## threshold — Threshold regression

### Description

`threshold` extends linear regression to allow coefficients to differ across regions. Those regions are identified by a threshold variable being above or below a threshold value. The model may have multiple thresholds, and you can either specify a known number of thresholds or let `threshold` find that number for you through the Bayesian information criterion (BIC), Akaike information criterion (AIC), or Hannan–Quinn information criterion (HQIC).

### Quick start

Threshold regression model for the dependent variable `y` with region-dependent intercepts for two regions of `x`

```
threshold y, threshvar(x)
```

Add the first lag of `x` as a region-invariant variable

```
threshold y l.x, threshvar(x)
```

Add the first lag of `y` as a region-dependent variable

```
threshold y l.x, threshvar(x) regionvars(l.y)
```

Threshold regression model of `y` with region-dependent intercepts for three regions determined by two threshold values of `x`

```
threshold y, threshvar(x) nthresholds(2)
```

Use BIC to select the number of thresholds from a maximum of 5 thresholds

```
threshold y, threshvar(x) optthresh(5)
```

### Menu

Statistics > Time series > Threshold regression model
## Syntax

```
threshold depvar [indepvars] [if] [in], threshvar(varname) [options]
```

`indepvars` is a list of variables with region-invariant coefficients.

<table>
<thead>
<tr>
<th>options</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td></td>
</tr>
<tr>
<td><em>threshvar(varname)</em></td>
<td>threshold variable</td>
</tr>
<tr>
<td>regionvars(varlist)</td>
<td>include region-varying coefficients for specified covariates</td>
</tr>
<tr>
<td>consinvariant</td>
<td>replace region-varying constant with a region-invariant constant</td>
</tr>
<tr>
<td>noconstant</td>
<td>suppress region-varying constant terms</td>
</tr>
<tr>
<td>trim(#)</td>
<td>trimming percentage; default is trim(10)</td>
</tr>
<tr>
<td>nthresholds(#)</td>
<td>number of thresholds; default is nthresholds(1); not allowed with optthresh()</td>
</tr>
<tr>
<td>optthresh(#[, ictype])</td>
<td>select optimal number of thresholds less than or equal to #; not allowed with nthresholds()</td>
</tr>
<tr>
<td><strong>SE/Robust</strong></td>
<td></td>
</tr>
<tr>
<td>vce(vcetype)</td>
<td><code>vcetype</code> may be oim or robust</td>
</tr>
<tr>
<td><strong>Reporting</strong></td>
<td></td>
</tr>
<tr>
<td>level(#)</td>
<td>set confidence level; default is level(95)</td>
</tr>
<tr>
<td>nocnsreport</td>
<td>do not display constraints</td>
</tr>
<tr>
<td>display_options</td>
<td>control columns and column formats, row spacing, line width, display of omitted variables and base and empty cells, and factor-variable labeling</td>
</tr>
<tr>
<td>nodots</td>
<td>suppress replication dots</td>
</tr>
<tr>
<td>dots(#)</td>
<td>display dots every # replications</td>
</tr>
<tr>
<td><strong>Advanced</strong></td>
<td></td>
</tr>
<tr>
<td>ssrs(stub*</td>
<td>newvarlist)</td>
</tr>
<tr>
<td>constraints(numlist)</td>
<td>apply specified linear constraints; not allowed with optthresh()</td>
</tr>
<tr>
<td>coeflegend</td>
<td>display legend instead of statistics</td>
</tr>
</tbody>
</table>

*threshvar() is required.

You must `tsset` your data before using `threshold`; see [TS] tsset.

`indepvars` and `varlist` may contain factor variables; see [U] 11.4.3 Factor variables.

`depvar`, `indepvars`, `varlist`, and `varname` may contain time-series operators; see [U] 11.4.4 Time-series varlists.

by, rolling, and statsby are allowed; see [U] 11.1.10 Prefix commands.

`coeflegend` does not appear in the dialog box.

See [U] 20 Estimation and postestimation commands for more capabilities of estimation commands.

<table>
<thead>
<tr>
<th>ictype</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bic</td>
<td>Bayesian information criterion (BIC); the default</td>
</tr>
<tr>
<td>aic</td>
<td>Akaike information criterion (AIC)</td>
</tr>
<tr>
<td>hqic</td>
<td>Hannan–Quinn information criterion (HQIC)</td>
</tr>
</tbody>
</table>
Options

Model

threshvar(varname) specifies the variable from which values are to be selected as thresholds.

threshvar() is required.

regionvars(varlist) specifies additional variables whose coefficients vary over the regions defined by the estimated thresholds. By default, only the constant term varies over regions.

consinvariant specifies that the constant term should be region invariant instead of region varying.

noconstant suppresses the region-varying constant terms (intercepts) in the model.

trim(#) specifies that threshold treat the value at the #th percentile of the threshold variable as the first possible threshold and the value at the (100 − #)th percentile as the last possible threshold. # must be an integer between 1 and 49. The default is trim(10).

nthresholds(#) specifies the number of thresholds. Specifying the number of thresholds is equivalent to specifying the number of regions because the number of regions is equal to # + 1 thresholds. The default is nthresholds(1), equivalent to 2 regions.

optthresh(# [, ictype]) specifies that threshold choose the optimal number of thresholds, up to a possible #. By default, the optimal number of thresholds is based on the BIC, but you may specify the information criterion (ictype) to be used. ictype may be bic (the default), aic, or hqic.

SE/Robust

vce(vcetype) specifies the type of standard error reported, which includes types that are derived from asymptotic theory (oim) and that are robust to some kinds of misspecification (robust); see [R] vce_option.

Reporting

level(#), nocnsreport; see [R] Estimation options.

display_options: noci, nopvalues, noomitted, vsquish, noemptycells, baselevels, allbaselevels, notvlabel, fvwrap(#), fvwrapon(style), cformat(%fmt), pformat(%fmt), sformat(%fmt), and nolstretch; see [R] Estimation options.

nodots and dots(#) specify whether to display replication dots. By default, one dot character is displayed for each successful replication. A red 'x' is displayed if command returns an error. You can also control whether dots are displayed using set dots; see [R] set.

nodots suppresses display of the replication dots.

dots(#) displays dots every # replications. dots(0) is a synonym for nodots.

Advanced

ssrs(stub*|newvarlist) creates a variable containing the sum of squared residuals (SSRs) that was computed for each tentative threshold value during the search for the kth threshold. For observations where the value of the threshold variable specified in threshvar() is not a tentative threshold, the corresponding value of the variable created by ssrs() for that observation will be missing.

If you specify stub*, Stata will create k new variables with the names stub1, . . . , stubk, which will contain the SSRs for the 1st, . . . , kth thresholds, where k is the # specified in nthresholds() or the optimal number of thresholds if optthresh() is specified.
threshold — Threshold regression

If you specify a list of new variable names, you may request SSRs for up to the number specified in nthresholds(). If you specify optthresh(#) and the optimal number of thresholds is less than #, any additional variables will contain only missing values.

constraints(numlist) specifies the constraints by number after they have been defined by using the constraint command; see [R] constraints. constraints() may not be specified with optthresh().

The following option is available with threshold but is not shown in the dialog box: coeflegend; see [R] Estimation options.

Remarks and examples

threshold extends linear regression to allow coefficients to differ across regions. Those regions are identified by a threshold variable being above or below a threshold value. The model may have multiple thresholds, and you can either specify a known number of thresholds or let threshold find that number for you by minimizing an information criterion.

These models are good alternatives to linear models for capturing abrupt breaks or asymmetries observed in most macroeconomic time series over the course of a business cycle. Common threshold regression models include the threshold autoregression model and self-exciting threshold model. In the threshold autoregression model, proposed by Tong (1983), the dependent variable is a function of its own lags; see Tong (1990) for details. In the self-exciting threshold model, the lagged dependent variable is used as the threshold variable. For a survey of threshold regression models in economics, refer to Hansen (2011).

Formally, consider a threshold regression with two regions defined by a threshold \(\gamma\). This is written as

\[
y_t = x_t'\beta + z_t'\delta_1 + \epsilon_t \quad \text{if} \quad -\infty < w_t \leq \gamma
\]

\[
y_t = x_t'\beta + z_t'\delta_2 + \epsilon_t \quad \text{if} \quad \gamma < w_t < \infty
\]

where \(y_t\) is the dependent variable, \(x_t\) is a \(1 \times k\) vector of covariates possibly containing lagged values of \(y_t\), \(\beta\) is a \(k \times 1\) vector of region-invariant parameters, \(\epsilon_t\) is an IID error with mean 0 and variance \(\sigma^2\), \(z_t\) is a vector of exogenous variables with region-specific coefficient vectors \(\delta_1\) and \(\delta_2\), and \(w_t\) is a threshold variable that may also be one of the variables in \(x_t\) or \(z_t\).

The parameters of interest are \(\beta\), \(\delta_1\), and \(\delta_2\). Region 1 is defined as the subset of observations in which the value of \(w_t\) is less than the threshold \(\gamma\). Similarly, Region 2 is defined as the subset of observations in which the value of \(w_t\) is greater than \(\gamma\). Inference on the nuisance parameter \(\gamma\) is complicated because of its nonstandard asymptotic distribution; see Hansen (1997, 2000).

threshold uses conditional least squares to estimate the parameters of the threshold regression model. The threshold value is estimated by minimizing the SSR obtained for all tentative thresholds; see Methods and Formulas for details.

Example 1: Threshold regression model

We are interested in the effect of inflation and the output gap on interest rates in a typical business cycle. Our dataset, usmacro.dta, contains quarterly data from 1954q3 to 2010q4 on the U.S. federal funds interest rate (fedfunds), the current inflation rate (inflation), and the output gap (ogap). These data were obtained from the Federal Reserve Economic Database, a macroeconomic database provided by the Federal Reserve Bank of Saint Louis; see [D] import fred.
In our model, we assume that the Federal Reserve sets the federal funds interest rate based on its most recent lag (l.fedfunds), the current inflation rate, and the output gap. We use the first lag of the federal funds interest rate as the threshold variable, and we assume one threshold, or two regions, so the model may be written as

\[
\text{fedfunds}_t = \delta_{10} + \delta_{11} l\text{.fedfunds} + \delta_{12} \text{inflation} + \delta_{13} \text{ogap} + \epsilon_t \text{ if } -\infty < \text{fedfunds} \leq \gamma
\]

\[
\text{fedfunds}_t = \delta_{20} + \delta_{21} l\text{.fedfunds} + \delta_{22} \text{inflation} + \delta_{23} \text{ogap} + \epsilon_t \text{ if } \gamma < \text{fedfunds} < \infty
\]

```
.use https://www.stata-press.com/data/r16/usmacro
(Federal Reserve Economic Data - St. Louis Fed)
.threshold fedfunds, regionvars(l.fedfunds inflation ogap)
> threshvar(l.fedfunds)
Searching for threshold: 1
(Running 177 regressions)

.................................................. 50
.................................................. 100
.................................................. 150

Threshold regression

<table>
<thead>
<tr>
<th>Order</th>
<th>Threshold</th>
<th>SSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.3500</td>
<td>155.4266</td>
</tr>
</tbody>
</table>

The output consists of two tables. The first table reports the estimated threshold and the corresponding SSR. The column labeled Order ranks the order in which the threshold was estimated. Because there is only a single threshold in this example, the order of 1 corresponds to the threshold value that contributes most in minimizing the SSR. The order is more relevant in the case of multiple thresholds.

The estimated threshold of 9.35% splits the sample into two regions. Region1 corresponds to the portion of the sample in which the federal funds interest rate from last quarter is less than or equal to 9.35%. Region2 corresponds to the portion of the sample in which the federal funds interest rate from last quarter is greater than 9.35%.
Coefficient estimates appear in the second table. In Region1, or the low federal funds interest rate region, the coefficient of 0.93 on the lag of fedfunds indicates that fedfunds is highly persistent. The coefficient on inflation is not significantly different from zero, which implies that the Federal Reserve does not attach any weight to the inflation rate in the low federal funds interest rate region and cares more about the output gap. In Region2, or the high federal funds interest rate region, the coefficient on the lag of fedfunds is only 0.70, which indicates that fedfunds is not as persistent as in Region1. In Region 2, the coefficient on ogap is not significantly different from zero, but the coefficient on inflation is, so we may infer that the Federal Reserve cares more about inflation than it does about the output gap.

Example 2: Selecting the threshold variable

In example 1, we use l.fedfunds as the threshold variable. The Federal Reserve may also consider the output gap to be an important factor that determines the interest rate. In this example, we fit models using the first and second lags of output gap as threshold variables. We store the estimates of each model for comparison using estimates store.

First, we store the estimates of example 1 as Model1.

```
. estimates store Model1
```

Next, we fit two models, one with l.ogap as the threshold variable and the other with l2.ogap as the threshold variable. We store the estimates as Model2 and Model3, respectively.

```
. threshold fedfunds, regionvars(l.fedfunds inflation ogap) threshvar(l.ogap)
   (output omitted)
. estimates store Model2

. threshold fedfunds, regionvars(l.fedfunds inflation ogap) threshvar(l2.ogap)
   (output omitted)
. estimates store Model3
```
We compare the SSR and information criteria of all fitted models. Combining all estimates, we get the following table:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model1</th>
<th>Model2</th>
<th>Model3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Region1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fedfunds</td>
<td>.92689581</td>
<td>.90860624</td>
<td>.8533835</td>
</tr>
<tr>
<td>L1. inflation</td>
<td>.0602282</td>
<td>.19755936</td>
<td>.28187753</td>
</tr>
<tr>
<td>ogap</td>
<td>.0990296</td>
<td>.29553563</td>
<td>.14449944</td>
</tr>
<tr>
<td>_cons</td>
<td>.19662232</td>
<td>1.4172835</td>
<td>.54280799</td>
</tr>
<tr>
<td><strong>Region2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fedfunds</td>
<td>.69741126</td>
<td>.90512493</td>
<td>.90879685</td>
</tr>
<tr>
<td>L1. inflation</td>
<td>.16764486</td>
<td>.0896271</td>
<td>.08361366</td>
</tr>
<tr>
<td>ogap</td>
<td>.05587384</td>
<td>.15549667</td>
<td>.15233276</td>
</tr>
<tr>
<td>_cons</td>
<td>2.1626095</td>
<td>.17554381</td>
<td>.15764634</td>
</tr>
<tr>
<td><strong>Statistics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ssr</td>
<td>155.42663</td>
<td>145.96457</td>
<td>142.0608</td>
</tr>
<tr>
<td>aic</td>
<td>-63.143795</td>
<td>-77.087586</td>
<td>-83.105746</td>
</tr>
<tr>
<td>bic</td>
<td>-35.922376</td>
<td>-49.866167</td>
<td>-55.884327</td>
</tr>
<tr>
<td>hqic</td>
<td>-52.153481</td>
<td>-66.097272</td>
<td>-72.115432</td>
</tr>
</tbody>
</table>

From the table above, we see that Model3 provides the best fit. This is the model that uses the second lag of output gap as the threshold variable.

Example 3: Selecting the number of thresholds

Instead of assuming a known number of thresholds, we can use model selection to choose the number of thresholds that minimizes a certain information criterion. In example 2, using \texttt{12.ogap} as the threshold variable provided the best fit. We fit a model with an unknown number of thresholds using \texttt{12.ogap} as the threshold variable. We can do this by specifying the maximum number of thresholds in the \texttt{optthresh()} option. In this example, we specify \texttt{5} as the maximum number of thresholds.
. threshold fedfunds, regionvars(1.fedfunds inflation ogap) threshvar(12.ogap)
> optthresh(5) nodots

Searching for threshold: 1
(Running 177 regressions)
Searching for threshold: 2
(Running 146 regressions)
Searching for threshold: 3
(Running 105 regressions)
Searching for threshold: 4
(Running 52 regressions)
Searching for threshold: 5
(Running 40 regressions)

Threshold regression
Full sample: 1955q3 - 2010q4 Number of obs = 222
Number of thresholds = 2 Max thresholds = 5
Threshold variable: L2.ogap BIC = -60.0780

<table>
<thead>
<tr>
<th>Order</th>
<th>Threshold</th>
<th>SSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-3.1787</td>
<td>142.0608</td>
</tr>
<tr>
<td>2</td>
<td>-0.5351</td>
<td>126.4718</td>
</tr>
</tbody>
</table>

| fedfunds       | Coef.  | Std. Err. | z     | P>|z|  | [95% Conf. Interval] |
|-----------------|--------|-----------|-------|------|---------------------|
| Region1 fedfunds|        |           |       |      |                     |
| L1.             | .8533835 | .0435617  | 19.59 | 0.000 | .7680042 | .9387628 |
| inflation       | .2818775 | .0679414  | 4.15  | 0.000 | .1487148 | .4150403 |
| ogap            | .1444994 | .072028   | 2.01  | 0.045 | .0033272 | .2856717 |
| _cons           | .542808 | .4297171  | 1.26  | 0.207 | -.299422  | 1.385038 |
| Region2 fedfunds|        |           |       |      |                     |
| L1.             | .9406721 | .0338085  | 27.82 | 0.000 | .8744087 | 1.006935 |
| inflation       | -.0191805 | .0462729 | -0.41 | 0.679 | -.1098737 | .0715128 |
| ogap            | .2387934 | .0565521  | 4.22  | 0.000 | .1279534 | .3496334 |
| _cons           | .638354 | .1591717  | 4.01  | 0.000 | .3263832 | .9503249 |
| Region3 fedfunds|        |           |       |      |                     |
| L1.             | .8892742 | .0593484  | 14.98 | 0.000 | .7729535 | 1.005595 |
| inflation       | .1851127 | .0532112  | 3.48  | 0.001 | .0808206 | .2894047 |
| ogap            | .1984744 | .039236   | 5.06  | 0.000 | .1215733 | .2753754 |
| _cons           | -.3086232 | .2215645 | -1.39 | 0.164 | -.7428817 | .1256352 |

We estimate two thresholds using the default BIC (bic). The first estimated threshold is 12.ogap = −3.18. A negative value of 12.ogap implies low economic growth two quarters ago. The second estimated threshold is −0.54 and also represents a negative output gap, although with a smaller magnitude. The two thresholds split the sample into three regions.

In the first region, Region1, the second lag of output gap is less than or equal to −3.18, indicating a recession period. In this case, the coefficients on inflation and ogap are both significantly different from zero, which implies that the Federal Reserve considers the current inflation rate and the output gap as important predictors of federal funds interest rate.
In the second region, Region2, the second lag of output gap is between $-3.18$ and $-0.54$. In this case, only the coefficient on output gap is significantly different from zero, which implies that the Federal Reserve only considers the output gap as a predictor of federal funds interest rate.

In the third region, Region3, the second lag of output gap is greater than $-0.54$. In this case, the coefficients on current inflation rate and output gap are both significantly different from zero, which implies that the Federal Reserve considers the current inflation rate and the output gap as important predictors of federal funds interest rate.

Stored results

threshold stores the following in e():

Scalars
- \text{e(N)}: number of observations
- \text{e(k)}: number of parameters
- \text{e(nthresholds)}: number of thresholds
- \text{e(optthresh)}: number of maximum thresholds; if specified
- \text{e(ssr)}: sum of squared residuals of the model
- \text{e(rank)}: rank of \text{e(V)}
- \text{e(aic)}: Akaike information criterion
- \text{e(bic)}: Bayesian information criterion
- \text{e(hqic)}: Hannan–Quinn information criterion
- \text{e(tmin)}: minimum time
- \text{e(tmax)}: maximum time

Macros
- \text{e(cmd)}: threshold
- \text{e(cmdline)}: command as typed
- \text{e(eqnames)}: names of equations
- \text{e(depvar)}: name of dependent variable
- \text{e(regionvars)}: list of region-specific variables
- \text{e(indepvars)}: list of region-invariant variables
- \text{e(threshvar)}: name of the threshold variable
- \text{e(criteria)}: information criteria if \text{optthresh($\#$, ictype)} is specified
- \text{e(title)}: title in estimation output
- \text{e(tsfmt)}: format for the current time variable
- \text{e(tmns)}: formatted minimum time
- \text{e(tmxs)}: formatted maximum time
- \text{e(vcetype)}: \text{vce} specified in \text{vce()}
- \text{e(vce)}: \text{vce} specified in \text{vce()}
- \text{e(properties)}: \text{b V}
- \text{e(predict)}: program used to implement \text{predict}
- \text{e(marginsnotok)}: predictions disallowed by \text{margins}
- \text{e(asbalanced)}: factor variables \text{fvset} as \text{asbalanced}
- \text{e(asobserved)}: factor variables \text{fvset} as \text{asobserved}

Matrices
- \text{e(b)}: coefficient vector
- \text{e(Cns)}: constraints matrix
- \text{e(V)}: variance–covariance matrix of the estimators
- \text{e(ssrmat)}: sum of squared residuals for each estimated threshold
- \text{e(thresholds)}: matrix of estimated thresholds
- \text{e(nobs)}: number of observations in each region

Functions
- \text{e(sample)}: marks estimation sample
Methods and formulas are presented under the following headings:

Introduction
Model with more than two regions

Introduction

Consider a threshold regression with two regions defined by a threshold $\gamma$. This is written as

$$
y_t = \mathbf{x}_t \beta + \mathbf{z}_t \delta_1 + \epsilon_t \quad \text{if} \quad -\infty < w_t \leq \gamma
$$

$$
y_t = \mathbf{x}_t \beta + \mathbf{z}_t \delta_2 + \epsilon_t \quad \text{if} \quad \gamma < w_t < \infty
$$

where $y_t$ is the dependent variable, $\mathbf{x}_t$ is a $1 \times k$ vector of covariates possibly containing lagged values of $y_t$, $\beta$ is a $k \times 1$ vector of region-invariant parameters, $\mathbf{z}_t$ is a vector of exogenous variables with region-specific coefficient vectors $\delta_1$ and $\delta_2$, $w_t$ is a threshold variable that may also be one of the variables in $\mathbf{x}_t$ or $\mathbf{z}_t$, and $\epsilon_t$ is an IID error with mean 0 and variance $\sigma^2$.

The estimated threshold ($\hat{\gamma}$) is one of the values in the threshold variable $w_t$. To estimate the threshold, we minimize the least squares of the following regression with $T$ observations and two regions,

$$
y_t = \mathbf{x}_t \beta + \mathbf{z}_t \delta_1 I(-\infty < w_t \leq \gamma) + \mathbf{z}_t \delta_2 I(\gamma < w_t < \infty) + \epsilon_t
$$

for a sequence of $T_1$ values in $w_t$, where $T_1 < T$. The default trimming percentage is set to 10%, which implies that $T_1$ corresponds to the number of observations between the 10th and the 90th percentile of $w_t$. The estimator for the threshold is

$$
\hat{\gamma} = \arg \min_{\gamma \in \Gamma} S_{T_1}(\gamma)
$$

where $\Gamma = (-\infty, \infty)$,

$$
S_{T_1}(\gamma) = \sum_{t=1}^{T} \{y_t - \mathbf{x}_t \beta - \mathbf{z}_t \delta_1 I(-\infty < w_t \leq \gamma) - \mathbf{z}_t \delta_2 I(\gamma < w_t < \infty)\}^2
$$

is a $T_1 \times 1$ vector of SSR, and $\gamma$ is a $T_1 \times 1$ vector of tentative thresholds.

Model with more than two regions

In general, a threshold regression model with $m$ thresholds has $m+1$ regions. Let $j = 1, \ldots, m+1$ index the regions. We can write the model as

$$
y_t = \mathbf{x}_t \beta + \mathbf{z}_t \delta_1 I_1(\gamma_1, w_t) + \cdots + \mathbf{z}_t \delta_{m+1} I_{m+1}(\gamma_{m+1}, w_t) + \epsilon_t
$$

$$
y_t = \mathbf{x}_t \beta + \sum_{j=1}^{m+1} \mathbf{z}_t \delta_j I_j(\gamma_j, w_t) + \epsilon_t
$$

where $\gamma_1 < \gamma_2 < \cdots < \gamma_m$ are ordered thresholds with $\gamma_0 = -\infty$ and $\gamma_{m+1} = \infty$. $I_j(\gamma_j, w_t) = I(\gamma_{j-1} < w_t \leq \gamma_j)$ is an indicator for the $j$th region. Conditional on all estimated thresholds ($\hat{\gamma}_1, \ldots, \hat{\gamma}_m$), the threshold regression model is linear, and the remaining parameters are estimated using least squares.
The thresholds are estimated sequentially as described below. Let $\gamma^*_1, \ldots, \gamma^*_m$ represent the $m$ thresholds in the order of estimation. Gonzalo and Pitarakis (2002) show that the thresholds estimated sequentially are $T$ consistent. The first threshold ($\gamma^*_1$) is estimated assuming a model with two regions as described in the previous section. Conditional on the first threshold, the second threshold is estimated as the value that yields the minimum sum of squared errors over all observations in $w_t$ excluding the first threshold. The estimator of the second threshold $\gamma^*_2$ is obtained by minimizing the least squares of a regression with three regions conditional on the first estimated threshold $\hat{\gamma}^*_1$. The estimator is given by

$$\hat{\gamma}^*_2 = \arg \min_{\gamma^* \in \Gamma_2} S_{T_2}(\gamma^* | \hat{\gamma}^*_1)$$

where $\Gamma_2 = (\gamma_0, \hat{\gamma}^*_1) \cup (\hat{\gamma}^*_1, \gamma_3)$ and $T_2 < T_1$.

In general, the $l$th threshold minimizes the SSR conditional on the $l - 1$ estimated thresholds and is given by

$$\hat{\gamma}^*_l = \arg \min_{\gamma^* \in \Gamma_l} S_{T_l}(\gamma^* | \hat{\gamma}^*_1, \ldots, \hat{\gamma}^*_{l-1})$$

where $\Gamma_l = (\gamma_0, \gamma_{m+1})$ excluding $\hat{\gamma}^*_1, \ldots, \hat{\gamma}^*_{l-1}$.

When the number of thresholds is not known a priori, threshold selects the optimal number of thresholds based on AIC, BIC, or HQIC, which is defined based on SSR from the fitted model as

$$\text{AIC} = T \ln(\text{SSR}/T) + 2k$$
$$\text{BIC} = T \ln(\text{SSR}/T) + k \ln(T)$$
$$\text{HQIC} = T \ln(\text{SSR}/T) + 2k \ln(\ln(T))$$

where $k$ is the number of parameters in the model. See Gonzalo and Pitarakis (2002) for Monte Carlo studies of selecting the number of thresholds based on information criteria.

References


Also see

[TS] **threshold postestimation** — Postestimation tools for threshold

[TS] **mswitch** — Markov-switching regression models

[TS] **tsset** — Declare data to be time-series data

[R] **regress** — Linear regression

[U] 20 **Estimation and postestimation commands**