Business Cycle Synchronization between the CEE Countries and the Eurozone

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Overview

1. Motivation
2. Dataset
3. Classical Approach via filtering
4. Wavelet Approach
5. Conclusions
6. Bibliography
Theoretical background of **Optimal Currency Areas (OCA)**, Mundell (1961):

- The Euro Area can produce more benefits than costs if a high degree of synchronization with the Euro Zone is previously achieved.

- Rogoff (1985) and Clarida et al. (1999): the Central Bank will respond more successfully to aggregate shocks and implement its policy with greater efficiency, if the union’s members have less volatile and more synchronized business cycles $\implies$ lower probability of asymmetric shocks.
Period covered: **2000Q1-2012Q4**

11 Countries from the CEE group:
- 8 *First Wave* (2004) - Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Slovenia and Hungary
- 2 *Second Wave* (2007) - Romania and Bulgaria
- Croatia - expected to join the EU in 2013
- Eurozone Aggregate indicator - EU-15 (over 90% of the EU GDP)

Indicator: Constant Price GDP and ESI, from the Eurostat Database
Part I - Classical Methodology

Univariate filtering techniques

- Quadratic Trend (QT) Filter
- Beveridge-Nelson (BN) Decomposition
- Hodrick-Prescott (HP) Filter
- Band-Pass (BP) Filter
- Unobserved Components (UC) Model
Aggregating the results

Darvas, Vadas (2005) Consensus Measure

\[ K_t^{(m)} = \frac{1}{I_t} \sum_{s=k+1}^{T} \left| (q_t - q_{t,s}^{(m)}) - (q_t - q_{t,s-1}^{(m)}) \right| \]  

(1)

Using the weights:

\[ \omega_m = \frac{1/K^{(m)}}{\sum_{i=1}^{p} 1/K^{(i)}} \]  

(2)
Results obtained from the filtering techniques

Figure: Estimated Business cycle for Romania 2000-2012
Combined Business Cycles 2000-2012

Czech Republic

Croatia

Estonia

Hungary

Latvia

Lithuania

Poland

Romania

Slovakia

Slovenia

Bulgaria

Eurozone

Consensus I

Consensus II

Consensus III
**Correlations between CEE countries and the Euro zone 2000-2012**

<table>
<thead>
<tr>
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<td>67.5</td>
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<td><strong>83.9</strong></td>
<td><strong>88</strong></td>
<td><strong>84.5</strong></td>
<td>83.6</td>
<td>62.5</td>
<td>67.5</td>
<td>78.1</td>
<td><strong>89.4</strong></td>
<td>72.8</td>
<td>82.7</td>
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The Highest Correlated Countries are:

- Slovenia
- Estonia
- Hungary
- Czech Rep.
Correlations between CEE countries and the Eurozone

\[ IC_{i,EA} = T^{-1} \left\{ \sum_{t=1}^{T} (S_{i,t} S_{EA,t}) + (1 - S_{i,t})(1 - S_{i,t}) \right\} \]  \hspace{1cm} (3)

where \( S_{i} \) is a binary variable, 1 for positive output gap, 0 for negative.

Lead/Lag Correlations

Two economies are synchronized if the maximum correlation occurs \textit{contemporaneously}.
### Additional Indicators

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<td>Lead/Lag</td>
<td>0.69</td>
<td>0.83</td>
<td>0.77</td>
<td>0.69</td>
<td>0.75</td>
<td>0.77</td>
<td>0.75</td>
<td>0.75</td>
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- According to CI, all countries are *in the same phase* as the Eurozone.
- Lead/Lag correlations show that **Romania** and **Bulgaria** are lagging behind the Eurozone, by **two quarters**.
Cluster Analysis

- Hierarchical Tree Clustering - countries are more related to nearby countries than to those farther away.

- Define the distance between two clusters as the average distance:

\[ d(r, s) = \frac{1}{n_r n_s} \sum_{i=1}^{n_r} \sum_{j=1}^{n_s} dist(x_{ri}, x_{sj}) \]

- Distance measure - Pearson’s correlation

Figure: Dendrogram for the CEE Countries
Two significant groups:

- **Eurozone**: Hungary, Slovenia and the Baltic States
- **CEE**: Romania and Bulgaria joined by Slovakia and Croatia

The **Czech Republic** can be included in both clusters. **Poland** is the most dissimilar country in the dataset.

Figure: Distance Map for the CEE countries
Economic developments are the results of the actions of several agents, who have different term objectives. Economic time series are an aggregation of components, functioning at different frequencies.

**Wavelets** - determine the underlying forces in the time series, over a range of different time horizons, can reveal remarkable insights into cycles, at different time scales.

- are capable to handle non-stationary data or structural breaks that appear in some time series.
What are Wavelets?

A wavelet is a wave-like oscillation with an amplitude that increases and then decreases back to zero. Mathematically, it has to fulfill the condition:

$$\int_{-\infty}^{\infty} \psi(t) \, dt = 0$$  \hspace{1cm} (4)

Starting with a mother wavelet, we can construct a family of ”daughter wavelets” by a simple process of scaling and translating:

$$\psi_{s,u}(t) = \frac{1}{\sqrt{|s|}} \psi \left( \frac{t-u}{s} \right)$$  \hspace{1cm} (5)
Discrete Wavelet Transform

The discrete version of the wavelet function is:

\[ \psi_{m,n} = a^{-\frac{m}{2}} \psi (a^{-m} t - nb) \]  \hspace{1cm} (6)

Define the Discrete Wavelet Transform of a function \( x(t) \) as:

\[ W_{m,n}(x) = a^{-\frac{m}{2}} \int_{-\infty}^{\infty} x(t) \psi (a^{-m} t - nb) \, dt \]  \hspace{1cm} (7)

**Basic Idea**: Convolve the series with a wavelet function and compute the coefficients
Multiresolution Analysis

The main tool used in wavelet theory - decomposes a signal into its constituent multiresolution components, allowing the separate analysis of these sub-processes (Mallat and Meyer):

\[ x(t) = \sum_k s_{J,k} \phi_{J,k}(t) + \sum_k d_{J,k} \psi_{J,k}(t) + \cdots + \sum_k d_{1,k} \psi_{1,k}(t) \]  

(8)

where \( s_{J,k} \) are the approximation coefficients and \( d_{J,k} \), the detail coefficients.
Mallat’s Pyramid Algorithm

This approach is equivalent to Subband Filtering Schemes, used in electrical engineering.
Daubechies Family of Wavelets

Figure: Scalling and Wavelet Functions (ablove)
The Four Filters associated with the db4 wavelet (below)
Figure: MRA results for Romania
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The correlations between the business cycles, obtained using the Multiresolution Analysis:

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<tr>
<td>07-12</td>
<td>86.2</td>
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<td>87.1</td>
<td>97.1</td>
<td>96.7</td>
<td>86.1</td>
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</tbody>
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We obtain similar results with the first part of the analysis:
Continous Wavelet Transform

In contrast to the DWT, its continuous counterpart operates on a continuous set of scales:

$$W_x(s, u) = \langle x(t), \psi_{s,u}(t) \rangle = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{|s|}} \psi \left( \frac{t-u}{s} \right) dt$$ (9)

The original function $x(t)$ is fully preserved by the wavelet transform, i.e. it can be perfectly reconstructed using:

$$x(t) = \frac{2}{C_\psi} \int_0^\infty \left[ \int_{-\infty}^{\infty} W_x(s, u) \psi_{s,u}(t) du \right] \frac{ds}{s^2}$$ (10)

Limiting the integration over a range of scales performs a band-pass filtering of the series.
Morlet family of Complex Wavelets

Analytic Formula for the Morlet Wavelet Family

\[ \psi_{\omega_0}(f) = Ke^{i\omega_0 t} e^{-\frac{t^2}{2}} \] (11)
Wavelet Power Spectrum

The **wavelet power spectrum** or scalogram is defined, in analogy with Fourier Theory, as:

\[
W_{PS_x} (u, s) = |W_x (u, s)|^2
\]  

(12)

- Measures the *variance distribution* present in the time series, over the time-scale plane
- Has the ability detect *cyclical behavior* present in a time series.
How to interpret the Wavelet Power Spectrum?

Figure: Wavelet Power Spectrum for Romania
Wavelet Power Spectrum - Results

Figure: WPS - Bulgaria

Figure: WPS - Hungary
Wavelet Power Spectrum - Results

Figure: WPS - Poland

Figure: WPS - Eurozone
Wavelet Coherency and Phase Difference

**Wavelet Coherency** - a measure of local correlation, in time and frequency, between two series:

$$R_{xy} = \frac{|S(W_{xy})|}{[S(|W_x|^2)S(|W_y|^2)]^{1/2}}$$

(13)

**Phase Difference** - Measures the delays of the oscillations between two time series:

$$\phi_{xy} = \text{Arctan} \left( \frac{\Im(S(W_{yy}))}{\Re(S(W_{xy}))} \right), \quad \phi_{xy} \in (-\pi, \pi)$$

(14)
Wavelet Coherence - Results

Romania vs the Eurozone – Coherency plot

Period
2000 2005 2010
2
4
6
8

Phase Difference

1.5–4.5 frequency band

Bulgaria vs the Eurozone – Coherency plot

Period
2000 2005 2010
1
3
5
7

Phase Difference

4.5–8 frequency band

Figure: Coherence Plot - Romania

Figure: Coherence Plot - Bulgaria
Wavelet Approach

Wavelet Coherence - Results

Figure: Coherence Plot - Slovenia

Figure: Coherence Plot - Latvia
Wavelet Coherence - Results

Figure: Coherence Plot - Estonia

Figure: Coherence Plot - Lithuania
Conclusions (1)

- The most synchronized countries from the CEE group are Slovenia, followed by the Czech Republic, the Baltic States and Slovakia.

- The Baltic States form the most homogeneous subgroup from the entire CEE region, with a highly correlated business cycle behaviour.

- At the bottom of the hierarchy we find Romania, Bulgaria and Poland, results confirmed by both the classical and wavelet approaches.

- Concerning lead/lag relationships, all the C.E.E. countries business cycles are in concordance with that of the Euro Area.
Some countries are in the **same phase** as the Eurozone i.e. Slovenia, Slovakia, Estonia and others, namely Bulgaria and Romania, are **significantly lagging** behind.

- Romania and Bulgaria are not yet prepared to become a part of the single currency area.

- Dating the **business cycle turning points**, using Markov-switching models, could provide further insight into the behavior of business cycles.

- Another direction worth exploring is the use of **structural models**, which rely on certain economic assumptions formulated in the underlying model.
Selective Bibliography


Thank you for your attention!