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Stata tip 58: nl is not just for nonlinear models

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1 Introduction

The `nl` command makes performing nonlinear least-squares estimation almost as easy as performing linear regression. In this tip, three examples are given where `nl` is preferable to `regress`, even when the model is linear in the parameters.

2 Transforming independent variables

Using the venerable `auto` dataset, suppose we want to predict the weight of a car based on its fuel economy measured in miles per gallon. We first plot the data:

```
. sysuse auto
. scatter weight mpg
```

Clearly, there is a negative relationship between `weight` and `mpg`, but is that relationship linear? The engineer in each of us believes that the amount of gasoline used to go one mile should be a better predictor of weight than the number of miles a car can go on one gallon of gas, so we should focus on the reciprocal of `mpg`. One way to proceed would be to create a new variable, `gpm`, measuring gallons of gasoline per mile and then to use `regress` to fit a model of `weight` on `gpm`. However, consider using `nl` instead:

```
. nl (weight = {b0} + {b1}/mpg)
(obs = 74)
Iteration 0: residual SS = 1.19e+07
Iteration 1: residual SS = 1.19e+07
```

Source	SS	df	MS			
Model	32190898.6	1	32190898.6	R-squared	=	0.7300
Residual	11903279.8	72	165323.33	Adj R-squared	=	0.7263
				Root MSE	=	406.5997
Total	44094178.4	73	604029.841	Res. dev.	=	1097.134

weight	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
/b0	415.1925	192.5243	2.16	0.034	31.40241	798.9826
/b1	51885.27	3718.301	13.95	0.000	44472.97	59297.56

Parameter b0 taken as constant term in model & ANOVA table

(You can verify that R^2 from this model is higher than that from a linear model of `weight` on `mpg`. You can also verify that our results match those from `regressing weight` on `gpm`.)

Here a key advantage of `nl` is that we do not need to create a new variable containing the reciprocal of `mpg`. When doing exploratory data analysis, we might want to consider using the natural log or square root of a variable as a regressor, and using `nl` saves us some typing in these cases. In general, instead of typing

```
. generate sqrtx = sqrt(x)
. regress y sqrtx
```

we can type

```
. nl (y = {b0} + {b1}*sqrt(x))
```

3 Marginal effects and elasticities

Using `nl` has other advantages as well. In many applications, we include not just the variable x in our model but also x^2 . For example, most wage equations express log wages as a function of experience and experience squared. Say we want to fit the model

$$y_i = \alpha + \beta_1 x_i + \beta_2 x_i^2 + \epsilon_i$$

and then determine the elasticity of y with respect to x ; that is, we want to know the percent by which y will change if x changes by one percent.

Given the interest in an elasticity, the inclination might be to use the `mfx` command with the `eyex` option. We might type

```
. generate xsq = x^2
. regress y x xsq
. mfx compute, eyex
```

These commands will not give us the answer we expect because `regress` and `mfx` have no way of knowing that `xsq` is the square of `x`. Those commands just see two independent variables, and `mfx` will return two “elasticities”, one for `x` and one for `xsq`. If x changes by some amount, then clearly x^2 will change as well; however, `mfx`, when computing the derivative of the regression function with respect to `x`, holds `xsq` fixed!

The easiest way to proceed is to use `nl` instead of `regress`:

```
. nl (y = {a} + {b1}*x + {b2}*x^2), variables(x)
. mfx compute, eyex
```

Whenever you intend to use `mfx` after `nl`, you must use the `variables()` option. This option causes `nl` to save those variable names among its estimation results.

4 Constraints

`nl` makes imposing nonlinear constraints easy. Say you have the linear regression model

$$y_i = \alpha + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \epsilon_i$$

and for whatever reason you want to impose the constraint that $\beta_2 \beta_3 = 5$. We cannot use the `constraint` command in conjunction with `regress` because `constraint` only works with linear constraints. `nl`, however, provides an easy way out. Our constraint implies that $\beta_3 = 5/\beta_2$, so we can type

```
. nl (y = {a} + {b1}*x1 + {b2=1}*x2 + (5/{b2})*x3)
```

Here we initialized β_2 to be 1 because if the product of β_2 and β_3 is not 0, then neither of those parameters can be 0, which is the default initial value used by `nl`.