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

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Abstract

We propose a transparent way of establishing a turning point chronology for the Euro-zone business cycle. Our 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. Firstly, we exploit the concept of recurrence plots on the US Industrial Production Index (IPI) series to serve as a beachmark for our analysis since there already exist reference chronology for the US business cycle, provided by the Dating Committee of the National Bureau of Economic Research (NBER). 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.

Keywords: Recurrence Plots, economic cycles, turning points, Euro-zone
JEL: C14, C22, C40, E32

1. Introduction

The interest in cycle turning point chronology in economic analysis is essential on establishing a reference cycle dating for a given country or economic area. Dating is an *ex post* exercise which makes it useful in comparing the cycles between nations and also to study the convergence or sychronization of these cycles. Announcing of the cycle turning points dates in the United States are often substantially delayed[1] . As such, it will be interesting to propose methods that will enhance the faster and accurate detection of the dates. Billio et al. (2007) provides an interesting review on the diverse Euro-zone turning point chronologies and the issues inherent to such constructions.

In literature, three types of cycles are usually considered: the growth rate cycle, classical business cycle and the growth cycle. The growth cycles refers to the deviations to the long-term

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

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trend of the series while the classical business cycle refers to fluctuations in the level of the underlying economic indicator. The growth cycle has not been studies much compared to the classical business cycle due to the de-trending problem of this concept. The growth rate cycle is often subject to very short-term fluctuations mainly due to transitory events making the peaks of such cycles extremely difficult to date. In this paper, we study the classical business cycle using monthly data to enhance accuracy of the dating. Our aim is to propose a method with some of these features:

1. Robustness to extreme values, non stationarity and to any length of data.
2. It must be replicable to every one. This enhances transparency of method.
3. Adaptability of the method to different time series.
4. The chronology must not be revised through time.

Recurrence Plot (RP) is an advanced graphical technique of nonlinear data analysis which reveals all the times when the phase space trajectory of the dynamical system visits roughly the same area in the phase space. Although, most applications of this technique has been in physics and biology, it has gained interest in a variety[2] of scientific fields (Marwan et al. (2007)). Recurrence plots and recurrence quantification analysis (Zbilut and Webber (1992); Marwan et al. (2002)) is gaining some attention in economics (Kyrtsou and Vorlow (2005); Strozzi et al. (2008); Belaire-Franch (2004); Holyst et al. (2001), among others) .This technique is applicable to any time series since it requires no a prior assumptions on the statistical properties, such stationarity, or mathematical structure of the time series. We find this technique as a promising means of analyzing economic data since it is robust against non-stationarity in the data (Marwan et al. (2007)). In this work, we will mainly use *distance plots*, which is sometimes called unthresholded recurrence plot in studying the turning points of business cycles.

In this article, our aims at constructing a turning point chronology for the Euro-zone business cycle. Our analysis exploits the concept of recurrence plots on an underlying economic indicator to locate hidden patterns, non-stationarity, and to examine the nature of these plots in events of economic crisis. In particular, we show the usefulness of recurrence plots in detection of crisis and construction of turning points chronology for the Euro-Zone.

The paper is organised as follows: We provide in section 2, the concept of recurrence plots and distance plots. In section 3, we present a comprehensive analysis of the feasibility of this approach to analyse both the US and Euro-zone economic cycle. Section 4 concludes.

2. Data Analysis based on recurrence plots

The method of recurrence plots (RP) was introduced to visualise the dynamics of phase space trajectories (Eckmann et al. (1987)). It is a graphical technique that depicts the different occasions when a dynamical system visits roughly the same area in the phase space. From Takens' embedding theorem (Takens (1981)), 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. 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

[2]A comprehensive introduction and bibliography about on recurrence plots is available on http://www.recurrence-plot.tk/ and Marwan et al. (2007)

values of the series. The parameters m and τ are referred to as the embedding dimension and time delay respectively. 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

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

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 $R_{i,j} = 1$. The recurrence plot is square matrix plot of the binary values $R_{i,j}$, 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) (Marwan et al. (2007)). In literature, further variations[3] of the recurrence plots have been proposed for different purposes. In this paper, we make use of a special type of recurrence plot referred to as unthresholded recurrence plots (Iwanski and Bradley (1998)). This recurrence plot is obtained by plotting a matrix of distances $D_{i,j} = \|\vec{x_i} - \vec{x_j}\|$ between the vectors $\vec{x_i}$ and $\vec{x_j}$. As such, it is appropriate to term the unthresholded recurrence plot as *distance plot*. In the section that follows, we will often use the term *distance plot* and recurrence plot interchangeably. In comparing the dynamics of any two time series simultaneously embedded in the same phase space, we employed the cross recurrence plot (Zbilut et al. (1998); Marwan and Kurths (2002)). This is useful in studying the simultaneous occurrence of a state in both series. The cross recurrence plot 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 $\vec{y_i}$ $(i = 1, \cdots, \vartheta)$ resulting in $\varepsilon \times \vartheta$ array

$$CR_{i,j}(\varepsilon) = \begin{cases} 1 & : \|\vec{x_i} - \vec{y_j}\| < \varepsilon. \\ 0 & : otherwise \end{cases} \tag{2}$$

3. Data Analysis

In this section, we perform analysis to characterize and detect turning points for the Euro-zone economic cycle considering Industrial Production Index (IPI). Firstly, we exploit the concept of recurrence plots[4] on the US 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[5]. 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.

The monthly US Industrial Production Index (IPI) time series[6] spanning over the period January, 1919 to July, 2012 is considered for the data analysis. Figure 1 is the plot of the monthly

[3]For more details on these variations, we refer the reader to http://www.recurrence-plot.tk/variations.php.

[4]The *distance plots* are generated with the Cross Recurrence Plot Toolbox in Matlab provided by Norbert Marwan upon request: http://tocsy.pik-potsdam.de/CRPtoolbox/

[5]National Bureau of Economic Research

[6]The data can be downloaded from Federal Reserve Bank of St. Louis

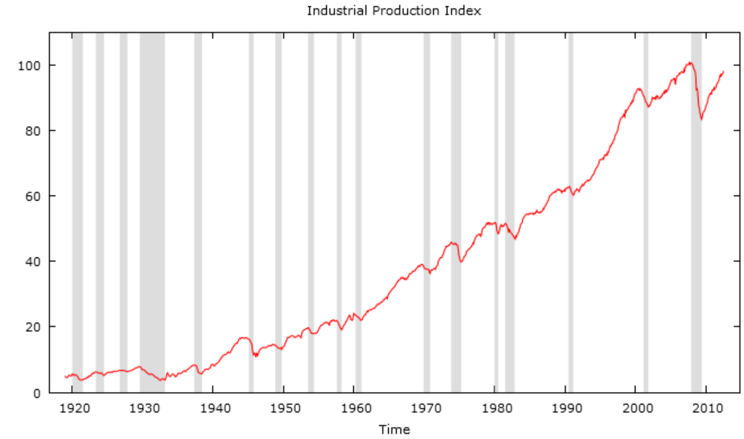

Figure 1: US Industrial Production Index (IPI) time seris. The plot of the monthly IPI series for the period: 1919:01 - 2012:07 (n = 1123), where the shaded regions corresponds to the US recessions from 1920 published by NBER.

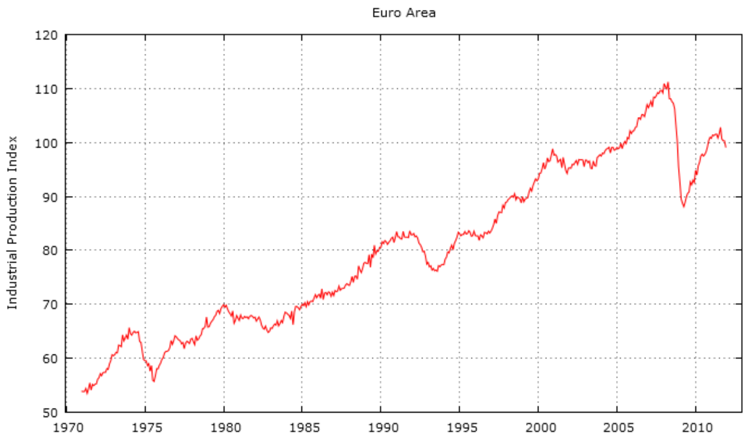

Figure 2: The plot of the monthly Euro-zone IPI series for the period: 1971:01 - 2011:12 (n = 492).

IPI series for the period: 1919:01 - 2012:07, implying 1123 observations, where the shaded regions corresponds to NBER[7] published dates for US recessions from 1920. Figure 2 is the plot of monthly Euro-zone[8] IPI series for the period: 1971:01 - 2011:12 (n = 492).

We provide in Figure 3 the unthresholded recurrence plots which is sometimes termed *distance plot* (Iwanski and Bradley (1998)) on the US IPI. It is a matrix plot with both vertical and horizontal axes corresponds to calender dates. The colormap corresponds to the distance to the

[7] http://www.nber.org/cycles.html
[8] Source: COE-Rexecode/GRETA and Eurostat.

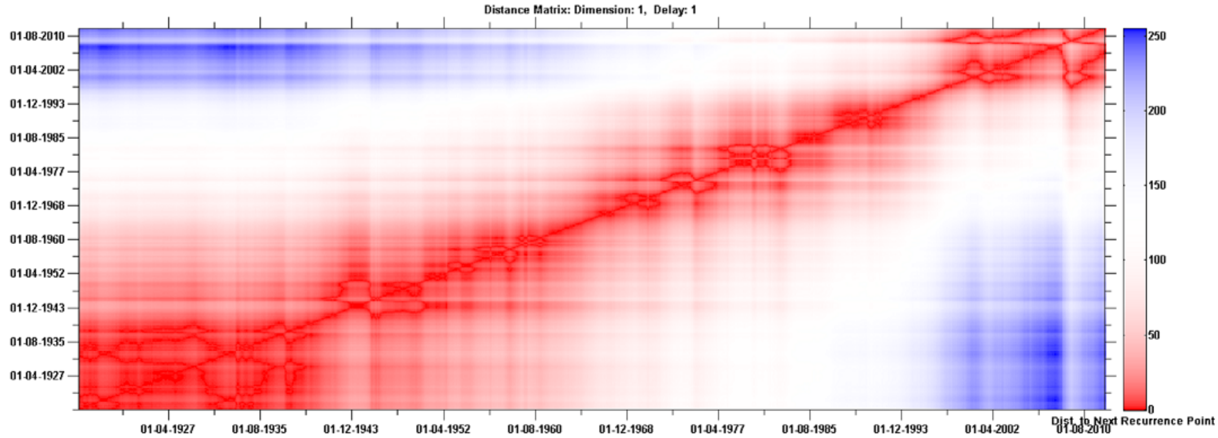

Figure 3: This is an unthresholded recurrence plot which is sometimes termed *distance plot* (Iwanski and Bradley (1998)). It is a matrix plot with calender time on both the vertical and horizontal axes. The colormap corresponds to the distance to the next recurrence of a state in the time series. This representation shows the distances between states and enhance understanding of the phase space trajectory of US IPI. The existence of *butterfly-like* structures, of a minimum size of six months, along the main diagonal (bisector) indicates economic crisis. In this case, the start and end of a economic crisis corresponds the start and end on the formation of *butterfly-like* structure along the main diagonal.

next recurrence of a state in the time series. In this paper, 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. Fixing a period or date on the horizontal axis, we are able to observe the recurrence of such events along the calender dates on the vertical axis. 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[9] of six months as economic crisis. Our results on the dating chronology obtained from the *distance plot*, figure 3, for US IPI are presented in Table 1 . The dates from the recurrence plots appears not to differ much from the official business cycle dates published by NBER. Interestingly, the main difference occurs in the detection of the peak date of two recession periods: 1973 and 2001 (see Table 1).

In this following, we focus on detecting and constructing the turning points for the Euro-zone business cycle. We proceed with the same analysis as done on the US data but now on the Euro-zone IPI series. We remark that embedding the original time series does not yield different

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

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

Table 1: Business Cycle Peaks and Troughs in the United States, 1920-2009. The peak and trough dates, in the format YYYY:MM, represent the start and end of "episodes" of some sort. The column *NBER* are the reference chronology for US business cycles published at http://www.nber.org/cycles.html . The results of turning points obtained from the *distance plot* of US IPI is displayed in column labelled *butterfly* dates.

results in terms of identification of the turning points associated with the business cycle. Our results on the dating chronology of the Euro-zone based on the IPI is presented in Table 2 .

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

Table 2: 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.

In Figure 5, we provide the *distance plots* for the US IPI and Euro-zone IPI for the period

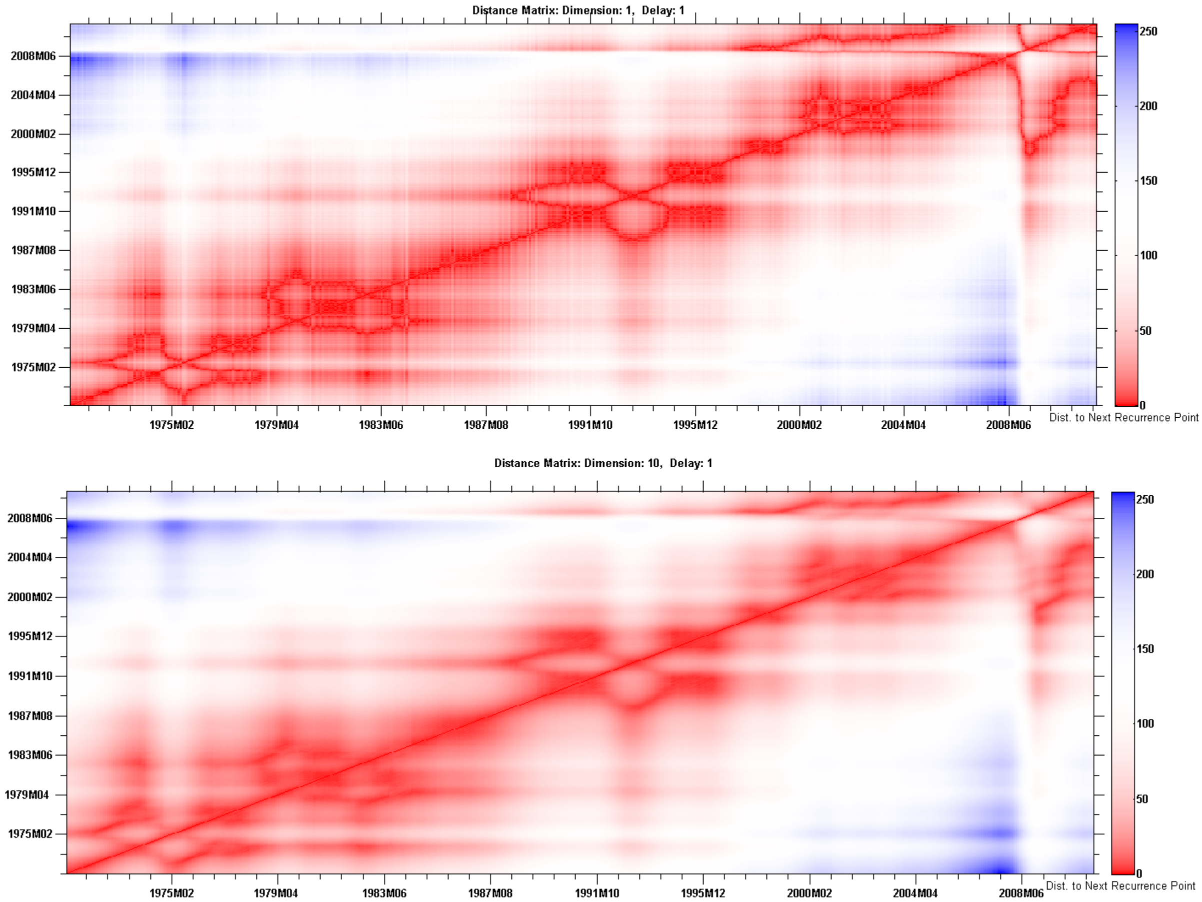

Figure 4: The *distance plot* for the Euro-zone IPI and it's embedded version. The existence of *butterfly-like* structures, of a minimum size of six months, along the main diagonal (bisector) indicates economic crisis. Embedding the original time series does not yield different results in terms of identification of the turning points associated with the business cycle.

1991:01 - 2012:07. The simultaneous occurrence of economic crisis in both US and Euro-zone for this period can be visualise on the cross recurrence plot displayed in figure 6 . These two economic systems were both hit by the crisis resulting from the blust of dot-com bubble and even more on the 2007-2012 global financial crisis, also known as the Global Financial Crisis and 2008 financial crisis. Similar features in the plots for this period suggests strong economic interdependence between the US and Euro-zone economic system.

4. Conclusion

In this work, we have demonstrated the usefulness of recurrence plots in identifying, dating and explaining economic crisis. The findings from the data analysis with recurrence plots, in this

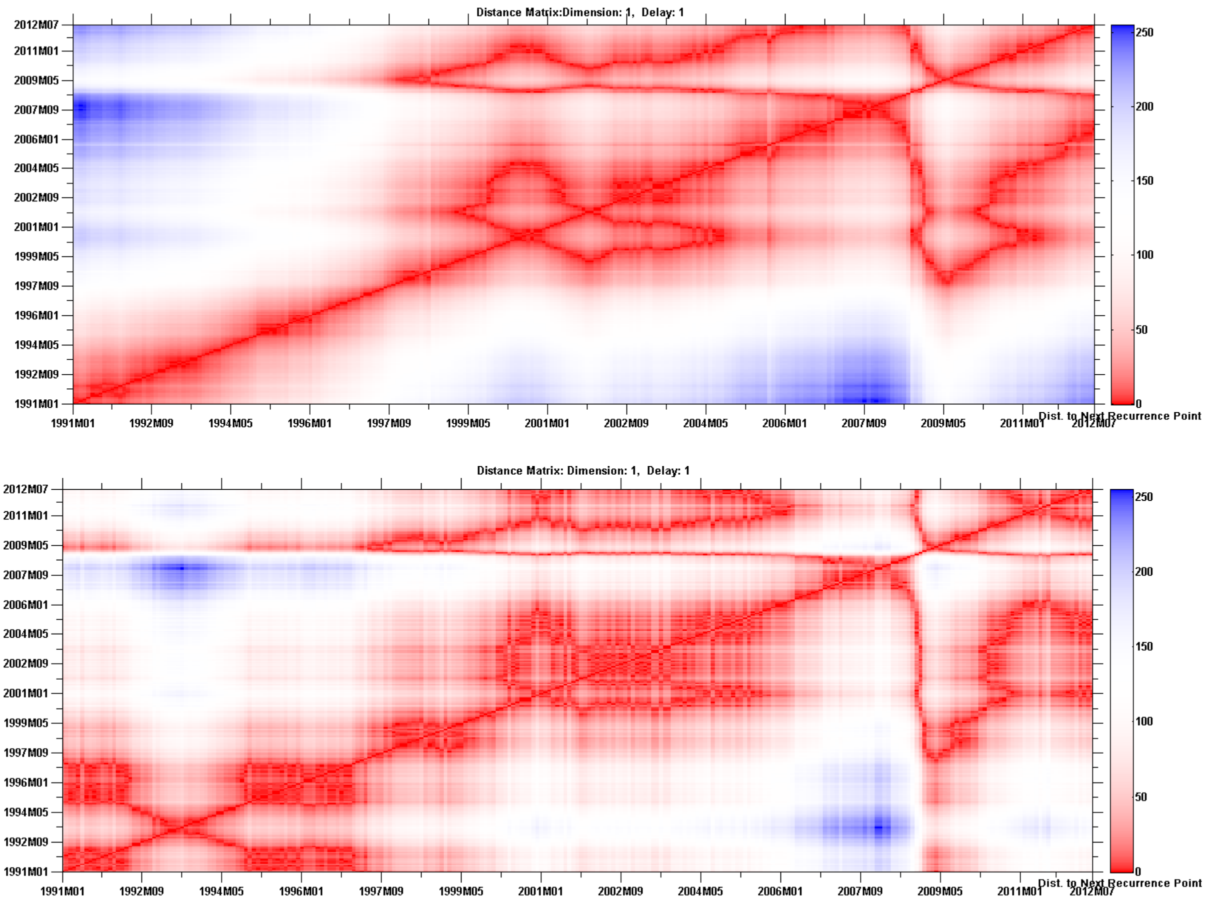

Figure 5: The *distance plots* of US IPI and Euro-zone IPI for the period 1991:01 - 2012:07. The top figure corresponds to the *distance plots* of US IPI. The second *distance plot* is for the Euro-zone IPI.

case *distance plots*, shows that these plots are robust to extreme values, non stationarity and applicable to both short and long data length. This approach is also replicable and transparent; is adaptive to any time series. In particular, we show that this approach provides a transparent chronology of business cycles since it avoids revision of crisis dates through time.

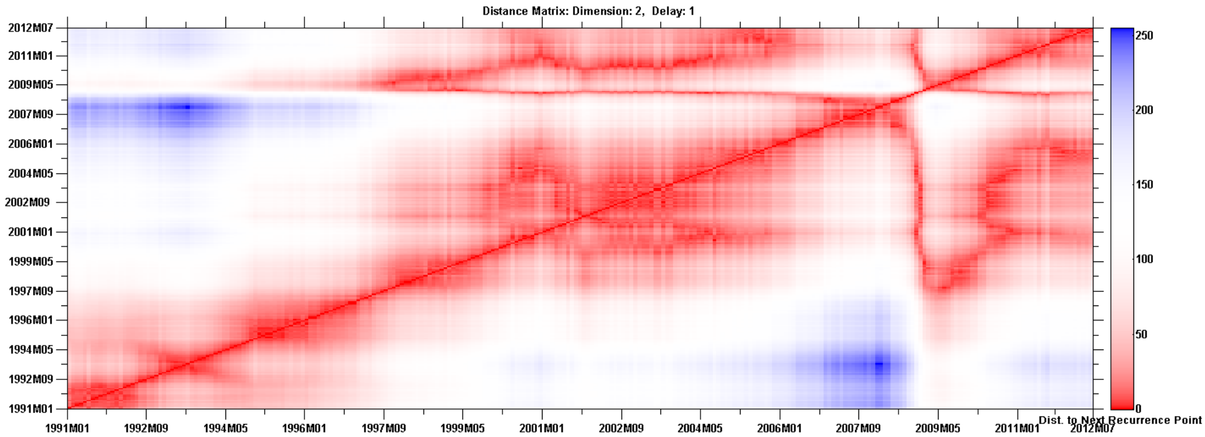

Figure 6: This is a cross recurrence plot to visualise the simultaneous occurrence of a similar state in both US IPI and Euro IPI.

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