Analysis of the Linkage between South African’s Exchange Rate and Stock Price Index

Hsin-Pei Hsueh\textsuperscript{1,2,3}, Fangjhy Li\textsuperscript{3} and Changqing Liu\textsuperscript{2*}

\textsuperscript{1} School of Business, Wuchang University of Technology, Wuhan 430223, China
\textsuperscript{2} College of Mathematics and Statistics, Baise University, Baise 533000, Guangxi, China
\textsuperscript{3} School of Finance, Hubei University of Economics, Wuhan 430205, China
E-mail: lcqing619@126.com

Abstract. In this study, we used a wavelet analysis method to analyze how stock price index is correlated with exchange rate in South African stock market and interest rate was choosen as the control variable. As indicated by the empirical results, first, stock index is significantly correlated with exchange rate in the stock market of South Africa, no matter in the short term (1-4 years) or the long term (4-8 years). There is a significant correlation period, with correlation coefficient greater than 0.8. Second, for the short-term (1-4 years) relationship, after adding control variables, South Africa’s short-term negative correlation will be led by the stock exchange rate. That is, in condition of the negativity of both stock market and exchange rate, the stock market leads. And interest rate greatly affects the short-term (1-4 years) exchange rate and the stock price index in South Africa. In the short term, the linkage between those two variables is not subject to the influence of 2008 financial crisis. Third, for the long-term (4-8 years) relationship, when we add control variables, regardless of its term, there is a negative correlation between stock market index and exchange rate in South African stock market, and stock market affects exchange rate. The long-term (4-8 years) correlation of stock price index and exchange rate in South African stock market was affected by the 2008 financial crisis. South African market is indeed the goal for investors to participating enthusiastically now. The above conclusions can serve as a lesson for hedging in corporate exchange rate, stock market, and also reference for global investors and all sorts of investor asset allocation.

Keywords. Exchange rate; stock market; wavelet analysis.

1. Introduction
South Africa enjoys abundant natural endowments, mainly minerals) and its economy accounts for about 24% of Africa’s GDP. Since the era of energy investment and development in the 1980s, South Africa has become more and more important in international investment, and it has become an investment object of concern to the world.

The formal economy of South Africa began in 1652 when Dutch colonists arrived. Later French and German citizens arrived, the colony area increased, and agriculture became the dominant conductor in South Africa's economy. At the end of the 18th century, Britain gained control of the colonies and brought agriculture into the interior. In 1870, diamonds were discovered, and the world's largest gold mine was discovered in 1886. Natural resources rapidly dominated the economy of South Africa and South Africa has entered a period of industrialization. In 1948 South Africa implemented a strict apartheid policy, and this policy divided the economy into privileged whites and impoverished...
blacks. The country’s economy was paralyzed by policy sanctions in the 1980s. The first multi-ethnic elections were held in 1994 to attempt to restore the economy damaged by sanctions.

The economy of South Africa was once optimistic. The BRICS countries invited South Africa to join at a summit held in China in 2011 and became the “BRICS”. However, the follow-up development was not as expected. After a short period of brilliant performance, South Africa’s economic growth continued to slow in 2015. In the third quarter of 2015, South Africa’s GDP grew by only 0.7%. State-owned power companies are heavily indebted, the power supply is unstable, and strikes are frequent, resulting in the downgrading of economic growth expectations and credit ratings.

In recent years, South Africa’s economy has fallen short of expectations and suffered huge losses due to COVID-19. The unemployment rate in the first quarter of 2020 reached 30.1%; the currency value plummeted, and Moody’s Credit Rating Agency reduced its credit rating to “junk” in March 2020. After the country was shut down by the epidemic, the South African currency hit a record low.

In June 2020, in order to accelerate the restart of the economy, the Reserve Bank of South African has reduced its benchmark interest rate to 3.75% for three consecutive times to resist the huge impact of the epidemic.

The bank interest rates of South African have been high over the years, which are attracting many investors, but often due to exchange rate fluctuations, offset a lot of interest income, making investors stay away. The South African stock market also has its potential. In 2011, South African market is indeed the goal for investors to start participating enthusiastically. The research data in this paper is the data before 2017. At that time, South Africa, which was included in the BRICS, was still topical. Then explore the leading and backward contact between its stock market and exchange rate. But at that time South Africa had gradually turned from a rising state to a weak position. At present, the South African economy is facing a problem of the century. If economic growth continues to stagnate and revise, South Africa will have a crisis of sovereign debt default.

South African market is indeed the goal for investors to participating enthusiastically now. This paper is expected that all sorts of investors and associated institutional units investing in South Africa will serve as their reference in terms of investment or hedging.

2. Literature Review

Abdalla and Murinde [1] Through observation about the contact of real exchange rate and stock price in emerging countries using unit root tests, vector autoregression (VAR), causality and other methods, conclude the influence that the exchange rate of South Korea, Pakistan, and India has on stock price. In the Philippines, the stock price generates certain influence on the exchange rate. As a result, it was learned that variation in the exchange rate would give rise to variation in stock price, so it is recommended that countries should pay more attention to the adjustment and control of exchange rate for improving the stock market.

Ajayi and Mougoue [2] find there exists a reciprocal causality of stock price index and exchange rate.

Whereas, Bahmani-Oskooee and Sohrabian [3] believe that such causality of stock price and exchange rate only prevails temporarily. At the same time, some empirical evidence also shows insignificant correlation between stock price and exchange rate (Bartov and Bodnar [4]). Chen [5] discovers that the rise or fall of stock price is ascribed to the variation of exchange rate. Moreover, no brief causality has been traced between the two. Franck and Young [6] showed a lack of any significant relationship between exchange rate and stock price change. Granger et al. [7] find that after the outbreak of the Asian financial crisis, stock price and exchange rate may become the leading exchange rate in a mutual feedback relationship, but before that, the relationship between the two in most Asian countries was not particularly remarkable. According to Mok [8], there exists a reciprocal causality of stock price index and exchange. Mukherjee and Nake [9] believe that empirical evidence also shows insignificant correlation between stock price and exchange rate.
3. Data and Descriptive Statistics

3.1. Data
In this paper, we used a wavelet analysis method to analyze how stock price index is correlated with exchange rate in South African stock market and interest rate was chosen as the control variable.

We used stock price index, exchange rate and interest rate, in which the stock price index referred to South Africa (TJOP), and the data was from the Datastream database during October 1996-December 2016. Taking the closing price at the end of each month as the stock index data for the current month, there are 243 months in total. Direct quotation is made in exchange rate. The chosen currency is the South African Rand (ZAR). The database during October 1996-December 2016. The monthly data consults the monthly first-day data registered in the Datastream database. Interest rates are also collected monthly, sourced from Aremos Economic Statistics Database. Control variable used the interest rate.

3.2. Descriptive Statistics
From table 1, we know that the highest value of the stock index is 54192.07 and the lowest value is 4459.50. The sample has a large degree of dispersion and high variability. Stock index volatility is high. Skewness>0, is the right-skewed distribution (positive skew), the right tail is long. Meet the common right-skewing situation of stock prices. For the exchange rate part, Skewness is the right-skewed distribution (positive skewness), and the right tail is long. The exchange rate data shows Kurtosis > 3 in South Africa, which is assigned to high narrow peaks, which means that it is more concentrated and steeper than the normal distribution.

Table 1. Descriptive statistics.

| South Africa | Statistics of stock price index and exchange rate |
|--------------|---------------------------------------------------|
|              | Stock Price Index | Exchange Rate Subhead |
| Mean         | 23277.67          | 8.16 |
| Median       | 20713.26          | 7.52 |
| Max          | 54192.07          | 16.37 |
| Min          | 4459.50           | 4.44 |
| Std. Dev     | 15667.34          | 2.51 |
| Skewness     | 0.558866          | 1.102141 |
| Kurtosis     | 2.016635          | 3.880193 |
| Jarque-Bera Test | 22.44033   | 57.04017 |
| Probability  | 0.000013          | <0.0001 |

***, **, * indicate at 10%, 5%, and 1% significant levels, respectively.

3.3. Indian Exchange Rate and Stock Price Index
From figure 1, we know the trend.

4. Research Methods and Results
We introduce the wavelet analysis method used in this study to verify the linkage between South African’s stock price index and exchange rate.

4.1. Research Method
The wavelet analysis method proposed the idea for Haar [10] in 1910, and then the French Fourier Transform was improved by French physicist Morlet [11] in 1984 to analyze the local properties of the seismic wave.
We select the wavelet analysis method to verify the linkage between tourism expansion and overall economic growth in the short-term (1–4 years) as well as the long-term (5–8 years). Wavelets in wavelet analysis can be long or short, fat or thin, that is, expandable and convertible. The wavelet operates on the signal through scaling and translation. Multiscale scaling and conversion gradually improve the signal, gradually multiscale refinement, and finally achieves time subdivision at high frequency (short-term) and low frequency (long-term). This is a milestone in the development history of wavelet analysis.

Continue Wavelet Transform
The wavelet transform function can be described as follows:

$$W_x(t, s) = \int_{-\infty}^{+\infty} \chi(t) \psi_\tau^* s (t) dt$$

Here * represents a complex conjugate, that is, $\psi_\tau^* (t)$ is a complex conjugate function of the $\psi_\tau (t)$ function, and $\psi_\tau (t)$ is the base wavelet function.

$$\psi_\tau^* s (t) = \frac{1}{\sqrt{s}} \psi (\frac{t - \tau s}{s})$$

where $s$ is the parameter table mother wavelet; $\tau$ parameter table mother wavelet translation; and $1/\sqrt{s}$ factor corresponds to the frequency.

Wavelet Coherence Coefficient: The ratio of $\chi (t)$ and $Y (t)$ can be measured using the ratio of each wave power spectrum of time series $\chi (t)$ and $Y (t)$ to each wavelet power spectrum.

$$R_n^2 (s) = \frac{|S^{-1}W_{xy}(\tau, s)|^2}{S(s^{-1}|W_x(\tau, s)|^2)S(s^{-1}|W_y(\tau, s)|^2)}$$

Phase Difference: The phase difference is defined as the ratio of the imaginary part $I$ to the real part $R$ of the crosswavelet power $W_{xy}(\tau, s)$:

$$\phi(\tau, s) = \tan^{-1} \left( \frac{\Im \{W_{xy}(\tau, s)\}}{\Re \{W_{xy}(\tau, s)\}} \right)$$

The End Match wavelet in wavelet analysis can be long or short and fat or thin, that is, expandable and convertible. The wavelet manipulates the signal by zooming and panning. Multiscale scaling and conversion can gradually improve the signal. Compared with the “Fourier transform,” the wavelet transform is a partial analysis of time (space) frequency. Its main feature is that it can fully highlight the characteristics of certain aspects of the problem through conversion, and can analyze the time (space) frequency.
4.2. Empirical Results

We use wavelet analysis as the main research method. Figure 1 is African’s exchange rate and stock market linkage analysis chart.

![Wavelet Coherence Chart](a) and (b)

Figure 2. South African exchange rate and stock market-interest rate with control variable.

Figure 2a: the exchange rate and stock market of South Africa have been found to be in island of correlation. In 2000-2003, 2005, 2007-2008, 2012, and 2015, there was a positive correlation (> 0.8). There were large regional red blocks in 2001-2002 and 2006-2012, and there was a positive correlation in 2014-2016. After adding the control variables, figure 2b, after the control variable, interest rate, in 1998, 2000, 2002-2003, 2004-2009, 2012-2016, and the long-term changes from 2002-2003. There were significant positive correlations at the end of 2005, the end of 2005 to the end of 2011, and the period of 2014-2016.

Figure 2c shows no significant change when no control variable is added, all of which are positively correlated. After adding the control variables, figure 2d, after the control variable, interest rate, has five negative correlations and all share prices are negative leading exchange rates. In 1998, there was a total positive correlation with covariance. 1998-Positive correlation in 2000, then quickly turned negative correlation in 2000-2001 (negative leading exchange rate in stock market), positive correlation in 2001-2005 (exchange rate leading stock market), and negative correlation again in the end of 2005-2007 (negative leading exchange rate in stock market) In that case, the exchange rate of the stock market clearly intersected, which was a rising point in the stock market of South Africa, with a rise of 2.28 times. Meantime, the exchange rate rose slightly from 5.92 to 7.01, and interest rates rose from 7.5% to 11%. A positive correlation from 2008 to 2012, At this time, from December 2011 to February 2013, there was an increase of 8,645 points, the second wave. The increase rate, the exchange rate interest rate remained unchanged in this range. 2013-2014 was a positive correlation and again a negative correlation in 2015-2016. It is obvious that stock market and exchange rate cross (shares fall and exchanges rise), confirming the negative relationship between the two.
Figure 2e, the long-term phase difference shows that there is a total positive correlation with covariance from 1998 to 2005, a positive correlation from 2005 to 2006, and a positive correlation from 2007. In 2011, it turned into negative correlation, in 2011 it turned into positive correlation, and from the end of 2011 to 2016, the stock market used to be led by exchange rate.

We used a wavelet analysis method to analyze how stock price index is correlated with exchange rate in South African stock market and interest rate was chosen as the control variable. Figure 2f, after the control variable, interest rate, has been added, the which obviously reverses the negative-correlated lead-lag relationship. After adding interest rate control variables from 2007 to 2011, it reversed to the same negative correlation but affected the exchange rate for a negative stock price lead. At this time, the interest rate increased from 8% in September 2006 to 12% in June 2008. It is common for the South African government began to raise interest rates in response to high inflation in 2006. The impact of interest rates is significant.

5. Conclusion
South Africa is becoming more and more important in the world economy. Many investors have already started investing before. They have selected their stock price index and exchange rate. We tested the stock price index and an exchange rate of South Africa with wavelet analysis and added control variable, interest rates, to explore whether there is a significant linkage effect. Our research shows empirically:

First, stock price index has significant correlation with exchange rate, and there is a significant correlation period, with the correlation coefficient greater than 0.8) either in the short term (1-4 years) or the long term (4-8 years).

Second, as to the short-term (1-4 years) relationship, there arise significant changes upon the introduction of a new control variable interest rate. When South African market is in a short-term negative correlation, in which the stock market leads the exchange rate, and there are multiple negative correlations in South Africa in the short term after adding the control variable. It is obvious that interest rate affects the short-term (1-4 years) exchange rate and stock price index of South Africa.

Finally, as to the long-term (4-8 years) relationship, following the introduction of the control variable, the direction of the phase difference figure in South Africa remains unchanged, but the time and year have changed significantly, representing that the interest rate affects both stock market and exchange rate. The long-term (4-8 years) relationship (including control variables) in South Africa is led by the stock market regardless of the short-term and long-term period.

Understanding the causality between its relevance and understanding has important implications. This study about the economic development of South Africa wants to examine how exchange rate is correlated to stock price index. The above conclusions can serve as a lesson for hedging in corporate exchange rate, stock market, and also reference for global investors and all sorts of investor asset allocation. It is expected that all investors and institutional units investing in South Africa will serve as their reference in terms of investment or hedging.

References
[1] Abdalla I S A and Murinde V 1997 Exchange rate and stock price interactions in emerging financial markets: Evidence on India, Korea, Pakistan and the Philippines Applied Financial Economics 7 (1) 25-35.
[2] Ajayi R A and Mougoue M 1996 On the dynamic relation between stock prices and exchange rates The Journal of Finance Research 2 193-207.
[3] Bahmani-Oskooee M and Sohrabian A 1992 Stock price and the effective exchange rate of the dollar Applied Economics 24 459-464.
[4] Bartov E and Bodnar G M 1994 Firm valuation, earnings expectations, and the exchange-rate exposure effect Journal of Finance 49 (5) 1755-1785.
[5] Chen Y 2017 Research on the contagion effect of China’s stock market based on continuous and discrete wavelet analysis *Contemporary Economy* 12 40-41 (in Chinese).

[6] Franck P and Young A 1972 Stock price reaction of multinational firms to exchange realignments *Financial Management* 1 (3) 66-73.

[7] Granger C W J and Newbold P 1974 Spurious regressions in econometrics *Journal of Econometrics* 2 111-120.

[8] Mok H M 1993 Causality of interest rate, exchange rate and stock prices at stock market open and close in Hong Kong, *Asia Pacific Journal of Management* 10 (2) 123-143.

[9] Mukherjee T K and Nake A 1995 Dynamic relations between macroeconomic variables and the Japanese stock market: An application of a vector error correction Model *Journal of Financial Research* 18 (2) 223-237.

[10] Haar A 1910 Zur Theorie der orthogonalen Funktionensysteme *Mathematische Annalen* 69 (3) 331-371.

[11] Grossmann A and Morlet J 1984 Decomposition of Hardy functions into square integrable wavelets of constant shape *SIAM Journal on Mathematical Analysis* 15 723-736.