xtdcce2: Estimating Dynamic Common Correlated Effects in Stata

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Introduction

- Formerly `xtdcce`, but name was "too nice".
- Setting: Model with an unobserved common factor (f_t) and a heterogeneous factor loading (γ_i):

$$
\begin{aligned}
y_{i,t} &= \beta_i x_{i,t} + u_{i,t}, \\
u_{i,t} &= \gamma_i' f_t + e_{i,t} \\
\beta_{MG} &= \frac{1}{N}\sum_{i=1}^{N}\beta_i
\end{aligned}
$$

$$i = 1, ..., N \; and \; t = 1, ..., T$$

- Aim: consistent estimation of β_i and β_{MG}:
  - Large N[1], T = 1: Cross Section; $\hat{\beta} = \hat{\beta}_i, \; \forall \; i$
  - N=1 , Large T: Time Series; $\hat{\beta}_i$
  - Large N, Small T: Micro-Panel; $\hat{\beta} = \hat{\beta}_i, \; \forall \; i$
  - <u>Large N, Large T: Panel Time Series; $\hat{\beta}_i$ and $\hat{\beta}_{MG}$</u>

[1] Large implies either fixed or going to infinity.

Introduction

- Estimation of most economic models requires heterogeneous coefficients. Examples: growth models (Lee et al., 1997), development economics (McNabb and LeMay-Boucher, 2014), productivity analysis (Eberhardt et al., 2012), consumption models (Shin et al., 1999) ,...
- Vast econometric literature on heterogeneous coefficients models (Zellner, 1962; Pesaran and Smith, 1995; Shin et al., 1999).
- Estimation of these models possible due to data availability.
- Theoretical literature how to account for unobserved dependencies between countries evolved (Pesaran, 2006; Chudik and Pesaran, 2015).

Common Correlated Effects

$$\begin{aligned} y_{i,t} &= \beta_i x_{i,t} + u_{i,t} \\ u_{i,t} &= \gamma_i' f_t + e_{i,t} \end{aligned} \tag{1}$$

- The heterogeneous coefficients are randomly distributed around a common mean, $\beta_i = \beta + v_i, \; v_i \sim IID(0, \Omega_v)$.
- f_t is an unobserved common factor and γ_i a heterogeneous factor loading.
- Pesaran (2006) shows that equation 1 can be consistently estimated by approximating the unobserved common factors with cross section means $\bar{x}_t$ and $\bar{y}_t$ under strict exogeneity.
- Estimated Equation:

$$y_{i,t} = \beta_i x_{i,t} + \delta_i \bar{x}_t + \eta_i \bar{y}_t + \epsilon_{i,t}$$

$$\bar{x}_t = \frac{1}{N}\sum_{i=1}^{N} x_{i,t}, \quad \bar{y}_t = \frac{1}{N}\sum_{i=1}^{N} y_{i,t}$$

Dynamic Common Correlated Effects

$$y_{i,t} = \lambda_i y_{i,t-1} + \beta_i x_{i,t} + u_{i,t}, \qquad (2)$$
$$u_{i,t} = \gamma_i' f_t + e_{i,t}.$$

- The lagged dependent variable is not strictly exogenous and therefore the estimator becomes inconsistent.
- Chudik and Pesaran (2015) show that the estimator gains consistency if $p_T = \sqrt[3]{T}$ cross section means are added.
- Estimated Equation:

$$y_{i,t} = \lambda_i y_{i,t-1} + \beta_i x_{i,t} + \sum_{l=0}^{p_T} \delta_{i,l}' \bar{z}_{t-l} + \epsilon_{i,t}$$
$$\bar{z}_t = (\bar{y}_t, \bar{y}_{t-1}, \bar{x}_t).$$

- The Mean Group Estimates are: $\hat{\pi}_{MG} = \frac{1}{N}\sum_{i=1}^{N} \hat{\pi}_i$ with $\hat{\pi}_i = (\hat{\lambda}_i, \hat{\beta}_i)$.

Pooled Mean Group

- Intermediate between mean group and pooled mean group, introduced by Shin et al. (1999).
- Eq. (2) is written as an error correction model:

$$\Delta y_{i,t} = \phi_i(y_{i,t-1} - \theta_i x_{i,t}) + \delta_{0,i} + \delta_{1,i}\Delta x_{i,t} + \epsilon_{i,t},$$

- where ϕ_i is the error correction speed of adjustment.
- Assumes long run effects (θ_i) to be homogeneous, short run effects (δ) heterogeneous.

Estimation in Stata

`xtmg` (Eberhardt, 2012)

- Estimates common correlated effects, but does not allow for pooled coefficients or dynamic common correlated effects.

`xtpmg` (Blackburne and Frank, 2007)

- Estimates pooled mean group estimator, but does not account for cross sectional dependence.

`xtdcce2` (Ditzen, 2016)

- Estimates dynamic common correlated effects and allows homo- and heterogeneous coefficients.
- Calculates cross sectional dependence test (CD-Test).
- Allows for endogenous regressors.
- Supports balanced and unbalanced panels.
- Small sample time series bias correction.

Syntax:

xtdcce2 *depvar* [*indepvars*] [*if*] [, pooled(*varlist*)
crosssectional(*varlist*) nocrosssectional cr_lags(#)
exogenous_vars(*varlist*) endogenous_vars(*varlist*) ivreg2options(*string*)
lr(*varlist*) lr_options(*string*) pooledconstant noconstant
reportconstant trend pooledtrend residuals(*string*) jackknife
recursive noomit nocd full lists noisily post_full]

xtcd2 [*varname*(max=1)] [, noestimation rho histogram
name(string)]

▸ More Details, ▸ Stored in e(), ▸ Bias Correction

xtdcce2

Options

$$y_{i,t} = \lambda_i y_{i,t-1} + \beta_i x_{i,t} + \sum_{l=0}^{p_T} \delta'_{i,l} \bar{z}_{t-l} + \epsilon_{i,t}$$

- `crosssectional`(*varlist*) specifies cross sectional means, i.e. variables in $\bar{z}_t$. These variables are partialled out.
- `cr_lags`(#) defines number of lags (p_T) of the cross sectional averages.
- `pooled`(*varlist*) constraints coefficients to be homogeneous ($\beta_i = \beta, \forall\ i \in N$).
- `reportconstant` reports constant and `pooledconstant` pools it.
- IV options:
  - `exogenous_vars`(*varlist*) and `endogenous_vars`(*varlist*) defines exogenous and endogenous variables.
  - `ivreg2options`(*string*) passes on further options to `ivreg2`.

xtdcce2

pmg-Options

- `lr`(*varlist*) defines the variables in the long run relationship.
- `xtdcce2` estimates internally

$$\Delta y_{i,t} = \phi_i y_{i,t-1} + \gamma_i x_{i,t} + \delta_{0,i} + \delta_{1,i} \Delta x_{i,t} + \sum_{l=0}^{p_T} \delta'_{i,l} \bar{z}_{t-l} + \epsilon_{i,t} \qquad (3)$$

while `xtpmg` (with common factors) is based on:

$$\Delta y_{i,t} = \phi_i (y_{i,t-1} - \theta_{1,i} x_{i,t}) + \delta_{0,i} + \delta_{1,i} \Delta x_{i,t} + \sum_{l=0}^{p_T} \delta'_{i,l} \bar{z}_{t-l} + \epsilon_{i,t}.$$

- where $\theta_i = -\frac{\gamma_i}{\phi_i}$. θ_i is calculated and the variances calculated using the Delta method.
- `lr_option`(*string*)
  - `nodivide`, coefficients are not divided by the error correction speed of adjustment vector (i.e. estimate (3)).
  - `xtpmgnames`, coefficients names in `e(b_p_mg)` and `e(V_p_mg)` match the name convention from `xtpmg`.

xtdcce2

Test for cross sectional dependence

- `xtdcce2` package includes the `xtcd2` command, which tests for cross sectional dependence (Pesaran, 2015).
- Under the null hypothesis, the error terms are weakly cross sectional dependent.

$$H_0 : E(u_{i,t} u_{j,t}) = 0, \forall \ t \text{ and } i \neq j.$$

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \right)$$

$$\hat{\rho}_{ij} = \hat{\rho}_{ji} = \frac{\sum_{t=1}^{T} \hat{u}_{i,t} \hat{u}_{jt}}{\left(\sum_{t=1}^{T} \hat{u}_{it}^2\right)^{1/2} \left(\sum_{t=1}^{T} \hat{u}_{jt}^2\right)^{1/2}}.$$

- Under the null the CD test statistic is asymptotically $CD \sim N(0,1)$.

Empirical Example

GDP Regression - Mean Group Estimates

```
. xtdcce2 log_rgdpo L.log_rgdpo log_hc log_ck log_ngd ,  /*
> */ cr(log_rgdpo L.log_rgdpo log_hc log_ck log_ngd) /*
> */ cr_lags(3) res(residuals) jackknife

Dynamic Common Correlated Effects - Mean Group

Panel Variable (i): id                                    Number of obs      =      3906
Time Variable (t): year                                   Number of groups   =        93
                                                          Obs per group (T)  =        42

                                                          F(    372,     1673)=      1.68
                                                          Prob > F           =      0.00
                                                          R-squared          =      0.69
                                                          Adj. R-squared     =      0.69
                                                          Root MSE           =      0.05

                                                          CD Statistic       =      1.55
                                                             p-value         =    0.1204
------------------------------------------------------------------------------------------
              log_rgdpo |     Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
------------------------+-----------------------------------------------------------------
Mean Group Estimates:   |
            L.log_rgdpo |   .359111    .035707    10.06   0.000     .2891259   .4290966
                 log_hc |  -1.00504    .467251    -2.15   0.031    -1.920835  -.0892454
                 log_ck |   .183464     .05775     3.18   0.001     .0702766   .2966517
                log_ngd |   .066033    .116476     0.57   0.571    -.1622554   .2943215
------------------------------------------------------------------------------------------
Mean Group Variables: L.log_rgdpo log_hc log_ck log_ngd
Cross Sectional Averaged Variables: log_rgdpo L.log_rgdpo log_hc log_ck log_ngd
Degrees of freedom per country:
 in mean group estimation            =  38
 with cross-sectional averages       =  18
Number of
 cross sectional lags                =  3
 variables in mean group regression  =  2233
 variables partialled out            =  1861
Heterogenous constant partialled out. Jackknife bias correction used.

. xtcd2 residuals
Pesaran (2015) test for cross sectional dependence
Postestimation.
H0: errors are weakly cross sectional dependent.

        CD =  1.5531389
   p_value =  .12038994
```

Empirical Example

GDP Regression - Pooled Coefficients

```
. xtdcce2 log_rgdpo L.log_rgdpo log_hc log_ck log_ngd , /*
> */ p(L.log_rgdpo log_hc log_ck log_ngd)  /*
> */ cr(log_rgdpo L.log_rgdpo log_hc log_ck log_ngd) cr_lags(3) pooledc

Dynamic Common Correlated Effects - Pooled

Panel Variable (i): id                                 Number of obs      =       3906
Time Variable (t): year                                Number of groups   =         93
                                                       Obs per group (T)  =         42
                                                       F(       4,     2042)=       1.98
                                                       Prob > F           =       0.09
                                                       R-squared          =       0.64
                                                       Adj. R-squared     =       0.64
                                                       Root MSE           =       0.06
                                                       CD Statistic       =      -0.19
                                                          p-value         =     0.8464
```

log_rgdpo	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Pooled Variables:						
L.log_rgdpo	.733953	.015036	48.81	0.000	.7044826	.7634228
log_hc	.103063	.102192	1.01	0.313	-.0972285	.3033553
log_ck	.136153	.013784	9.88	0.000	.1091362	.1631697
log_ngd	.001699	.022768	0.07	0.941	-.0429254	.0463232

```
Pooled Variables:  L.log_rgdpo log_hc log_ck log_ngd
Cross Sectional Averaged Variables: log_rgdpo L.log_rgdpo log_hc log_ck log_ngd
Degrees of freedom per country:
 in mean group estimation            =  38
 with cross-sectional averages       =  18
Number of
 cross sectional lags                =  3
 variables in mean group regression  =  1864
 variables partialled out            =  1860
Homogenous constant removed from model.
```

Empirical Example

Comparison to xtmg

```
. use manu_stata9.dta

. xtset nwbcode year
       panel variable:  nwbcode (strongly balanced)
        time variable:  year, 1970 to 2002
                delta:  1 unit

. eststo xtmg95: qui xtmg ly lk, trend

. eststo xtmg06: qui xtmg ly lk, cce trend

. eststo xtdcce95: qui xtdcce2 ly lk , cr(ly lk) trend nocross reportc

. eststo xtdcce06: qui xtdcce2 ly lk  , cr(ly lk) cr_lags(0) trend reportc

. estout xtmg95 xtdcce95 xtmg06   xtdcce06  , c(b(star fmt(4)) se(fmt(4) par)) /*
> */ mlabels("xtmg - mg" xtdcce2 "xtmg - cce" xtdcce2 ) s(N cd cdp , fmt(0 3 3 )) /*
> */ rename(__000007_t trend) collabels(,none) drop(*_ly *_lk)
```

	xtmg - mg	xtdcce2	xtmg - cce	xtdcce2
lk	0.1789*	0.1789*	0.3125***	0.3125***
	(0.0805)	(0.0805)	(0.0849)	(0.0849)
trend	0.0174***	0.0174***	0.0108**	0.0108**
	(0.0030)	(0.0030)	(0.0035)	(0.0035)
_cons	7.6528***	7.6354***	4.7860***	4.7752***
	(0.8546)	(0.8531)	(1.3227)	(1.3202)
N	1194	1194	1194	1194
cd		6.686		-0.201
cdp		0.000		0.841

Empirical Example

Comparison to xtpmg

```
. use jasa2, clear

. tsset id year
       panel variable:  id (unbalanced)
        time variable:  year, 1960 to 1993
                delta:  1 unit

. eststo xtpmg:  qui xtpmg d.c d.pi d.y if year>=1962, lr(l.c pi y) ec(ec) replace pmg

. eststo xtdcce2_mg:  qui xtdcce2 d.c d.pi d.y if year >= 1962 , /*
> */ lr(l.c pi y) p(l.c pi y) nocross lr_options(xtpmgnames)

. eststo xtdcce2_mg2: qui xtdcce2 d.c d.pi d.y if year >= 1962 , /*
> */ lr(l.c pi y) p(l.c pi y) nocross lr_options(nodivide xtpmgnames)

. eststo xtdcce2_cce: qui xtdcce2 d.c d.pi d.y if year >= 1962 , /*
> */ lr(l.c pi y) p(l.c pi y) cr(d.c d.pi d.y) cr_lags(0) /*
> */ lr_options(xtpmgnames)

. esttab xtpmg xtdcce2_mg xtdcce2_mg2 xtdcce2_cce /*
> */ , mtitles("xtpmg - mg" "xtdcce2 - mg" "xtdcce2 - mg" "xtdcce2 - cce" )  /*
> */ modelwidth(13)  se  s(N cd cdp)
```

	(1)	(2)	(3)	(4)
	xtpmg - mg	xtdcce2 - mg	xtdcce2 - mg	xtdcce2 - cce
ec				
pi	-0.466***	-0.194**	-0.0327**	-0.276***
	(0.0567)	(0.0690)	(0.0119)	(0.0686)
y	0.904***	0.903***	0.152***	0.940***
	(0.00868)	(0.0160)	(0.0142)	(0.0167)
SR				
ec	-0.200***	-0.168***	-0.168***	-0.184***
	(0.0322)	(0.0149)	(0.0149)	(0.0169)
D.pi	-0.0183	-0.0548	-0.0548	0.0237
	(0.0278)	(0.0299)	(0.0299)	(0.0317)
D.y	0.327***	0.380***	0.380***	0.384***
	(0.0574)	(0.0350)	(0.0350)	(0.0431)
_cons	0.154***			
	(0.0217)			
N	767	767	767	767
cd		4.101	4.101	0.671
cdp		0.0000410	0.0000410	0.502

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Empirical Example

Comparison to xtpmg - Hausman Test

```
. eststo mg: qui xtdcce2 d.c d.pi d.y if year >= 1962 , /*
> */ lr(l.c pi y)  nocross

. eststo pmg: qui xtdcce2 d.c d.pi d.y if year >= 1962 , /*
> */ lr(l.c pi y) p(l.c pi y) nocross

. eststo pooled: qui xtdcce2 d.c d.pi d.y if year >= 1962 , /*
> */ lr(l.c pi y) p(l.c pi y d.pi d.y) nocross

. hausman mg pooled, sigmamore

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |       mg         pooled       Difference          S.E.
-------------+----------------------------------------------------------------
pi           |
         D1. |   -.0253642    -.0280826        .0027184        .0308165
y            |
         D1. |    .2337588     .3811944       -.1474357        .0537059
c            |
         L1. |   -.3063473    -.1794146       -.1269326        .0331055
          pi |   -.3529095     -.266343       -.0865666        .1240246
           y |    .9181344     .9120574        .0060771        .0290292
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtdcce2
            B = inconsistent under Ha, efficient under Ho; obtained from xtdcce2

    Test:  Ho:  difference in coefficients not systematic

                  chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       17.77
                Prob>chi2 =      0.0032

. hausman pmg pooled, sigmamore

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |      pmg         pooled       Difference          S.E.
-------------+----------------------------------------------------------------
c            |
         L1. |   -.1683577    -.1794146        .0110569         .004927
          pi |   -.1941238     -.266343        .0722191        .0311994
           y |    .9025766     .9120574       -.0094807        .0073838
pi           |
         D1. |   -.0548234    -.0280826       -.0267408        .0266521
y            |
         D1. |    .3802491     .3811944       -.0009453        .0283331
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtdcce2
            B = inconsistent under Ha, efficient under Ho; obtained from xtdcce2

    Test:  Ho:  difference in coefficients not systematic

                  chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        2.45
                Prob>chi2 =      0.7845
                (V_b-V_B is not positive definite)
```

Conclusion

`xtdcce2`...

- introduces a new routine to estimate a heterogeneous panel model using dynamic common correlated effects.
- allows for mean group, pooled and pooled mean group estimations.
- supports instrumental variable regressions.
- small sample time series bias corrections using jackknife or recursive mean method.
- includes `xtcd2` to test for cross sectional dependence.
- works with balanced and unbalanced panels.
- available on SSC.

Saved values ‣ back

Scalars

e(N)	number of observations	e(N_g)	number of groups
e(T)	number of time periods	e(K)	number of regressors
e(N_partial)	number of variables partialled out	e(N_omitted)	number of omitted variables
e(N_pooled)	number of pooled variables	e(mss)	model sum of square
e(rss)	residual sum of squares	e(F)	F statistic
e(ll)	log-likelihood (only IV)	e(rmse)	root mean squared error
e(df_m)	model degrees of freedom	e(df_r)	residual degree of freedom
e(r2)	R-squared	e(r2_a)	R-squared adjusted
e(cd)	CD test statistic	e(cdp)	p-value of CD test statistic

Scalars (unbalanced panel)

e(minT)	minimum time	e(maxT)	maximum time
e(avgT)	average time		

Macros

e(tvar)	name of time variable	e(idvar)	name of unit variable
e(depvar)	name of dependent variable	e(indepvar)	name of independent variables
e(omitted)	name of omitted variables	e(lr)	long run variables
e(pooled)	name of pooled variables	e(cmd)	command line
e(cmd_full)	command line including options		
e(insts)	instruments (exogenous) variables	e(instd)	instrumented (endogenous) variables

Matrices

e(b)	coefficient vector (mean group or individual)	e(V)	variance–covariance matrix (mean group or individual)
e(b_p_mg)	coefficient vector (mean group and pooled)	e(V_p_mg)	variance–covariance matrix (mean group and pooled)
e(b_full)	coefficient vector (individual and pooled)	e(V_full)	variance–covariance matrix (individual and pooled)

Functions

e(sample)	marks estimation sample

Options

▸ back

- pooled(*varlist*) specifies homogeneous coefficients. For these variables the estimated coefficients are constrained to be equal across all units ($\beta_i = \beta \ \forall \ i$). Variable may occur in *indepvars*. Variables in exogenous_vars(), endogenous_vars() and lr() may be pooled as well.
- crosssectional(*varlist*) defines the variables which are included in z_t and added as cross sectional averages ($\bar{z}_{t-l}$) to the equation. Variables in crosssectional() may be included in pooled(), exogenous_vars(), endogenous_vars() and lr(). Default option is to include all variables from *depvar*, *indepvars* and endogenous_vars() in z_t. Variables in crosssectional() are partialled out, the coefficients not estimated and reported.

Options I

▸ back

- cr_lags(#) specifies the number of lags of the cross sectional averages. If not defined but crosssectional() contains *varlist*, then only contemporaneous cross sectional averages are added, but no lags. cr_lags(0) is equivalent to omitting it.
- nocrosssectional prevents adding cross sectional averages. Results will be equivalent to the Pesaran and Smith (1995) Mean Group estimator, or if lr(*varlist*) specified to the Shin et al. (1999) Pooled Mean Group estimator.
- xtdcce2 supports instrumental variable regression using ivreg2 by Baum et al. (2003, 2007). Endogenous and exogenous variables are set by:
  - endogenous_vars(*varlist*) specifies the endogenous and
  - exogenous_vars(*varlist*) the exogenous variables. See for a further description ivreg2.

Options II

▸ back

- ivreg2options passes further options on to ivreg2. See ivreg2, options for more information.
- fulliv posts all available results from ivreg2 in e() with prefix *ivreg2_*.
- noisily shows the output of wrapped ivreg2 regression command.
- lr(*varlist*): Variables to be included in the long-run cointegration vector. The first variable is the error-correcting speed of adjustment term.
- lr_options(*string*) Options for the long run coefficients. Options may be:
  - nodivide, coefficients are not divided by the error correction speed of adjustment vector.
  - xtpmgnames, coefficients names in e(b_p_mg) and e(V_p_mg) match the name convention from xtpmg.
- noconstant suppress constant term.

Options III

back

- `pooledconstant` restricts the constant to be the same across all groups ($\beta_{0,i} = \beta_0, \ \forall i$).
- `reportconstant` reports the constant. If not specified the constant is treated as a part of the cross sectional averages.
- `trend` adds a linear unit specific trend. May not be combined with `pooledtrend`.
- `pooledtrend` a linear common trend is added. May not be combined with `trend`.
- `jackknife` applies the jackknife bias correction for small sample time series bias. May not be combined with `recursive`.
- `recursive` applies recursive mean adjustment method to correct for small sample time series bias. May not be combined with `jackknife`.
- `residuals(`*varname*`)` saves residuals as new variable.
- `nocd` suppresses calculation of CD test statistic.

Options IV

back

- `cluster(`*varname*`)` clustered standard errors, where *varname* is the cluster identifier.
- `nomit` suppress checks for collinearity.
- `full` reports unit individual estimates in output.
- `lists` shows all variables names and lags of cross section means.
- `post_full` requests that the individual estimates, rather than the mean group estimates are saved in `e(b)` and `e(V)`. Mean group estimates are then saved in `e(b_p_mg)` and `e(V_p_mg)`.

xtdcce2

Small Sample Time Series Bias Corrections

"half panel" jackknife

$$\hat{\pi}^J_{MG} = 2\hat{\pi}_{MG} - \frac{1}{2}\left(\hat{\pi}^a_{MG} + \hat{\pi}^b_{MG}\right)$$

- where $\hat{\pi}^a_{MG}$ is the mean group estimate of the first half ($t = 1, ..., \frac{T}{2}$) of the panel and $\hat{\pi}^b_{MG}$ of the second half ($t = \frac{T}{2} + 1, ..., T$) of the panel.

Recursive mean adjustment

$$\tilde{w}_{i,t} = w_{i,t} - \frac{1}{t-1}\sum_{s=1}^{t-1} w_{i,s} \text{ with } \quad w_{i,t} = (y_{i,t}, X_{i,t}).$$

- Partial mean from all variables, except the constant, removed.
- Partial mean is lagged by one period to prevent it from being infuenced by contemporaneous observations.

back

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