Improved Tests for Granger Non-Causality in Panel Data

Jiaqi Xiao[1], Arturas Juodis[2], Yiannis Karavias[1], Vasilis Sarafidis[3], Jan Ditzen[4]

[1]University of Birmingham, Birmingham, UK

[2]University Amsterdam, Amsterdam, The Netherlands, UK

[3]BI Norwegian Business School, Oslo, Norway

[4]Free University of Bozen-Bolzano, Bozen, Italy

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Motivation

- “Granger Causality”: a statistical concept of causality (Granger, 1969)
- A variable x “Granger-causes” a variable y, if the variable y can be better predicted using past values of both x and y, than using solely past values of y
- Adopted in economics, medicine, chemistry, physics, biology, engineering, and beyond
- Widely used in panel data analysis

Literature

- Holtz-Eakin, Newey and Rosen (1988)
  - Homogeneous panels, large N, small T
  - `pvargranger` by Abrigo and Love (2016)
- Dumitrescu and Hurlin (2012)
  - Heterogeneous panels, large T, small N
  - `xtgcause` by Lopez and Weber (2017)
- Juodis, Karavias and Sarafidis (2021)
  - large N, small-moderate T with heterogeneous coefficients
- `xtgranger` introduces the JKS test in Stata.

The JKS test

- We consider the following linear dynamic panel data model:

$$y_{i,t} = \phi_{0,i} + \sum_{p=1}^{P} \phi_{p,i} y_{i,t-p} + \sum_{p=1}^{P} \beta_{p,i} x_{i,t-p} + \varepsilon_{i,t},$$

- $\beta_{p,i}$ are the heterogeneous feedback coefficients, or Granger causality parameters.

- The hypothesis of Granger non-causality is:

$$H_0 : \quad \beta_{p,i} = 0, \quad \text{for all } i \text{ and } p.$$

The alternative hypothesis is:

$$H_1 : \quad \beta_{p,i} \neq 0 \quad \text{for some } i \text{ and } p.$$

The JKS test: key estimation ideas

- Idea 1: under the null hypothesis: $\beta_{p,i} = 0$, for all i and p, and thus we can use a more efficient ($\sqrt{NT}$) pooled estimator

$$\hat{\beta} = \left(\sum_{i=1}^{N} \mathbf{X}_i' \mathbf{M}_{\mathbf{Z}_i} \mathbf{X}_i \right)^{-1} \left(\sum_{i=1}^{N} \mathbf{X}_i' \mathbf{M}_{\mathbf{Z}_i} \mathbf{y}_i \right).$$

distributed as

$$\sqrt{NT} \left(\hat{\beta} - \beta_0 \right) \to \mathbf{J}^{-1} N \left(-\kappa \mathbf{B}, \mathbf{V} \right),$$

- Idea 2: Remove the bias using the half panel jackknife estimator (Dhaene and Jochmans, 2015):

$$\tilde{\beta} = \hat{\beta} + \left(\hat{\beta} - \frac{1}{2} \left(\hat{\beta}_{1/2} + \hat{\beta}_{2/1} \right) \right) = \hat{\beta} + T^{-1} \hat{\mathbf{B}}.$$

The JKS test: key estimation ideas

- As $N, T \to \infty$ with $N/T \to \kappa^2 \in [0, \infty)$, we have:

$$\hat{W}_{HPJ} = NT\tilde{\beta}' \left(\hat{\mathbf{J}}^{-1}\hat{\mathbf{V}}\hat{\mathbf{J}}^{-1}\right)^{-1}\tilde{\beta} \to \chi^2(P),$$

  where $\hat{\mathbf{J}} = (NT)^{-1}\sum_{i=1}^{N}\mathbf{X}_i'\mathbf{M}_{\mathbf{Z}_i}\mathbf{X}_i$.

- Power against both homogeneous as well as heterogeneous alternatives
- Cross-section heteroskedasticity
- Weak Cross-section dependence
- Multivariate $x_{i,t}$
- Fast computation

The xtgranger command

- The command syntax is:

  `xtgranger` *depvar* [*indepvars*] [*if*] [*in*] [, *options*]

  Data must be `xtset` before using `xtgranger`. The panel must be balanced.

- `lags(#)` specifies the number of lags of dependent and independent variables to be added to the regression. If `lags(#)` is not specified, the default is `lags(1)`.

- `maxlags(#)` specifies the upper bound of lags. The BIC criterion is used to select the number of lags that provides the best model fit.

- `het` allows for cross-sectional heteroskedasticity.

- `bootstrap(`*reps*`, seed(`*seed*`))` employs a bootstrap variance estimator in the HPJ Wald statistic with the custom set *seed* and *reps* repetitions.

Determinants of Bank Profitability

- We examine temporal relation between profitability, cost efficiency and asset quality in the U.S. banking industry.

- Random sample of 450 U.S. bank holding companies (BHC), each one observed over 56 time periods, namely 2006:Q1-2019:Q4.

- We estimate

$$ROA_{i,t} = \phi_{0,i} + \sum_{p=1}^{P} \phi_{p,i} ROA_{i,t-p} + \sum_{p=1}^{P} \beta_{1,p,i} INEFFICIENCY_{i,t-p} + \sum_{p=1}^{P} \beta_{2,p,i} QUALITY_{i,t-p} + \varepsilon_{i,t},$$

Determinants of Bank Profitability

```
. xtgranger roa inefficiency quality, maxlags(4) het
Juodis, Karavias and Sarafidis (2021) Granger non-causality Test
-------------------------------------------------------------------------------
Number of units= 450                         Obs. per unit (T) = 55
Number of lags = 1                           BIC               = -34257.34
-------------------------------------------------------------------------------
JKS non-causality test
H0: Selected covariates do not Granger-cause roa.
H1: H0 is violated.
HPJ Wald test  : 30.2387
p-value        : 0.0000
-------------------------------------------------------------------------------
BIC selection:
lags = 1, BIC = -34257.336*
lags = 2, BIC = -33371.195
lags = 3, BIC = -32727.595
lags = 4, BIC = -32715.923
-------------------------------------------------------------------------------
Results for the Half-Panel Jackknife estimator
Cross-sectional heteroskedasticity-robust variance estimation
```

	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
inefficiency L1.	.2562039	.0572807	4.47	0.000	.1439358	.368472
quality L1.	-.0162294	.0444754	-0.36	0.715	-.1033996	.0709409

```
. xtgranger roa inefficiency, maxlags(4) het
Juodis, Karavias and Sarafidis (2021) Granger non-causality Test
-----------------------------------------------------------------------------
Number of units= 450                         Obs. per unit (T) = 55
Number of lags = 1                           BIC               = -33295.8
-----------------------------------------------------------------------------
JKS non-causality test
H0: inefficiency does not Granger-cause roa.
H1: inefficiency does Granger-cause roa for at least one panelvar.
HPJ Wald test  : 24.3174
p-value        : 0.0000
-----------------------------------------------------------------------------
BIC selection:
lags = 1, BIC = -33295.799*
lags = 2, BIC = -32170.227
lags = 3, BIC = -31112.604
lags = 4, BIC = -30724.676
-----------------------------------------------------------------------------
Results for the Half-Panel Jackknife estimator
Cross-sectional heteroskedasticity-robust variance estimation
```

	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
inefficiency L1.	.2549723	.0517052	4.93	0.000	.1536319	.3563127

```
. xtgranger roa quality, maxlags(4) het
Juodis, Karavias and Sarafidis (2021) Granger non-causality Test
-------------------------------------------------------------------------------
Number of units= 450                       Obs. per unit (T) = 55
Number of lags = 1                         BIC               = -33816.06
-------------------------------------------------------------------------------
JKS non-causality test
H0: quality does not Granger-cause roa.
H1: quality does Granger-cause roa for at least one panelvar.
HPJ Wald test  : 0.2090
p-value        : 0.6476
-------------------------------------------------------------------------------
BIC selection:
lags = 1, BIC = -33816.061*
lags = 2, BIC = -32649.24
lags = 3, BIC = -31479.433
lags = 4, BIC = -30607.217
-------------------------------------------------------------------------------
Results for the Half-Panel Jackknife estimator
Cross-sectional heteroskedasticity-robust variance estimation
```

	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
quality L1.	-.0201426	.0440637	-0.46	0.648	-.1065059	.0662207

Determinants of Bank Profitability

```
. xtgranger roa inefficiency quality, maxlags(4) het sum, if cluster==2 & time>20
Juodis, Karavias and Sarafidis (2021) Granger non-causality Test
-----------------------------------------------------------------------------
Number of units= 183                       Obs. per unit (T) = 34
Number of lags = 2                         BIC               = -10307.93
-----------------------------------------------------------------------------
JKS non-causality test
H0: Selected covariates do not Granger-cause roa.
H1: H0 is violated.
HPJ Wald test  : 36.3572
p-value        : 0.0000
-----------------------------------------------------------------------------
BIC selection:
lags = 1, BIC = -10249.44
lags = 2, BIC = -10307.934*
lags = 3, BIC = -9788.8299
lags = 4, BIC = -9963.9685
-----------------------------------------------------------------------------
Sum of Half-Panel Jackknife coefficients across lags (lags>1)
Cross-sectional heteroskedasticity-robust variance estimation
```

	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
inefficiency	.4906756	.2405474	2.04	0.041	.0192113	.9621398
quality	-.1765458	.1235961	-1.43	0.153	-.4187897	.0656981

Conclusions

- Introduced new community contributed package called `xtgranger`
- Tests for Granger non-causality when N is large and T is moderate/small
- The command allows for cross-section heteroskedasticity, weak cross-section dependence, multivariate systems
- The command is available on the SSC Archive
- `ssc install xtgranger`
- More information in the paper Improved Tests for Granger Non-Causality in Panel Data