ESRI INTERNATIONAL CONFERENCE 2018

STRUCTURAL CHANGE AND BUSINESS CYCLE FLUCTUATIONS PART 2

Tokyo, 31 July 2018

Makoto HAZAMA

ESRI, Cabinet Office

Research Questions for the 2nd Study

- Research questions

1. Are there any economic structural changes in Japan?
2. Is there business cycle indicator that is robust to economic structural changes?

- To be specific about “Economic structural changes” and “Business cycle”, I rely on
- PC-DFM (principal component estimation of dynamic factor model)
  - “Economic structural changes” as changes on parameters of DFM.
  - “Business cycle” as a cyclical composite indicator (CCI) within PC-DFM.

PC-DFM

(Technical notes on analytical framework)

- DFM is a statistical model, in which many (N)time series variables are commonly driven by much less (r) unobserved factors.

$$\underset{(N\times 1)}{X_t} = \underset{(N\times r)}{\Lambda}\ \underset{(r\times 1)}{F_t} + \underset{(N\times 1)}{\varepsilon_t} \quad (t = 1, \cdots, T),$$

$$X_{it} = \underset{(1\times r)}{\lambda_i'}\ \underset{(r\times 1)}{F_t} + \varepsilon_{it} \quad (i = 1, \cdots, N;\ t = 1, \cdots, T)\ ,$$

F_t: common factors, $\lambda_i' F_t$: common component,

λ_i: factor loadings, ε_{it}: idiosyncratic component.

- PC analysis is a general statistical tool to reduce the dimensions of information.
  - DFM including large number of variables under realistic assumptions (approximate DFM) are suitably estimated by PC analysis (Stock & Watson 2002, Forni et al. 2000, 2005).

Specifications of the "Economic Structural Changes" and the "Business Cycle"

- "Economic structural changes"

  defined as changes on factor loadings in DFM.

$$X_{it} = \begin{cases} \lambda_i^{(1)\prime} F_t + \varepsilon_{it} & (t = 1, \cdots, T_i^*) \\ \lambda_i^{(2)\prime} F_t + \varepsilon_{it} & (t = T_i^* + 1, \cdots, T) \end{cases}$$

- "Business Cycle"

  defined as CCI within DFM.

  - Two types of CCI:
    1. Estimated common factor of single factor model (Stock & Watson 1989).
    2. Estimated common component of canonical time series (Altissimo et al. 2001, 2010).
  - If the number of factors is one, the former is included in the latter.

Statistical Methods on Research Question 1

Question 1

"Are there any economic structural changes in Japan?"

Tests for instability of individual series (H_0: $\lambda_i^{(1)} = \lambda_i^{(2)}$)	
Breitung & Eickmeier 2011 (BE test)	Structural change is observationally equivalent to inflated dimensions of factor space
Yamamoto & Tanaka 2015 (YT test)	Coping with non-monotonic power of BE test
Tests for instability of all series (H_0: $\Lambda^{(1)} = \Lambda^{(2)}$)	
Chen, Dolado, & Gonzalo 2014 (CDG test)	Structural change in terms of factor loading is observationally equivalent to change in second moments of factors
Han & Inoue 2015 (HI test)	

Estimation of break type and date	
Cheng, Liao, & Schorfheide 2016	For now just partly refer to the idea that the sum of estimated # of factors for split subsamples is minimized at break date

Theoretical Answer to Research Question 2

Question 2

"Is there a business cycle indicator that is robust to economic structural changes?"

- From the literature of stability test with PC-DFM,

  CCI based on components decomposition within PC-DFM is not affected by "economic structural changes."

- Under mild (but unverifiable) conditions,
  - if the magnitude of the change in λ is small in a sense, PC analysis can consistently estimate the DFM (Stock and Watson 2002, Bates et al. 2013);
  - even if the change in λ is not small, $\lambda_i' F_t$ and ε_{it} are identified in PC estimation (Breitung and Eickmeier 2011, Chen et al. 2014).

Empirical Questions and Summary of Results

- Do we observe:

1. Economic structural change in Japan?
2. Robust CCI for Japan?

- To this end, using Japanese macroeconomic data,
  1. I will perform **recently proposed tests** for structural change,
  2. and compare **CCIs based on full- and sub-samples.**
- Summary of Results
  1. Structural changes had happened; Not clear about the break date
  2. Theory-consistent except Feb. 2009 and Mar. 2011.

Data

- Japanese monthly N=148 time series + quarterly GDP
- April 1983 – May 2017 (T=410)
- See annex for details.

Production	20
Labor & earnings	17
Commercial sales	18
Household consumption	10
House construction	8
Inventory	5
Asset prices	10
Interest rates & spreads	9
Money & credit	17
Prices & wages	16
Others	18
Quarterly GDP	1

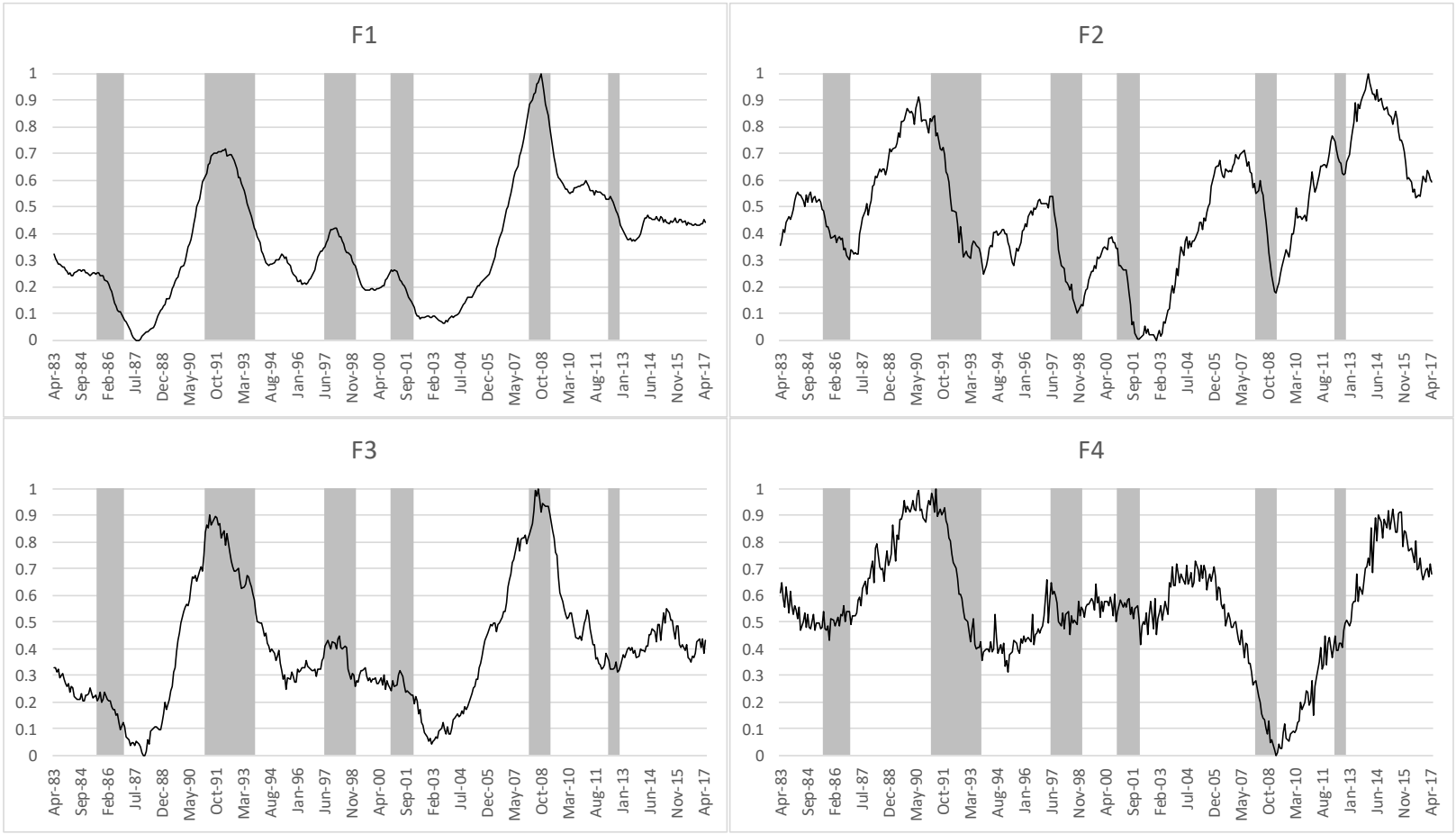
Estimated # of Factors r

Determine the number of factors by several ways
→ 4 factors for CCI calculation

# of factors	Contribution of factor	Accumulative contribution of factors	information criteria			
			ICp1	ICp2	ICp3	AH
1	0.077	0.077	-0.040	-0.037	-0.049	1.239
2	0.063	0.140	-0.067	-0.061	-0.086	**1.502**
3	0.042	0.182	-0.073	-0.065	-0.102	1.078
4	0.039	0.220	**-0.079**	**-0.067**	-0.116	1.288
5	0.030	0.250	-0.075	-0.061	-0.122	1.138
6	0.026	0.277	-0.067	-0.050	**-0.124**	1.109
7	0.024	0.300	-0.058	-0.038	-0.123	1.190
8	0.020	0.320	-0.043	-0.021	-0.118	1.044
9	0.019	0.339	-0.029	-0.003	-0.113	1.089

Notes: ICp1, ICp2, and ICp3 are three mutually-alternative information criteria of Bai and Ng (2002).
AH is the consecutive eigenvalue ratio of Ahn and Horenstein (2013).

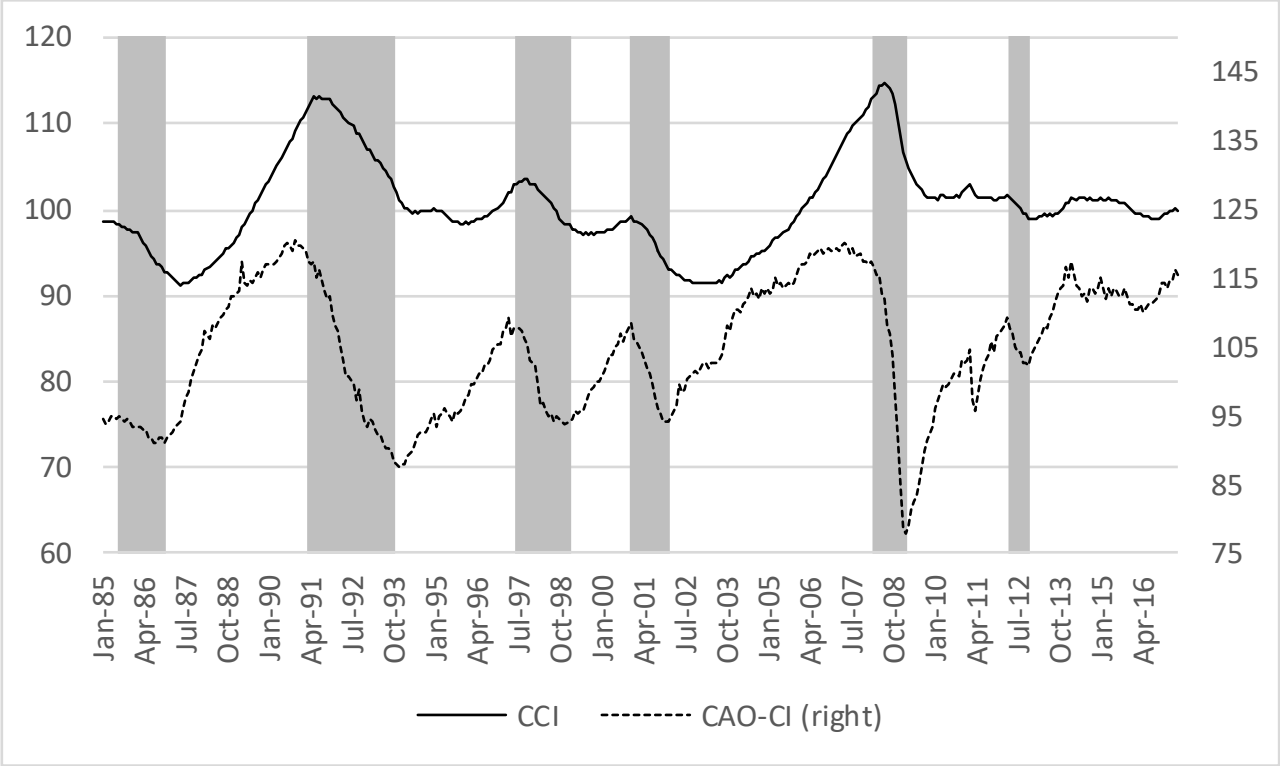
Factor Space



- Note: Integrated factors from 1st to 4th.

CCI (Compared with CAO-CI)

- CCI: Common component of quarterly GDP in DFM of monthly 148 series
  + quarterly GDP.
- CAO-CI: The coincident CI (monthly) released by ESRI-CAO (based on 9 series)



Notes:

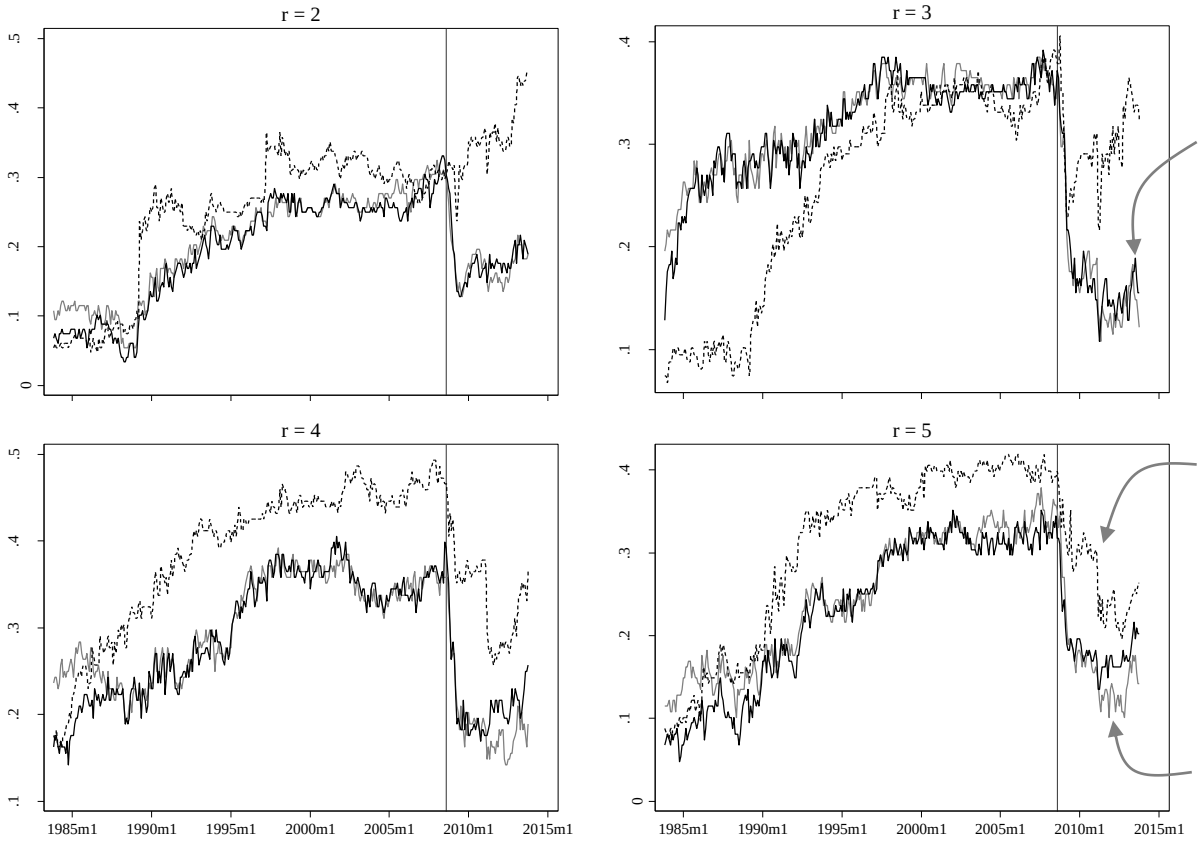
- Mixed data handling: Stock & Watson 1998.
- CCI is growth cycle (excluding trend); CAO-CI is classical cycle (including trend).

Overview of Results on Structural Changes in DFM

Tests for instability of individual series (H_0: $\lambda_i^{(1)} = \lambda_i^{(2)}$)	
Breitung & Eickmeier 2011 (BE test)	About 30% of 148 series shows economic structural changes
Yamamoto & Tanaka 2015 (YT test)	Non-monotonic power problem is not serious
Tests for instability of all series (H_0: $\Lambda^{(1)} = \Lambda^{(2)}$)	
Chen, Dolado, & Gonzalo 2014 (CDG test)	There is structural break for the number of factors more than 4
Han & Inoue 2015 (HI test)	

Estimation of break type and date	
Cheng, Liao, & Schorfheide 2016	Provides hint on break dates of Feb. 2009 and March 2011

Results of BE Test (LM)



Black solid line:
Base case
(outlier adjusted & variable variance)

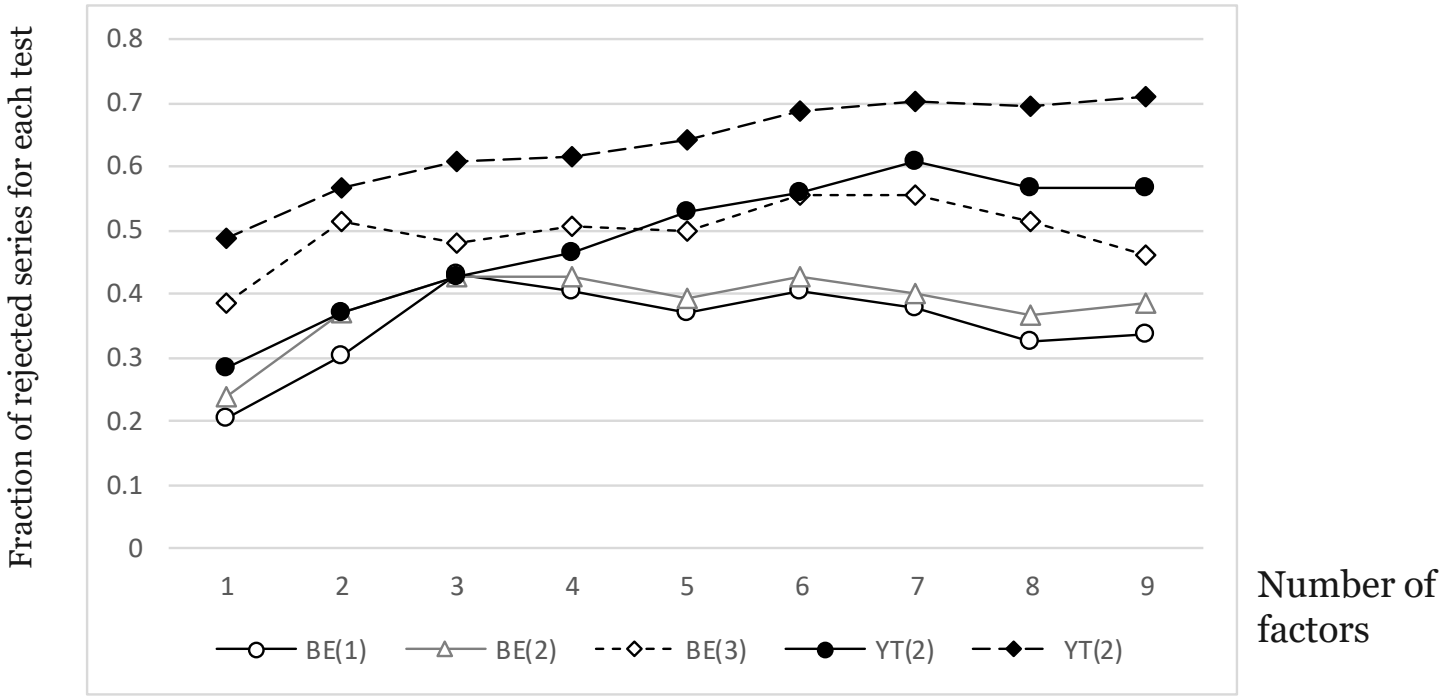
Black dashed line:
outlier not adjusted

Gray solid line:
constant variance

Notes:

1. The fraction of rejected series in 148 variables by Breitung-Eickmeier LM test for each # of factors with the significance level of 0.05.
2. The vertical line indicates Sep. 2008.

Results of BE and YT Tests (sup-LM)



Notes:

BE(1): BE test with variable variance and outlier adjusted

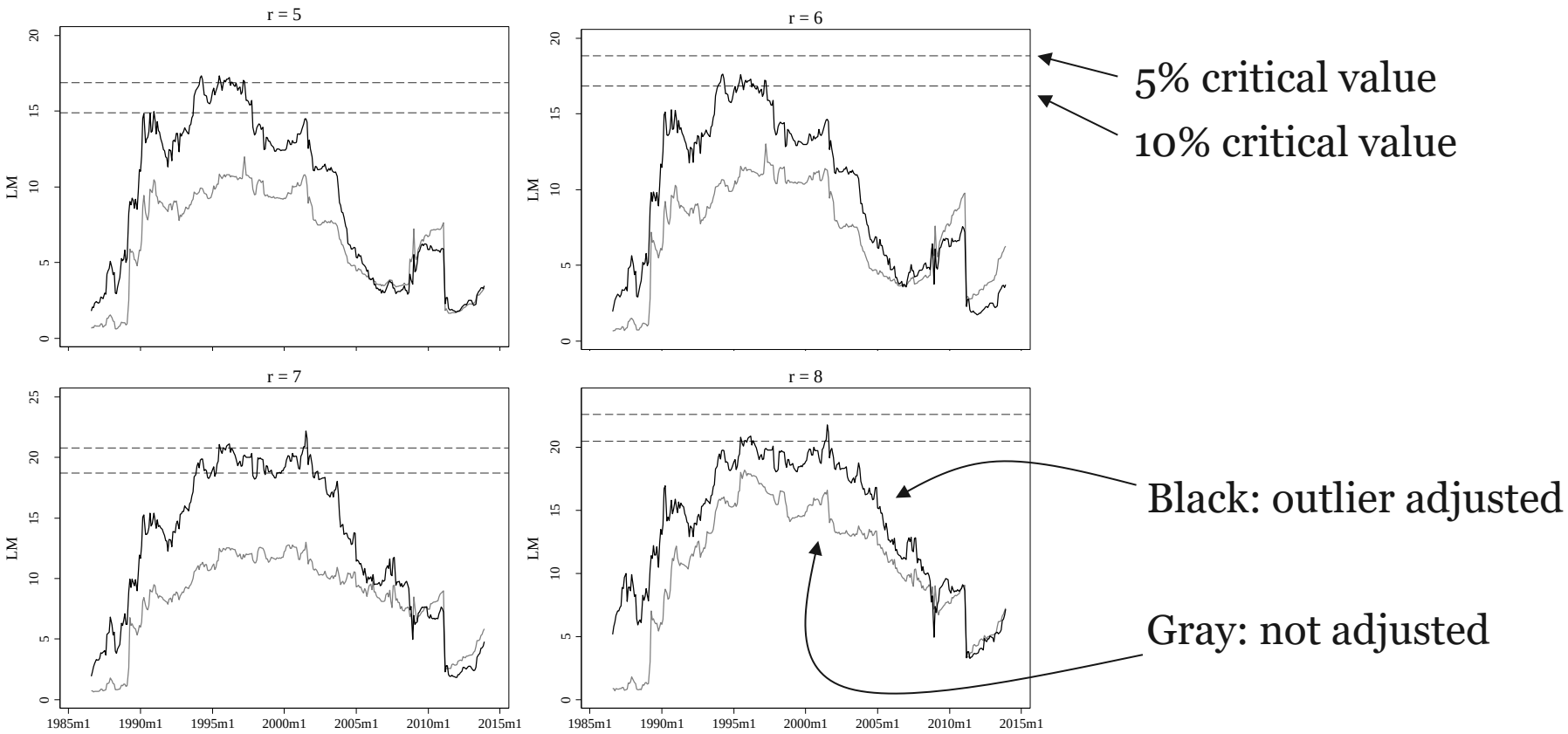
BE(2): BE test with constant variance and outlier adjusted

BE(3): BE test with variable variance and outlier not adjusted

YT(1): YT test with outlier adjustment

YT(2): YT test without outlier adjustment

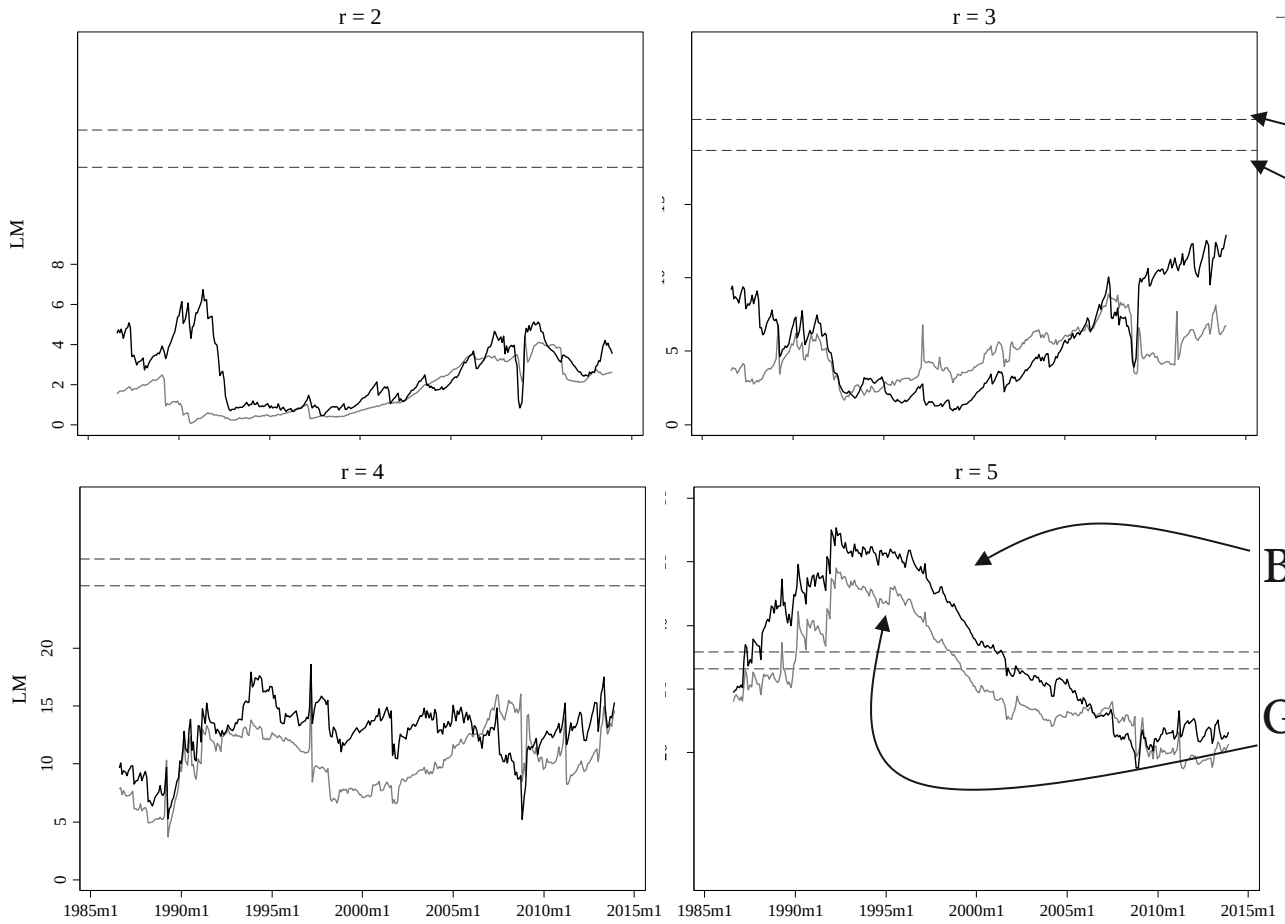
Results of CDG Test (sup-LM)



Notes:

- sup-LM test of CDG2014 for Japanese 148 variables DFM.
- Regressions of the first factor on the others.

Results of HI Test (sup-LM)



5% critical value

10% critical value

Black: outlier adjusted

Gray: not adjusted

Notes:

- sup-LM test of HI2015 for Japanese 148 variables DFM.
- Black line: outlier adjusted. Gray line: outlier unadjusted. Two horizontal dashed lines indicates critical values for significance level of 0.05 (upper) and 0.10 (lower).

Hint for Break Dates

- The figure below shows the number of factors selected by Bai & Ng's (2002) ICp2 for the subsamples before and after each of the predicated break dates.
- Total number of factors of before and after subsample takes minimum at Feb. 2009 and Mar. 2011., suggesting the strong candidate of the break date. (i.e. Cheng et al. 2016)

Black solid line:
Total

Gray solid line:
before-subsample

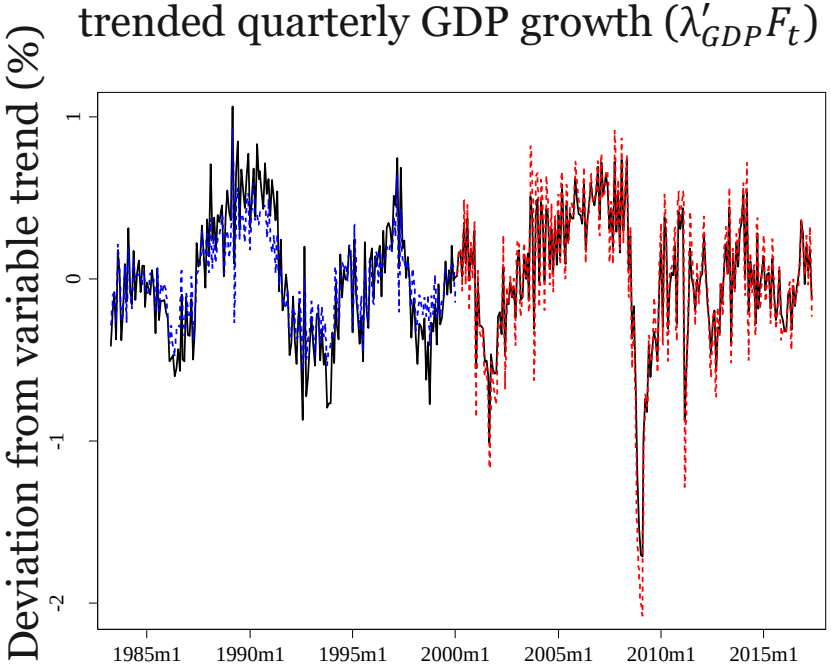
Black dashed line:
after-subsample

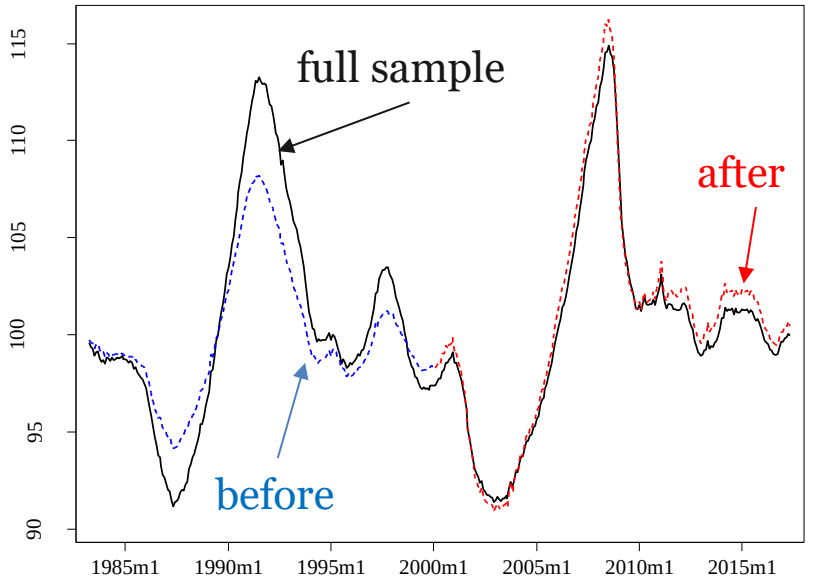
CCIs Based on Full- and Sub-samples

- For example, suppose that Jan. 2000 is suspected to be a break date.
- Compare the CCI of full sample with CCIs of samples split at the suspected date.

Estimated common component of de-trended quarterly GDP growth ($\lambda'_{GDP}F_t$)

$$CCI_t = CCI_{t-1} \times exp(\lambda'_{GDP}F_t)$$

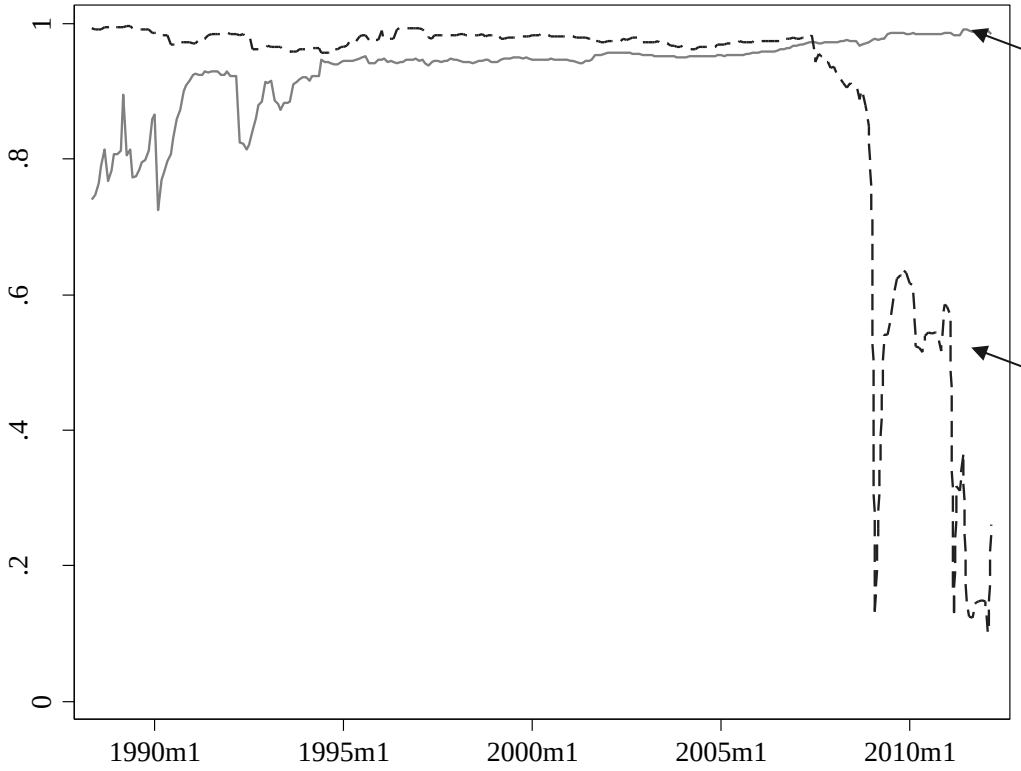




Correlation of Full- and Sub-Sample CCIs

Result

- Persistently high correlation is theory-consistent for mid 1990s to 2008.
- $\text{Corr}_{\text{after}}$ declines dramatically at Feb.2009 and Mar.2011.



$\text{Corr}_{\text{before}} \equiv$

$$\text{Corr}\begin{pmatrix} \hat{\lambda}'_{GDP}\hat{F}_t \text{ of full sample,} \\ \hat{\lambda}'_{GDP}\hat{F}_t \text{ of } \textbf{before} \text{ subsample} \end{pmatrix}$$

$\text{Corr}_{\text{after}} \equiv$

$$\text{Corr}\begin{pmatrix} \hat{\lambda}'_{GDP}\hat{F}_t \text{ of full sample,} \\ \hat{\lambda}'_{GDP}\hat{F}_t \text{ of } \textbf{after} \text{ subsample} \end{pmatrix}$$

Note: Plots in neighborhood of end points suffer from inadequacy of sample periods.

Summary for the 2nd Study

- Results of cursory application of tests for instability in DFM show that structural breaks have occurred.
- The tool of Cheng et al. 2016 may provide clearer results.
- Theoretical implication of the effects of economic structural change on CCI of PC-DFM is valid for the sample period except Feb. 09 and Mar. 11.

Subjoinder (not shown in detail)

- Diagnostics show low commonality of common factors;

  Poor fitness of dynamic factor models to Japanese economy may discourage the introduction of large-scale factor model based economic monitoring.
- Long-term effect of structural change is neglected in stationary DFM set up.

Conclusive Words

- Two studies presented a number of empirical analyses to examine developments in the business cycle under economic structural change.

The first study

- While in some areas such as hours worked and employment, changes in business cycle patterns can be observed by examining individual macroeconomic time series, in most other areas, no major changes can be observed.

The second study

- Structural changes have happened. As for break date, quick applications of sophisticated methods demonstrate the necessity for more advanced empirical analyses.
- In addition, empirical results confirm the robustness of CCI based on PC-DFM as suggested by previous theoretical works.

Annex – List of 148 series (1)

	Series	T
1	Index of production, capital goods	5
2	construction goods	5
3	durable consumer goods	5
4	non-durable consumer goods	5
5	producer goods	5
6	Index of producer's shipments, capital goods	5
7	construction goods	5
8	durable consumer goods	5
9	non-durable consumer goods	5
10	producer goods	5
11	Index of operating ratio, iron & steel	1
12	non-ferrous metals	1
13	fabricated metals	1
14	transport equipment	1
15	ceramics, stone & clay products	1
16	chemicals	1
17	petroleum & coal products	1
18	pulp, paper, and paper products	1
19	textiles	1
20	electrical machinery	1
21	Disposable income (worker's households)	5
22	Regular employment index, industries covered (30 more persons)	5
23	Non-scheduled hours worked index, industries covered (30 more persons)	5
24	Scheduled hours worked index, industries covered (30 more persons)	5
25	Unemployment rate, 15-24 years old, male	2
26	25-34 years old, male	2
27	35-44 years old, male	2
28	45-54 years old, male	2
29	55-64 years old, male	2
30	15-24 years old, female	2
31	25-34 years old, female	2
32	35-44 years old, female	2
33	45-54 years old, female	2
34	55-64 years old, female	2
35	Active job opening-to-applicants ratio	2
36	New applications, part timers	5
37	, excluding part timers	5

1=level, 2=difference, 3=second difference, 4=ln, 5=difference of ln, 6=second difference of ln

Annex – List of 148 series (2)

	Series	T
38	Department stores sales value per unit area	5
39	Department stores sales value per employee	5
40	Large-scale retailers sales value	5
41	Retail sales value, general merchandise	5
42	fabrics, apparel & accessories	5
43	food & beverages	5
44	motor vehicles	5
45	machinery & equipment	5
46	Wholesale sales value, general merchandise	5
47	textiles	5
48	apparel & accessories	5
49	livestock & aquatic products	5
50	food & beverages	5
51	building materials	5
52	chemicals	5
53	minerals & metals	5
54	machinery & equipment	5
55	medicine & toiletries	5
56	Total floor area of new dwelling units, owned houses	5
57	rented houses	5
58	issued houses	5
59	ready built houses	5
60	New dwelling units, owned houses	5
61	rented houses	5
62	issued houses	5
63	ready built houses	5
64	Index of producer's inventory ratio, capital goods	1
65	construction goods	1
66	durable consumer goods	1
67	non-durable consumer goods	1
68	producer goods	1
69	Machinery orders, non-manufacturing (excluding volatile orders)	5
70	manufacturing	5
71	TSE stock price index, 1st section, construction	5
72	chemicals	5
73	machinery	5
74	electric appliances	5

1=level, 2=difference, 3=second difference, 4=ln, 5=difference of ln, 6=second difference of ln

Annex – List of 148 series (3)

	Series	T
75	TSE stock price index, 1st section, transportation equipment	5
76	information & communication	5
77	wholesale trade	5
78	retail trade	5
79	banks	5
80	services	5
81	Producer price index, scrap & waste	5
82	Nikkei index of commodity prices (42 items, monthly)	5
83	Exchange rates, yen per US. $ (spot, middle, monthly average)	5
84	Effective exchange rate (real)	5
85	Basic loan rate (official discount rate)	2
86	Prime interest rate (long term credit banks, end of month)	2
87	Yields to subscribers, government bond, interest bearing (10 years)	2
88	Average interest rates on loans & discounts, domestic banks	2
89	Ave. int. rates on loans & dis., domestic banks, short-term loan	2
90	Ave. int. rates on certificates of deposit, domestically banks	2
91	Prime interest rate – basic loan rate spread	1
92	Yields to subscribers (government bond) – basic loan rate spread	1
93	Average interest rate on loan – basic loan rate spread	1
94	Money stock, average amounts outstanding, M1	5
95	M2	5
96	Money stock, amounts outstanding at end of the period, M1	5
97	Monetary base average amounts outstanding	5
98	Bank account of city banks, asset, cash	5
99	deposits	5
100	call loans	5
101	securities	5
102	Bank account of city banks, liabilities, deposits	5
103	call money	5
104	certificates of deposit	5
105	Bank account of regional banks, asset, cash	5
106	deposits	5
107	securities	5
108	Bank account of regional banks, liabilities, deposits	5
109	call money	5
110	certificates of deposit	5

1=level, 2=difference, 3=second difference, 4=ln, 5=difference of ln, 6=second difference of ln

Annex – List of 148 series (4)

	Series	T
111	Producer price index, manufacturing industry products	6
112	agriculture, forestry & fishery products	6
113	minerals	6
114	electric power, gas & water	6
115	Consumer price index, food	6
116	housing	6
117	fuel, light & water charges	6
118	furniture & household utensils	6
119	clothes & footwear	6
120	transportation & communication	6
121	culture & recreation	6
122	miscellaneous	6
123	Export price index (yen basis), all commodities	6
124	Import price index (yen basis), all commodities	6
125	Wage index, total cash earnings, industries covered (30 more persons)	5
126	Real wage index, total cash earnings, industries covered (30 more persons)	5
127	MOF quantum index, exports, total	5
128	MOF quantum index, imports, total	5
129	Customs clearance, value of exports, grand total (yen)	5
130	Bank clearing, all clearing houses (number)	5
131	(value)	5
132	Consumer confidence index (all households)	2
133	Monthly survey of small businesses, sales D.I.	2
134	sales forecast D.I.	2
135	profits D.I.	2
136	Index of consumption expenditure level, food	5
137	housing	5
138	fuel, light & water charges	5
139	furniture & household utensils	5
140	clothing & footwear	5
141	medical care	5
142	transportation & communication	5
143	education	5
144	culture & recreation	5
145	miscellaneous	5
146	Index of tertiary industry activities, business related services	5
147	transport & postal activities	5
148	Corporation tax revenue (including tax refunds)	5

1=level, 2=difference, 3=second difference, 4=ln, 5=difference of ln, 6=second difference of ln

Annex –Test Details

- BE test;

(sup-)Wald, (sup-)LR, or (sup-)LM for $H_0: \gamma_i = 0$ in the regression,

$$X_{it} = \beta_i' \hat{F}_t + \gamma_i' \left(1[t > \lfloor \tau T \rfloor] \times \hat{F}_t\right) + error\ .$$

- YT test;

Maximize Sup-W, sup-LR, or sup-LM for $H_0: \gamma_i = 0$ in the regression,

$$X_{it} = \beta_i \hat{F}_{jt} + \gamma_i \left(1[t > \lfloor \tau T \rfloor] \hat{F}_{jt}\right) + error\ ,$$

with respect to $j \leq \bar{r}$.

- CDG test;

(sup-)Wald, (sup-)LR, or (sup-)LM for $H_0: \delta = 0$ in the regression,

$$\hat{F}_{jt} = \beta' \hat{F}_{(-j)t} + \delta' \left(1[t > \lfloor \tau T \rfloor] \times \hat{F}_{(-j)t}\right) + error\ .$$

- HI test;

Test statistics $T(C(\tau)V(\tau)^{-1}C(\tau)')$

$$C(\tau) \equiv \text{vech}\left(\tau^{-1} \sum_{t=1}^{\lfloor \tau T \rfloor} \hat{F}_t \hat{F}_t' + (1-\tau)^{-1} \sum_{t=\lfloor \tau T \rfloor + 1}^{T} \hat{F}_t \hat{F}_t'\right)$$

$$V(\tau) \equiv HAC\ est.of\ \text{Var}\, C(\tau)$$