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Chaotic analysis of the foreign exchange rates during 2008 to 2009 recession

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We investigated chaotic property of foreign exchange rates (ForExRate) of several countries in which daily data were considered for twelve countries (Das and Das, 2007), mostly over the period January 1971 to December 2005. Everyone is aware of the acute recession into which the world economy entered since around July 2008. To investigate what effect this has on ForExRate of different countries, here we concentrated on data during the period of January 2008 to December 2009. Here we calculated the largest Lyapunov exponent (LLE) and compared the changes in its values before and during the recession period. We find that our earlier classification of countries based on LLEs holds true. Also we can conclude that the more nonlinear structure its foreign exchange rate shows the more its LLE changes. We also examined the relation of balance of trade (BoT) -being one of the fundamental news with financial market to ForExRate. For some countries, the ForExRate is falling sharply as BoT is increasing in the same period. The BOT curves for all the countries considered here show that the US was facing less exports to other countries which may indicate the advent of a recession era.

Key words: Foreign exchange rate, balance of trade, surrogate, nonlinearity, Lyapunov exponent, chaos.

INTRODUCTION

The foreign exchange market is a 24 hour financial market. 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. 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 (De Grauwe and Grimaldi, 2003). There is plenty of literature showing basic factors that influence 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 (Das and Das 2007). Characterizing the nature of the relationship between exchange rate change and the news in its underlying fundamentals has long been an objective of empirical international macroeconomics (De Grauwe and Vansteenkiste, 2001).

Fernández-Rodríguez 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). The regime confronted by the exchange rates of the major industrialized countries comes close to the regime identified to be the one producing complexity, speculative noise and structural breaks between exchange rates and underlying fundamentals. What makes the exchange rate changes in the recession era much more complicated is the intervention

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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. For example, in January 2009, the US passed \$787 billion economic stimulus package (The New York Times), Japan announced \$100bn stimulus in April 2009 (CRIENGLISH), China announced a 580 billion US dollar stimulus package in December, 2008 (Seager, 2009). Other reports suggest this, one can for example refer to Euro News for country wise crisis (both EU and non-EU countries) (Federal Reserve Bank). For the present purpose, we like to see if all these initiatives have effect on the exchange rate in the said time period.

In this work, we do not attempt to make any analysis of present crisis. We investigated the chaotic property of foreign exchange rates of several countries (Das and Das, 2007). 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 Deutsche 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 and Vansteenkiste (2001) stressed that it is generally difficult to conclusively find evidence for the existence of chaotic dynamics because the available techniques do not allow separating the exogenous noise from chaos. This lack of strong evidence for the existence of chaos has been confirmed by researchers (De Grauwe and Grimaldi (2003) and references therein). There are conflicting claims that are common in nonlinear analyses of financial data which was emphasized (Çoban et al., 2009; Das and Das, 2007).

In line with our previous work, 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. Now 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 have thus a time series for each country as described in the area of data collection. We test the nonlinearity in the data by surrogate method as presented in test for nonlinearity using surrogate data method, we also calculated the largest Lyapunov exponent (LLE). We compared the LLE values calculated in previous work to the present values—that is LLE values previous and during recession. We also investigated in our earlier work, in particular 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 then, finally results were given and conclusion was drawn with further comments made about the study.

METHODOLOGY

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 (2010), 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. Daily data were collected for twelve countries Australia, Canada, China, India, Japan, Malaysia, Singapore, Sri Lanka, Sweden, Switzerland, Thailand and UK for the periods of January 1973 to October 2009. So we have 12 data sets most of which contain more than 9200 points each. For China, Thailand and Singapore, available data are from January 1981 to October 2009, so for these countries, each data set contain nearly 7200 points.

BoT data for any 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. 5). We collected annual BoT data from the US Bureau of Economic Analysis which maintains downloadable data for several countries (U.S. Census Bureau, 2010). In our case, for most of the countries, BoT data from year 1985 to 2009 were used for analysis as given in Table 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 work [6] or as used with additional noise reduction (Çoban et al., 2009, 2012). 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 up to year 2008. We are not repeating the same analysis because we are considering the same countries and compared to our previous data, we now have 450 more points, which is only 5% of total only (from January 2008 to October 2009). But we certainly have to use the results.

Finding lyapunov exponent using tstool package

Chaotic processes are characterized by positive Lyapunov Exponent (LE)s calculated following the approach of Wolf et al. (1985; Das et al., 2002). Again, we used the TSTOOL to find the 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 (1985; Das et al., 2002). In the particular MATLAB code, largelyap, the average exponential growth of the distance of neighbouring orbits is studied in a logarithmic scale, this

Table 1. United States trade in goods: (imports - exports = balance) by country (in millions of U.S. dollars).

Year	Australia	Canada	China	India	Japan	Malaysia	Singapore	Sri Lanka	Sweden	Switzerland	Thailand	UK
1985	2604	-21755	-6	-653	-46152	-761	-784	-209	-2199	-1188	-579	-3664
1986	2923	-22920	-1665	-747	-55029	-691	-1345	-271	-2549	-2276	-811	-3978
1987	2489	-11271	-2796	-1065	-56326	-1024	-2148	-340	-2865	-1099	-676	-3227
1988	3432	-9776	-3489	-439	-51794	-1550	-2206	-299	-2285	-415	-1248	388
1989	4458	-9144	-6234	-857	-49059	-1874	-1658	-306	-1753	197	-2092	2518
1990	4091	-7706	-10431	-711	-41105	-1847	-1778	-400	-1533	-644	-2293	3302
1991	4416	-5914	-12691	-1193	-43385	-2202	-1153	-483	-1238	-19	-2369	3633
1992	5188	-8036	-18309	-1863	-49601	-3931	-1687	-612	-1871	-1104	-3540	2707
1993	4979	-10772	-22777	-1776	-59355	-4499	-1120	-799	-2180	834	-4776	4708
1994	6579	-13967	-29505	-3016	-65668	-7013	-2338	-895	-2522	-749	-5441	1842
1995	7466	-17144	-33790	-2431	-59137	-8639	-3227	-981	-3177	-1367	-4683	1927
1996	8140	-21682	-39520	-2841	-47581	-9283	-3623	-1182	-3722	581	-4139	1984
1997	7461	-15467	-49696	-3715	-56115	-7247	-2378	-1466	-3985	-98	-5252	3766
1998	6531	-16653	-56927	-4673	-64014	-10043	-2662	-1576	-4026	-1443	-8198	4220
1999	6538	-32111	-68677	-5383	-73398	-12365	-1944	-1575	-3852	-1167	-9346	-830
2000	6044	-51897	-83833	-7019	-81555	-14631	-1372	-1797	-5043	-206	-9768	-1775
2001	4453	-52844	-83096	-5980	-69022	-12983	2652	-1801	-5367	138	-8738	-655
2002	6606	-48165	-103065	-7717	-69979	-13665	1416	-1639	-6063	-1600	-9933	-7540
2003	6674	-51671	-124068	-8076	-66032	-14526	1422	-1653	-7896	-2029	-9343	-8967
2004	6412	-66480	-162254	-9463	-76237	-17329	4027	-1793	-9439	-2348	-11211	-10372
2005	8246	-78486	-202278	-10886	-83323	-23224	5356	-1885	-10106	-2282	-12633	-12465
2006	9342	-71782	-234101	-12157	-89722	-24089	6057	-1909	-9744	145	-14551	-8103
2007	10563	-68169	-258506	-9104	-84304	-20948	7225	-1838	-8551	2279	-14418	-6876
2008	11630	-78342	-268040	-8022	-74120	-17787	11969	-1679	-7480	4242	-14472	-4988
2009	11408	-18664	-227660	-4742	-43811	-12742	6357	-1363	-3520	1676	-11953	-1673

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 neighbouring orbits converges to the direction corresponding to the λ_{\square} the LLE. During phase II, the distance grows exponentially with $\exp(\lambda_{\square}k)$ 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_{\square} 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 Figure 1. By finding the slope of the phase II, we estimated LLEs in each case. We calculated LLEs for each country by following three periods during: I) the period 1973 to 2007 (done in earlier work) II) during 1973 to 2009 (that is, entire available data) and III) during January 2008 to October 2009.

In Figure 1, we draw series of figures - one for each country where we show foreign exchange data of the previously mentioned phase II, with that for phase III is given as inset. Another inset shows LLEs of the three phases- each figure being properly marked. Another inset shows LLEs calculated for i) the period up to 2005 (in green) ii) up to November 2009 (in blue) and iii) during January 2008 to October 2009 (during recession period).

Balance of trade (BOT)

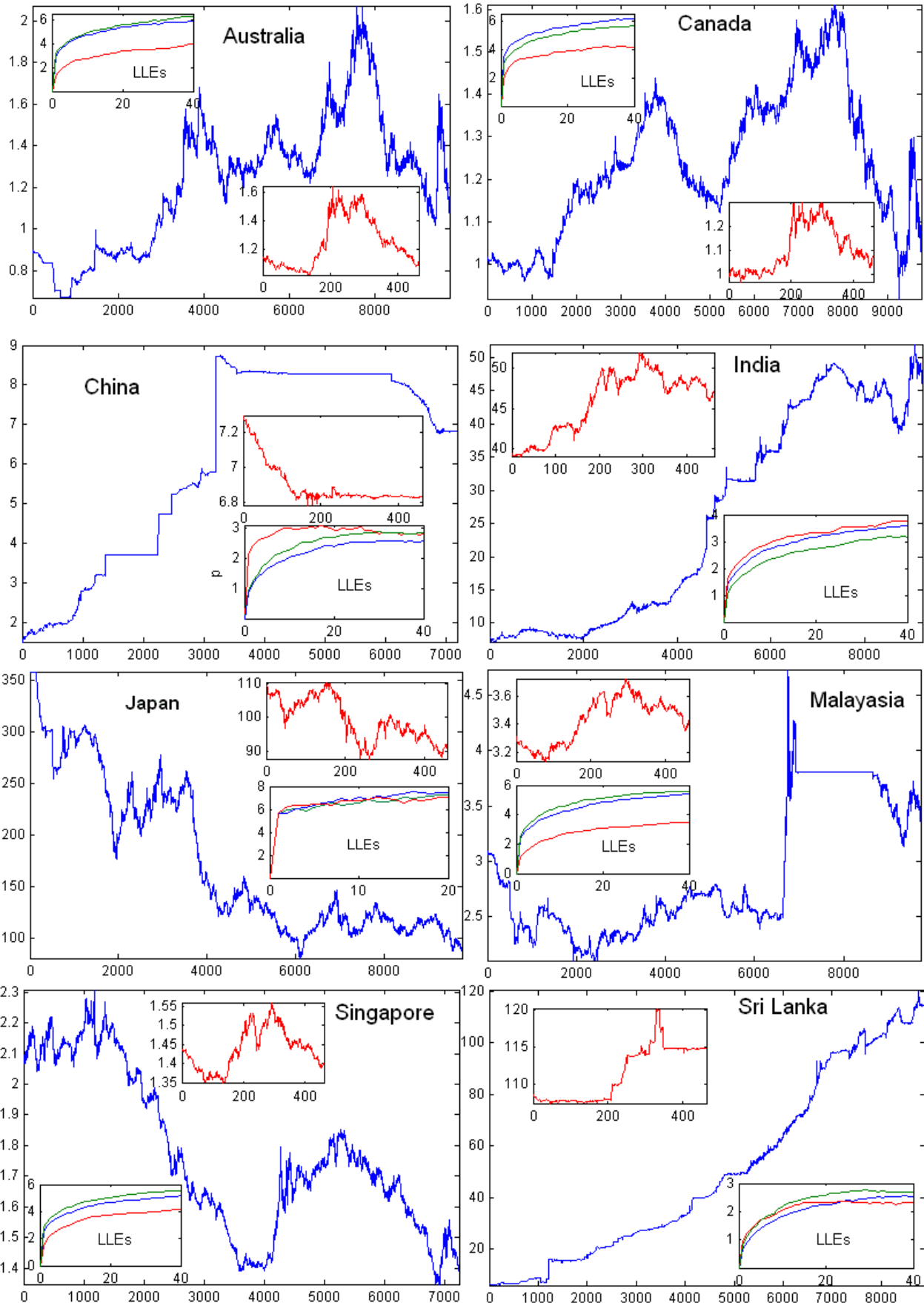
To check for the relation of one of the fundamental news to foreign

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 1985 to 2009, 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 annual TD deficit and monthly ForExRate against time scale 1985 to 2009.

RESULTS

From Figure 1, we get the LLEs for twelve countries for the three periods and summarized them in Table 2. We like to check, if the results during the recession period have significantly changed from our previously calculated values. We calculated percent difference of LLE values for selected countries over respective surrogate sets to test the existence of nonlinearity and chaos (Das and Das, 2007). In terms of the results, following groups were made:

Group A: For some countries (India, China, Sri Lanka)



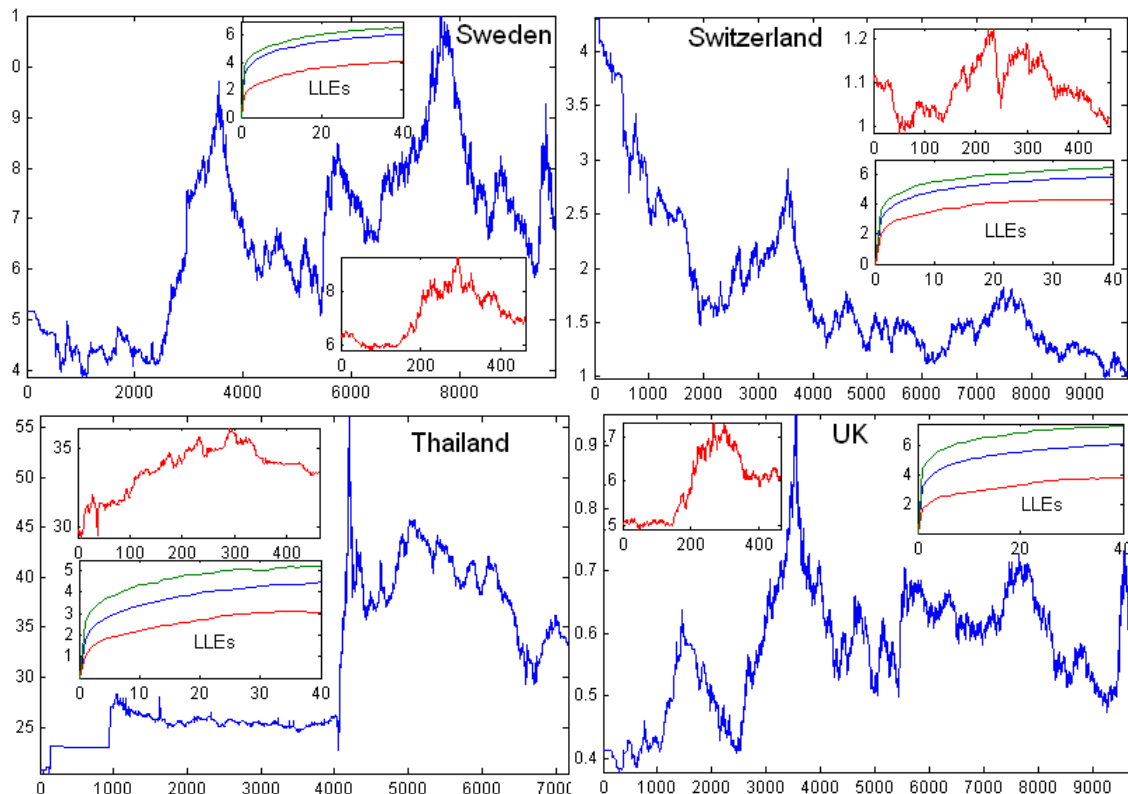


Figure 1. Plot of the foreign exchange data for twelve countries as described in data collection, up to November 2009 and in inset for the period January 2008 to October 2009 (in red), daily data for period shown in the horizontal axis.

the difference was too high (nearly 100%).

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

Group C: For some countries (Canada, Japan, Singapore, Sweden, Switzerland, UK) the difference was small (nearly 20%). So, in terms of nonlinearity Group A > Group B > Group C. Also, it was found that except slight differences for Singapore and Malaysia, the LLE values for countries follow the relation:

Group A < Group B < □ Group C

In the present work, we find that for countries whose LLE change is positive (nearly 20%) are China, India and Sri Lanka. They exactly correspond to earlier result of Group A. So we can say that countries with more the nonlinear structure in its ForExRate data, LLE change were positive. For other countries, we divide the change in two groups:

When change is high (nearly -50% or more): Australia, Malaysia, Thailand and UK

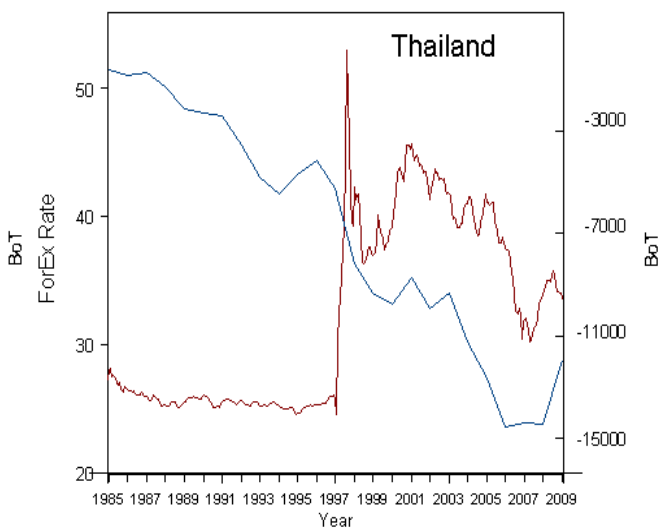
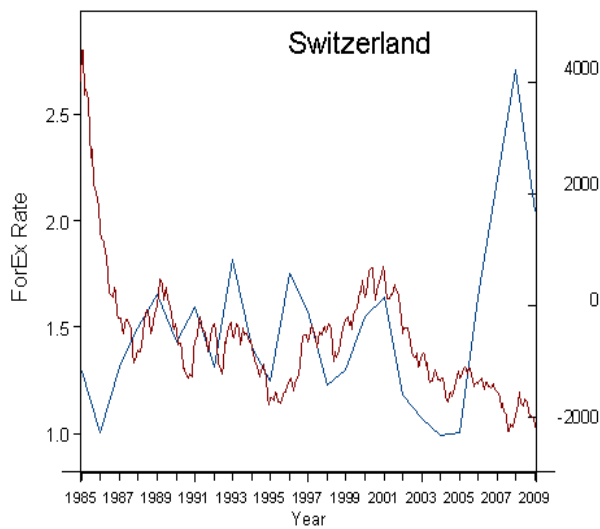
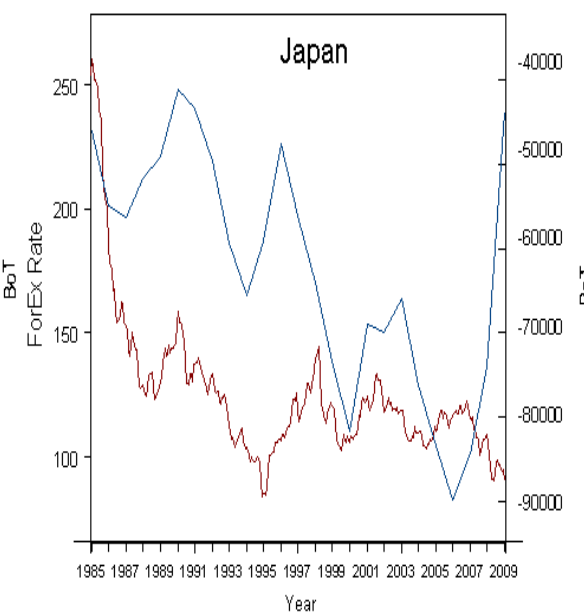
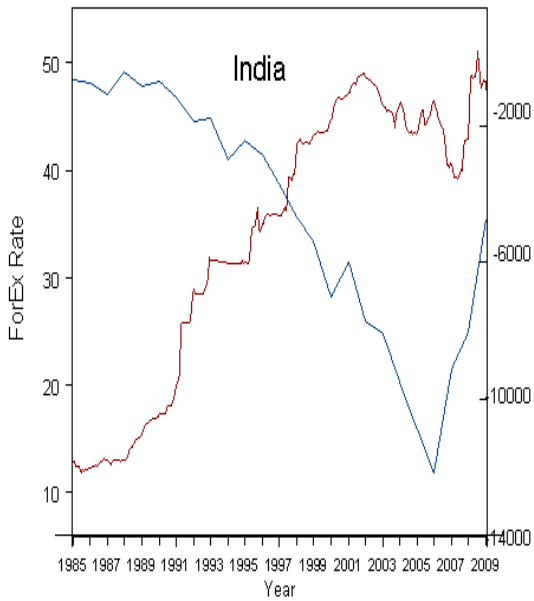
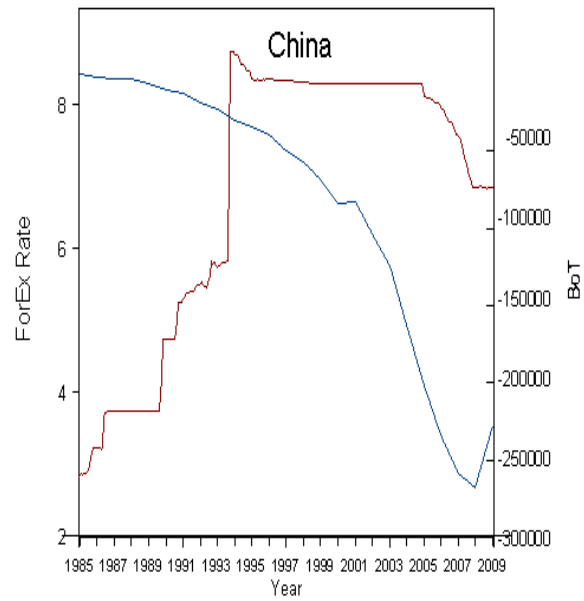
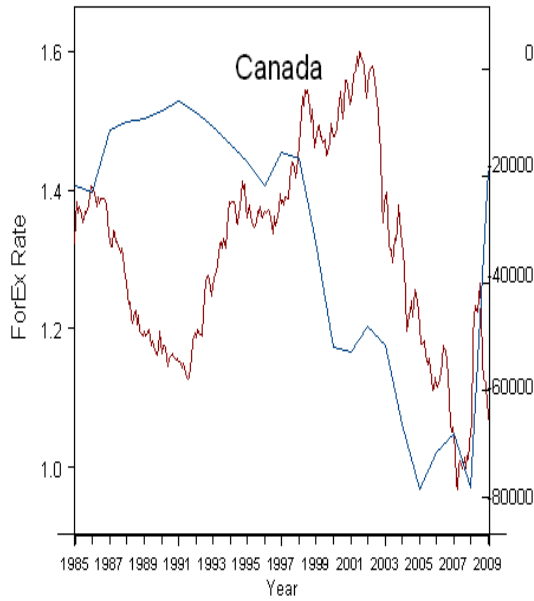
When change is moderate (between -20 and -30%): Canada, Japan, Singapore, Sweden, Switzerland.

Again, we see that the countries falling in group B (except UK) has suffered high change.

Finally, countries showing moderate change correspond to Group C. So, on the basis of change in LLE value during recession, we can conclude that the more nonlinear structure its foreign exchange rate shows the more its LLE changes.

From Figure, 2 we can see that for countries in Group A, namely India, China and Sri Lanka, the ForExRate falling sharply as BoT is increasing in the same period. Note that BoT are negative values so a downward curve actually shows BoT increasing. This means that these countries get fewer US dollar for the same volume of export in one hand and on the other hand, pays more dollars for the same volume of import.

For some countries in Group C, namely Canada, Japan, Singapore, Sweden and Switzerland, the relation between BoT and ForExRate are not such antagonist. The two curves intersect several times with their own ups and downs. For the other Group C, the situation is moderate. Another interesting point is that if we look closely at the 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) decreases from around 2007. This can be stated in another way that the US was facing



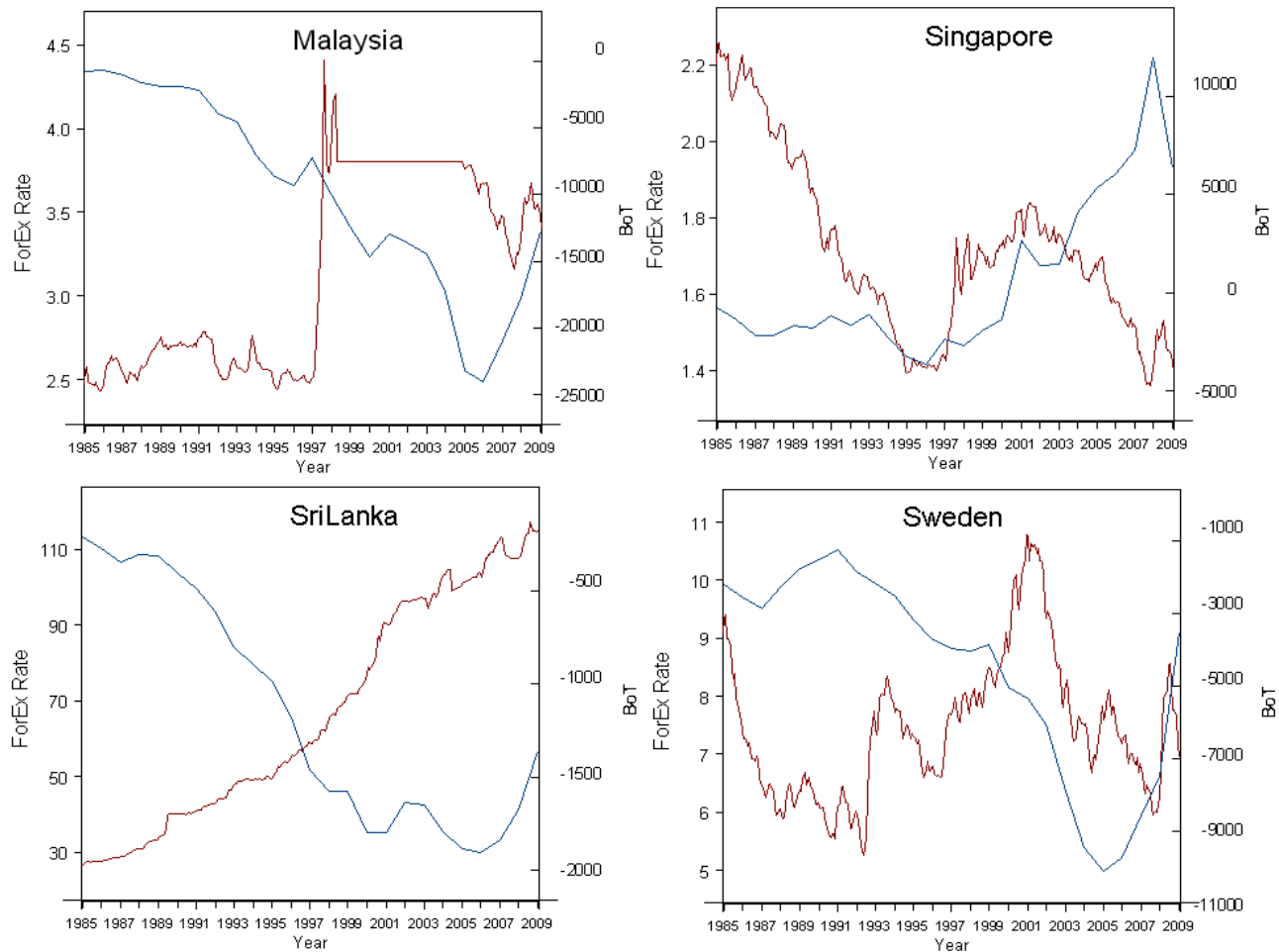


Figure 2. Showing annual trade deficit (TD in blue, left vertical axis) and monthly foreign exchange rate (ForExRate in red, right vertical axis) for ten countries during time period of year 1985 to 2009.

Table 2. Results of LLEs and percent change during the recession period.

Country	January 2008 to October 2009 (red)	Up to 2005 (green)	Up to October 2009 (blue)	Red changed over green	% change during recession
Australia	2.4	4.5	4.4	-2.1	-46.67
Canada	3.3	4.2	4.7	-0.9	-21.43
China	3.0	2.5	1.8	0.5	20.00
India	2.8	2.2	2.6	0.6	27.27
Japan	4.0	5.8	4.6	-1.8	-31.03
Malaysia	2.4	4.6	4.1	-2.2	-47.83
Singapore	3.3	4.4	4.2	-1.1	-25.00
Sri Lanka	2.4	2.0	1.8	0.4	20.00
Sweden	3.0	5.2	4.9	-2.2	-42.31
Switzerland	3.6	5.2	4.8	-1.6	-30.77
Thailand	1.8	4.4	3.3	-2.6	-59.09
UK	2.3	6.2	4.9	-3.9	-62.90

less exports to other countries which may indicate the advent of a recession era.

Conclusions

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 LLE. As indicated in the theory that various news as well as agents control the exchange rate, but there is nonlinear relationship among them. This is reinforced in our finding. We grouped countries in terms of the LLEs in their ForExRate in our earlier work and in this work; we see that the same grouping also holds considering recession or the BoT as discussed. BoT is only one of the many fundamentals acting in ForExRate market. Another important point to consider as news is the different forms of large governmental interventions, particularly during the recession as described in the introduction section. Considering more such news for larger time scale for many more countries may give more precise results.

REFERENCES

- Bask M (1996). Dimensions and Lyapunov exponents from exchange rate series. *Chaos Solitons Fractals*, 7(12): 2199-2214.
- Bask M (2002). A positive Lyapunov exponent in Swedish exchange rates? *Chaos Solitons Fractals*, 14(5): 1295-1304.
- Çoban G, Büyüklü AH (2009). Deterministic flow in phase space of exchange rates: Evidence of chaos in filtered series of Turkish Lira–Dollar daily growth rates. *Chaos Solitons Fractals*, 42(2): 1062–1067.
- Çoban G, Büyüklü AH, Das A (2012). A linearization based non-iterative approach to measure the gaussian noise level for chaotic time series. *Chaos Solitons Fractals*, 45(3): 266–278.
- CRIENGLISH.com, 2008-12-05, 12:22:20 at <http://english.cri.cn/4026/2008/12/05/2041s430055.htm>
- Das A, Das P (2007). Chaotic Analysis of the Foreign Exchange Rates. *Appl. Math. Comput.*, 185(1): 388-396.
- Das A, Das P, Roy AB (2002). Nonlinear data analysis: A comparison between experimental [EEG] data and theoretical [ANN] data. *Complexity*, 7(3): 30-40.
- Economic Research (2010). Federal Reserve Bank of St. Louis and are free downloadable at <http://research.stlouisfed.org/fred2/categories/15> Visited Jan.
- Euro News (2010). Country wise crisis (both EU and non-EU countries) at <http://euronews.eu/tag/financial-crisis/> Visited Jan., 2010
- Fernández-Rodríguez F, Sosvilla-Rivero S, Andrada-Félix JN (2005). Testing Chaotic Dynamics via Lyapunov Exponents. *J. Appl. Econ.*, 20: 911–930.
- De Grauwe P, Grimaldi M (2003). Intervention in the foreign exchange market in a model with noise traders. Draft at Univ. of Leuven.
- Investopedia (2011) .at <http://www.investopedia.com/terms/b/bot.asp> Visited April,
- De Grauwe P, Vansteenkiste I (2001). Exchange rates and fundamentals. A non-linear relationship? Center for Econ. Studies and Ifo Inst. for Econ. Res. Working Paper No. 577 available at www.CESifo.de Visited April 2006, Jan., 2010.
- LeBaron B (1994). Chaos and nonlinear forecastability in economics and finance. *Philosophical Trans. R. Soc. London (A)*, 348: 397-404
- MATLAB Release13, the MathWorks, Inc., (2002). *Phil. Trans. R. Soc. London. Ser. A.*, 348: 397-404.
- Parlitz U (1998). Nonlinear time series analysis, in: Suykens JAK, Vandewalle J (Eds.) *Nonlinear Modeling - Advanced Black-Box Techniques*. Kluwer Acad. Pub. Boston.
- Parlitz U, Wedekind I, Lauterborn W, Merkwirth C (2001). TSTOOL & User Manual, Ver. 1.11, DPI Göttingen, free download at www.physik3.gwdg.de/tstool/gpl.txt.
- U.S. Census Bureau (2010). Country Data: Trade Balance, Foreign Trade Division, Washington at <http://www.census.gov/foreigntrade/balance/>.
- Seager A (2009). China announced a 580 billion US dollar stimulus package in Dec. 2008. guardian.co.uk, 6 April.
- The New York Times (2009). Times Topics: Economic Stimulus.
- Theiler J, Eubank S, Longtin A, Galdrikian B, Farmer J (1992). Testing for nonlinearity in time series: The method of surrogated data. *Physica D*, 58: 77–94.
- Wolf A, Swift JB, Swinney LH, Vastano JA (1985). Determining Lyapunov exponent from a time series. *Physica D*, 16: 285–317.