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Comparison of Recession During 2008 - 2009 and 2009-2013 Through Chaotic Analysis of The Foreign Exchange Rates

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***A*bstract:** Chaotic processes are characterized by positive Lyapunov Exponent (LE)s as LE measures the rate at which information is lost from a system. We consider here the chaotic analysis of Foreign Exchange (ForEx) market data. Our previous works (2007, 2012) made nonlinear data analysis of the data during period before recession (up to 2005), and then investigated data from the same 12 countries for the periods of January 2008 to October 2009, to assess the effect of recession. In these works, we calculated the largest LE (LLE)s during recession and compared them with the LLE found before onset of recession. It was concluded that for a country, the more nonlinear structure its foreign exchange rate shows the higher LLE changes. Four years after the eruption of the global financial crisis, the world economy is still struggling to recover. During 2012, global economic growth has weakened further. In this context, this paper reinvestigates the daily ForEx market data again of the same twelve countries as well as European Union (EU) region for the period of Jan, 2009 to March, 2013. Here this paper finds that LLE values have increased over previous two years, implying that ForEx market may have become more chaotic. Also, LLE values are slowly approaching their pre-recession values which may be positive aspect for the ForEx market. Gross Domestic Product (GDP) growth rate of selected countries are also compared to address this finding. As before, the balance of trade (BoT) of these countries is investigated with the US.

JEL Classifications: C65, C80, F31

Keywords: Foreign exchange rate; Balance of trade; Nonlinearity; Lyapunov exponent; Chaos

1. Introduction

Foreign Exchange (ForEx) reserve deals with conversion of currencies between the countries and thus allows easy money flow. The trading in the foreign exchange markets generally involves the US dollar. In the present globalized economy, most countries accept pegging their currencies to the US dollar. The global demand crumpled and led to an imbalance in the global economics. However, the global recession means fewer opportunities for trading and profitability in other areas, such as the stock market, commodities futures and real estate. ForEx trading kept growing right on through the 2008 financial crisis. Since 2007, trading skyrocketed by nearly 40%. According to the Bureau for International Settlements, average daily ForEx trading in 2010 was $4.4 trillion, compared to $3.2 trillion traded per day in 2007. Even this was up 30% from $2 trillion per day traded in 2004 (King and Rime 2010).

The foreign exchange market is a 24-hour financial market. There are several reasons for this creeping return to pegged exchange rates. Most of the countries are buying the US dollar in order to curb the appreciation of their currencies (Grauwe, 2003). There is plenty of literature showing basic factors that influences changes in the exchange rate. Changes in the exchange rates are related to the news in fundamentals. Set of the fundamentals covers: (i) The inflation for the country concerned, (ii) The money supply for the country under scrutiny, (iii) The Money Market Rate, which is used as a measure of the short term interest rate, (iv) The trade balance relative to the GDP etc. This has been mentioned in our earlier work (Das et al., 2007, 2012) in more details. Characterizing the nature of the relationship between exchange rate changes and the news in its underlying fundamentals has long been an objective of empirical international macroeconomics (Grauwe et al., 2001). Rodri ́guez et al. (2001) discussed largest Lyapunov exponent (LLE) in financial time series and have tested for deterministic chaos in three exchange rate series corresponding to the French franc, the Canadian dollar and the German mark, all against the US dollar (each series is from January 1971 to 31st December 1998).

What makes the exchange rate changes in the recession era much more complicated is the intervention from the governments. Apart from usual complex rules governing the exchange rate, during the recession, most of the countries tried to resist it by direct interventions. Sometimes it could be change in policy or some times pumping huge amount of money into financial market or imposing restrictions on pay or interest rates etc. stimulus package were announced in different countries, some examples are given in our previous work (2012). We investigated if all these initiatives have effect on the exchange rate in the said time period and found no considerable change to resist the recession. Attempts to resorted stability by pumping in public money have had some effect but the sums of money are tiny relative to the problem (Paddy 2009).

We do not attempt here to make any analysis of present crisis. In a series of work, we investigated the chaotic property of Foreign Exchange Rates of several countries (Das et al., 2007, 2012). Some of the related earlier works found evidence of chaotic structures in foreign exchange rates (for example, in case of the Canadian and Australian dollars over their floating rate periods), some studies found little evidence of chaos, however, many of them showed evidence of nonlinear structure. Earlier studies found little evidence of chaos, however, many of them showed evidence of nonlinear structure (LeBaron, 1994). Bask (1996, 2002) considered Swedish Kroner versus Deutche Mark, ECU, US $ and Yen in his study using data of daily observation from January 1986 to August 1995 (2409 points). By measuring the LLE, the study found indication of deterministic chaos in all exchange rate series.

De Grauwe et al. (2001) stressed that it is generally difficult to conclusively find evidence for the existence of chaotic dynamics because the available techniques do not allow to separate the exogenous noise from chaos. This lack of strong evidence for the existence of chaos has been confirmed by researchers (see Grauwe (2003) and references therein). There are conflicting claims are common in nonlinear analyses of financial data which was emphasized in work by Çoban at al., 2009 and as shown in our work (2007). .

In our previous work (2007), we made nonlinear data analysis of the data during which the economic recession had started. In that work, we considered daily data for twelve countries, over the span of nearly 36 years. In our last work (2012) we investigated data from the same 12 countries for the periods of January 2008 to October 2009, as the present recession had started around July 2008. We calculated the largest Lyapunov exponent (LLE) and compared the LLE values found before onset of recession.

After suffering a major setback during 2011, global prospects are gradually strengthening again, but downside risks remain elevated. Soon after the September 2011, the euro area went through another acute crisis. (World Economic outlook, April 2012, Growth Resuming, Dangers

Remain) Four years after the eruption of the global financial crisis, the world economy is still struggling to recover. During 2012, global economic growth has weakened further. A growing number of developed economies have fallen into a double-dip recession. Those in severe sovereign debt distress moved even deeper into recession, caught in the downward spiraling. The US is already sliding into what the IMF predicts will be a "mild recession" but there is mounting pessimism about the ability of the rest of the world to escape unscathed, the IMF said in its twice-yearly World Economic (Global Economic Outlook, UN, 2013)

In this background, we investigate the daily ForEx market data of same twelve countries for the period of Jan, 2009 to March, 2013. We calculated LLEs of different countries and compared to them to LLEs during 2008 to 2009, as well as LLEs of long data series starting from 1973 (for some countries 1981 as indicated later) to 2005 as calculated in previous works (2007 and 2012). The source and period of data are given in Section 2. Mathematical tools used for nonlinear data analysis are explained under Section 3. As before, we investigate the balance of trade (BoT) of these countries with the US in order to explain the respective of LLEs calculated from the foreign exchange rate (ForExRate) data under Section 4. We attempted same analysis for EU currency Euro in Section 5. Finally Results are given in Section 6 and some concluding remarks are made in Section 7.

2. Data Collection

Board of Governors of the Federal Reserve System has daily as well as monthly Foreign Exchange Rates for different countries (Federal Reserve Bank) based on noon buying rates in New York City for cable transfers payable in foreign currencies. Exchange Rates data are provided by Economic Research, Federal Reserve Bank of St. Louis and are freely downloadable for research purpose. The data are available in ASCII text as well as XLS format. We collected daily data for twelve countries Australia, Canada, China, India, Japan, Malaysia, Singapore, Sri Lanka, Sweden, Switzerland, Thailand & UK for the periods of January 2009 to March 2013. So we have 12 data sets most of which contain more than 1318 points each. In previous work, we considered historical data from January, 1973 to December 2005. For China, Thailand and Singapore, available data are from January 1981. In our earlier work, we investigated data for two years of recession, that is 2008 to 2009. In the present work, we consider data from 2009, the starting year is repeated in present calculation to preserve its effect on further four years, that is 2010- to 2013.

BoT data for a country with respect to the US is defined as Balance on goods and services (difference between the monetary value of exports and imports, as discussed in Sec. 4). We collected annual BoT data from the Bureau of Economic Analysis which maintains downloadable data for several countries (U.S. Census Bureau). In present case, BoT and ForEx monthly data from January 2008 to February 2013, that is 230

Table 1. BoT of 12 selected countries (Million $)

Country	2008	2009	2010	2011	2012
Australia	-11630	-11588	-13214.7	-17300.7	-21672
Canada	78342	21590	28542.46	34456.89	31803.23
China	268040	226877	273063.2	295422.5	315053.5
India	8022.3	4724.6	10282.47	14651.55	18182.67
Japan	74120	44669	60059.63	63218.52	76341.28
Malaysia	17787	12879	11820.48	11530.19	13079.2
Singapore	-11969	-6527	-11590.2	-12110	-10336.6
Sri Lanka	1678.7	1363.2	1569.556	1782.889	2033.525
Sweden	7480.1	3624.7	5788.622	6229.215	4966.176
Switzerland	-4242	-1451	-1551.21	-67.7537	-474.738
Thailand	14472	12164	13716.2	13930.5	15173.73
UK	4988.3	1776.3	1361.497	-4644.63	117.7159

points are used for analysis as given in Table 1 above.

3. Mathematical Tools Used

In order to process large amount of data as described in the previous section, we have to use different mathematical tools. Before attempting nonlinear analysis, nonlinear nature of data under investigation should be established through Surrogate Data method as described below in Section 3.1. Chaotic nature of the data can be characterized by calculating Lyapunov Exponent which is described below in Section 3.2.

3.1 Test for nonlinearity using Surrogate Data Method

We follow the approach of Theiler et al. (1992). The surrogate signal is produced by phase-randomizing the given data. It has spectral properties similar to the given data, that is, the surrogate data sequence has the same mean, the same variance, the same autocorrelation function, and therefore the same power spectrum as the original sequence, but (nonlinear) phase relations are destroyed. Details of the method for the countries considered has been given in the previous works (2007, 2012) or as used with additional noise reduction (Çoban et al., 2009). We used the TSTOOL package by Parlitz et al. (1998), under MATLAB (2002) software to create surrogate data for a scalar time series. From this analysis, we got some idea about the degree of nonlinearity associated with the time series of foreign exchange data as described. We are not repeating the same results, but we certainly have to use the results.

3.2 Finding Lyapunov Exponent Using TSTOOL Package

Chaotic processes are characterized by positive Lyapunov Exponent (LE)s. LE measures the rate at which information is lost from a system. Positive LE means that information about initial conditions are easily lost, implying chaos. The larger the LE, the faster is the loss and hence system is more chaotic. (Chris Brooks, 1998). There are several approaches to calculate the LE, here we follow the approach of Wolf et al. (1985). For details, please refer to our earlier work (2002). Again, we used the TSTOOL to find the largest LE (LLE). The function used is largelyap which is an algorithm based on work by Wolf (1985), it computes the average exponential growth of the distance of neighboring orbits via the prediction error. The increase of the prediction error versus the prediction time allows an estimation of the LLE. For details, please refer to our previous work. In the particular MATLAB code, largelyap, the average exponential growth of the distance of neighboring orbits is studied on a logarithmic scale, this time via prediction error p(k). Dependence of p(k) on the number of time steps may be divided into three phases. Phase I is the transient where the neighboring orbits converges to the direction corresponding to the λ_1 of LLE. During phase II, the distance grows exponentially with $\exp(\lambda_1 t_k)$ until it exceeds the range of validity of the linear approximation of the flow. Then phase III begins where the distance increases slower than exponentially until it decreases again due to folding in the state space. If the phase II is sufficiently long, a linear segment with slope λ_1 appears in the p(k) versus k diagram (Parlitz, 1998).

While calculating the LLE, we have obtained the prediction error p(k) versus k diagrams as output and are given as insets in Fig.1. By finding the slope of the phase II, we estimate LLEs in each case. We calculated LLEs for each country in following three periods during: I) The period 1973 - 2005) II) during 2008 - 2009 (done in earlier works, repeated here) and III) during Jan 2009 to March 2013.

In the following Fig. 1, we draw series of figures - one for each country where we show LLE calculated from foreign exchange data for three different periods mentioned.

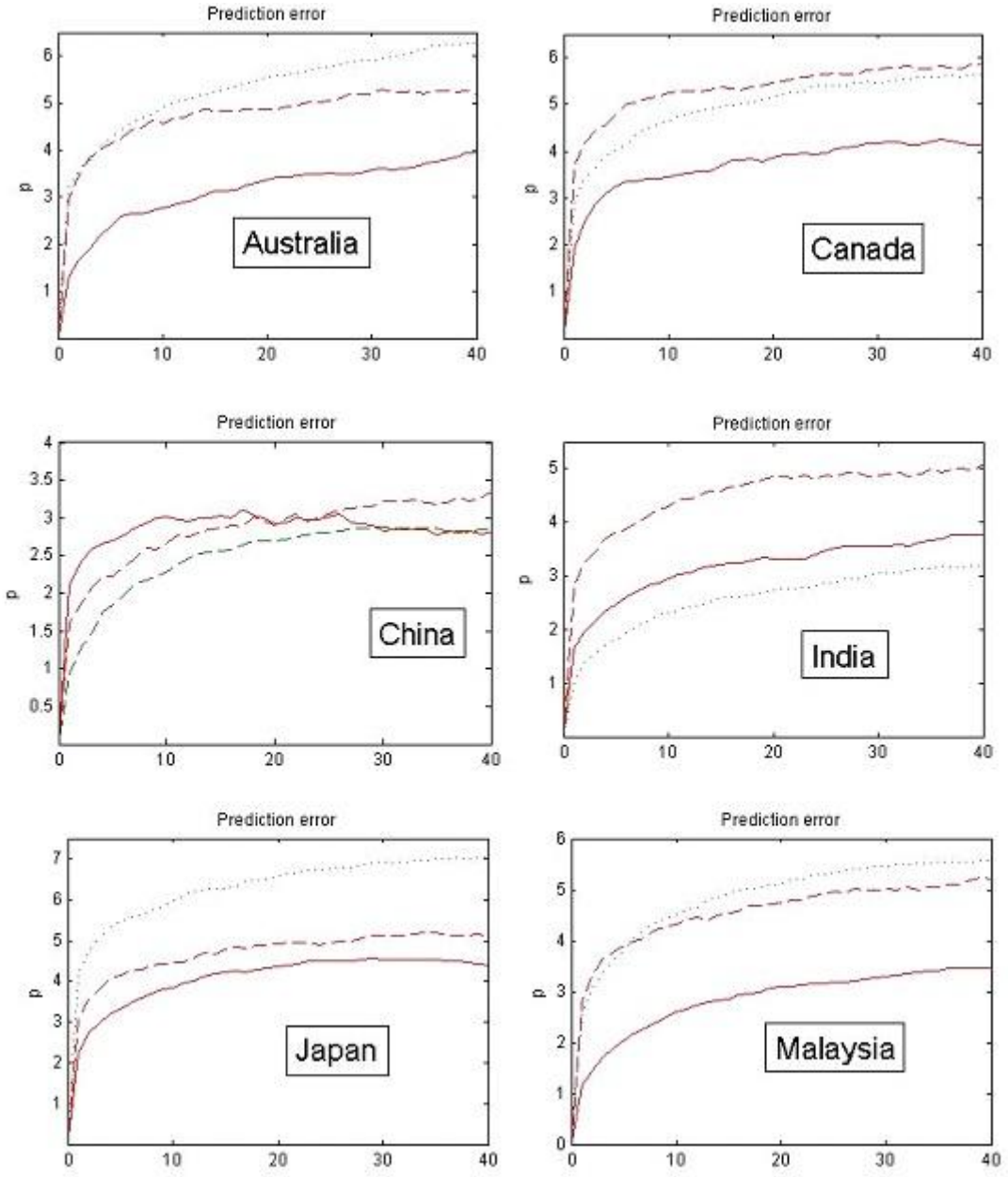


Figure 1(First 6 of 12 countries)

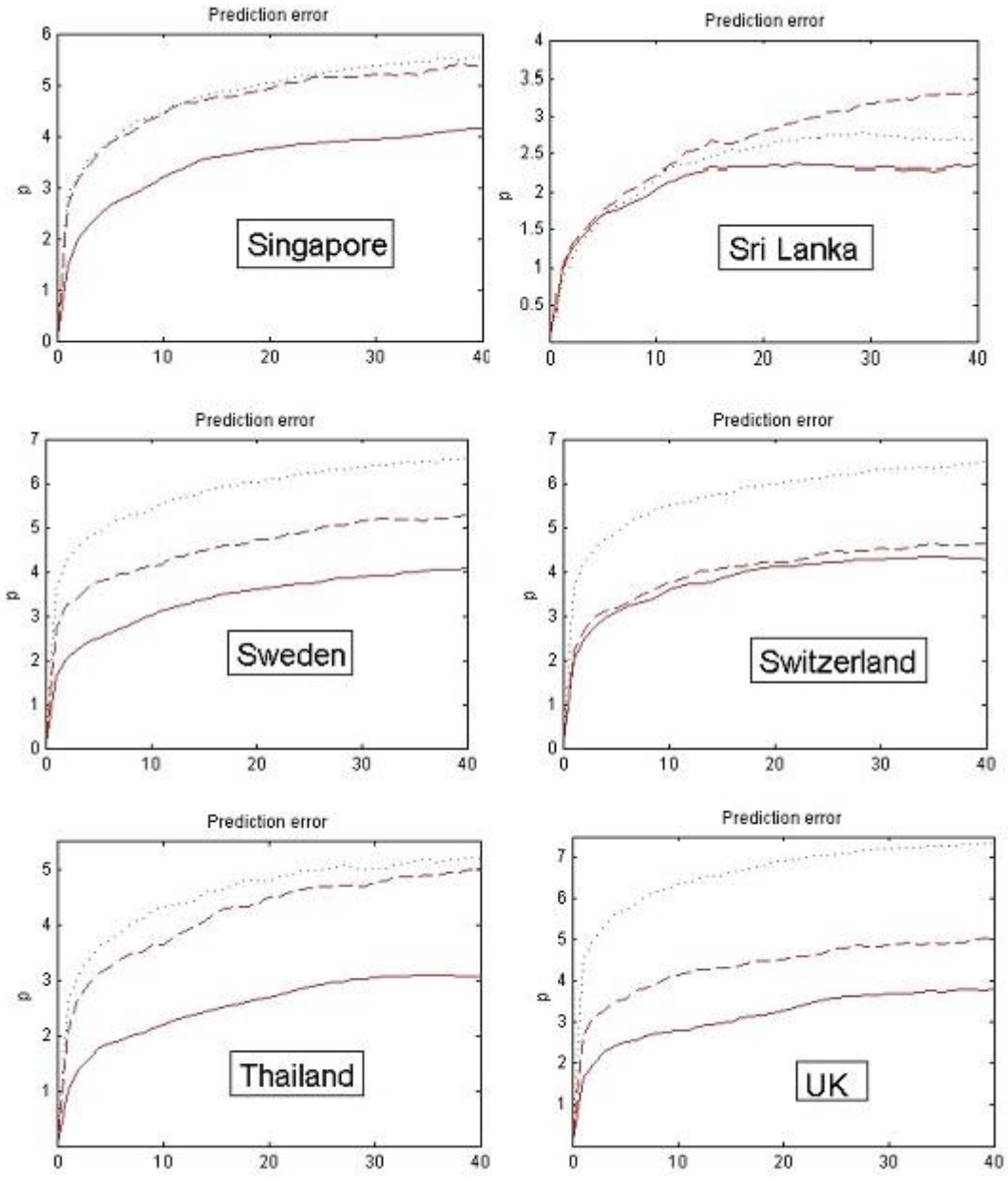


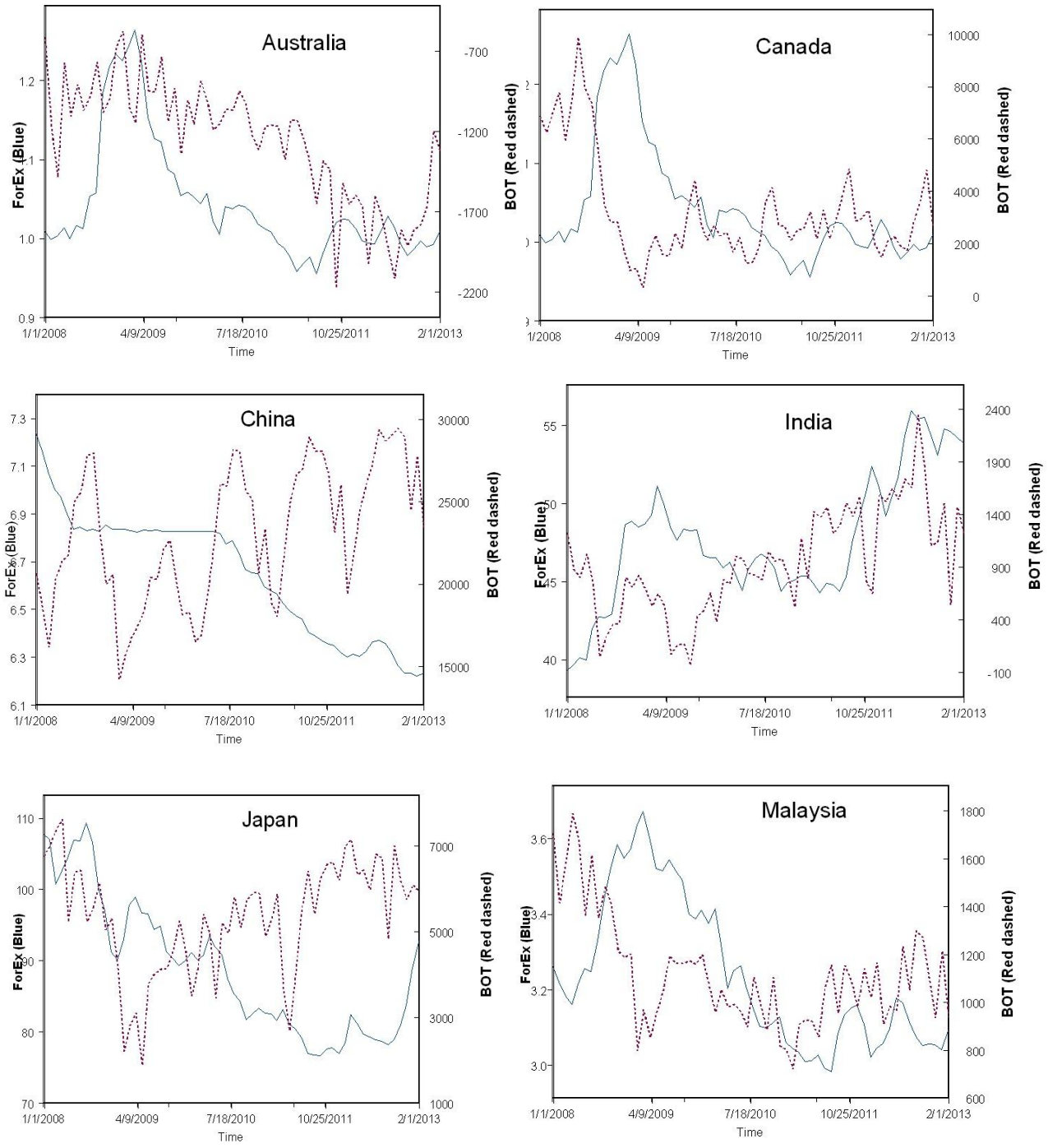
Figure 1(Last 6 of 12 countries): Plot of the largest Lyapunov Exponent (LLE) from foreign exchange daily data for twelve countries for the period Jan. 2009 to Mar. 2013 (in Red, dashed line), Jan. 2008 to Oct. 2009 (in blue), and historical data up to 2005 (in Blue dotted line); LLEs are plotted against number of neighbors used in the algorithm. We are interested in the slopes of lines to estimate LLEs.

4. Balance of Trade (BoT)

There are many factors affecting the Exchange Rates (Hansen et al, 2000). Here we discuss one particular parameter that has direct relation to Forex rate of a particular country.

To check for the relation of one of the fundamental news to foreign exchange rate, we present in Table 1 the balance of payment of the select countries with respect to the US. BoT is the

difference between a country's imports and its exports. A country has a trade deficit (TD) if it imports more than it exports; the opposite scenario is a trade surplus (Investopedia). Here we have collected data for time span of January, 2009 - February, 2013, given in Table 1 which shows a clear trade deficit for most of the countries except Australia. If the exchange value of local currency falls, same volume of goods export will bring fewer US dollar in one hand and the country has to pay bigger amount of dollar for same volume of import on the other hand as shown in Figure 2 where we have plotted monthly BOT and monthly ForEx Rate against time scale 2009 to 2013.



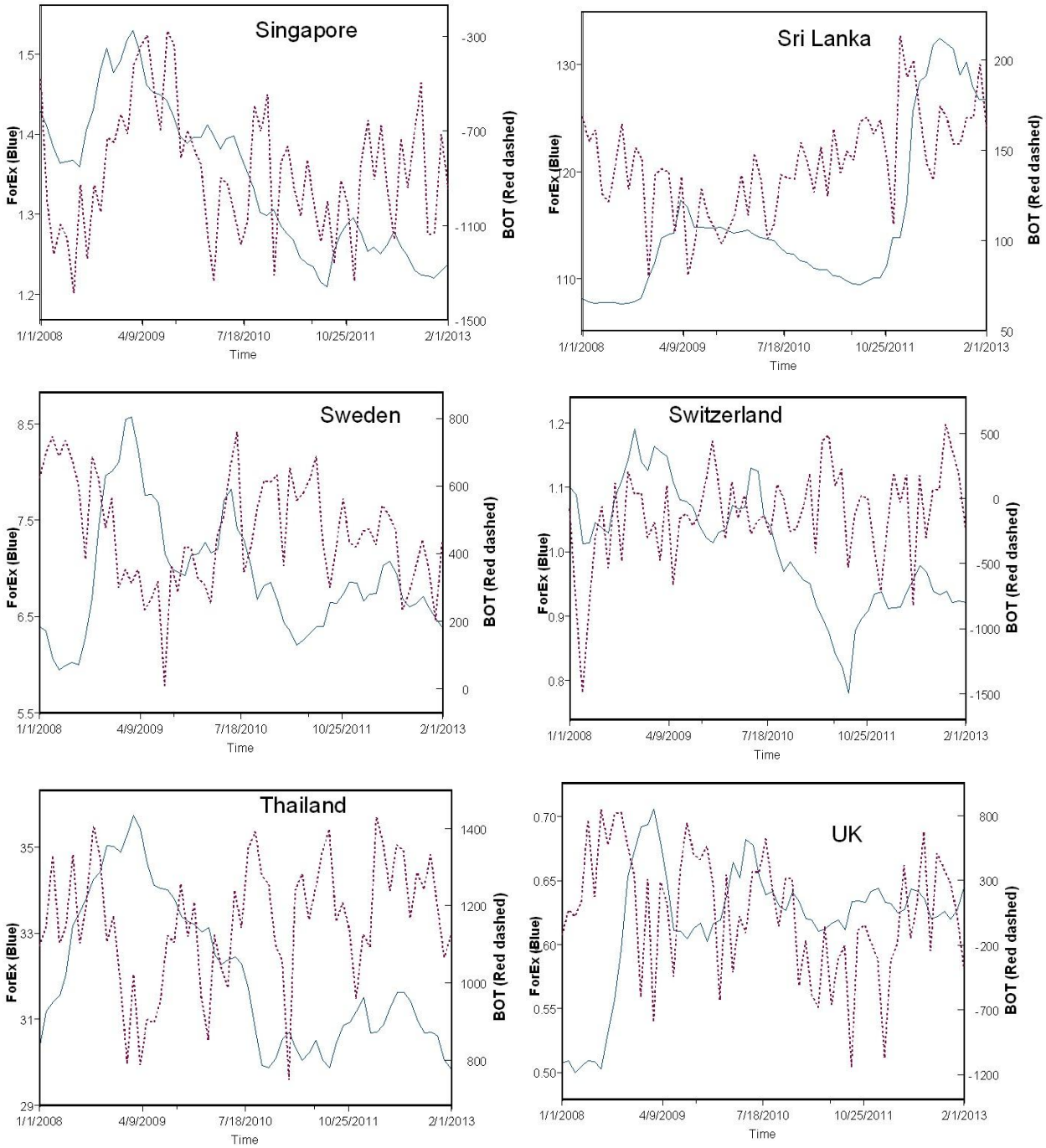


Figure 2. Monthly BoT(blue, left vertical axis) and monthly Foreign Exchange Rate (ForEx Rate in red, right vertical axis) for twelve countries during the period of year 2009 - 2013.

5. European Union (EU)

We have analyzed ForEx rate of different countries. In case of EU, the situation is different as member countries have the same currency Euro and therefore same ForEx rate. The Euro is also deep crisis. In fact, since its birth, Euro has faced many difficulties and that has sharpened during recession- particularly in last four years.

(Moneyland.time.com, September, 2011). Döhring (2008) discussed the bilateral euro exchange rate against the USD up to 2008, have identified fluctuations though not in the context of chaos. There are sharp differences in economic situations in different countries under EU region, though they have same ForEx rate for their currency. We investigate Euro versus USD exchange rate by calculating LLEs as well as monthly ForEx-BOT during last four years of recession as given in Figure 3 below.

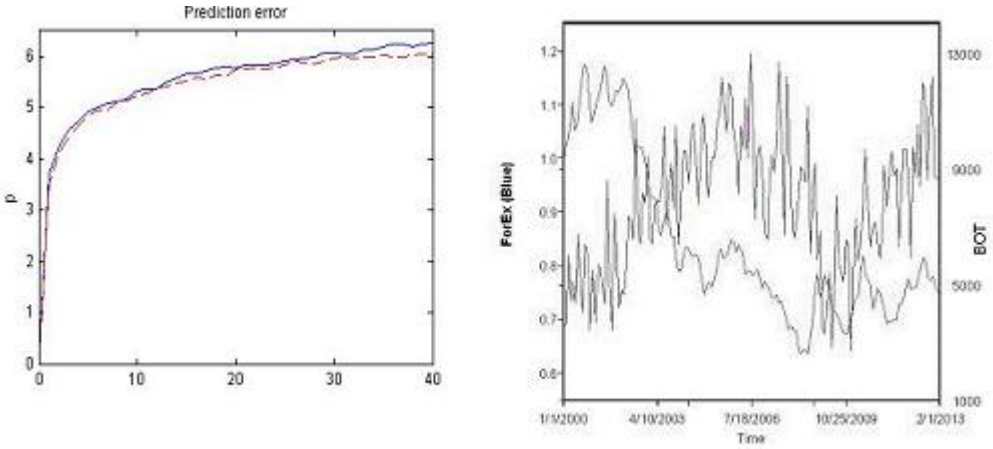


Figure 3. In EU region, the LLE during 2001 – 2008(in blue) and 2009-2013(in red); Right plot: monthly ForEx Rate & BoT as before

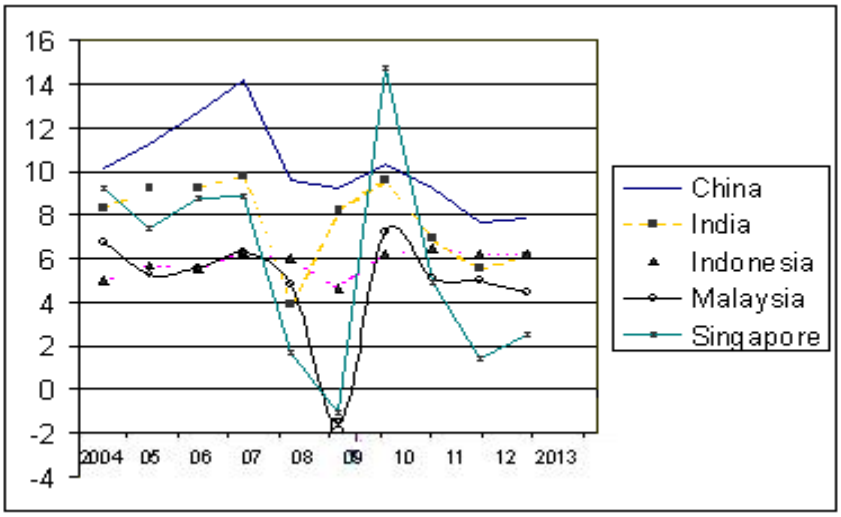


Figure 4. GDP growth rate for selected countries during 2004 – 2012 and 2013 (estimate)

6. Results

From Fig 1, we get the LEEs for twelve countries for the three periods: i) Last four years of recession, which is from January 2009 to March 2013; ii) Previous two years of recession, which is from January 2008 to December 2009; and iii) before entering recession, that is data up to December 2005. They are summarized in the Table 2. We would like to check, if the results during these periods have significant differences.

Table 2. Results of LLEs & percent change during the mentioned periods

Country	Jan. 2009 to Mar. 2013, Last four years	Jan. 2008 to Oct. 2009, Previous two years	up to 2005	Change in last four years in %	Change over pre-recession years in %
Australia	4.5	2.4	4.5	87.50	0.00
Canada	4.8	3.3	4.2	45.45	14.29
China	2.5	3.0	2.5	-16.67	0.00
India	4.4	2.8	2.2	57.14	100.00
Japan	4.2	4.0	5.8	5.00	-27.59
Malaysia	4.3	2.4	4.6	79.17	-6.52
Singapore	4.3	3.3	4.4	30.30	-2.27
Sri Lanka	2.4	2.4	2.0	0.00	20.00
Sweden	3.5	3.0	5.2	16.67	-32.69
Switzerland	3.6	3.6	5.2	0.00	-30.77
Thailand	3.8	1.8	4.4	111.11	-13.64
UK	4.0	2.3	6.2	73.91	-35.48

In our earlier work (2007) we found, through surrogate test to ascertain existence of nonlinearity and chaos, that following grouping can be made:

Group A: For some countries (India, China, Sri Lanka) the difference is too high (nearly 100%).

Group B: For some countries (Australia, Malaysia, Thailand) the difference is moderate (between 20 to 40%).

Group C: For some countries (Canada, Japan, Singapore, Sweden, Switzerland, UK) the difference is small (nearly 20 %).

So, before the advent of recession, in terms of nonlinearity,

Group A > Group B > Group C

Also, it was found that except slight differences for Singapore and Malaysia, it is found that LLE values for countries follow the relation:

Group A < Group B < Group C

During 2008 - 2009, it was also found that for countries in Group A, LLE change is positive (nearly 20%). So we can say that countries with more the nonlinear structure in its ForEx Rate data, LLE change is positive. Also it was found that the countries falling in group B (Except UK) has suffered high change in LLE and finally, countries showing moderate change correspond to Group C. So, on the basis of change in LLE value during recession, we conclude that the more nonlinear structure its foreign exchange rate shows the higher LLE changes.

During the last four years of recession, we find that except for China, LLE values have increased over previous two years, implying that ForEx market may have become more chaotic. For Sri Lanka and Switzerland, there is no change in LLE values. For EU market, LLE has changed from 4.9 to 5.2 in past four years compare to previous eight years. For Australia, India, Malaysia, Thailand and UK, the change is too high (more than 50%) implying more chaotic situation.

Also it may be mentioned that grouping countries based on our previous work does not hold. The possible reason may be that recession has spread to a greater extent globally, affecting developed as well as developing economies.

Another important observation is that if we compare LLE values for last four years to values calculated before advent of present recession, the changes are more or less 35%, (except for India), compare it to even 80-100% change over previous two years. This indicates that the ForEx market may be slowly approaching to pre-recession era values. This may be positive aspect for the ForEx market, obviously indeed if some major shock does not again throw it out of gear. Refer to Fig 4 which shows Gross Domestic Product (GDP) growth rate of some select countries for a period 2004 to 2012, with estimate of 2013. For this countries, the GDP growth rate is slowly returning to its value in 2005, that is before recession started. (Global economic outlook, ibid).

From Fig 2, where we plot monthly values of ForEx and BoT, one can see that: After peak values around 2008 in ForEx indicating ongoing acute recession, al Forex rates for all countries (including EU), apart from their chaotic fluctuations, have come down in and around mid-2011, where recession became less acute. But this did not happen in case of India and Sri Lanka. At the same time, except Australia, Canada and Malaysia, BOT curve for of all the countries considered here, we see a rise (meaning lower BoT, that is difference between export to and import from the US by the concerned country). For China, the BOT shows almost periodicity of rise and fall while ForEx remains steady or let slide down with increasing ForEx rate afterwards 2010, possibly due to governmental intervention.

Finally, for all countries considered here including the EU, from 2013 onwards, BOT increases in favor of the US at a time when ForEx rate is low may indicate an attempt to exit from recession.

7. Conclusions

Markets are nonlinear dynamic systems. The Chaos theory consists in a mathematical analysis tool of such kind of nonlinear dynamic systems. The Chaos theory excludes the opportunity of studying the market history by mathematical and statistical methods and revelation of some repeating time periods and cycles existence. This tool shows that market prices have a random character with a small trend component. One more peculiarity of chaotic markets is “sensibility to initial conditions”. That is what makes the dynamic market systems hardly predictable. This was outlined at the beginning of this work. Any other approach may fail to capture the real situation and proper management of the market. For example, the International Monetary Fund (IMF) Report in 2007, just few months before the recession started in 2008, although noted the “Downside risks have increased significantly”, was confident that “So far, despite the significant ongoing correction in financial markets, global growth remains solid, though some slowdown could be expected” (IMF, 2007).

We attempted series of nonlinear studies to analyze the effect of recession in ForEx market. We have found that nonlinearity of varying degree exists in Foreign Exchange market. Evidence of chaos for different countries was also detected in terms of positive LE. This type work should be periodically attempted to measure the effect of recession in ForEx market. If more number of countries are included in future studies, important relation of BoT, ForEx market and GDP may be more effectively established. Particularly, varying degree of effect of recession on GDP in EU countries who have as such same ForEx rate may be an interesting topic in this context.

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