Spurious periodicities in cliometric series

simultaneous testing

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Outline

Introduction

- Motivation
  - **Spectral analysis** of cliometric and economic time-series by Cendejas et al. (2015b), Metz (2011, 2010), Pollock (2013, 2014), Diebolt (2014)
  - Works on the **significance testing of frequency peaks** by Mann and Lees (1996) and Thomson (1982)
  - **Slutzky-Yule Effect**
- Long debate on the duration of business cycles
  - The long waves of Kondratjew (1926) of 45-60 years; Kuznets (1930) cycles of 15-25 years; Juglar (1862) cycles of 7-11 years and to much shorter Kitchin (1923) cycles of 3-5 years
- Research questions
  - How do spurious periodicities emerge?
  - Is it possible to test and identify them?
- Strategy
  - Perform a controlled experiment with an anticipated measurement error through filtering and differencing
  - Estimate spectral distribution of each type of signals
  - Simultaneously test the significance of the frequencies

Literature overview I, business cycles

- Kitchin cycles: duration of 3-5 (up to 8) years; Kitchin (1923) used the UK and the USA data on clearings, prices and interest rates; series were detrended with a linear trend allowing for a structural break.
- Juglar cycles: duration of 4-5 up to 7-11 years; Juglar (1862) performed descriptive analysis.
- Kuznets cycles: duration of 15-25 years; Kuznets (1930) used the USA production and price series and detrended them with a logistic non-linear curve and smoothed with a moving-average.
- Kondratjew waves: duration of 45-60 years; Kondratjew (1926) detrended the data with a quadratic trend and smoothed with a 9-year moving-average.
- Modern literature: durations of 2-19 years (Korotayev and Tsirel, 2010, Metz, 2010, 2011, Diebolt, 2014, Cendejas et al., 2015a, Christoffersen, 2000, Bergman et al., 1998); methods including but not limited to Hodrick-Prescott, Baxter-King, Christiano-Fitzgerald, structural models ... Bry-Boshan method, spectral analysis, wavelets ...

Literature overview II, spurious periodicities

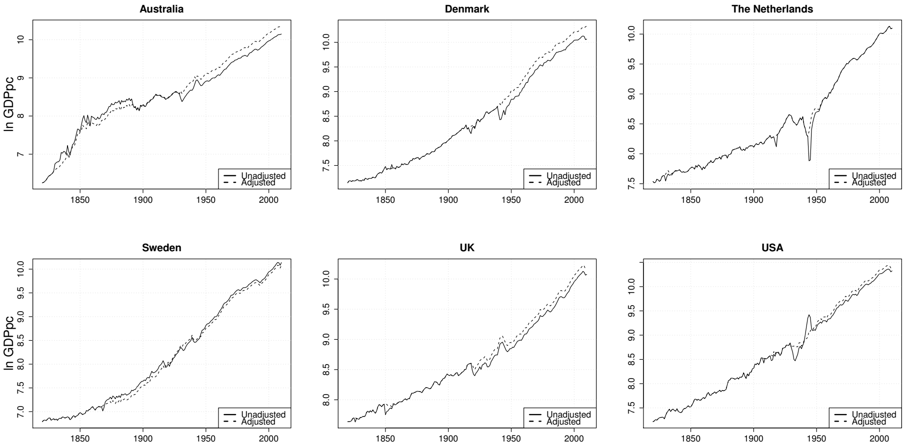
- Significance testing: to test whether certain peaks in spectral density are significantly different from the spectral density of noise, Thomson (1982) used a white noise model; whereas Mann and Lees (1996) used red noise.
- Spurious periodicities in the data: Nelson and Kang (1981) showed that even randomly generated series can exhibit periodicities, which have no underlying reason and are spurious.
- Spurious periodicities in detrending: Pollock (2013) notes that "differencing ... severely attenuates the elements of the data that are adjacent in frequency to the zero frequency of the trend ... it also amplifies the high frequency elements of the data". On the contrary, summation operator "gives unbounded power to the elements that have frequencies in the vicinity of zero". This issue to a certain extent is noted in the works of Metz (2011), Pollock (2013, 2014), Woitek (1997, 1998).

Data and methods

- Data: GDP pc series are taken from Bolt and van Zanden (2013) for Australia, Denmark, the Netherlands, Sweden, the UK, the USA; time frames 1820-2010; uniform methodology is applied to all series;
- Strategy: outlier adjustment (ARIMA) $\rightarrow$ testing for long memory (fractional integration tests) $\rightarrow$ detrending (filtering and differencing) $\rightarrow$ testing for stationarity (unit root test) $\rightarrow$ background noise generation (simulation) $\rightarrow$ spectral analysis and simultaneous testing against noise (spectral window and confidence intervals)

Outlier adjustment I

Figure 1: Outlier adjustment with ARIMA: AO, LS, TC, IO



Outlier adjustment II

The pin-pointing of the events related to outliers is based on Darné and Diebolt (2004). Additional information was obtained from: Chisholm (1963), Shaw (1984), Hickson and Turner (2002), Neal (1998), Butlin (1963), Abildgren et al. (2011), Haeger et al. (2011), Campbell (2012), Herrick (1908), Coghlan (2011).

Table 1: Detailed outlier information

Country	Year	Type	Coef.	T-stat.	Event
Australia	1830	LS	0.162	4.029	End of drought of 1829
	1835	TC	0.148	3.943	Series of droughts
	1839	AO	-0.117	-3.484	Severe drought
	1842	TC	-0.226	-5.864	Financial crises (1841-1843)
	1850	AO	-0.142	-4.250	Severe drought
	1853	AO	0.139	4.139	End of South Australian devaluation of 1852
	1858	AO	-0.216	-6.451	Drought of 1857
	1892	LS	-0.178	-4.371	Banking crisis of 1890s
	1930	LS	-0.188	-4.581	Great Depression
	1942	TC	0.148	3.900	WWII
Denmark	1855	AO	0.078	3.884	Recession and Monetary crisis of 1855-1858
	1917	TC	-0.099	-4.310	WWI
	1918	AO	-0.078	-3.742	WWI
	1940	LS	-0.172	-6.998	WWII
	1941	TC	-0.155	-6.551	WWII
	1945	AO	-0.104	-5.155	WWII
	2009	LS	-0.089	-3.681	Global financial crisis

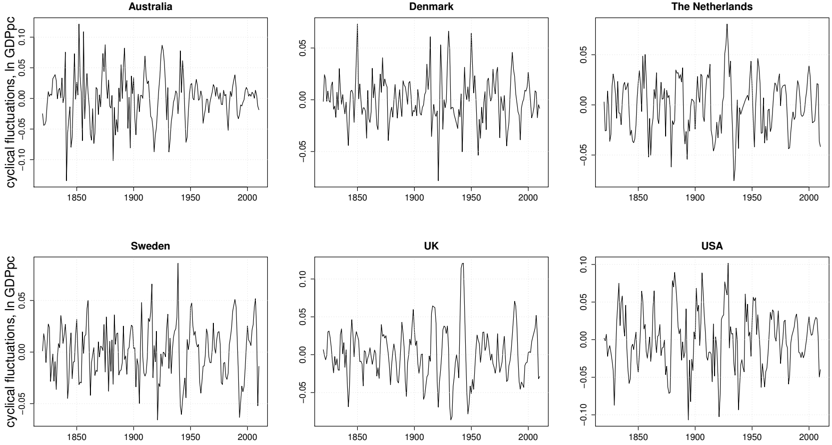
Outlier adjustment III

Table 2: Detailed outlier information

Country	Year	Type	Coef.	T-stat.	Event
The Netherlands	1830	TC	-0.113	-4.277	The Belgian Revolution
	1917	AO	-0.102	-4.60	WWI
	1918	AO	-0.19	-8.61	WWI
	1944	TC	-0.488	-18.17	WWII
	1945	AO	-0.263	-13.491	WWII
Sweden	1868	TC	-0.103	-3.943	Severe famine of 1866-1868
	1870	LS	0.104	3.680	End of famine
	1918	LS	-0.139	-5.098	WWI
	1932	TC	-0.094	-3.776	Great Depression
	1946	LS	0.094	3.469	End of WWII
UK	1826	AO	-0.067	-4.420	Financial crisis of 1825-1826
	1850	TC	-0.173	-8.297	Commercial/financial crisis of 1847-1848
	1919	LS	-0.102	-4.095	End of WWII
	1926	AO	-0.060	-3.977	General Strike
USA	1908	AO	-0.095	-3.421	Financial crisis of late 1907
	1914	TC	-0.114	-3.575	WWI
	1931	TC	-0.125	-3.764	Great Depression
	1932	TC	-0.186	-5.715	Great Depression
	1933	TC	-0.122	-3.710	Great Depression
	1941	TC	0.117	3.553	WWII
	1942	TC	0.184	4.920	WWII
	1943	TC	0.166	4.657	WWII
	1946	LS	-0.263	-7.097	End of WWII

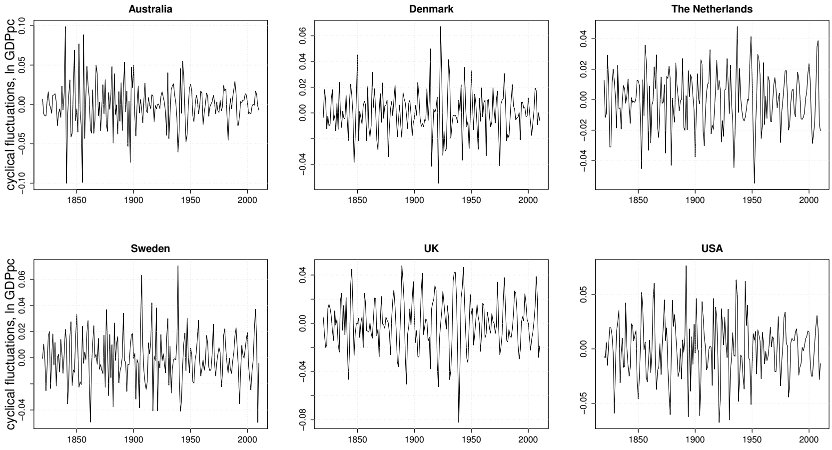
Asymmetric Christiano-Fitzgerald filter I

Figure 2: CF25



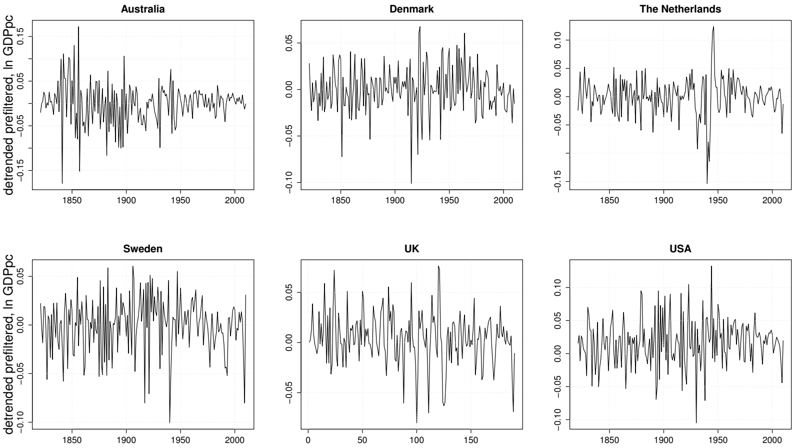
Asymmetric Christiano-Fitzgerald filter II

Figure 3: CF11



First differences

Figure 4: FD



Fractional integration tests

Table 3: Tests on fractional integration, d coefficients and their equality

Phillips (2007) Modified Log Periodogram Regression estimator, deterministic trend removed, H_0: d=1												
	lnAUSTRALIA_adj		lnDENMARK_adj		lnNETHERLANDS_adj		lnSWEDEN_adj		lnUK_adj		lnUSA_adj	
Power	d	P>z	d	P>z	d	P>z	d	P>z	d	P>z	d	P>z
0.50	1.131	0.461	1.031	0.859	1.007	0.969	1.167	0.347	1.167	0.346	0.934	0.711
0.55	1.141	0.364	1.039	0.800	1.085	0.586	1.075	0.628	0.912	0.571	0.916	0.589
0.60	1.119	0.375	0.991	0.949	0.959	0.760	1.134	0.315	0.847	0.252	0.831	0.206
0.65	1.112	0.341	0.999	0.994	0.999	0.992	1.093	0.427	0.816	0.117	0.962	0.747
0.70	1.097	0.345	0.915	0.405	0.922	0.448	1.002	0.987	0.919	0.429	1.002	0.984
Robinson (1995) test for equality of d coefficients, H_0: d coefficients are the same for all six series												
$F(5,666) = 0.2834$ and $P>F = 0.9223$												

Unit root tests I

Table 4: Stationarity test of the filtered Kuznets cycles

CF filtered, Kuznets	KPSS Test for Level Stationarity	
	Test statistic	P value
Australia	0.0139	> 0.1
Denmark	0.0183	> 0.1
The Netherlands	0.0135	> 0.1
Sweden	0.0135	> 0.1
UK	0.0121	> 0.1
USA	0.0164	> 0.1

Table 5: Stationarity test of the filtered Juglar cycles

CF filtered, Juglar	KPSS Test for Level Stationarity	
	Test statistic	P value
Australia	0.0089	> 0.1
Denmark	0.0076	> 0.1
The Netherlands	0.0065	> 0.1
Sweden	0.0076	> 0.1
UK	0.0065	> 0.1
USA	0.0065	> 0.1

Unit root tests II

Table 6: Stationarity test of the detrended prefiltered series (FD)

Detrended and prefiltered	KPSS Test for Level Stationarity	
	Test statistic	P value
Australia	0.2151	> 0.1
Denmark	0.1523	> 0.1
The Netherlands	0.0376	> 0.1
Sweden	0.1995	> 0.1
UK	0.3279	> 0.1
USA	0.1974	> 0.1

Confidence intervals for red/blue noise

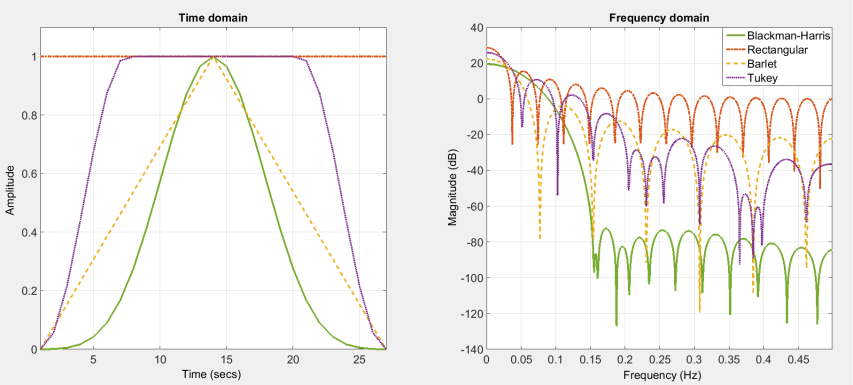
Table 7: Estimated coefficients for generation of noise

	AR(1) coefficient		
	CF (25)†	CF (11)	Prefiltered (FD)
Australia	0.488	0.0153	-0.236
Denmark	0.526	0.148	-0.229
The Netherlands	0.662	0.243	0.128
Sweden	0.476	0.125	-0.145
UK	0.76	0.499	0.329
USA	0.673	0.281	-0.0815

† for presentation purposes only the background noise for CF (11) and detrended prefiltered signals is displayed on the figures

Spectral Analysis

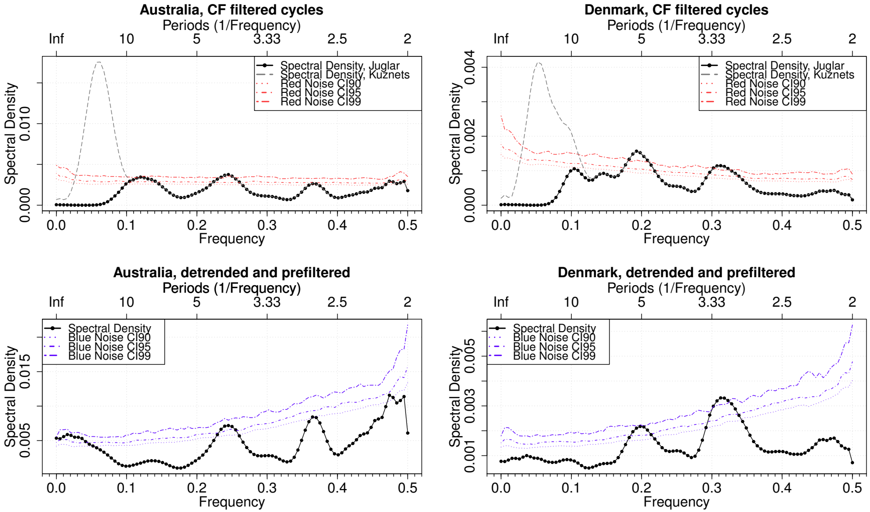
Figure 5: Properties of various windows



- **Blackman-Harris** is a general-purpose window with the one of the best side-lobe depression after 0.15 frequency (see Prabhu, 2013); for lower frequencies spectral leakage is almost the same; a window length of 27 periods (years) is set with a 50% overlapping.

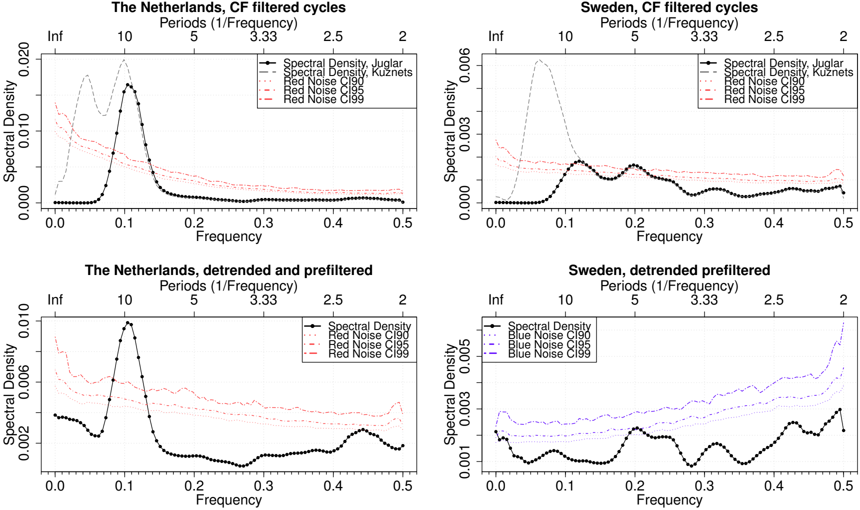
Results I

Figure 6: Filtered (above) and prefiltered spectral densities (below)



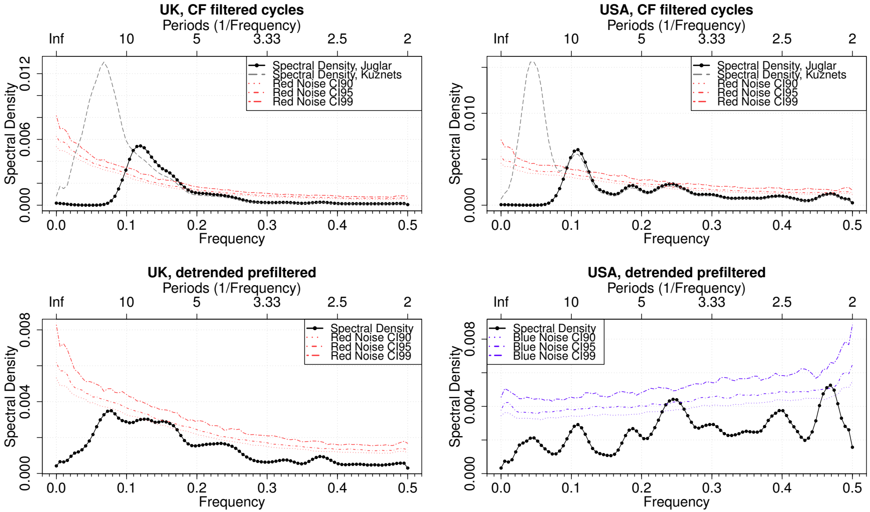
Results II

Figure 7: Filtered (above) and prefiltered spectral densities (below)



Results III

Figure 8: Filtered (above) and prefiltered spectral densities (below)



Results IV

Table 8: Significant periodicities of CF filtered cycles in years, Kuznets

Frequency peak	Australia	Denmark	The Netherlands	Sweden	UK	USA
1st	17.455	19.2	21.33	16	14.769	24
2nd	8.348	5.189 ∘	10.11	5.053 ∘	-	9.143
3rd	4.085 ∗	3.2 ∗	-	-	-	4.085 ∗
4th	2.743 ∗	-	-	-	-	2.133 ∗
5th	2.110 ∗	-	-	-	-	-

Table 9: Significant periodicities of CF filtered cycles in years, Juglar

Frequency peak	Australia	Denmark	The Netherlands	Sweden	UK	USA
1st	8.348	5.189 ∘	9.6 ∗	8.348	8.348 ∗	9.143
2nd	4.085 ∗	3.2 ∗	-	5.053 ∘	-	4.085 ∗
3rd	2.743 ∗	-	-	-	-	2.133 ∗
4th	2.110 ∗	-	-	-	-	-

Table 10: Significant periodicities of detrended and prefiltered cycles

Frequency peak	Australia	Denmark	The Netherlands	Sweden	UK	USA
1st	4.085 ∗	5.053 ∘	9.6 ∗	4.923 ∘	8.348 ∗	4.085 ∗
2nd	2.743 ∗	3.2 ∗	2.26	-	6.621	2.133 ∗
3rd	2.110 ∗	-	-	-	-	-

* denotes simultaneous significance of the peak value at least at the 90% level

∘ denotes simultaneous significance of a nearest neighbour peak value (within 0.15 years) at the 90% level

Discussion I

- Our results after conducting simultaneous significance testing in general confirm the findings from other works on duration of cycles:
  - Woitek (1997, p. 92): OECD; 8.14 years and for the differenced data - around 7.13.
  - Bergman et al. (1998, p. 74): from 3.8 to 4.6 for Denmark; from 3.4 to 5.5 for the Netherlands; from 4.7 to 5 for Sweden; from 3.5 to 6 for the UK and from 4.1 to 6.3 for the USA.
  - Cashin and Ouliaris (2001, p. 16): from 3.2 to 6.1 for Australia.
  - Cendejas et al. (2015b, pp. 22-25) 6.9 for Australia; 5.3 for Denmark; 3.9 for the Netherlands; 4.5 for Sweden; 3 for the UK and 5.2 for the USA.
  - For the UK Metz (2011, p. 235) finds irregular cycles with a length of around 11 years which is closer to our estimate of 8.348 than the findings of other researchers. In addition, Mills (2007, p. 222), reports cycles of 8.2 years for the UK real interest rates.
  - Diebolt and Guiraud (2000), Diebolt (2014) report longer periodicities, corresponding to Juglar and Kuznets cycles from 7 to 22 years.

Discussion II

- Simulation vs. cliometric data: in case of simulated time series we know the true parameters (planned); however, no simulation can outperform nature in creativity of distortions.
- Asymmetric vs. symmetric weights: the asymmetric CF filter is unlikely to generate spurious periodicities outside of the cut-off frequencies, but is not phase-neutral and may create spurious results within the frequency range.
- Spectral analysis vs. wavelets: both allow significance testing and are theoretically equally exposed to biases resulting from detrending.

Conclusion I

How do spurious periodicities emerge?

- Data preparation: seasonal (higher frequencies) and outlier adjustment (lower frequencies)
- Detrending: differencing (higher frequencies) and filtering (lower frequencies)
- Spectral analysis: spectral leakage and spurious peaks not significantly different from blue/red/white noise (all frequencies)

Is it possible to identify them?

Providing that the background noise model is appropriate, it is possible to identify periodicities, not significantly different from the spectral density of noise.

Conclusion II

Implications

- For time series: VARs (outliers; optimal lag length; related tests); avoiding *blind* usage of Box-Jenkins approach; accounting for long-memory properties.
- For filtering: investigating phase-shift bias of asymmetric filters; identifying prefiltered benchmark signal.
- For spectral analysis: simultaneous significance testing using filtered and prefiltered signals; attention to spectral leakage.
- For business cycle research: cycles with duration longer than 10 years are likely to be spurious.

Thank you for your attention!

Merci beaucoup pour votre attention!

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