Changes in International Business Cycle Affiliations

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Motivation

- Have international business cycle affiliations changed?

  Many important issues for modelling and policy:

  - Are major recession periods different from “normal” times?
  - Has “globalization” changed cross-country links?
  - What effect from establishing the Euro Area?

- Lack of consensus to date!

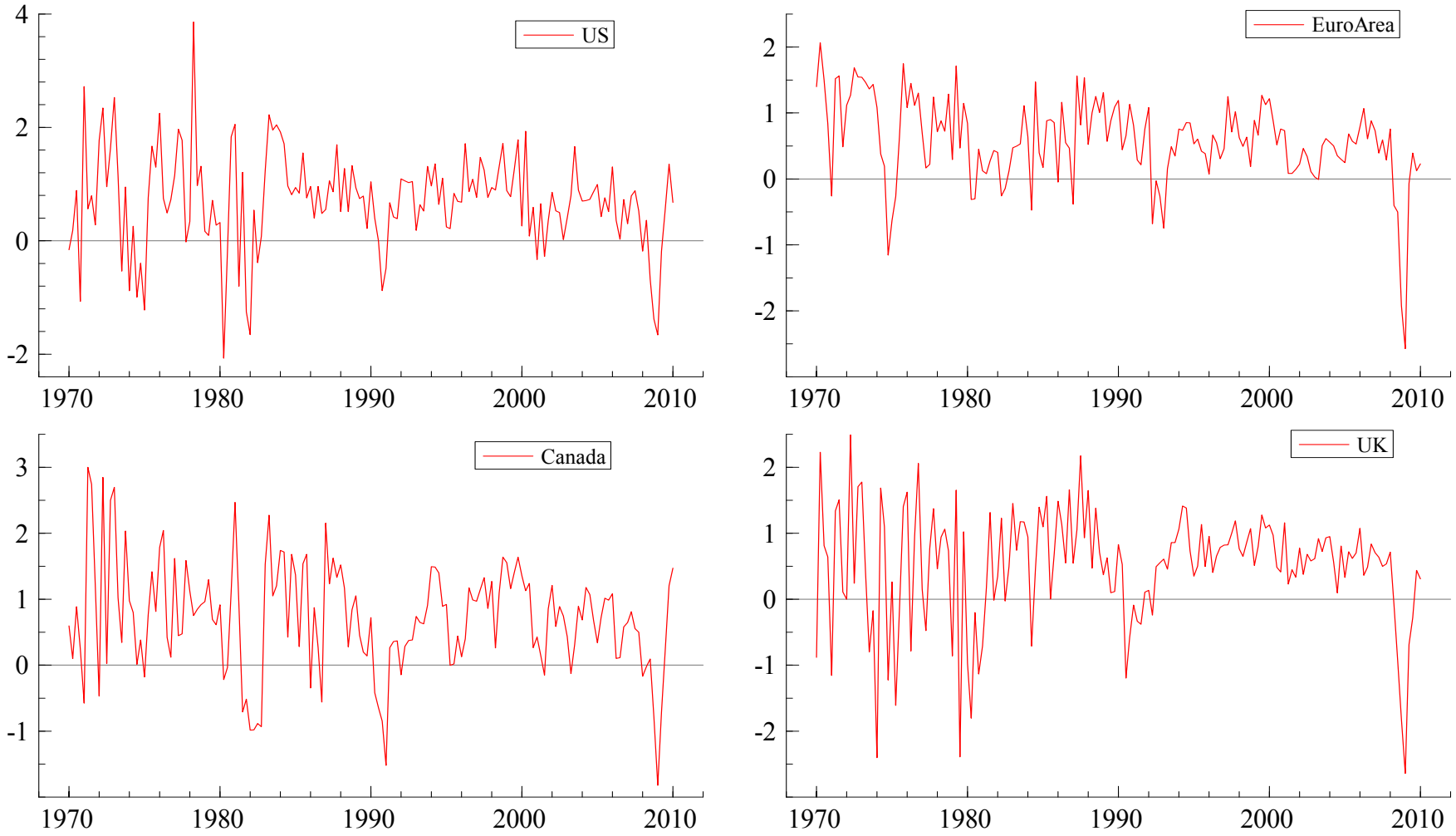
Route map of talk:

1. Data & preliminary analysis
2. Literature overview
3. Methodology
4. Results: System breaks & dynamics
5. Results: Volatility and correlation changes
6. Conclusions

1. Data & Preliminary Analysis

- Examine G-7 countries, exc. Japan
  - Quarterly GDP growth, 1970Q1 – 2010Q1
  - Real, seasonally adjusted data
  - Characteristics time-varying!

- Interactions studied through 2 systems:
  - US, Canada, UK, Euro Area (aggregate of 12)
  - Germany, France, Italy (E-3 countries)


US
EuroArea
Canada
UK
1970
1980
1990
2000
2010


Germany
5.0
2.5
0.0
-2.5
1970
1975
1980
1985
1990
1995
2000
2005
2010
France
2
1
0
-1
1970
1975
1980
1985
1990
1995
2000
2005
2010
Italy
2.5
0.0
-2.5
1970
1975
1980
1985
1990
1995
2000
2005
2010

- Characteristics:
  - Volatility change(s)
  - Communality of 2008/09 recession
  - Also mid-1970s & early 1980s recessions

- Univariate analysis finds widespread volatility breaks:
  - All countries except France
  - Volatility generally declines between 1980 & 1983
  - Again in early 1990s (Canada, UK, EA, Germany)
  - Increases around 2000 (Canada, UK, EA, Germany)
  - Little evidence of changes in means or dynamics

2. Literature Overview

- Interest in international business cycle linkages (even prior to last recession):

  Doyle & Faust *RevEcStat* (2005)
  Heathcote & Perri *JET* (2004)
  Kose, Otrok & Whiteman *JIE* (2008)
  Stock and Watson *JEEA* (2005)

  - General conclusion of unchanged (or declining) international effects since 1970s/1980s
  - Testing complicated by output volatility changes

    Sometimes motivates sample splitting
  - Little use of formal break tests (unknown dates)

- Distinct literature on European business cycle
  - Broad agreement that affiliations increase with monetary integration
    - de Haan, Inklaar and Jong-a-Ping (2008)
    - Artis and Zhang (1997, 1999)
    - Koopman and Azevedo (2008)
  - But may not be monotonic
    - Inklaar and de Haan (2001)
    - Massmann and Mitchell (2004)
  - Dates of change assumed known
- Euro Area & broader affiliation changes rarely considered together

3. Methodology

System approach

Capture international interactions through VAR:

$$\mathbf{y}_t = \boldsymbol{\delta} + \Phi_1 \mathbf{y}_{t-1} + \ldots + \Phi_p \mathbf{y}_{t-p} + \mathbf{u}_t$$

$$E(\mathbf{u}_t \mathbf{u}_t') = \boldsymbol{\Sigma}$$

- Formally test **VAR coefficients** and **error covariance matrix** constancy over time
  - Based on system structural breaks approach of Qu and Perron (2007)
  - But we sequentially test coefficient then covariance breaks

- Allow unknown number of breaks (max 3 for each)
  - Estimate number of breaks & break dates
  - But find **NO** significant changes in dynamics

- Hence focus on covariance matrix Σ
  - Aim to separate volatility & correlation breaks, given covariance break dates
  - Detecting correlation breaks difficult (Doyle & Faust, 2005)

Decomposing covariance breaks

➢ Overview:

For (diagonal) standard deviation matrix $\mathbf{D}$ & correlation matrix $\mathbf{P}$, with m identified breaks in $\mathbf{\Sigma}$:

- Definition: $\mathbf{\Sigma} = \mathbf{D}\,\mathbf{P}\,\mathbf{D}$
- Recursively drop least significant break from $\mathbf{D}$, until all significant
- Recursively drop least significant break from $\mathbf{P}$, until all significant
- Based on parametric bootstrap inference

- Volatility algorithm, use VAR residual vector e_t & estimated covariance break dates $\hat{T}_j^{(C)}$, j = 1, ..., m:

  0. Set $\hat{T}_j^{(Cor)} = \hat{T}_j^{(Vol)} = \hat{T}_j^{(C)}$, j = 1, ..., $m = m^{(Vol)} = m^{(Cor)}$.

  1. Test each H_0: $\mathbf{D}_j = \mathbf{D}_{j+1}$, j = 1, ..., $m^{(Vol)}$

     Implemented as test of constant mean for e_t^2 over regimes j & j+1

     Inference through finite sample bootstrap (Resample residual vectors & re-estimate VAR; given break dates).

  2. Unless all significant (5%), drop least significant volatility break, reduce $m^{(Vol)}$ and repeat test; Result is $m^{(Vol)} \leq m$ volatility breaks.

➢ Correlation algorithm:

0. Standardise residuals for volatility breaks as $v_t = e_t \hat{\mathbf{D}}_j^{-1}$ using volatility regimes $j = 1, \ldots, m^{(Vol)}$.

1. Using v_t, apply Jennich test for H_0: $\mathbf{P}_j = \mathbf{P}_{j+1}$, for each correlation regime $j = 1, \ldots, m^{(Cor)}$

   Inference through finite sample bootstrap.

2. Unless all significant (5%), drop least significant correlation break, reduce $m^{(Cor)}$ and repeat test; Result is $m^{(Cor)} \leq m$ correlation breaks.

Monte Carlo analysis

- VAR(1) for n = 3 variables & T = 200
  - Constant VAR coefficients:

$$\mathbf{A} = \begin{bmatrix} 0.7 & 0.1 & 0.5 \\ 0.2 & 0.3 & 0.4 \\ 0 & 0 & 0.5 \end{bmatrix}$$

  - Volatility & correlation regimes:

$$\mathbf{D}_1^* = [0.02, 0.02, 0.035], \quad \mathbf{D}_2^* = [0.015, 0.015, 0.015]$$

$$\mathbf{P}_1 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \qquad \mathbf{P}_2 = \begin{bmatrix} 1 & 0.5 & 0.2 \\ 0.5 & 1 & 0.2 \\ 0.2 & 0.2 & 1 \end{bmatrix}$$

  - Up to two covariance breaks at known date(s) 0.25T, 0.50T or 0.75T

Break Dates Detected (5% significance level)

	$T^{(Vol)} = 0.00T$		$T^{(Vol)} = 0.25T$		$T^{(Vol)} = 0.50T$		$T^{(Vol)} = 0.75T$	
	Cor.	Vol.	Cor.	Vol.	Cor.	Vol.	Cor.	Vol.
$T^{(Cor)} = 0.00T$	N.A.	N.A.	0.049	**1.000**	0.051	**1.000**	0.049	**1.000**
$T^{(Cor)} = 0.25T$	**0.868**	0.065	**0.867**	**1.000**	**0.807** 0.128	0.050 **1.000**	**0.871** 0.084	0.048 **1.000**
$T^{(Cor)} = 0.50T$	**0.926**	0.043	0.071 **0.919**	**1.000** 0.050	**0.925**	**1.000**	**0.909** 0.075	0.056 **1.000**
$T^{(Cor)} = 0.75T$	**0.820**	0.046	0.064 **0.833**	**1.000** 0.042	0.096 **0.786**	**1.000** 0.044	**0.817**	**1.000**

- Very good **size** & (unit) power for volatility test
- Fairly reliable size for correlation test & good power

4. Results I

System tests

System Structural Break Test Results [VAR(1)]

International VAR (Canada, UK, EA, US)		**Euro Area VAR** (France, Germany, Italy)	
Coefficients	**Covariance**	**Coefficients**	**Covariance**
WD*max* Test Statistics [and 5% Critical Values]			
32.32 [45.42]	**149.82** [27.91]	**44.35** [32.78]	**75.42** [21.09]

- Overall null is no break (max 3 breaks)
  - Weak evidence of intercept/coefficient breaks
  - Very strong evidence of covariance breaks

- Sequentially test 2 vs 1 break, 3 vs 2, etc:

Sequential Test Statistics [and 5% Critical Values]			
N.A.	**58.96** [29.55]	**10.38** [32.31]	**50.61** [22.06]
	60.94 [30.71]		**24.30** [22.98]

- 3 covariance breaks in both systems
- 1 coefficient break in International VAR

Estimated Break Dates	
1984Q2	**1984Q2**
1993Q1	**1993Q1**
2002Q1	**2002Q1**

- "Testing down" finds only coefficient break for Euro area is an intercept break

  ⇒ **No breaks in cross-country dynamics**

- VAR coefficients (% bootstrap *p*-values)

International VAR				
	Canada	**UK**	**Euro Area**	**US**
Canada	**0.15** (22.56)	**-0.02** (86.99)	**0.07** (37.96)	**0.10** (35.93)
UK	**0.02** (83.46)	**0.07** (56.36)	**-0.06** (35.54)	**0.18** (5.87)
Euro Area	**0.19** (12.51)	**0.20** (22.00)	**0.45** (0.00)	**0.07** (58.01)
US	**0.39** (0.02)	**0.25** (3.59)	**0.18** (1.82)	**0.18** (8.41)

Euro Area VAR			
	France	**Germany**	**Italy**
France	**0.35** (0.22)	**0.37** (25.66)	**0.32** (7.59)
Germany	**-0.04** (30.24)	**-0.15** (48.98)	**0.02** (68.54)
Italy	**0.27** (0.01)	**0.31** (9.74)	**0.40** (0.73)

- Cross-country effects generally small & insignificant
  - International role of the US is an exception
  - Italy leads for the E-3

5. Results II

Volatility results

	International VAR				
Subsample	**Break *p*-Value (%)**	**Canada**	**UK**	**Euro Area**	**US**
1970Q1-1984Q2		0.88	1.14	0.55	1.15
1984Q3-1993Q1	**0.00**	0.72	0.64	0.62	0.41
1993Q2-2002Q1	**0.00**	0.41	0.47	0.43	0.54
2002Q2-2010Q1	43.99	↓	↓	↓	↓

- 1993 break: introduction of inflation targeting (Canada), stable period after 1992 ERM crisis (UK, EA) & German reunification (EA)

	Euro Area VAR			
Subsample	**Break *p*-Value (%)**	**France**	**Germany**	**Italy**
1970Q1-1984Q2		0.48	1.05	0.95
1984Q3-1993Q1	**0.73**	0.46	1.24	0.53
1993Q2-2002Q1	**0.32**	0.43	0.81	0.57
2002Q2-2010Q1	55.82	↓	↓	↓

- Latest covariance break NOT a volatility break
  - Contrast with univariate analysis

Correlation results

	International VAR				
Subsample	**Break *p*-Value (%)**	**Economy**	**Canada**	**UK**	**Euro Area**
1970Q1-1984Q2		**UK**	0.20		
		Euro	0.13	0.29	
		US	0.40	0.18	0.13
1984Q3-1993Q1	24.92				
1993Q2-2002Q1	83.25				
2002Q2-2010Q1	**2.66**	**UK**	0.45		
		Euro	0.41	0.75	
		US	0.59	0.65	0.60

	Euro Area VAR			
Subsample	**Break *p*-Value (%)**	**Economy**	**France**	**Germany**
1970Q1 - 1984Q2		**Germany**	0.42	
		Italy	0.00	0.18
1984Q3 - 1993Q1	**0.06**	**Germany**	0.30	
		Italy	**0.58**	0.18
1993Q2 - 2002Q1	22.69			
2002Q2 - 2010Q1	**0.05**	**Germany**	0.74	
		Italy	0.79	0.83

- Also considered 6 country VAR:
  - Effectively unchanged break dates & cross-country dynamics
  - 1993 significant as correlation break at 10%
- US & E-3 VAR finds 2 covariance breaks, 1984Q1 & 1999Q2
  - Last is correlation break (p-value 0.05%) & may be volatility (*p*-value 9.3%)
- Suggests may be missing some 1990s international correlation changes

Extract from 6 country VAR results:

Subsample	Economy	UK	US	France	Germany
1970Q1-1983Q4	US	0.30			
	France	0.28	0.26		
	Germany	0.46	0.13	0.38	
	Italy	0.08	0.09	-0.09	0.12
1984Q1 - 1992Q2	US	-0.18			
	France	0.04	-0.11		
	Germany	0.01	-0.14	0.46	
	Italy	0.05	-0.19	0.67	0.28
1992Q3 - 2002Q1	US	0.21			
	France	0.38	0.16		
	Germany	0.08	0.32	0.12	
	Italy	0.23	-0.11	0.33	-0.06

- Suggests 1990s similar to 1970s

6. Concluding Remarks

- Cross-country dynamics stable since 1970s
- Volatility and correlation change
  - Some evidence (6 country VAR) of correlation increases from early 1990s
  - Not just during 2008/09 recession
- Correlation breaks worth more investigation!