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Estimating Geweke's (1982) measure of instantaneous feedback

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Abstract. In this article, we describe the `gwke82` command, which implements a measure of instantaneous feedback for two time series following Geweke (1982, *Journal of the American Statistical Association* 77: 304–313).

Keywords: st0287, gwke82, Geweke, Granger, causality, vector autoregression, time series, instantaneous feedback

1 Introduction

Tests of statistical causality are really tests of whether lags of one variable can be used to predict current values of another variable. If data are measured frequently, and the causality is not instantaneous, then this is adequate. However, if data are measured infrequently (for example, most macroeconomic data are measured yearly), then standard Granger (1969) causality tests may miss much of the contemporaneous correlation between variables. Geweke (1982) proposed a measure of instantaneous correlation, calculated from the residuals of standard Granger causality tests, that captures "instantaneous feedback". Our command, `gwke82`, quickly estimates such Geweke-type instantaneous feedback between pairs of variables.

Granger-type causality is quite common in financial economics research as well as other disciplines. Geweke-type causality, however, has not received this kind of research attention.[1] We think that this is due to the lack of econometric software coverage of Geweke-type causality. Our suggested command, `gwke82`, is intended to fill this void.

1. Interestingly, Geweke-type causality has received attention from neuroscience; for example, see Zhang et al. (2010).

While the Geweke (1982) method applies to any vector-valued linear function, the intuition behind the technique can be more easily seen for a system of two random variables that can be estimated using the standard vector autoregression methodology:[2]

$$x_t = \sum_{s=1}^{p} E_{1s} x_{t-s} + u_{1t}, \qquad \mathrm{Var}(u_{1t}) = \Sigma_1 \tag{1}$$

$$y_t = \sum_{s=1}^{p} G_{1s} y_{t-s} + v_{1t}, \qquad \mathrm{Var}(v_{1t}) = T_1 \tag{2}$$

$$x_t = \sum_{s=1}^{p} E_{2s} x_{t-s} + \sum_{s=1}^{p} F_{2s} y_{t-s} + u_{2t}, \qquad \mathrm{Var}(u_{2t}) = \Sigma_2 \tag{3}$$

$$y_t = \sum_{s=1}^{p} G_{2s} y_{t-s} + \sum_{s=1}^{p} H_{2s} x_{t-s} + v_{2t}, \qquad \mathrm{Var}(v_{2t}) = T_2 \tag{4}$$

$$x_t = \sum_{s=1}^{p} E_{3s} x_{t-s} + \sum_{s=0}^{p} F_{3s} y_{t-s} + u_{3t}, \qquad \mathrm{Var}(u_{3t}) = \Sigma_3 \tag{5}$$

$$y_t = \sum_{s=1}^{p} G_{3s} y_{t-s} + \sum_{s=0}^{p} H_{3s} x_{t-s} + v_{3t}, \qquad \mathrm{Var}(v_{3t}) = T_3 \tag{6}$$

If all the coefficients for the lags of x (H_2) are statistically significant, then it is said that "x Granger-causes y". Such estimation, however, potentially leaves a lot of correlation between x and y unexploited. Specifically, if y_t is correlated with x_t after controlling for their lags, then there is instantaneous correlation left between them. This is the basis of the Geweke (1982) measure of instantaneous feedback. Geweke proposed that the variance–covariance matrix of residuals from the vector autoregression estimation be used to estimate the linear feedback between y to x and x to y, and the instantaneous linear feedback between x and y.

If x does not Granger-cause y, then (4) can be rewritten as (2). If y does not Granger-cause x, then (3) can be rewritten as (1). Comparing (1) and (3), then, gives us an estimate of the impact of y on x. Specifically, Geweke (1982) proposed the following as measures of linear feedback:

$$n \times F_{X \rightarrow Y} = n \times \ln \left(T_1 / T_2 \right) \qquad \sim \chi^2_p$$

$$n \times F_{Y \rightarrow X} = n \times \ln \left(\Sigma_1 / \Sigma_2 \right) \qquad \sim \chi^2_p$$

$$n \times F_{X \times Y} = n \times \ln \left(T_2 \times \Sigma_2 / |\Upsilon| \right) \tag{7}$$

$$= n \times \ln \left(\Sigma_2 / \Sigma_3 \right) \tag{8}$$

$$= n \times \ln \left(T_2 / T_3 \right) \qquad \sim \chi^2_1 \tag{9}$$

$$n \times F_{X,Y} = n \times \ln \left(\Sigma_1 \times T_1 / |\Upsilon| \right) \qquad \sim \chi^2_{(2p+1)}$$

2. We follow the notations in Geweke (1982).

where $|\Upsilon| = \begin{bmatrix} \Sigma_2 & C \\ C & T_2 \end{bmatrix}$ and $C = \text{cov}(u_{2t}, v_{2t})$. $F_{X\rightarrow Y}$ and $F_{Y\rightarrow X}$ are the Granger-type causation F statistics. n is the number of observations for the unrestricted estimations. $F_{X\times Y}$ is the measure of instantaneous causation (instantaneous feedback). $F_{X,Y}$ is the measure of total feedback between x and y. $F_{X,Y}$ also equals to $F_{X\rightarrow Y} + F_{Y\rightarrow X} + F_{X\times Y}$. Geweke showed that the measures above are asymptotically distributed as F distributions. He also proved that (7), (8), and (9) are equal, implying that instantaneous causality can be verified directly by comparing (5) with (3) and (6) with (4), or indirectly by using the variance–covariance matrix of (3) and (4). Computationally, the `gwke82` command uses (7) for instantaneous causality.

Geweke generalized the above results to include vector-valued functions (so that the measures are asymptotically chi-squared) and allowed for more than two endogenous variables and also for the inclusion of exogenous variables. The `gwke82` command does not allow for vector-valued functions, but it does allow for exogenous variables and more than two endogenous variables.

2 The gwke82 command

2.1 Syntax

`gwke82` *varlist* [*if*] `,` [`m(`*integer*`)` `exog(`*varlist*`)` `detail`]

2.2 Options

`m(`*integer*`)` specifies the number of lags for both variables to be included within all estimations. The default is `m(2)`.

`exog(`*varlist*`)` specifies the exogenous variables to be included within all estimations.

`detail` stores all estimation results.

3 Computing Geweke's measure of instantaneous causality

```
. use http://www.stata-press.com/data/r12/lutkepohl2
(Quarterly SA West German macro data, Bil DM, from Lutkepohl 1993 Table E.1)
. tsset
       time variable:  qtr, 1960q1 to 1982q4
               delta:  1 quarter
. gwke82 dln_inv dln_inc dln_consump if qtr<=tq(1978q4), detail
```

Granger Causation	Chi2	df	P-value
dln_inv -> dln_inc	3.7061	2	0.1568
dln_inv -> dln_cons~p	2.0599	2	0.3570
dln_inc -> dln_inv	0.1042	2	0.9492
dln_inc -> dln_cons~p	12.1271	2	0.0023
dln_cons~p -> dln_inv	3.1568	2	0.2063
dln_cons~p -> dln_inc	3.6042	2	0.1650

Instantaneous feedback	Chi2	df	P-value
dln_inv <-> dln_inc	1.2561	1	0.2624
dln_inv <-> dln_cons~p	5.9162	1	0.0150
dln_inc <-> dln_cons~p	26.1724	1	0.0000

Total correlation	Chi2	df	P-value
dln_inv , dln_inc	5.0664	5	0.4078
dln_inv , dln_cons~p	11.1330	5	0.0488
dln_inc , dln_cons~p	41.9037	5	0.0000

The estimation reveals that `dln_inc` Granger-causes `dln_cons~p`. There is evidence of instantaneous feedback between `dlin_inv` and `dln_cons~p`, and between `dln_inc` and `dln_cons~p`. The total correlation between `dln_inc` and `dln_cons~p` is statistically significant.

The causality statistics and corresponding p-values reported after the `gwke82` command are also saved as return matrices.

```
. return list
matrices:
              r(total_P) :  3 x 3
                r(total) :  3 x 3
             r(geweke_P) :  3 x 3
               r(geweke) :  3 x 3
            r(granger_P) :  3 x 3
              r(granger) :  3 x 3
```

The `detail` option stores all estimation results. These stored estimations can be accessed with the `estimates dir` command.

```
. estimates dir

--------------------------------------------------------
        name | command      depvar       npar  title
-------------+------------------------------------------
unrestrict~2 | sureg        mult. depvar   14
restricted_1 | regress      dln_inv         5
restricted_2 | regress      dln_inc         5
unrestrict~3 | sureg        mult. depvar   14
restricted_3 | regress      dln_consump     5
unrestrict~3 | sureg        mult. depvar   14
--------------------------------------------------------

. estimates restore unrestricted_1_2
(results unrestricted_1_2 are active now)
. ereturn list
scalars:
                  e(ic) =  0
                e(k_eq) =  2
            e(dfk2_adj) =  73
                  e(ll) =  349.9775201862861
                e(rank) =  14
  (output omitted)
                   e(k) =  14
                   e(N) =  73
macros:
          e(properties) : "b V"
             e(eqnames) : "dln_inv dln_inc"
              e(depvar) : "dln_inv dln_inc"
  (output omitted)
                 e(cmd) : "sureg"
    e(_estimates_name) : "unrestricted_1_2"
matrices:
                   e(b) :  1 x 14
                   e(V) :  14 x 14
               e(Sigma) :  2 x 2
```

4 References

Geweke, J. 1982. Measurement of linear dependence and feedback between multiple time series. *Journal of the American Statistical Association* 77: 304–313.

Granger, C. W. J. 1969. Investigating causal relations by econometric models and cross-spectral methods. *Econometrica* 37: 424–438.

Zhang, L., G. Zhong, Y. Wu, M. G. Vangel, B. Jiang, and J. Kong. 2010. Using Granger–Geweke causality model to evaluate the effective connectivity of primary motor cortex, supplementary motor area and cerebellum. *Journal of Biomedical Science and Engineering* 3: 848–860.

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