

Changes in International Business Cycle

Affiliations

Denise Osborn

Centre for Growth and Business Cycle Research,
Economics, University of Manchester

On-going work with:

Erdenebat Bataa, University of Lancaster

Marianne Sensier, University of Manchester

Dick van Dijk, Erasmus University Rotterdam

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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!

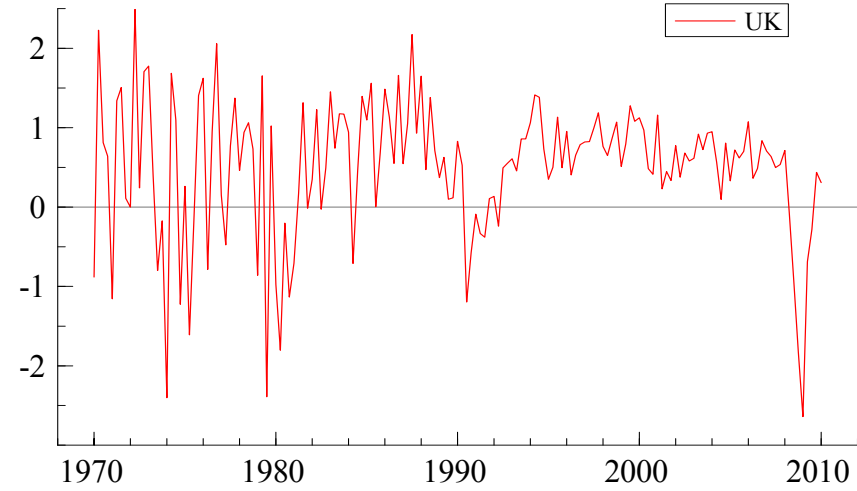
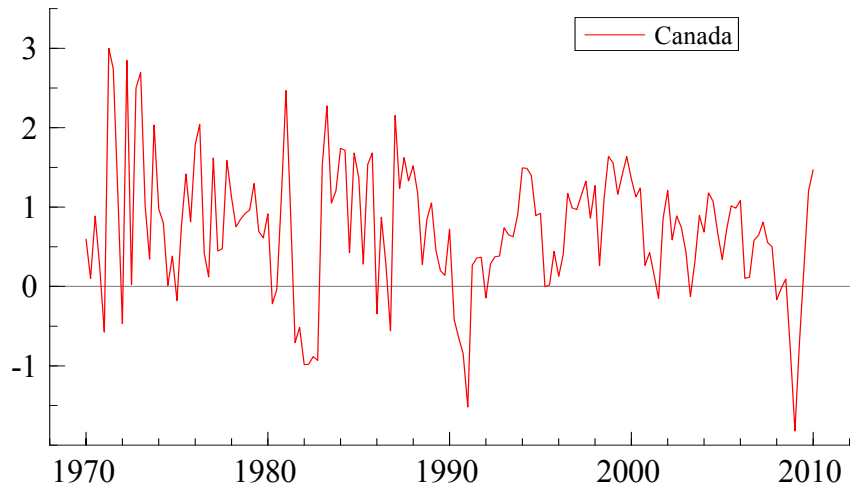
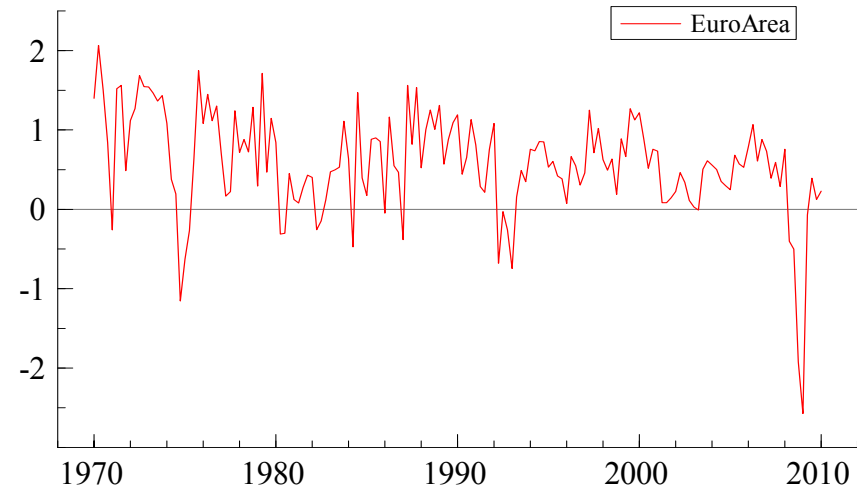
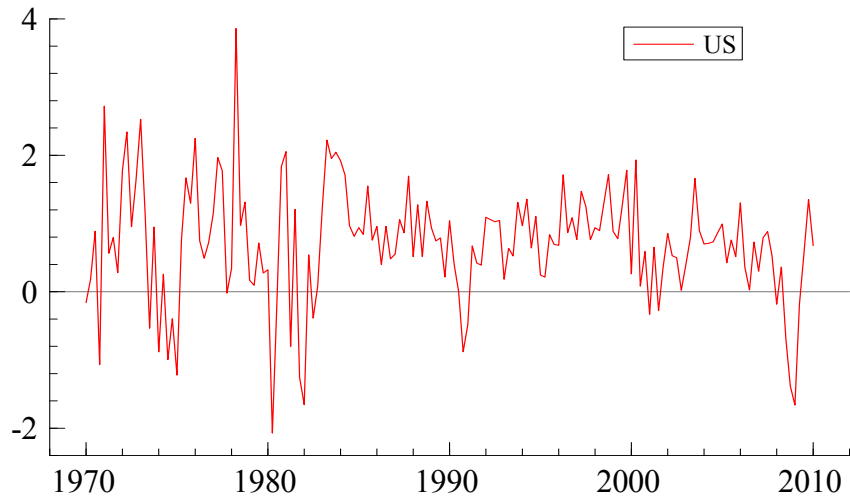
Route map of talk:

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)





- Characteristics:
 - Volatility change(s)
 - Communalities 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:

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

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

- 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 Σ :

- Definition: $\Sigma = \mathbf{D} \mathbf{P} \mathbf{D}$
- 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 $\hat{T}_j^{(C)}$, $j = 1, \dots, m$:

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

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

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

$$v_t = e_t \hat{\mathbf{D}}_j^{-1} \quad \text{using volatility regimes } j = 1, \dots, m^{(Vol)}.$$

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

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:

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

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

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

Break Dates Detected (5% significance level)

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

- 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
<u>WD_{max} Test Statistics [and 5% Critical Values]</u>			
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:

<u>Sequential Test Statistics [and 5% Critical Values]</u>			
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

<u>Estimated Break Dates</u>	
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

Subsample	International VAR				
	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)

Subsample	Euro Area VAR			
	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

Subsample	International VAR				
	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

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