Turning point chronology for the Euro-Zone: A Distance Plot Approach

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Introduction

- Since the early work by Burns and Mitchell (1946), many attempts have been made to measure and forecast business cycles.
- The main aim of business cycle analysis is to detect and anticipate economic fluctuations with a particular attention paid to turning points location (Anas et al.(2008)).
- very few countries have official dating procedures (among them the USA (National Bureau of Economic Research, NBER) and Japan (Economic and Social Research Institute))
- Since the establishment of the Euro area, there does not yet exists an official dating for the Euro area
- Dating is an *ex post* exercise, and in this respect accuracy is an important criterion since dating is useful for economic decision-making.
- Governments and central banks are usually very sensitive to indicators showing signs of deterioration in growth to allow them to adjust their policies sufficiently in advance, avoiding more deterioration or a recession.

- In this respect, timing is important and the earlier the signal, the better (Anas et al. (2007)).
- Announcing of the cycle turning points dates in the United States are often substantially delayed[a] .
- As such, it will be interesting to propose methods that will enhance the faster and accurate detection of the dates.
- Previous works documenting the Euro-zone business cycle are quite limited by: stationarity of data, choice of filters and usually model-based approaches (see Hamilton (1989); Artis et al. (2002, 2003b); Hodrick and Prescott (1997); Anas et al. (2007); Anas and Ferrara (2006); Monch and Uhlig (2005); etc).
- For instance, the work by Monch and Uhlig (2005) first constructs a Euro area monthly real GDP series by interpolation and then applies a modified version of a nonparametric algorithm, the Bry-Boschan procedure (Bry and Boschan (1971)), to determine peaks and troughs in univariate time series.

[a] For more information on announcement of these dates, see http://www.nber.org/cycles.html

- It is unclear whether information is lost or gained after such interpolation.
- It is worth noting that the proposed Bry-Boschan procedure by Monch and Uhlig (2005) as a turning point selection method is unsuitable when multivariate time series are considered for dating.
- To our best of knowledge, most of the existing dating methodologies are restrictive in terms of assumptions on model specification and usually not suitable for short and non-stationary data.
- There is a need for procedures that are essentially data-driven approach with no a priori assumptions on the statistical properties on the underlying economic indicator(s).

Our Mission

- Our aim to provide a transparent way of establishing a turning point chronology for the Euro-zone business cycle.
- The analysis is achieve by exploiting the concept of recurrence plots, in this case distance plot, to characterize and detect turning points in the business cycle for any economic system.
- The approach has these features:
  - Robustness to extreme values, non stationarity and to any length of data.
  - It must be replicable to every one. This enhances transparency of method.
  - Adaptability of the method to different time series.
  - The chronology must not be revised through time.
- A comprehensive analysis of the feasibility of this approach is provided.

What did we do?

- Firstly, we exploit the concept of recurrence plots on the US Industrial Production Index (IPI) series to characterize and detect recessions periods.
- The essence of starting the analysis with the US data is to use it as a beachmark for our analysis
  - since there already exist reference chronology for the US business cycle, provided by the Dating Committee of the NBER[a].
- We then use this concept in constructing a turning point chronology for the Euro-zone business cycle.
- In particular, we show that this approach permits to detect turning points and study the business cycle without *a priori* assumptions on the statistical properties on the underlying economic indicator.

[a]National Bureau of Economic Research

Data Analysis based on recurrence plots

- The method of recurrence plots (RP) is a graphical technique that depicts the different occasions when a dynamical system visits roughly the same area in the phase space (Eckmann et al. (1987); Marwan (2008)).
- From Takens' embedding theorem , the dynamics can be appropriately presented by a reconstruction of the phase space trajectory $\vec{x}(t) = \vec{x_i} \in \mathbb{R}^m$ ($i = 1, \cdots, \eta$, $t = i\Delta t$, where Δt is the sampling rate) in the $m-$dimensional phase space.
- The phase space trajectory of a system refers to the path traced in a high dimensional space representing the time evolution and the dynamics of the system.
- For a given one-dimensional time series $\{u_i\}_{i=1}^{N}$, the phase space vectors $\vec{x}$ can be reconstructed by embedding the series using Takens' time delay method $\vec{x_i} = (u_i, u_{i+\tau}, \cdots, u_{i+(m-1)\tau})$.
- The coordinates of this vector correspond to the present and lead values of the series.

- The parameters m and τ are referred to as the embedding dimension and time delay respectively ((Takens (1981); Gautama et al. (2003); Addo et al. (2012a, 2012b, 2013)).
- We refer to the case for which $m = 1$ and $\tau = 1$ as an unembedded time series.

The recurrence plot is the calculation of an $\eta \times \eta$ matrix

$$R^x_{i,j} = \begin{cases} 1 & : \|\vec{x_i} - \vec{x_j}\| < \varepsilon \\ 0 & : otherwise \end{cases} \vec{x_i} \in \mathbb{R}^m, i, j = 1, \cdots, \eta, \quad \eta = N - (m-1)\tau, \quad (1)$$

where $\| \cdot \|$ is a norm (e.g Euclidean or maximum norm) and ε is the cut-off distance which defines a region centered at $\vec{x_i}$.

- If $\vec{x_j}$ falls within this region, the state will be near to $\vec{x_i}$ and is taken to be a recurrence of the state $\vec{x_i}$, which implies $R^x_{i,j} = 1$.
- The recurrence plot is square matrix plot of the binary values $R^x_{i,j}$, in which the matrix element correspond to those calender times at which a state of a dynamical system recurs (columns and rows correspond then to a certain pair of calender times).
- Zbilut and Webber (1994) suggest to set a threshold level equal to the lower 10% of the maximum distance between the embedded vectors.

In this study, we make use of a special type of recurrence plot referred to as unthresholded recurrence plots. This recurrence plot is obtained by plotting a matrix of distances

$$D^x_{i,j} = \|\vec{x_i} - \vec{x_j}\| \tag{2}$$

between the vectors $\vec{x_i}$ and $\vec{x_j}$.

– Cross recurrence plot (CRP) entails testing for closeness of each point of the first trajectory $\vec{x_i}$ $(i = 1, \cdots, \eta)$ with each point of the second trajectory $\vec{y_j}$ $(j = 1, \cdots, \vartheta)$ resulting in $\eta \times \vartheta$ array

$$CR^{xy}_{i,j} = \begin{cases} 1 & : \|\vec{x_i} - \vec{y_j}\| < \varepsilon. \\ 0 & : otherwise \end{cases} \tag{3}$$

– Joint recurrence plot (JRP) is the element-wise product of the recurrence plot of the first system and the recurrence plot of the second system, i.e. for two systems $\vec{x}$ and $\vec{y}$, the joint recurrence plot is

$$JR^{xy}_{i,j} = R^x_{i,j} \cdot R^y_{i,j}, \quad \vec{x_i} \in \mathbb{R}^m, \quad \vec{y_j} \in \mathbb{R}^n, \quad i,j = 1,2,\cdots,\eta\vartheta. \tag{4}$$

Data Analysis

- Application to US IPI data
  - The monthly US Industrial Production Index (IPI) time series[a] spanning over the period January, 1919 to July, 2012 ($n = 1123$) is considered for the data analysis.
- Application to Euro-zone IPI data
  - monthly Euro-zone[b] IPI series for the period: January, 1971 to December, 2011 ($n = 492$).

[a]The data can be downloaded from Federal Reserve Bank of St. Louis
[b]Source: COE-Rexecode/GRETA and Eurostat.

US Industrial Production Index

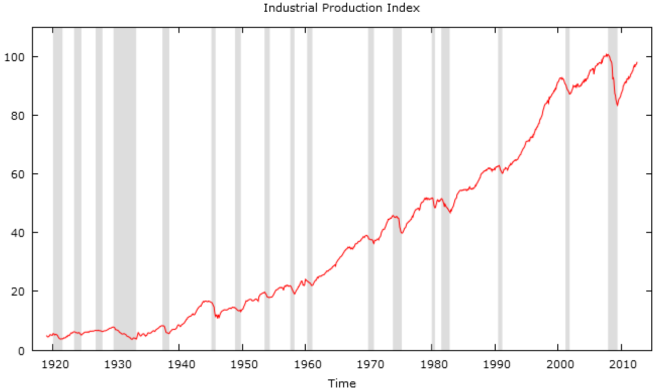


Figure: US Industrial Production Index (IPI) time seris. The plot of the monthly IPI series for the period: 1919:01 - 2012:07 ($n = 1123$), where the shaded regions corresponds to the US recessions from 1920 published by NBER.

- We mainly consider the case when the embedding parameters are $m = 1$ and $\tau = 1$ since the results obtained for unembedded and embedded version of the time series do not differ in terms of identification of the turning points associated with the business cycle.

- The recurrence plot shows the distances between states and enhance understanding of the phase space trajectory of the series. The recurrence plots allows to study the recurrence of a state at a particular calender date.

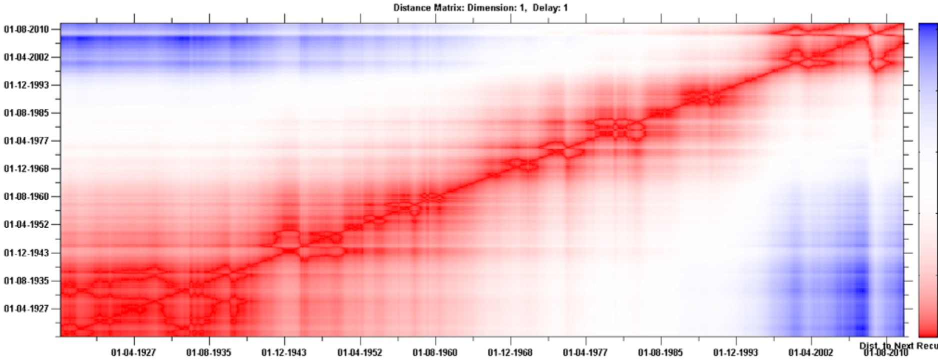
- The existence of *butterfly-like* structures along the main diagonal (bisector) indicates economic crisis.

- In this case, the start and end of a declining economic activity corresponds the start and end on the formation of *butterfly-like* structure along the main diagonal.

- In this paper, we designate any *butterfly-like* structure with a minimum size[a] of six months as economic crisis.

[a] The size refers to the length in time from the start and end on the formation of *butterfly-like* structure along the main diagonal.

Distance plot for US Industrial Production Index



NBER dates vrs *Butterfly* dates for the United States

NBER dates		*butterfly* dates	
Peak	Trough	Peak	Trough
1920:01	1921:07	1920:02	1921:08
1923:05	1924:07	1923:05	1924:08
1926:10	1927:11	1926:10	1927:11
1929:08	1933:03	1929:08	1933:04
1937:05	1938:06	1937:05	1938:02
1945:02	1945:10	1945:02	1945:10
1948:11	1949:10	1948:08	1949:10
1953:07	1954:05	1953:07	1954:01
1957:08	1958:04	1957:09	1958:04
1960:04	1961:02	1960:01	1961:03
1969:12	1970:11	1969:10	1970:11
1973:11	1975:04	1974:09	1975:04
1980:01	1980:07	1980:00	1980:08
1981:07	1982:11	1981:08	1983:01
1990:07	1991:03	1990:08	1991:03
2001:03	2001:11	2000:09	2001:11
2007:12	2009:06	2007:12	2009:06

Sensitivity Analysis on Embedding Parameters

- Sensitivity analysis on the *distance* plot with respect to the embedding dimension m and the time delay τ reveals that for fixed $\tau = 1$ and for any chosen $m > 1$, the turning points identified are same as setting $m = 1$ and $\tau = 1$.
- In particular, we observe much sharper picture of the *butterfly-like* structures as the embedding dimension is set close to 1.
- We noticed that for any given m, as the time delay parameter increases ($\tau \geq 1$), the *butterfly-like* structures grow dimmer making it not easy to clearly identify the peaks and troughs of the business cycle.
- As such, we recommend that the time delay parameter τ be set to 1 for better identification of turning points.

Euro-zone Industrial Production Index

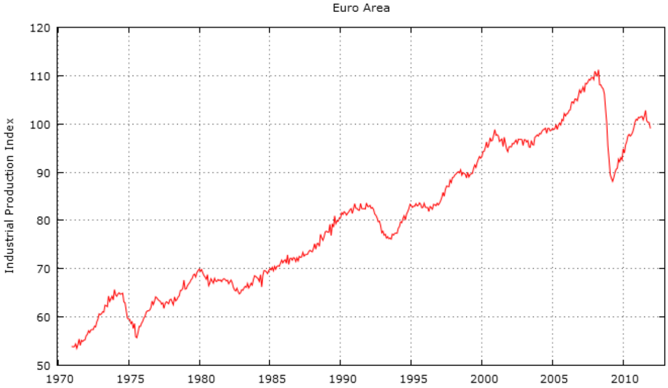


Figure: The plot of the monthly Euro-zone IPI series for the period: 1971:01 - 2011:12 ($n = 492$).

Chronology for the Euro-Zone business cycle

butterfly dates for Euro-Zone	
Peak	Trough
1974:06	1975:08
1980:01	1980:10
1982:05	1982:12
1992:04	1993:06
2000:12	2001:11
2007:12	2009:04
2011:07	

Table: Industrial business cycle dating chronology for the Euro-zone from 1971-2011. The peak and trough dates, in the format YYYY:MM, represent the start and end of "episodes" of some sort. The end of the last recession period that started 2011:07(q3) was not determined considering the sample period.

Butterfly dates for the Euro Area Business Cycles

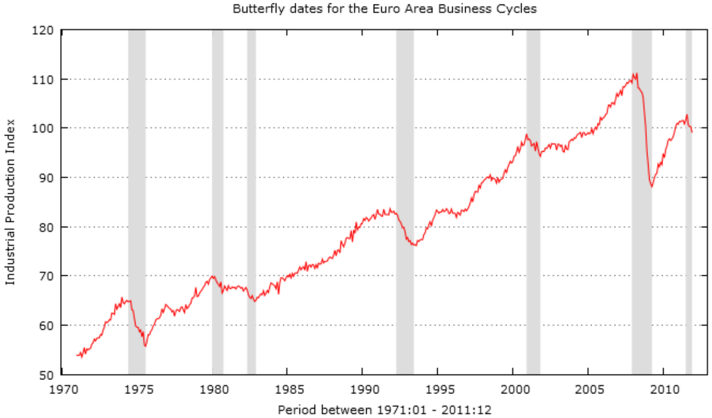


Figure: The end of the last recession period that started 2011:07(q3) was not determined considering the sample period.

Comparison of turning points for the Euro-Zone

butterfly dates		*Anas et al. (2007)* dates		*CEPR* dates		*MU* dates	
Peak	Trough	Peak	Trough	Peak	Trough	Peak	Trough
1974:06	1975:08	1974:04	1975:04	1974:(q3)	1975:(q1)	1974:08	1975:04
1980:01	1980:10	1980:02	1981:01	1980:(q1)	1982:(q3)	1980:03	1980:09
1982:05	1982:12	1981:10	1982:12			1982:04	1982:07
1992:04	1993:06	1992:01	1993:05	1992:(q1)	1993:(q3)	1992:02	1993:01
2000:12	2001:11	2000:12	2001:12				
2007:12	2009:04			2008:(q1)	2009:(q2)		
2011:07							

Table: The *CEPR* dates are the quarterly turning points determined by the Centre for Economic Policy Research (CEPR) using the euro area real GDP. *MU* dates are turning points identified by the Bry-Boschan algorithm when applied to the Moench/Uhlig (MU) monthly series of euro area real GDP.

Conclusion

- Identifying, dating and explaining economic crisis.
- The turning points provided by NBER for the US can be obtained with only IPI data using the distance plot approach.
- The distance plot is replicable and ensures effective dating chronology.
- It is transparent and adaptive to any time series.
- Provide useful information even for short and non-stationary data.
- Can easily be used in dating business cycles in country-specific time series for the European economies.
- Finally, a direct extension will be to consider the use of joint recurrence plots on multivariate time series.

Thank you for your attention