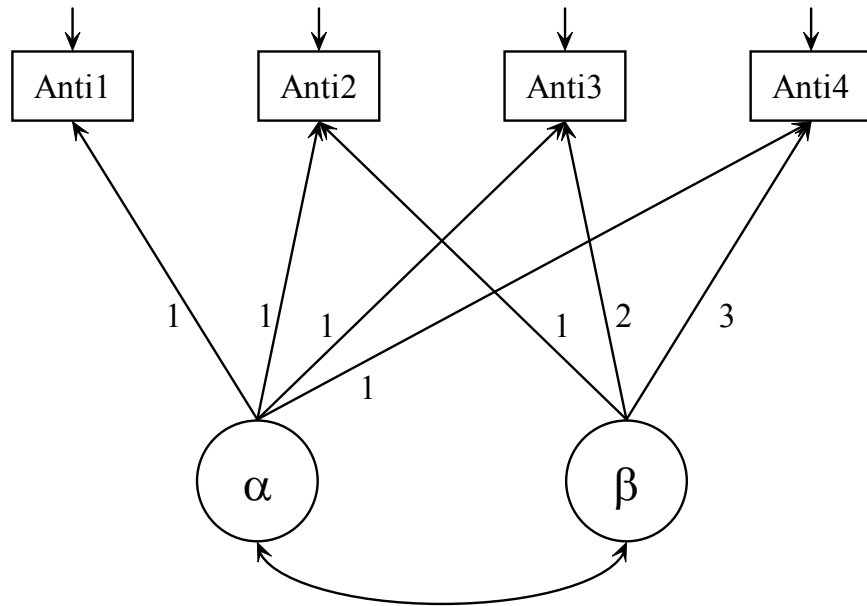


Figure 1. A pictorial representation of the LTM of antisocial behavior.

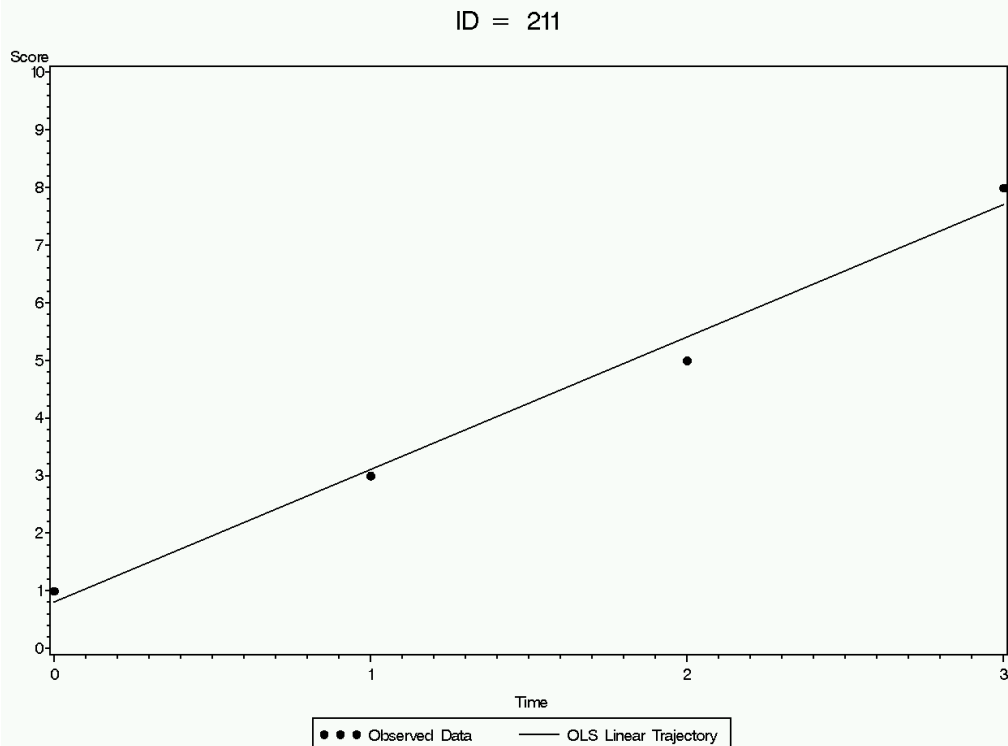
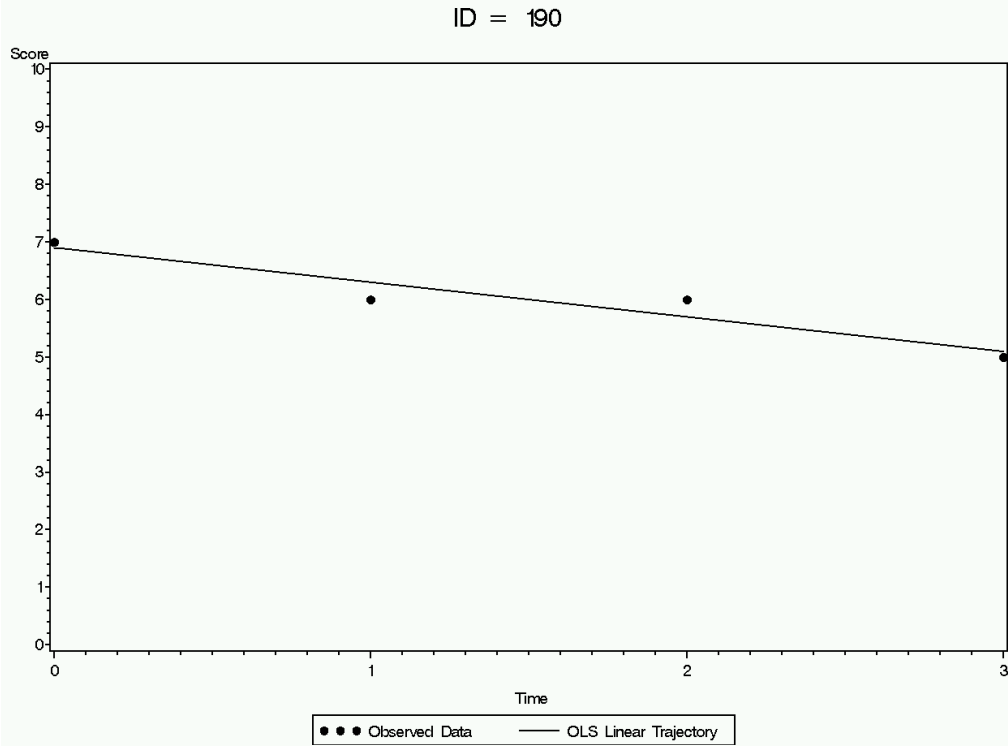


Figure 2. Two children for whom a linear functional form appears to represent growth well.



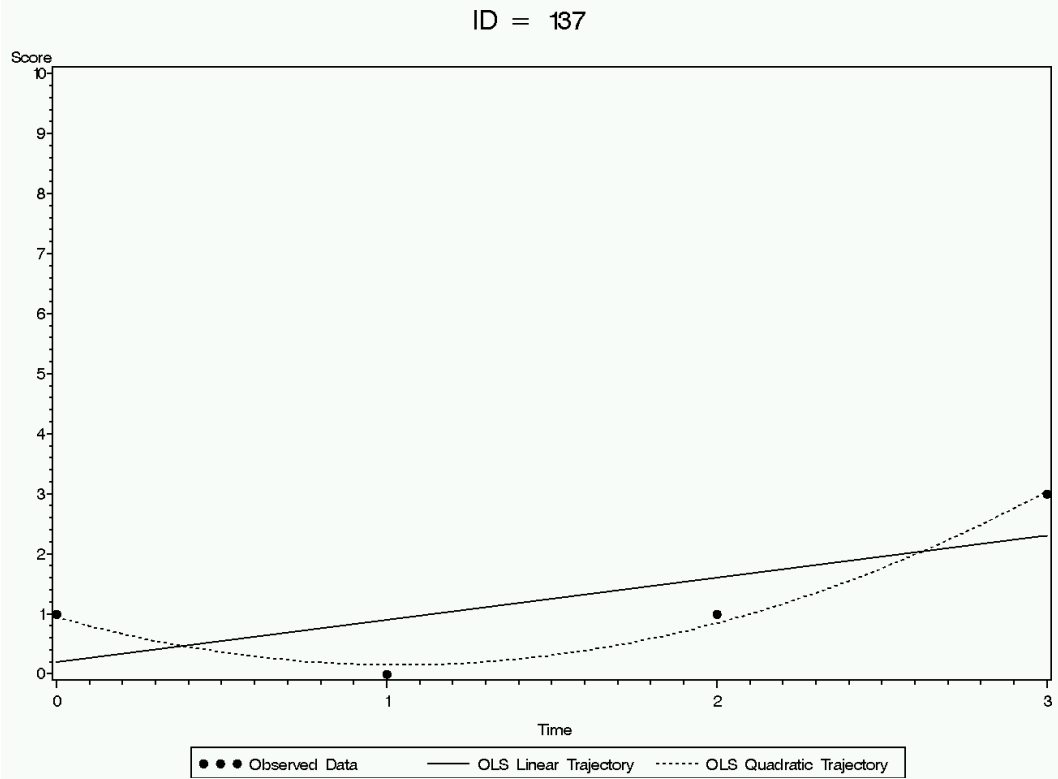
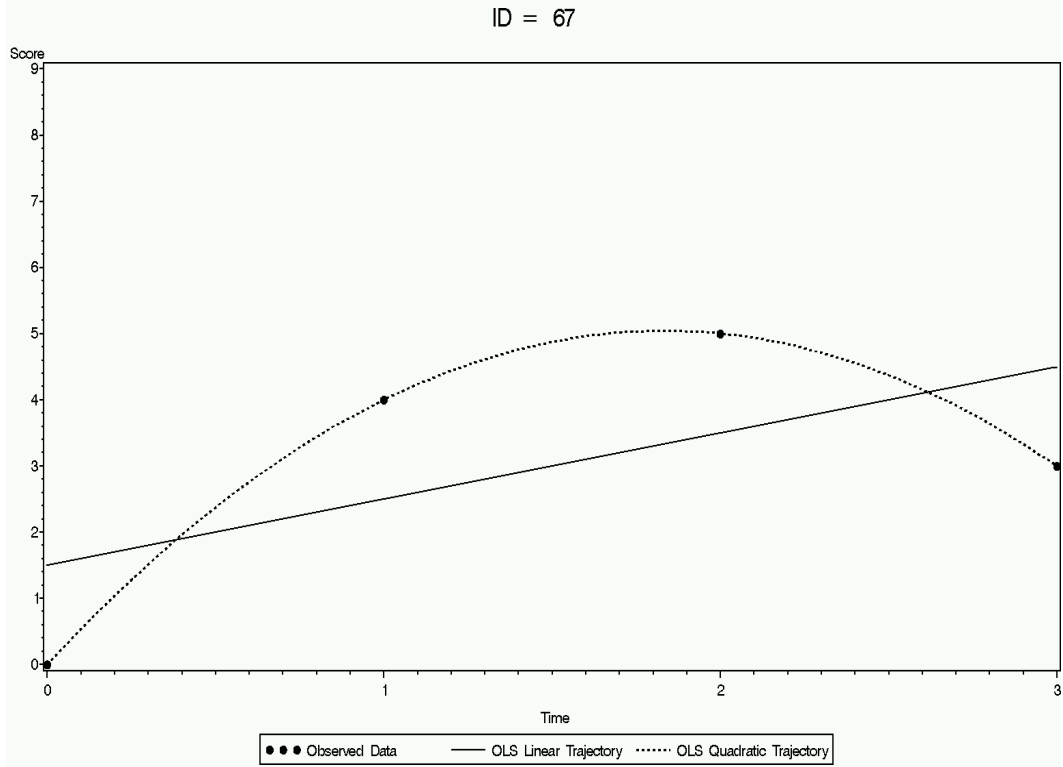


Figure 3. Two children for whom a quadratic functional form of growth appears to better fit the data than a linear functional form.

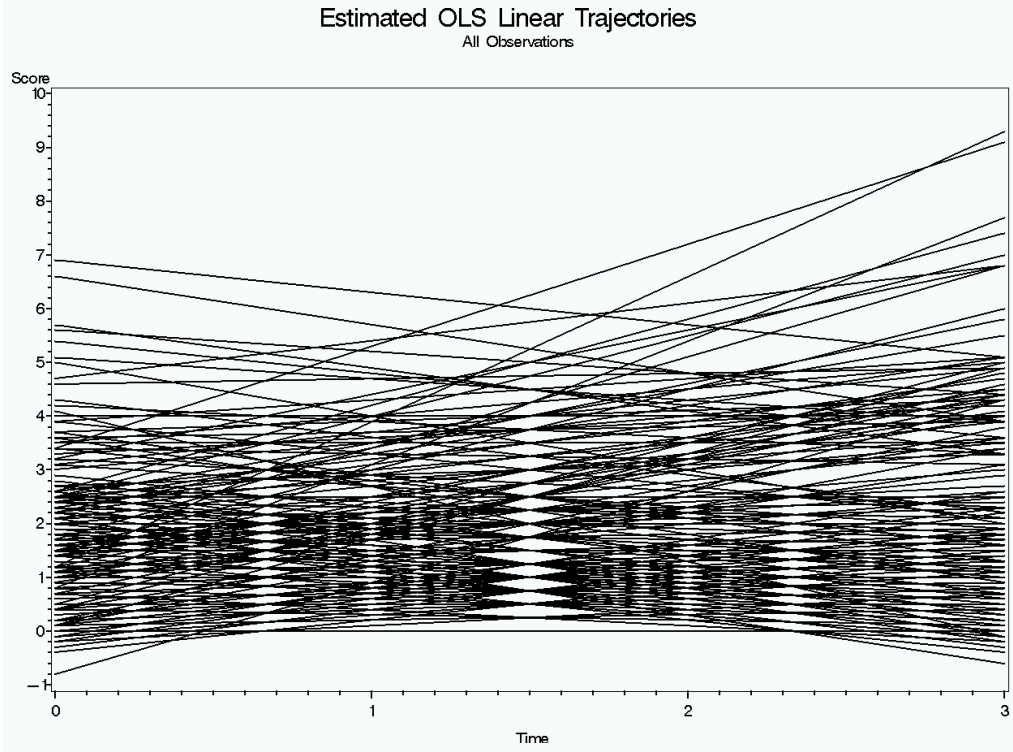


Figure 4. Overlaid OLS-estimated trajectories plot ( $N = 221$ ).

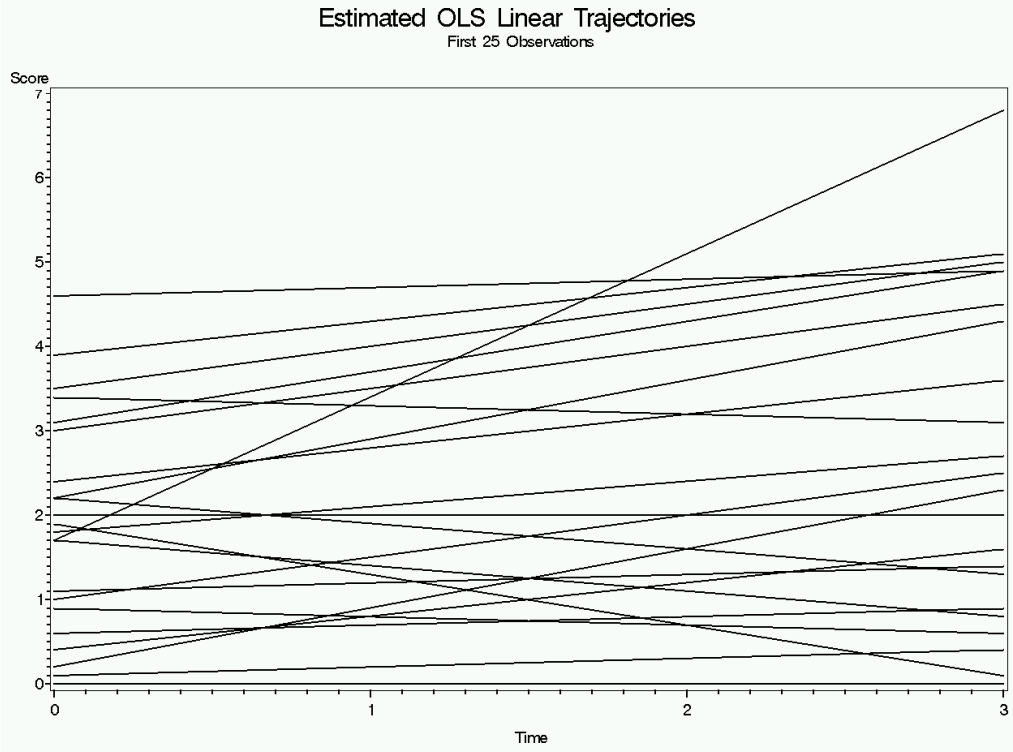


Figure 5. Overlaid OLS-estimated trajectories plot ( $n = 25$ ).

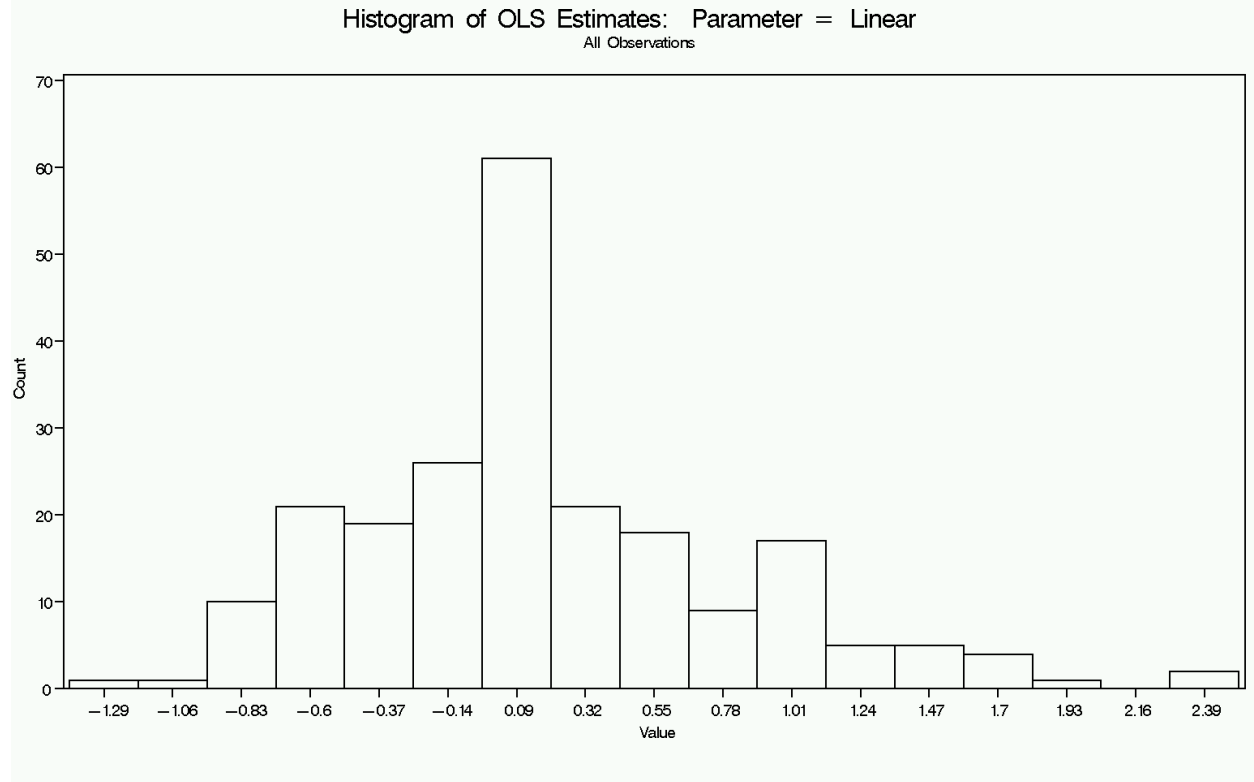


Figure 6. Histogram of OLS-estimated slopes ( $N = 221$ ).

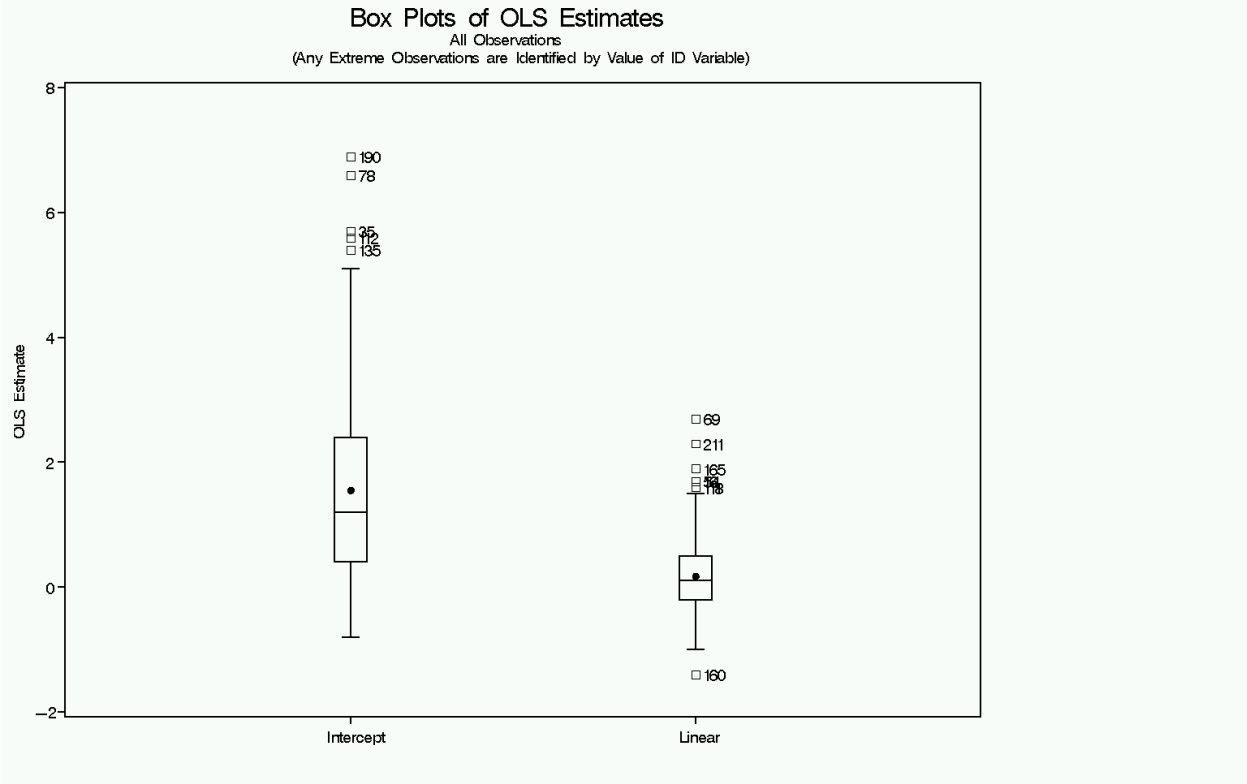


Figure 7. Box-and-whisker plots of OLS-estimated intercepts and slopes ( $N = 221$ ).

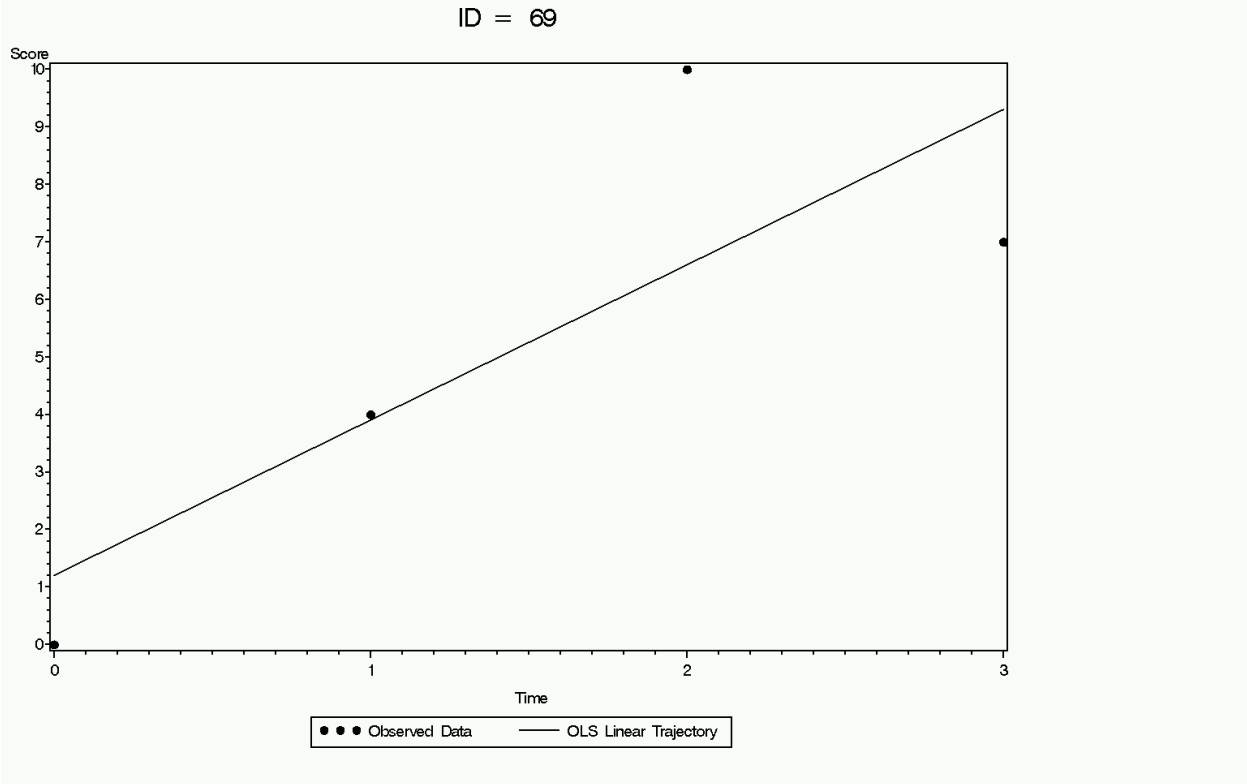


Figure 8. Estimated individual trajectory plot for ID 69, identified as a possible outlier by its extreme OLS-estimated slope.