An Analysis of the Co-movement of Price Change Volatility in Forex Market

Watthana Pongsena, Prakaidoy Ditsayabut, Nittaya Kerdprasop and Kittisak Kerdprasop

Abstract—**Foreign exchange or Forex is the largest global distribution market in the world where all currencies are traded. This market not only produces profits or losses for the traders but also influences the exchange rate of currencies around the world. This research focuses on using the historical data of Forex to identify the strength of the relation and the currency co-movement between pairwise of currencies based on statistical analysis approaches. The empirical results have identified the top ten strongest relations between the currency pairs. In addition, the strong co-movement of price change between the EURUSD and others currency pairwise are identified. The results of our analysis are confirmed that these relations are significant correlations. The knowledge discovered in this research is beneficial for the Forex traders in terms of providing the empirical statistic evidences in order enhance their knowledge. This will make it possible to increase their trading profits.**

Index Terms—**Currency Co-Movement; Data Mining and Knowledge Discovery; Factor Analysis; Forex; Statistical Analysis**

I. Introduction

FOREX or foreign exchange is the global distributed market where all currencies around the world are traded. For over the past few years, the number of investors, who trade in Forex market rapidly grow [1]. This makes a daily trading volume in the Forex market exceeds five trillion US dollars. For this reason, Forex becomes the largest future trading market in the world [2].

In Forex market, any two-exchangeable currency is defined as a currency pairwise. A pair of currency is the quotation of the relative value of a currency unit against another currency where a currency, which is quoted in relation is called base currency while another currency, which is used as the reference is called counter currency [5]. All currency pairs in the Forex market are systematically defined as a symbol by concatenating the ISO currency codes of the base currency and the counter currency. For example, a symbol "EURUSD" is the indicative of the European against the US dollar where EUR represents the European and USD represents the US dollar. Considering the quotation of EURUSD traded at a quotation of 1.5000, EUR is the base currency and USD is the quote currency. The quotation of EURUSD 1.5000 means that 1 European can be exchangeable to 1.5000 US dollars. If the EURUSD quotation rises from 1.5000 to 1.5100, means the relative value of the European has increased. This could be because either value of the European has strengthened, or the value of US dollar has weakened, or it could be because of both cases, and vice versa if the EURUSD quote drops from 1.5000 to 1.4900. Trading in the Forex market, for instance, a trader buys EURUSD, if he or she believes that the quotation of EURUSD will be increased. On the contrary, the sell order of EURUSD will be performed, if he or she have confidence that the quotation will be decreased.

Since the Forex becomes a significant market, which not only produces profits, or losses, for foreign currency traders [3] but also influences the exchange rate of currencies around the world [4], a number of research have been conducted in various aspects. Some research attempt to discover a novel trading strategy [6] – [11] while some aim to develop a model for forecasting or predicting the price change or trend of the market [12] – [18]. As the volatility in the Forex market is influenced by various factors, the price change and trend in Forex market have fluctuated in an unpredictable manner [20]. Many researchers focus on another aspect of the Forex market domain. Their research attempt to identify the currency co-movement phenomenon [19] – [21], which are similar to the main objective of this research. However, our research is different from their research in term of the target audiences. The provided information or knowledge from the existing research in [20] – [21] are beneficial to the general audiences and the international businesses, which the exchange rate is extremely important for them, whereas this research focuses on providing information specifically for the Forex traders. Hence, in this research, we aim to investigate correlation and co-movement of the currency pairs using the Forex historical time-series data based on statistical analysis approaches in order to enhance the knowledge and understanding for the Forex traders. More importantly, this will make it possible for them to increase their trading profits.

Manuscript received March 5, 2018; revised March 28, 2018.

Watthana Pongsena is the is a doctoral student of the School of Computer Engineering, Suranaree University of Technology, Nakhonratchasima 30000 Thailand (phone: +66 90-319-9889; e-mail: watthana.p@sskru.ac.th).

Prakaidoy Ditsayabut is a doctoral student of the School of Biotechnology, Institute of Agricultural Technology, Suranaree University of Technology, Nakhonratchasima 30000 Thailand (e-mail: prakaidoy_sut@hotmail.com).

Nittaya Kerdprasop is an associate professor with the School of Computer Engineering, Suranaree University of Technology, Nakhonratchasima 30000 Thailand (e-mail: nittaya.k@gmail.com).

Kittisak Kerdprasop is an associate professor and chair of the School of Computer Engineering, Suranaree University of Technology, Nakhonratchasima 30000 Thailand (e-mail: kittisakthailand@gmail.com).

ISBN: 978-988-14047-9-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

The rest of this research is organized as follows. Section II describes the datasets used for analyzing. In addition, the methodologies and techniques used for conducting this research are illustrated in this section. The empirical results are discussed in section III. Finally, section IV represents our conclusions and makes suggestions for future research.

II. Materials and Methods

A. Research Framework

The main objective of this research is to investigate the correlation and co-movement of the 28th currency pairs based on the Forex historical data utilizing statistical analysis approaches. In this section, we describe a framework used for conducting this research. The experimental process is divided into three phases including data preparation, data transformation, and data analysis. The description of each phase is described as followed.

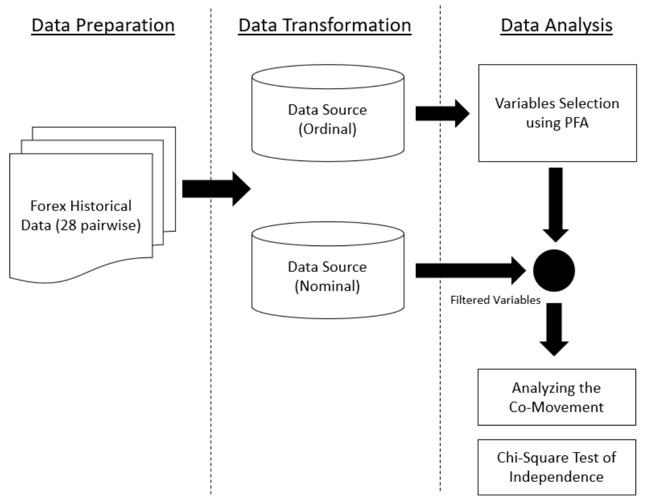

Fig. 1. Framework used for conducting this research.

TABLE I
EXAMPLE OF HISTORICAL DATA OF EURUSD

Date	Time	Open	High	Low	Close	Volume
2017.01.02	9:00	1.05143	1.05223	1.05141	1.05216	164
2017.01.02	9:15	1.05218	1.05218	1.05176	1.05176	74
2017.01.02	9:30	1.0518	1.05234	1.05171	1.05182	926
2017.01.02	9:45	1.05181	1.05184	1.0512	1.05148	302
2017.01.02	10:00	1.05146	1.05182	1.05142	1.05152	1530
2017.01.02	10:15	1.05138	1.05152	1.0509	1.05114	591
2017.01.02	10:30	1.05111	1.05148	1.05098	1.05116	1496
2017.01.02	10:45	1.05115	1.05115	1.04865	1.04886	828
2017.01.02	11:00	1.04886	1.04921	1.04759	1.04787	1388
2017.01.02	11:15	1.04786	1.04829	1.04784	1.04814	1666
2017.01.02	11:30	1.04818	1.04888	1.04812	1.04874	1448

B. Data Preparation

The data, which are used for analyzing in this research are exported from a Forex trading platform called Meta Trader 4 (MT4) of FXCM [22]. We select the most traded pairs of currencies called the Majors. They perform the largest share of the Forex market, approximately 85 percent [23] and therefore they exhibit high market liquidity. The selected currencies are: EUR, USD, JPY, GBP, CHF, NZD and CAD. Therefore, the dataset consists of totally 28 currency pairs. In addition, in this research, we target for providing information for short-term traders, who using a small time-frame (5 to 30 minutes) for their technical analysis. For this reason, all data are exported from the time-frame 15 minutes from 2st January 2017 – 29th December 2017 (totally 24,790 records). Table I show the example of the historical data of EURUSD of time-frame 15 minutes.

C. Data Transformation

In data transformation phase, we start with creating a new variable (column) that represents the movement of the price including up, neutral, and down. The following formula is used to determine whether the movement is Up, Neutral, or Down.

$$\text{The movement} = \begin{cases} \text{Up, if close} - \text{open} > 0 \\ \text{Neutral, if close} - \text{open} = 0 \\ \text{Down, if close} - \text{open} < 0 \end{cases} \qquad (1)$$

Then, we combine a new variable from all selected currency pairs into a single file. As a result, a data source, which is a nominal data type (28 columns) is ready to be analyzed. The example of the nominal data source show in Table II.

TABLE II
EXAMPLE OF THE NOMINAL DATA SOURCE

Date	Time	AUDCAD	AUDCHF	AUDJPY	AUDNZD
2015.01.02	9:00	Down	Down	Up	Down
2015.01.05	9:15	Up	Down	Up	Down
2015.01.06	9:30	Down	Down	Up	Down
2015.01.07	9:45	Down	Down	Down	Down
2015.01.08	10:00	Down	Down	Up	Up
2015.01.09	10:15	Down	Down	Down	Down
2015.01.12	10:30	Down	Down	Down	Up
2015.01.13	10:45	Down	Up	Down	Down
2015.01.14	11:00	Down	Down	Down	Down
2015.01.15	11:15	Down	Up	Up	Down
2015.01.16	11:30	Up	Down	Up	Up

For further analysis, the nominal data source is transformed to be an ordinal data type. The transformation technique is that we convert the value for each data, which include Up, Neutral, and Down to 1, 0, and -1 respectively as show in Table III.

TABLE III
EXAMPLE OF THE NOMINAL DATA SOURCE

Date	Time	AUDCAD	AUDCHF	AUDJPY	AUDNZD
2015.01.02	9:00	-1	-1	1	-1
2015.01.05	9:15	1	-1	1	-1
2015.01.06	9:30	-1	-1	1	-1
2015.01.07	9:45	-1	-1	-1	-1
2015.01.08	10:00	-1	-1	1	1
2015.01.09	10:15	-1	-1	-1	-1
2015.01.12	10:30	-1	-1	-1	1
2015.01.13	10:45	-1	1	-1	-1
2015.01.14	11:00	-1	-1	-1	-1
2015.01.15	11:15	-1	1	1	-1
2015.01.16	11:30	1	-1	1	1

D. Data Analysis

In data analysis phase, the two data sources including the nominal and the ordinal data sources are used for analyzing the co-movement and the relationship between pair of currencies by utilizing statistical analysis approaches including Principal Factor Analysis and Chi-Square Test of Independence.

Principal Factor Analysis

Principal Factor Analysis (PFA) is a multivariate statistical technique used to identify important components or factors that explain most of the variances of ordinal data [24]. PFA is considered as a technique for reducing the number of variables to a small number of components or factors [25], which attempt to preserve the relationships between variables in the original data. In this research, we utilize PFA technique in order to reduce the number of input variables, which are the currency pairwise and to understand what constructs underlie the data.

Generally, a PFA method consists of the following five steps [26]. The first step starts by performing the input variables x_1, x_2, …, x_p to have zero means and unit variance (i.e., standardization of the measurements to ensure that they all have equal weights in the analysis). The second step is the calculation of the covariance matrix C. The third step is finding the eigenvalues λ_1, λ_2, ..., λ_p and the corresponding eigenvectors a_1, a_2, …, a_p. The fourth step is to discard any components or factors that only account for a small proportion of the variation in data sets. In this research, we select the factor that the proportion of the variation is over 50 percent. The final step is to develop the factor loading matrix and perform a varimax rotation on the factor loading matrix to infer the principal component.

Chi-Square Test of Independence

The chi-square Test of Independence is used to determine whether there is a significant relationship between the two nominal variables [27] – [28]. The frequency of each category of the first variable is compared across the categories of the second variable by a contingency table where each row represents a category for one variable and each column represents a category for the other variable. Normally, this technique consists of four steps including (1) state of the hypotheses, (2) formulating an analysis plan, (3) analyzing data, and (4) result interpretation.

The first step is state of the hypotheses. In this step, we assume that the null hypothesis (H_0) for the test is that there is no dependency between the testing variables. The alternative hypothesis (H_a) is that there is a dependency between them.

The second step is formulating an analysis plan. The analysis plan illustrates how to accept or reject H_0 by specify the significance level (α). In this research, α is equal to 0.05.

For the third step, data are analyzed by finding the degrees of freedom, expected frequencies, the test statistic or chi-square value (X^2), and the critical value called the P-Value associated with the X^2.

The degrees of freedom (DF) is calculated as followed:

$$DF = (r-1)(c-1) \tag{2}$$

where: r is the number of levels for first variable, and c is the number of levels for the second variable.

The expected frequency counts are computed separately for each level of the first variable at each level of the second variable. The expected frequencies can be calculated by following equation.

$$E(r,c) = \frac{nr \times nc}{n} \tag{3}$$

where: $E_{(r,c)}$ is the expected frequency count for level r of the first variable and level c of the second variable, nr is the total number of data sampling at level r of the first variable, nc is the total number of data sampling at level c of the second variable, and n is the total number of data.

The test statistic is a chi-square random variable (X^2) defined by the following equation.

$$X^2 = \sum \frac{(O_{(r,c)} - E_{(r,c)})^2}{E_{(r,c)}} \tag{4}$$

where: $O_{(r,c)}$ is the observed frequency count at level r of the first variable and level c of the second variable, and $E_{(r,c)}$ is the expected frequency count at level r of the first variable and level c of the second variable.

The critical value (P-value) is the probability of an observed data sampling statistic, which can use the degrees of freedom computed above and the Chi-Square Distribution Calculator [29] to assess the probability associated with the test statistic (X^2).

The fourth step is result interpretation. If the P-value is less than α, rejecting H_0. This means that there is a dependency between the first variable and the second variable at the significance level is equal to 0.05. On the contrary, If the P-value is greater than α, accepting H_0 means there is no dependency between the variables.

In this research, we utilize the Chi-Square Test of Independence in order to ensure that there is a significant relationship between the selected pairwise of currencies.

III. Results and Discussions

A. Principal Factor Analysis

Since the dataset consist of a large number of variables, PFA analysis is performed in order to reduce the number of variables for further analysis and identifies overall structure of the dataset. The rotation method of PFA analysis is Varimax with Kaiser Normalization [30]. We identify the three-different factors that are more likely to best represent sub-group of the data as much as possible [31] as illustrated in Figure 2.

As can be seen in Figure 2, the selected variables are variables that their factor loading is greater than 0.5 (50%). We could take all three factors to analyze the correlation between variables in each factor. However, in this research, a component or factor correlation coefficient that is greater than 50 percent are considered significant. The result of factor correlation coefficient of the three factors are 35.626, 46.561 and 57.030 percent respectively. Therefore, the appropriate factor that can be pass the threshold is Factor 3 only. As a result, we reduce the variable from 28 to 6

ISBN: 978-988-14047-9-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

significant variables (AUDJPY , CADJPY, CHFJPY, EURJPY, EURUSD and USDJPY). These variables are appropriate and are taken for further analysis.

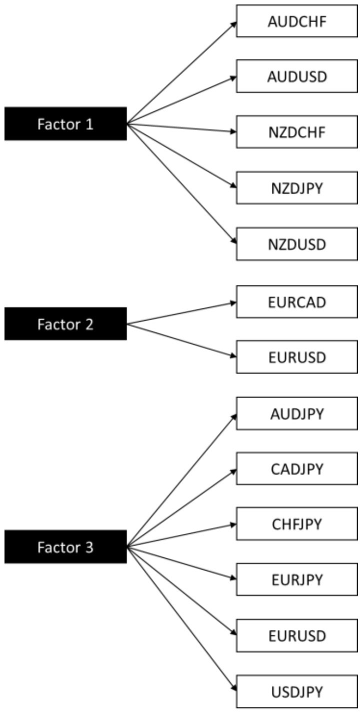

Fig. 2. The three-different factors resulted from PFA.

B. *Chi-Square Test of Independence*

In order to confirm that the selected variables resulted from the PFA technique are significantly dependence to each other, the Chi-Square Test of Independence is utilized. We calculate the P-Value for every two variables as demonstrated in Table 4.

TABLE IV
P-VALUE OF EACH CURRENCY PAIR

	AUDJPY	CADJPY	CHFJPY	EURJPY	EURUSD	USDJPY
AUDJPY		0.000	0.000	0.000	0.017	0.000
CADJPY	0.000		0.000	0.000	0.000	0.000
CHFJPY	0.000	0.000		0.000	0.000	0.000
EURJPY	0.000	0.000	0.000		0.000	0.000
EURUSD	0.017	0.000	0.000	0.000		0.000
USDJPY	0.000	0.000	0.000	0.000	0.000	

In Table 4, the underlined values are the P-Value of top ten of the strongest relation between the two currency pairs. As is illustrated in Table 4, all of the P-Value of the top ten of the strongest relation between the two currency pairs is equal to 0.000. These results appear to confirm that all of them have a significant relationship between their pairwise of currencies.

C. *The Co-Movement of Price Change Volatility*

In order to identify the correlation or the co-movement of price change between the selected currency pairs, we create the matrix that record the frequency of the price change of the any two variables that have the same value. Instead of display the result in table or matrix, we display the result as a network graph. Doing so, it is much easier to understand these results.

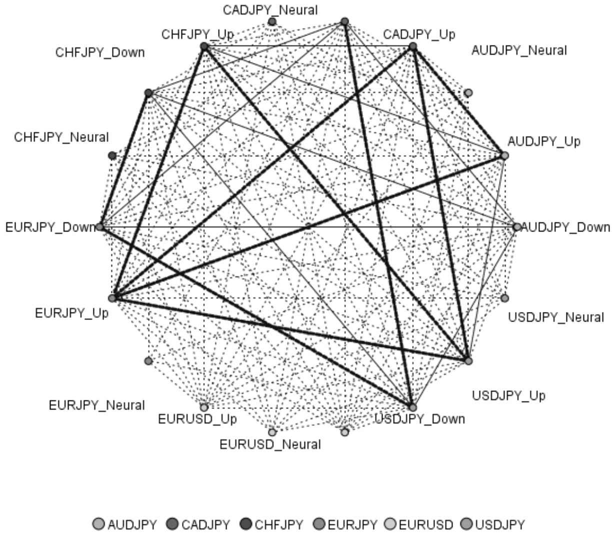

Fig. 3. The network graph of the relationship between each pair of currencies in Factor 3.

Fig. 3 shows the result of network graph, which illustrates the co-movement of price change volatility of the six currency pairs. A node in the graph represents the price change of each currency pair, and the thickness of each link between nodes represents the strength of the relation between nodes.

Based on this result, we can identify the top ten of the strongest price change co-movement are:

1. CHFJPY = Up and EURJPY = Up
2. CHFJPY = Down and EURJPY = Down
3. CADJPY = Up and USDJPY = Up
4. AUDJPY = Up and CADJPY = Up
5. EURJPY = Up and USDJPY = Up
6. CADJPY = Up and EURJPY = Up
7. CADJPY = Down and USDJPY = Down
8. AUDJPY = Up and EURJPY = Down
9. CHFJPY = Up and USDJPY = Up
10. EURJPY = Down and USDJPY = Down

These findings appear to demonstrate that the Japanese currency (JPY) is more likely to be a central currency as it presences in all pair of currencies.

THE STRONG CO-MOVEMENT BETWEEN EURUSD AND OTHERS

Price change of the EURUSD	Co-Movement of other currencies
Up	EURJPY = Up USDJPY = Down CHFJPY = Down CADJPY = Down AUDJPY = Up
Down	USDJPY = UP EURJPY = Down CHFJPY = Down CADJPY = Up AUDJPY = Down

ISBN: 978-988-14047-9-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Furthermore, as the EURUSD is the most traded pairwise [32], the result from this analysis is crucial for the Forex traders to increase their benefits by expanding their order of other pair of currencies. We additionally list the co-movement of the currency pairs, which strongly related to the EURUSD as illustrated in Table V.

Based on these findings, it could be stated that we have identified the hidden co-movement between EURUSD and other currency pairs, which are not in a quotation with EUR and USD such as, CHFJPY, CADJPY, and AUDJPY.

TABLE V

IV. Conclusions and Future Works

In this research, the correlation of the co-movement of price change volatility in Forex market are identified used statistical analysis approaches including PFA and Chi-Square Test of Independence. The PFA analysis is used for variable reduction and for identifying the significant factors that best explain most of the variances of the data. The results of Chi-Square Test of Independence have confirmed that the filtered variables resulted from the PFA analysis are significantly dependence to each other. Finally, the top ten of the strongest price change co-movement of the filtered currency pairs is identified by counting the frequency distribution of the price change of every two currency pairwise, which are in the same values. In addition, we have identified the explicit correlation between the EURUSD and other currency pairwise. This research contributes knowledge, which is beneficial for the traders who usually use the time-frame 15 minutes for their technical analysis as they can incorporate this information in their trading strategies in order to increase their profits. Future research will be included the dataset exported from different time-frame for gain more knowledge. The set of data will be extended in order to support the accurate the hypotheses and conclusions.

Acknowledgment

The authors are grateful to National Science and Technology, Thailand for providing research funding.

References

[1] A. Chatri, E. Ezzahid, F. Talbi, and others, "The Moroccan Foreign Exchange Market and the Dynamics of the Bid-ask Spread of the USD/MAD Quotes," *J. Financ. Invest. Anal.*, vol. 2, no. 4, pp. 1–8, 2013.

[2] L. L. Jacque, Management and control of foreign exchange risk. *Springer Science & Business Media*, 2013.

[3] B. S. Abbey and J. A. Doukas, "Is technical analysis profitable for individual currency traders?," *J. Portf. Manag.*, vol. 39, no. 1, p. 142, 2012.

[4] C. Shu, D. He, and X. Cheng, "One currency, two markets: the renminbi's growing influence in Asia-Pacific," *China Econ. Rev.*, vol. 33, pp. 163–178, 2015.

[5] U. Wystup, *FX options and structured products*. John Wiley & Sons, 2015.

[6] P. R. Kaltwasser, "Uncertainty about fundamentals and herding behavior in the FOREX market," *Phys. A Stat. Mech. its Appl.*, vol. 389, no. 6, pp. 1215–1222, 2010.

[7] J. Korczak, M. Hernes, and M. Bac, "Risk avoiding strategy in multi-agent trading system," in *Computer Science and Information Systems (FedCSIS), 2013*, pp. 1131–1138.

[8] M. Amiri, M. Zandieh, B. Vahdani, R. Soltani, and V. Roshanaei, "An integrated eigenvector--DEA--TOPSIS methodology for portfolio risk evaluation in the FOREX spot market," *Expert Syst. Appl.*, vol. 37, no. 1, pp. 509–516, 2010.

[9] C. J. Neely and P. A. Weller, "Lessons from the evolution of foreign exchange trading strategies," *J. Bank. Financ.*, vol. 37, no. 10, pp. 3783–3798, 2013.

[10] L. Dymova, P. Sevastjanov, and K. Kaczmarek, "A Forex trading expert system based on a new approach to the rule-base evidential reasoning," *Expert Syst. Appl.*, vol. 51, pp. 1–13, 2016.

[11] S. Masteika and A. V. Rutkauskas, "Research on futures trend trading strategy based on short term chart pattern," *J. Bus. Econ. Manag.*, vol. 13, no. 5, pp. 915–930, 2012.

[12] L. Mendes, P. Godinho, and J. Dias, "A Forex trading system based on a genetic algorithm," *J. Heuristics*, vol. 18, no. 4, pp. 627–656, 2012.

[13] P. Czekalski, M. Niezabitowski, and R. Styblinski, "ANN for FOREX Forecasting and Trading," in *Proc. 20th International Conference on Control Systems and Computer Science (CSCS), 2015*, pp. 322–328.

[14] Y. Vyklyuk, D. Vukovic, and A. Jovanovic, "FOREX prediction with neural network: USD/EUR currency pair," *Актуальні проблеми економіки*, no. 10, pp. 261–273, 2013.

[15] M. Ozturk, I. H. Toroslu, and G. Fidan, "Heuristic based trading system on Forex data using technical indicator rules," *Soft Comput.*, vol. 43, pp. 170–186, 2016.

[16] A. S. Tawfik, A. A. Badr, and I. F. Abdel-Rahman, "One rank cuckoo search algorithm with application to algorithmic trading systems optimization," *Int. J. Comput. Appl.*, vol. 64, no. 6, 2013.

[17] P. Myszkowski and A. Bicz, "Evolutionary algorithm in forex trade strategy generation," in *Proc. the International Multiconference, 2010*, pp. 81–88.

[18] M. Kordos and A. Cwiok, "A new approach to neural network based stock trading strategy," in *Proc. International Conference on Intelligent Data Engineering and Automated Learning, 2011*, pp. 429–436.

[19] G. Cao, Q. Zhang, and Q. Li, "Causal relationship between the global foreign exchange market based on complex networks and entropy theory," *Chaos, Solitons & Fractals*, vol. 99, pp. 36–44, 2017.

[20] Y. Mai, H. Chen, J.-Z. Zou, and S.-P. Li, "Currency co-movement and network correlation structure of foreign exchange market," *Phys. A Stat. Mech. its Appl.*, vol. 492, pp. 65–74, 2018.

[21] S. Liao, P. Chu, and Y. You, "Mining the co-movement between foreign exchange rates and category stock indexes in the Taiwan financial capital market," *Expert Syst. Appl.*, vol. 38, no. 4, pp. 4608–4617, 2011.

[22] L. Chan and W.-K. Wong, "Expert advisor development on MT4/MT5 for automated algorithmic trading on EURUSD M1 data," 2013.

[23] D. F. DeRosa, *Options on foreign exchange*, vol. 437. John Wiley & Sons, 2011.

[24] R. P. McDonald, "The theoretical foundations of principal factor analysis, canonical factor analysis, and alpha factor analysis," *Br. J. Math. Stat. Psychol.*, vol. 23, no. 1, pp. 1–21, 1970.

[25] A. L. Comrey and H. B. Lee, *A first course in factor analysis*. Psychology Press, 2013.

[26] M. Reyes, M. A. G. Ballester, N. Kozic, R. M. Summers, and M. G. Linguraru, "Hierarchical patch generation for multilevel statistical shape analysis by principal factor analysis decomposition," In *Medical Imaging 2010: Biomedical Applications in Molecular, Structural, and Functional Imaging, 2010*, vol. 7626, p. 762617.

[27] M. L. McHugh, "The chi-square test of independence," *Biochem. medica Biochem. medica*, vol. 23, no. 2, pp. 143–149, 2013.

[28] G. Argyrous, "The chi-square test for independence," in *Statistics for Social Research*, Springer, 1997, pp. 257–284.

[29] J. Hull and A. White, "Value at risk when daily changes in market variables are not normally distributed," J. Deriv., vol. 5, pp. 9–19, 1998.

[30] J. M. Wood, D. J. Tataryn, and R. L. Gorsuch, "Effects of under-and overextraction on principal axis factor analysis with varimax rotation.," Psychol. Methods, vol. 1, no. 4, p. 354, 1996.

[31] U. Hessinger, W. K. Chan, and B. T. Schafman, "Data mining for significance in yield-defect correlation analysis," IEEE Trans. Semicond. Manuf., vol. 27, no. 3, pp. 347–356, 2014.

[32] M. Costantini, J. C. Cuaresma, and J. Hlouskova, "Forecasting errors, directional accuracy and profitability of currency trading: The case of EUR/USD exchange rate," J. Forecast., vol. 35, no. 7, pp. 652–668, 2016.