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The Dynamics of Philippine Foreign Exchange Rates (2013-2017): A Test for Chaos

Ma. Carlota B. Decena, Kristine Nicole T. Francisco, Mervinjohn M. Yatco

Abstract*: In most studies on dynamics of time series financial data, the absence of chaotic behavior is generally observed. However, this theory is not yet established in the dynamics of foreign exchange rates. Conflicting claims of presence and absence of chaos in foreign exchange rates open door for further investigation considering various deterministic factors. This work examines the dynamics of exchange rate of the Philippine Peso against selected foreign currencies. Time series data were collected for eight (8) of Philippine's top trading partners as categorized according to economic condition. The data obtained with permission from the Central Bank of the Philippines covered the years 2013 to 2017. Data sets were plotted revealing non-linear movement of Philippine exchange rates against time. The foreign exchange rate time series obtained per currency were examined for chaotic behavior by computing the Largest Lyapunov Exponents (LLE). A positive Lyapunov exponent is an indication of sensitivity dependence, i.e, a chaotic dynamics; whereas, a negative Lyapunov exponent indicates otherwise. Computed LLE's varied per currency but all were found to be negative. Therefore, using the Largest Lyapunov Exponent Test (LLE), analysis of the time series of Philippine foreign exchange rates shows little evidence of chaotic patterns.

***Index Terms*: chaos, deterministic factors, foreign exchange rate, largest lyapunov exponent**

I. INTRODUCTION

Understanding the dynamics of foreign exchange rate movement is essential to investors, economists and policy makers [1]-[2]. Forecasting exchange rates is necessary to determine the profits and risks of an investment. However, due to several socio-economic factors, exchange rate patterns fluctuate every moment making empirical predictions quite a big challenge [3]-[4]. Economic theories have explained movement in some financial market. According to random walk theory, financial market moves randomly and cannot be predicted from past behavior [5]. Similarly, the efficient market hypothesis suggests that current market prices reflect all available information [6]. A market which is in weak form efficient implies that future exchange rates are not associated with current and past exchanges. On the contrary, chaos theory which states that although a behavior may seem random, there is an underlying deterministic relationship between dynamical systems [7]. Chaos describes an erratic behavior of a deterministic system that is highly sensitive on initial conditions. This means that a small alteration in the initial conditions of the system would make the outcome completely different. Furthermore, a chaotic system is characterized by a lack of long-term predictability whereas short-term forecasting is possible. Thus, if an exchange market is chaotic, accurate short-term run predictability can generate increased profit. The search for chaos in exchange rate continues despite of claims of unpredictability by some economic theories. While most empirical studies reveal the absence of chaos in foreign exchange rate, there are still reports of chaos in other foreign exchange markets [8-10]. It is therefore noteworthy to examine foreign exchange markets individually. In this study, the dynamics of the exchange rates of Philippine peso (PHP) against selected currencies is examined empirically. Philippines' top eight (8) trading partners selected are: United States of America (USD), Germany (EUR), Japan (JPY), South Korea (KRW), China (CNY), Hong Kong (HKD), Singapore (SGD), Thailand (THB). The study is restricted to a five-year interval (2013-2017). The study by Patel, et al. [11], emphasizes various factors affecting currency movement. These factors are inflation rates, rates of interest, balance of payments, role of speculators, cost of manufacture, debt of the country, gross domestic product, economic performance, employment data, relative strength of other currencies, and macroeconomic and geopolitical events. It is also concluded in this study that prediction of a currency is mainly based by these factors. Moreover, in the work of Hopper (1997), exchange rates are shown to be affected by fundamental economic factors. A well-forecasted value of these factors can lead to a more accurate prediction of the exchange rates [12]. This study, therefore, extends to investigate possible association of the degree of 'uncertainty' or 'certainty' of Philippine exchange rates with selected economic factors, namely: inflation rate, interest rates, balance of payments, OFW remittances and net foreign direct investments of the Philippines.

II. THE PHILIPPINE FOREIGN EXCHANGE MARKET: AN OVERVIEW

The foreign exchange market is the world's largest financial market. This market is where the currency of one country is exchanged for that of another country, the rate of exchange between currencies is determined, and foreign exchange transactions are physically completed. At present, the Philippine exchange rate policy supports a freely floating exchange rate system whereby Bangko ng Sentral ng Pilipinas (BSP) leaves the determination of the exchange rate to market forces.

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*****Correspondence Author(s)
Ma. Carlota B. Decena, Department of Mathematics and Physics, College of Science, University of Santo Tomas, Manila, Philippines. Research Center for the Natural and Applied Sciences, University of Santo Tomas, Manila, Philippines. Graduate School, University of Santo Tomas, Manila, Philippines
Kristine Nicole T. Francisco, Department of Mathematics and Physics, College of Science, University of Santo Tomas, Manila, Philippines.
Mervinjohn M. Yatco, Department of Mathematics and Physics, College of Science, University of Santo Tomas, Manila, Philippines.

Under a market-determined exchange rate framework, the BSP does not set the foreign exchange rate but instead allows the value of the peso to be ndetermined by the supply of and demand for foreign exchange [13]. Moreover, BSP stated that exchange rate movements can affect the Philippines'external sector through its impact on foreign trade.

II. DATA GATHERING

Historical data of Philippine foreign exchange rates were retrieved from the Online Interactive Statistics Database of Bangko Sentral ng Pilipinas. The time series data of eight (8) of Philippine's top trading partners were chosen and categorized by their economic condition. Moreover, data sets of factors that may affect exchange rates such as inflation rates, interest rates of each country, balance of payments, net foreign direct investments, and OFW Remittance from each country were collected from the public database of Bangko Sentral ng Pilipinas. The data obtained covered the years 2013 to 2017. Data sets were plotted revealing non-linear movement of Philippine exchange rates against time. The graphs are shown in Fig. 2 (a)-(b).

III. LARGEST LYAPUNOV EXPONENT FOR CHAOS TEST

Chaos in a dynamical system is defined as stochastic behavior occurring in a deterministic system [14]. Systems that exhibit complex behavior which can be described by non-linearities in time series are said to be chaotic. A chaotic system has therefore two important characteristics. That is, it is highly sensitive to initial conditions, and it involves nonlinear feedback forces that can produce unexpected results [15]. The main focus of this study is to determine the existence of chaos in the Philippine foreign exchange rates.

One of the most used tests in checking for the existence of chaos on a financial time series data is the Largest Lyapunov Exponent (LLE) test. The LLE test is a test for the sensitivity dependence on the initial conditions. Moreover, this test is necessary to quantify the stability of orbits around an attractor. The Lyapunov exponents are the rates at which those orbits will converge or diverge. A positive Lyapunov exponent is an indication of sensitivity dependence whereas a negative Lyapunov exponent indicates otherwise.

In this study, the Largest Lyapunov Exponent (λ) is used to characterize the dynamics of Philippine exchange rates as a measure of its sensitivity to a change in initial conditions. The Philippine exchange rates time series were imported to MATLAB. Using the Curve Fitting Tool for n data points, cubic spline interpolation was utilized to obtain the discrete time series function map $f(t)$ necessary in the LLE computations. The Largest Lyapunov Exponent (λ) is generated according to the formula:

$$\lambda = \lim_{n\to\infty} \frac{1}{n} \sum_{i=0}^{n-1} \ln \left| f'(t_i) \right| \qquad (1)$$

Positive value of LLE (λ) indicates the presence of chaos whereas a negative LLE (λ) indicates otherwise. The main procedures performed are illustrated in Fig. 1

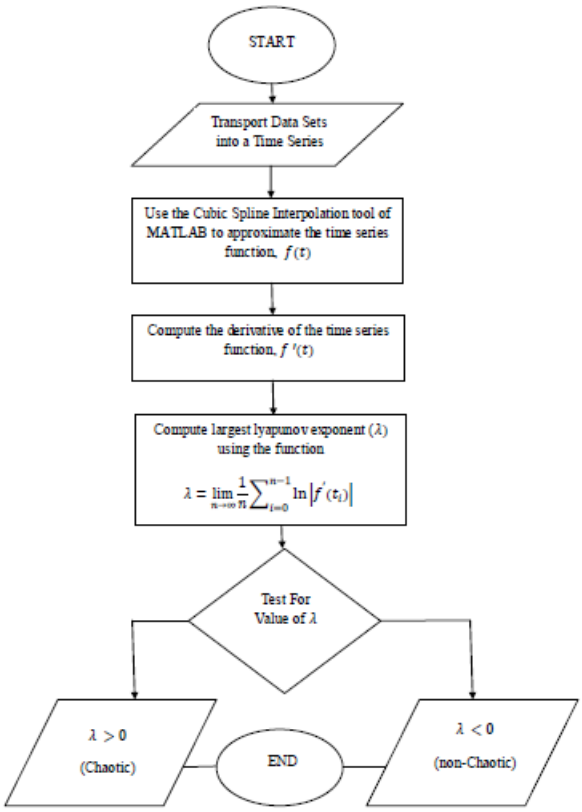

Fig. 1 Flowchart of the Largest Lyapunov Test for Chaos

IV. RESULTS

The function map $f(t)$ for the time series of Philippine exchange rates per currency was approximated using Cubic Spline Interpolation. Using a constructed MATLAB code values of the LLE's (λ) per country were generated for each year. The results are presented in Table 1. A positive LLE would indicate the presence of chaos whereas a negative LLE indicates otherwise.

Table 1. LLE's (λ) for each currency per year

Currency	2013	2014	2015	2016	2017
USD	-2.7905	-2.8357	-2.9612	-2.6188	-2.8095
JPY	-6.2581	-6.7726	-6.8731	-6.2498	-6.5496
EUR	-1.7621	-1.9589	-1.5190	-1.9086	-1.7735
KRW	-9.3704	-9.3886	-8.9565	-8.7869	-8.8916
CNY	-4.6092	-4.6800	-4.7269	-4.4798	-4.4337
HKD	-4.8825	-4.8893	-4.9880	-4.7165	-4.8491
SGD	-2.7139	-2.7587	-2.5375	-2.5137	-2.6742
THB	-5.9656	-6.0922	-6.1726	-6.1509	-6.0779

The results show that time series of Philippine exchange rates for all countries have negative LLEs throughout all the years. This indicates that no evidence of chaos is found in the movement of exchange rates for all the 8 trading partners of the Philippines. Moreover, the results indicate that throughout the observation period, the exchange rates dynamics have been consistently non-chaotic. Exchange rates, whether the counter currency are from a developed country or a developing country, remained to have regular dynamics. For investors and players in the Philippine financial market, this

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dynamics is quite a big challenge as short-term prediction of exchange rates may seem to be impossible. However, this dynamics may suggest deterministic characteristics whereby external factors affecting the non-linear movements can be monitored over time. However, it is interesting to note that while 6 of the 8 top trading partners of the Philippines almost had constant value of LLE's from 2013 to 2017, the LLE's for the time series exchange rate for EUR and KRW are varying significantly each year. The difference in LLE's is most observable in the year 2014-2015.

V. SUMMARY AND CONCLUSION

In summary, all time series generated from the foreign exchange rates (2013-2017) per currency of the top 8 trading partners of the Philippines are non-linear. Furthermore, having yielded all negative values of the Largest Lyapunov Exponent, λ, for each time series of currency exchange, showed that all of the tested foreign exchange rates time series did not exhibit chaotic behavior. Since the Philippine foreign exchange market for these 8 countries, namely, United States of America (USD), Germany (EUR), Japan (JPY), South Korea (KRW), China (CNY), Hong Kong (HKD), Singapore (SGD), and Thailand (THB), is not chaotic, then short-term prediction of foreign exchange rates may not be possible. However, long-term prediction may be possible. Hence, it is highly suggested that future studies check whether forecasting foreign exchange rates in long-term is possible. The absence of chaos on the Philippine foreign exchange rates over the covered period also implies that a small change in its deterministic factors may have little to no effect in the foreign exchange rates. This might indicate that there is stability in the foreign exchange rates during the covered period. Consequently, the stability of exchange rates may point towards economic growth which is beneficial in a country.

VI. RECOMMENDATIONS AND FUTURE OUTLOOK

Though this study did not confirm the existence of chaos in the movement patterns of Philippine foreign exchange rates in the year 2013-2017, further tests can be implemented with different parameters. Investigation of different patterns on the exchange rates is recommended to gain better results in the future. The dynamic behavior of the foreign exchange market could implicate the existence of possible deterministic factors that can make exchange rates fluctuate. Thus, the authors will investigate these factors in their future studies.

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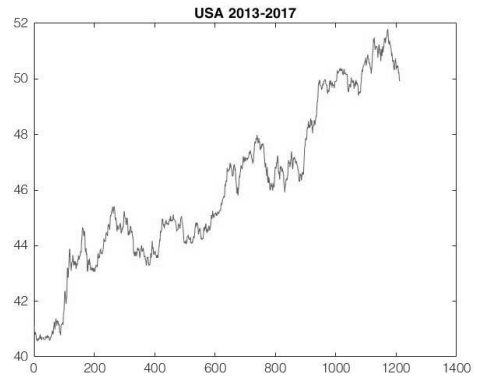

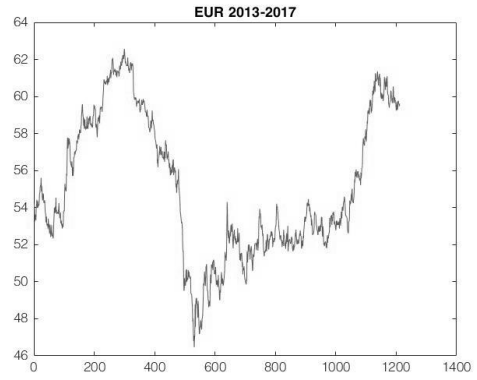

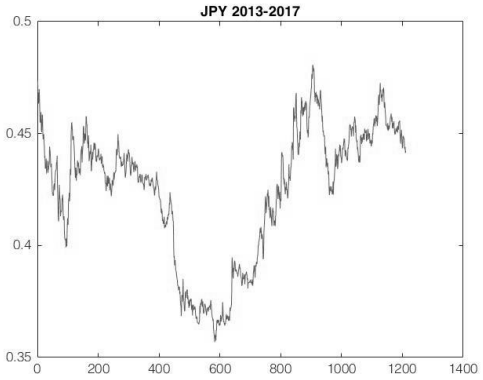

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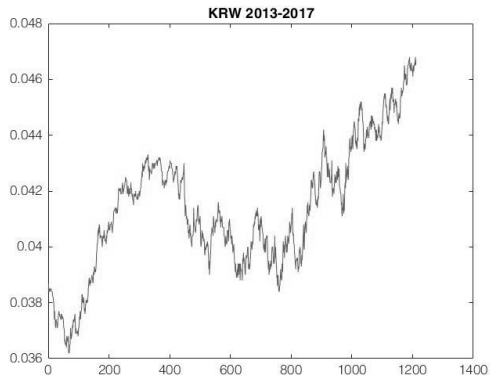


Fig. 2 (a) Plot of Philippine foreign exchange rate for four developed countries versus time in days from the period 2013-2017

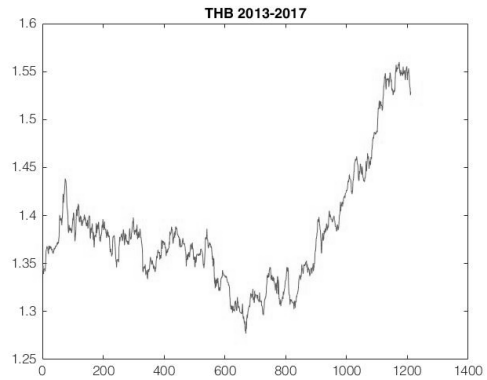
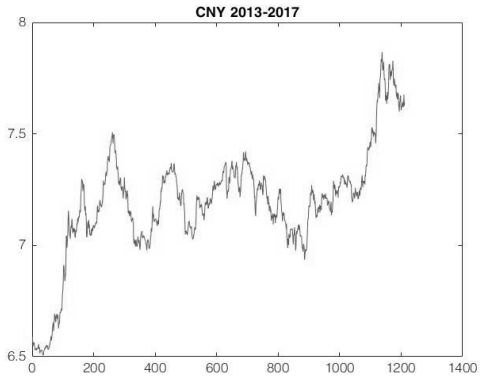
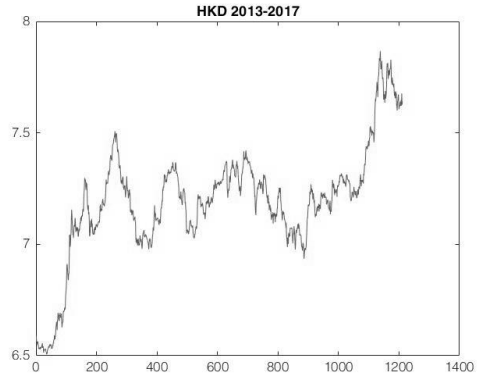
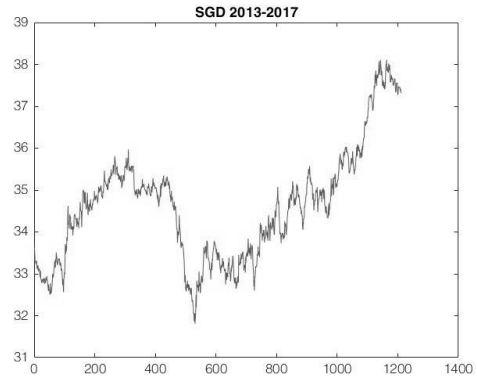


Fig. 2 (b) Plot of Philippine foreign exchange rate for four developing countries versus time in days from the period 2013-2017







AUTHORS PROFILE

Ma. Carlota B. Decena is a professor of mathematics from the College of Science, University of Santo Tomas, Philippines. She holds a doctoral degree in Mathematics from the Ateneo de Manila University, from the same country. Her research interests include analysis, group representation theory and mathematical crystallography. She is a resident researcher at the Research Center for the Natural and Applied Sciences, University of Santo Tomas.

Kristine Nicole T. Francisco holds a bachelor's degree in Applied Mathematics major in Actuarial Science from the University of Santo Tomas. She recently passed the SOA/CAS Probability Exam and plans to attain a designation in the Society of Actuaries. Her research interests include chaos and data analytics.

Mervinjohn M Yatco is a graduate from the College of Science, University of Santo Tomas, Philippines. He holds a bachelor's degree in Applied Mathematics majoring in Actuarial Science. He is preparing to take up his licensure exams at the Society of Actuaries. Currently, he is employed as an Actuarial Analyst at E. M. Zalamea Actuarial Services, Inc., Philippines. His research interests include chaos and analysis.

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