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Meifen Chu

Abstract

The objective of this study is to examine the characteristics of the Euro exchange rate. The Euro is an 18-year old young currency. However, it experienced two huge financial crises during such a short time period, the Global Financial Crisis and the European Sovereign Debt Crisis. Since its establishment in 1999, the Euro grew rapidly and became the second most traded currency in the world. The high-speed development of the Euro drew much attention of researchers and policymakers. This paper detects the characteristics of the Euro exchange rate by using the multifractal detrended fluctuation analysis (MF-DFA), which is widely applied in physics, engineering, medical science and other fields. This paper separates the entire Euro exchange rate series into four sub-series according to the most significant events and then detects the multifractal features of the series respectively. Next, by using the moving window approach, it generates 16 sub-series and scan the entire series year by year. Such that, it examines the detailed patterns of the Euro exchange rate and detects the degrees of complexity of the Euro exchange rate. Further, this paper examines the effectiveness of the monetary policies on the stabilizing the exchange rate.

Keywords: Euro Exchange Rate, Nonlinear Time Series Analysis, Multifractal, MF-DFA

Introduction

The EURO was adopted as the official sole currency in the Eurozone in January 1999. At its introduction as the single currency, only 15 countries comprised the EU, with a population of 376 million. However, the EU has expanded dramatically since 1999, with 28 member countries and a population of 508 million. Nineteen of the 28 member countries and a few non-EU countries, accept the Euro as their only official currency. Although there has been numerous discussion on the advantages and disadvantages of the introduction of the Euro, the EU economy has no doubt grown to became one of the most important economies in the world. Regarding the GDP share in the world, the EU overcame the USA to be the world's largest economic region between 2003 to 2014. The Euro's trading volume has increased and as a settlement currency, its share was 27.2% of all, just second to the US dollar. The Euro's movement relative to other currencies has been paid increasing attention by the policy makers and researchers because the Euro's fluctuations impact individual EU countries and the world economy. While the Euro's history is comparatively short, it has been hit by two historical huge crises – the Global Financial Crisis and the European Sovereign Debt Crisis. The Global financial crisis started in 2008 in USA and rapidly spread globally. In the Euro and non-Euro EU areas, some of the financial institutions were bankrupted while most experienced business difficulties with declines in their asset base. For example, the financial sectors in Germany and UK suffered from the loss of about 38 billion Euros and 1.09 billion pounds due to the global financial crisis (G-Crisis). Unfortunately, the European sovereign debt crisis (E-Crisis) occurred only few years after the G-Crisis, which inflicted a double hit on the Euro Zone's economies. The Euro, as a young currency, experienced such a sever and prolonged depreciation and the Euro Zone a double-dip recession in such a short period.

These unprecedented happenings to the Euro motivate the author to analyze the characteristics of the EURO exchange rate and its monetary effectiveness. Therefore, this paper uses the entire time series of the Euro Exchange Rate in order to identify the features of the exchange rate before, during and after the two crises.

Many researchers have been conducting the studies on the Euro exchange rate. Especially, most of them studied what factors influence the fluctuation of the Euro exchange rate. For example, Shams (2005) made a deep study on the Euro exchange rate and determined that the belief in the Euro is much more important than its financial fundamentals in explaining the characteristics of the Euro. De Zwart et al. (2007) concluded that both the fundamentals and technical factors were important in prediction of Euro exchange rate, but that short-term movement was related to technical factors. Further, De Grauwe and Grimaldi (2002) proposed that the fluctuation of Euro exchange rate had no correlation with fundaments. De Grauwe, P. (2000) analyzed the influence factors from both the EU and the USA, but only focused on the fundamentals. As all known, in addition to the fundamentals there are many of other unforeseeable factors, like financial crisis, affect the Euro exchange rate movement. The shortage of risk factors analysis need to be compensated. Furthermore, so far numerous studies focus on the period before the Euro's introduction or before the Global Financial Crisis. It is need to conduct a deeper analysis of the Euro exchange rate not only before, but also during and aftermath of the crises.

Additionally, it has been shown that most financial time series follow the nonlinear processes (Mandelbrot (1982), Campbell, et al. (1997), and L. Calvet, L., and Fisher, A. (2002)). Other researchers have also determined that foreign exchange markets bear nonlinearity rather than linearity (Kantz and Schreiber (1997), Chu (2007)). Many researchers employed the ARCH (Autoregressive Conditional Heteroscedastic) model which was proposed by Engle (1982) to conduct estimation of the exchange movements. As an alternative approach, multifractal analysis has been successfully employed by Fisher, A., Calvet, L., Mandelbrot, B. (1997). They found evidence of a multifractal scaling law in Deutschemark/US dollar exchange rate. Multifractal characteristics became much more important statistical property as they are frequently observed in the financial time series. The multifractal concept has been widely applied and has been recognized as one of the key features in complex systems. This paper focuses on multifractal analysis and its application to understanding the characteristics of the Euro exchange rate.

The contributions of this study are listed as follows: First, this paper applies multifractal detrended fluctuation analysis (MF-DFA) – one of the nonlinear analysis approaches to detecting the characteristics of the EURO exchange rate. This style of analysis has not been conducted in many previous studies. Second, this paper divides the time series based on three different perspectives: 1) according to the development of the EU economy; 2) by a moving window approach; 3) by focusing on the two significant events. The separation and generation of data enable a more detailed and sophisticated analysis of the characteristics of the Euro exchange rate. Third, the empirical analysis is novel in the context of checking the monetary policies' effectiveness. This new idea can be easily applied by the policy-makers and researchers in the future.

The rest of this paper is organized as follows. Section 2 introduces the multifractal analysis based on detrended fluctuation analysis. In section 3, empirical analysis is applied to the Euro exchange rate. The conclusion as well as the directions for the future research are given in section in the closing section.

2. Multifractal Detrended Fluctuation Analysis

As it may be noted that the Chaos is a typical nonlinear property of time series. However, there are various nonlinear properties, like multifractility which is a statistical feature that describes self-similarity. By calculating the fractal dimension, the degree of multifractility can be detected. The higher degree of multifractility of a time series, the more complex and unstable it is. There are two main approaches that can be applied to calculate the multifaractility, one is the wavelet transform-based analysis and the other is the multifractal detrended fluctuation analysis (MF-DFA). Both are widely employed to detect the degree of multifractality and similar results can be reached (Kantelhardt, et al. (2002), (2003)). However, according Kantelhardt, et al.'s explanation, the later one is more reliable and convenient to be applied. This paper uses the MF-DFA to detect the multifractalilty of the Euro exchange rate so that the stability and safety of the Euro can be examined.

MF-DFA is a methodology to examine the multifractal properties of a time series by removing the time series trend. This approach was first proposed by Peng (1994) and extended by Kantelhardt, et al. (2002). As well known, it has been widely applied in physics, medical and engineering science. Recently it has been applied in the economics field. For example, Zunino, et al. (2008) applied the MF-DFA to the developing market analysis and concluded that the higher degree of multifractility is associated to less development of market. Dewandaru et al.(2015) employed the MF-DFA analysis on the Islamic stock market and captured both persistence and anti-persistence in Islamic stock prices. Wang, et al. (2011) applied the MF-DFA to the US dollar exchange rates against different currencies and discovered that the US dollar exchange rates perform significant multifractal behavior.

According to Kantelhardt, et al. (2002), there are mainly the four steps to calculate the multifractal properties. (See appendix 1). In the following section, the application of MF-DFA is conducted using the real EURO/USD exchange rate data and the singularity of the series is then captured.

3. Data and empirical results

3.1 Data Set

In this paper, the EURO/USD (EURO vs US Dollar) exchange rate is analyzed because the US dollar is highly correlated with the EURO (M. Chu (2017)). The daily closing data for the EURO/USD from 1999.01.04 to 2018.8.31 (year, month, day) are used. Data are extracted from the database provided by European Central Bank. This paper analyzes the multifractality feature of the Euro exchange rate during different periods. Since the period during the Euro's introduction is significantly different from other periods, the period from 1999 to 2004 should be classifies as a special period. Therefore, the entire time series of the Euro exchange rate can be divided into four periods. The first period (Period A) from 1999 to 2003 is during and after the introduction of the Euro; the second period (Period B) from 2004 to 2007 is before the G-Crisis; the third period (Period C) from 2008 to 2013 is the period of the twin crises; the final period (Period D) from 2014 to 2018 is the period of aftermath of the crises.

The two financial crises happened, the G-Crisis, starting in 2008, and the E-Crisis, starting in late 2009, were supposed to have heavily impacted on the movement of the Euro exchange rate. To figure out whether there are any significant differences during the periods of the G-Crisis and the E Crisis, this paper examines two important periods, from 2005 to 2009, and from 2010 to 2014.

Further, the paper applies a moving window approach to make a detailed analysis of the characteristics of the entire time series. This paper sets the window length as four years and then moves the window year by year, such that, 16 periods are generated. The 16 time periods are displayed in table 1.

Table 1. The 16 periods generated by moving window

period 1	period 2	period 3	period 4	period 5	period 6	period 7	period 8
1999/1/4	2000/1/3	2001/1/2	2002/1/2	2003/1/2	2004/1/2	2005/1/3	2006/1/2
2003/1/2	2004/1/8	2005/1/3	2005/12/28	2006/12/27	2007/12/27	2009/1/2	2010/1/5
period 9	**period 10**	**period 11**	**period 12**	**period 13**	**period 14**	**period 15**	**period 16**
2007/1/2	2008/1/2	2009/1/2	2010/1/4	2011/1/3	2012/1/2	2013/1/2	2014/1/2
2010/12/30	2011/12/27	2012/12/24	2013/12/27	2015/1/2	2016/1/5	2017/1/2	2018/1/2

Overall, this paper conducts empirical analyses in the following three aspects:

a. Multifractal analysis of the four periods of the Euro exchange rate

b. Multifractal analysis of the 16 time periods generated by moving window approach

c. Multifractal analysis of the periods during the two huge Crises

3.2 Time Series Description

Figure 1 shows the time series of the exchange rates for the EURO/USD. It can be seen, at the birth of the EURO, there was an initial decrease in the Euro that lasted for almost one year, before the Euro appreciated. However, the persistent upward Euro movements were cut short by the G-Crisis originating in the USA. The EURO exchange rate suddenly declined in 2008 and began to display a volatile moving pattern after that. In late 2013, there were large fluctuations in the Euro exchange rate, and the Euro dropped significantly. These huge fluctuations were due in large part to the European Debt Crisis.

Regarding the four Euro periods, Period B and Period C saw the Euro move strongly when compared to Period A and Period D. In Period A, the Euro kept declining from January 1999 until the end of 2000, and displayed an upward trend for more than 3 years. In period D, the Euro dropped sharply from the beginning of 2014, however, it stopped declining and showed some stability after the end of 2014.

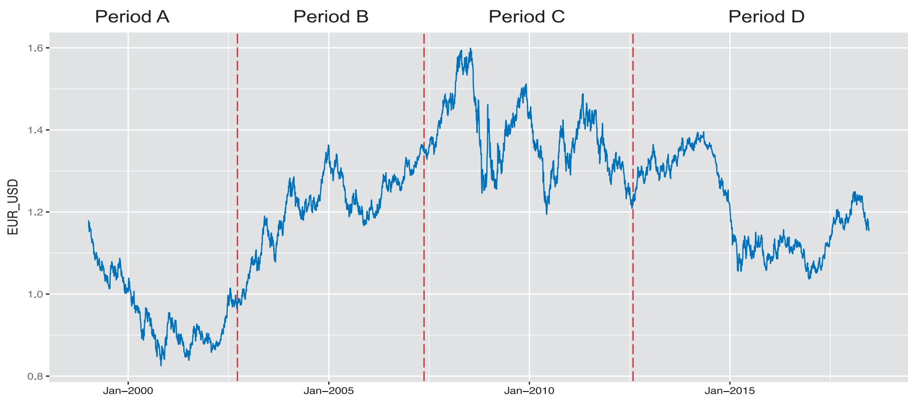


Figure 1. Euro/Dollar Time Series

3.3 Multifractal analysis results for the four periods

The fluctuation spectra and the multifractal degrees of the four series are plotted on figure 2. It is clear that all the four series have fractal characteristics. It can be suggested that the Euro exchange rate in all of the four periods moved volatilely and unstably.

According to the multifractal theory, the difference between α_{max} and α_{min} (denoted as $\Delta\alpha$) is the statistic to examine the strength of the multifractality. The wider the difference, the stronger the strength of multifractal. The results show that the series in Period B moved most divergently with a spectrum width more than 0.68 while the Period C moved strongly as well with a large spectrum at 0.59. As for Period A, it moved comparatively calmly with a spectrum width of 0.5. However, in the last period (Period D) its movement was obviously narrow with a spectrum width of only 0.34. The spectrum width ranks for the four series can be concluded as follows:

$\Delta\alpha$(period B) = 0.68291175 > $\Delta\alpha$(period C) = 0.589979585 > $\Delta\alpha$(period A) = 0.505474369 > $\Delta\alpha$(period D)= 0.342430369.

These results reveal that, before and during the twin crises, the Euro series fluctuated largely, which means the Euro exchange rate movement was not stable. Further, in the first period (period A) when the Euro was introduced, the market also displayed instability. However, after the twin crises, the multifractal spectrum became much smaller, which indicates that the market became more stable. It can be then suggested that the monetary policies adopted during the crises periods were effective.

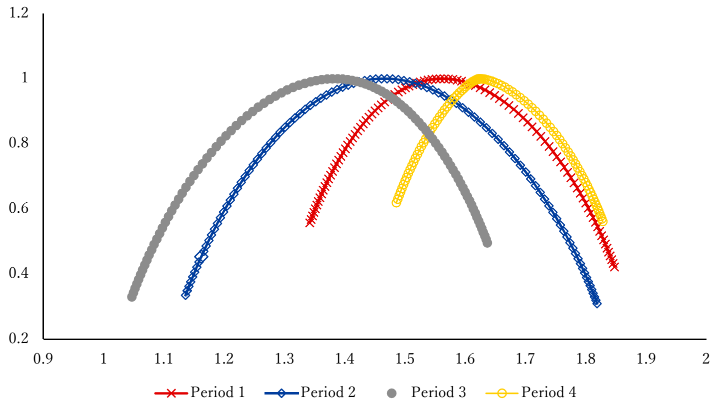


Figure 2. Multifractal analysis results for the four periods

3.4 Multifractal analysis results of the 16 periods generated by a moving window approach

The multifractal analysis results (figure 3) for the 16 periods generated by moving windows demonstrate that the multifractal spectra in period 7, period 8 and period 9 are the highest. This indicates where the Euro exchange rate market fluctuated the most and was the most unstable. This result is consistence with the discussion in the previous section. It can also be noticed that, from period 1 to period 6, multifractal spectrum

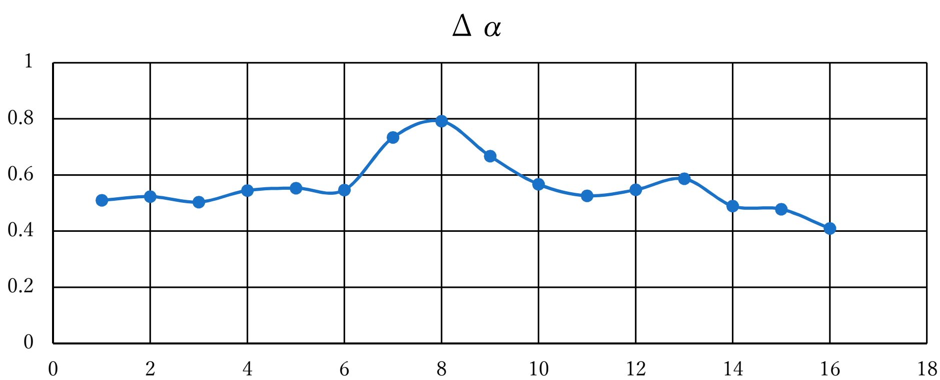
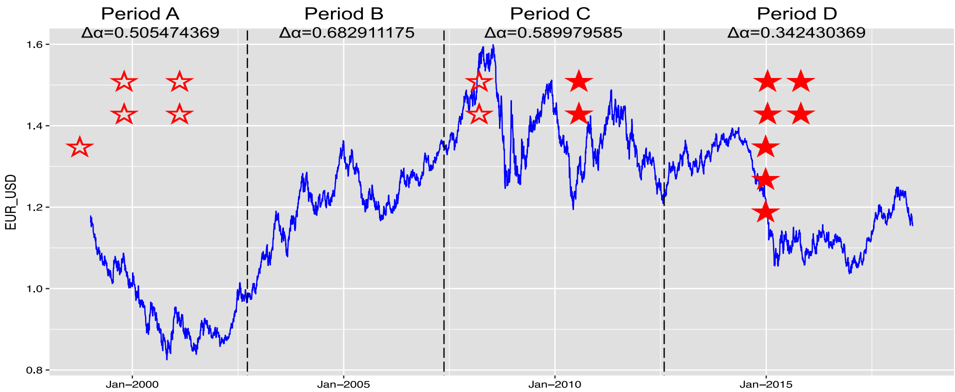


Figure 3. Multifractal results for the 16 periods



Source: "ECB Monetary Policy and the Euro Exchange Rate" by Martina Cecioni
☆ : Conventional Monetary Policies
★ : Unconventional Monetary Policies

Figure 4. Conventional and Unconventional Monetary Policies

width $\Delta\alpha$ kept at the level between 0.5 to 0.6, which means the time series during these periods carried similar patterns. On the other hand, the multifractal width fell below 0.6 since Period 10. Although it slightly rose up in Period 13, it dropped down again after Period 14 and reached to 0.34 in Period 16. The declining of the $\Delta\alpha$ during Period 14, Period 15 and Period 16 suggests that there were some external power made positive impacts on the Euro exchange rate. As Martina Cecioni (2018) stated, there were 10 major conventional and 10 important unconventional monetary policies during the Euro's history. It can be seen most conventional monetary policies were conducted before 2010 while the unconventional ones were adopted after 2010, especially after 2013. Since the Euro exchange rate became stable after 2013, it can be considered these monetary policies were contributed in stabilizing the Euro exchange rate.

3.5 Multifractal analysis results of the periods during the two huge Crises

The G-Crisis occurred in 2008 while the E-Crisis started in the end of 2009. As early mentioned, by a moving window approach, 16 periods have been generated and examined. The results display that in Period 8 the multifractal degree is the highest at 0.7914. Period 8 is from 2006/1/2 to 2010/1/5, which can represent the G-Crisis period. As known, the European Debt Crisis began at the end of 2009 and the situation had improved by 2014. Period 12 (from 2010/1/4 to 2013/12/27) can represent the period during the E-Crisis period. Comparing G-Crisis period and D-Crisis period, it is clear that the fluctuation of Euro exchange rate was much higher in G-Crisis period than E-crisis period. Referring figure 4, there were no significant monetary policies adopted by the government but after the E-crisis happened, some important monetary policies both conventional and unconventional policies were imposed. This suggests that monetary policies, especially the unconventional monetary policies were effective on stabilizing the Euro exchange rate.

4. Conclusion

This study's analysis contributes a deeper analysis of the characteristics of the Euro/USD exchange rates by applying MF-DFA approach based on multifractal theory. MF-DFA has rarely been applied in financial data analysis despite being widely used in engineering, medical sciences, and other fields. This paper takes use of this advanced detecting approach to figure out the multifractility of the Euro exchange rate in order to examine the Euro's stability and safety. Furthermore, using a moving window approach made the results much clearer.

The results of the multifractal analysis show the EURO exchange rates bear the multifractality. This indicates that the Euro exchange rate has moved with high fluctuation and displayed an unstable status. It also suggests that the Euro is not especially strong and is easily influenced by financial shocks.

Additional understanding can be gained by comparing the characteristics of the four periods, it can also be understood that, in the pre-crisis period the Euro exchange rate moved most fiercely. The market was most unstable. By using the moving window method, it can be determined that in Period 7, Period 8 and Period 9, the exchange rate displayed the largest mulfractality, which implies that before and during the twin crises, the Euro exchange rate was most unstable. However, it has calmed down since Period 10, which suggests that the monetary policies were effective on stabilizing the Euro exchange rate.

Moreover, by comparing the G-Crisis period and E-Crisis period, it concludes that the Euro exchange rate market in the G-Crisis period displayed much more unstable than that in the E-crisis period. It suggests that the monetary policies conducted in the G-Crisis period were not effective while the policies especially the unconventional policies carried out in the E-crisis period were effective.

Future research should focus on nonlinearity tests with different approaches. Moreover, determining the structural changes in time series is important when analyzing real financial data. Using the multifractal theory to detect the structural changes in time series is another research topic. Furthermore, future research should deeply examine the effectiveness of EU monetary policies.

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Appendix 1

Step 1.

Let $x(i)$ represent a time series (i=1,2,...). Generate a time series $y(i)$ from the next formula.

$$y(i) = \sum_{k=1}^{i}(\mathrm{x(k)} - \overline{x}) \tag{1}$$

while $x(k)$ is the k^{th} point of the time series and $\bar{x}$ is their average.

Step 2.

Create N_s boxes of small length s to cover all the $y(i)$. The trend of a given box $v(1 \le v \le N_s)$ is calculated by using the least-squares method in a q-order poly nominal. $y_v(i)$ is the optimized solution, which represents the best-fit curve. Then, remove the trend by subtracting $y_v(i)$ from $y(i)$, $i = 1,2,\ldots,N_s$. The fluctuations are calculated as follows:

$$F_2(s,v) = \frac{1}{s}\sum_{i=1}^{s}\left(\left|y\left((v-1)s+i\right) - y_v(i)\right|\right)^2 \tag{2}$$

Step 3.

Compute the q-order moment by averaging the appropriate function of $F_q(s)$ so that the following scaling relation with box size s can be gained.

$$F_2(s,v) = \left\{\frac{1}{N_s}\sum_{v=1}^{N_s} F_2(s,v)^{q/2}\right\}^{1/q} \sim s^{h(q)} \tag{3}$$

Here, $h(q)$ is the exponent depending on q. The multifractal scaling exponent $\tau(q)$ is depending on $h(q)$ with the following relationship.

$$\tau(q) = qh(q) - D_f \tag{4}$$

Step 4.

The multifractal spectrum is calculated by a Legendre transform of $\tau(q)$ as defined by

$$f(\alpha) \equiv \alpha q - \tau(q),\ \ \alpha \equiv \frac{d\tau(q)}{dq} \tag{5}$$

where $f(\alpha)$ is defined as dimension of the time series. If the value of α is constant, the time series is mono-fractal, otherwise, it is multifractal.

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