Trading of the South African Rand Utilizing Entropy Analytics

AUTHORS

Darrol J. Stanley, D.B.A
Graziadio School of Business and Management
Pepperdine University, Malibu, CA. USA

Levan Efremidze, Ph.D.
Graziadio School of Business and Management
Pepperdine University, Malibu, CA. USA

Jannie Rossouw
School of Economic and Business Sciences
University of Witwatersrand
Johannesburg, South Africa

CONTACT

Darrol J. Stanley
Department of Finance and Accounting
Graziadio School of Business and Management
Pepperdine University
Malibu, California 90263
Phone: 818.501.1629
Email: Darrol.Stanley@pepperdine.edu

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Abstract

We investigate the predictability of the USD/ZAR (South African Rand) exchange rate with sample entropy analytics for the period of 2004-2015. We calculate sample entropy based on the daily data of the exchange rate and conduct empirical implementation of several market timing rules based on these entropy signals. The dynamic investment portfolio based on entropy signals produces better risk adjusted performance than a buy and hold strategy. The returns are estimated on the portfolio values in U.S. dollars. These results are preliminary and do not yet account for reasonable transactions costs, although these are very small in currency markets.

1. Introduction

Market timing has been an important global topic for market traders, investors and investment management. Today, due to the emergence of countless international vehicles, it can concern a variety of issues such as (1) entering or exiting any global market; (2) global sector rotation; (3) global style emphasis; (4) global economic factor emphasis; and (5) many other specific emphasis global investment strategies. Further, the investment strategies can include almost any type of investment vehicle such as stocks, bonds, commodities, currencies, and the like.

In the US, one only needs to understand the reasoning behind the Dow Jones Industrial Average to realize market timing's continuous and pervasive appeal and importance in investments. The Dow Jones Industrial Average (DJIA) is probably the best known and most widely quoted indicator of stock market performance in the global investment scene predominately due to the fact that it was the first actively utilized index in the U.S. The second index was the Dow Jones Transportation Index, initially the Railroad Index. Charles H. Dow used these two indices to postulate the Dow Theory in articles and editorials in The Wall Street Journal around the turn of the last century. It is the foundation of modern day market technical analytics.

The Dow Theory itself is predominately a market timing system based on investors' behavior patterns. While the Dow Theory did not initially address volatility, Robert Rhea in his famous book on The Dow Theory noted the concept of "excessive activity" at key points in advancing or declining markets. This is clearly an indirect interface with volume, volatility, and, in declining markets, fear.

Capital Market Theory and Efficient Market Hypothesis moved the orientation from one focusing on predicting market moves to one more focused on risk and return under the equilibrium conditions with a clear "buy and hold" orientation. The Dow Theory, other technical theories, and more recently developed theories in behavioral finance and complexity economics believe that the markets are sometimes in dis-equilibrium. If one can effectively time the phases and turning points of the market or a particular asset, then it may be possible to outperform buy-and-hold investment strategy on a risk adjusted basis.

Often market timing is associated only with technical analysis, but this is not correct. Market timing is associated with both fundamental and technical analysis. There are a number of market timing models that are unrelated to typical technical indicators such as price and volume. An example of a fundamental market timing model in the US is the Value Line Dow Jones Model which "prices" the market based on (1) Earnings Changes; (2) Dividend Changes; and (3) AAA Bond Rate Changes. Market timers could use this model to judge entry or exit from the market, in addition to other indicators. One such additional indicator is the Value Line Price Appreciation Model. It is an econometrically formulated estimate of the price appreciation of the Value Line 1700. When the model approaches 50% potential appreciation, it is argued by this model that the market is fully priced and the market is likely to decline. Almost all major global indices have similar fundamental indicators for timing purposes.

This paper is concerned with entropy analytics which involves the analysis of a price series. These are the primary variables of a technician and one may think that entropy analysis is also a simple technical tool. But entropy methodology conceptually seeks to uncover underlying risk level in the series (a type of risk different from volatility), which makes it, in many ways, similar to fundamental analysis.

Entropy based measures the degree of randomness in a system have proven to be a powerful tool in physics, astronomy, biology, and medicine (Pincus, 2008). Entropy has not been actively utilized in the analysis of financial markets including currency trading.

2. South African Rand

This study focuses on the market timing of the South African rand. Currency trading has become a major investment management vehicle globally. Due to various economic reasons dealing with South Africa, the rand and its relationship to other currencies has taken on new importance to domestic investors. Specifically, currency trading can enable a domestic investor the ability to hedge the underlying value change of the Rand.

(A) Offshore Allowance. A domestic citizen of South Africa is faced with offshore controls. Specifically, one may be subject to the offshore allowance of R4 million per annum.

(B) Exchange Traded Funds. The emergence of Exchange Traded Funds (ETF) has been deemed the most innovative investment vehicle in decades. Further many investment managers, especially in the USA, have stated that ETFs have fundamentally changed the construction of investment portfolios. We use herein the term exchange traded funds to include Exchange Traded Notes (ETNs). Exchange Traded Notes have significantly different financial and legal characteristics but clearly fall in the same general category.

(C) Currency Exchange Traded Funds (ETFs). Exchange Traded Funds are now available for almost every conceivable investment category. One such category is currency investments. Previously, in general, it was necessary to enter the foreign exchange market. This involved a substantial degree of sophistication and resources that often prohibited investment professionals, but especially individual investors, from trading such instruments.

(D) South Africa Currency Exchange Traded Notes (ETNs). Exchange Traded Notes (ETNs) have, as noted above, various different characteristics than ETFs. They behave, however, from an investment perspective, the same.

(E) ABSA Currency ETNs. While there ultimately be numerous currency ETNs in South Africa, we principally want to note the existence of three currency ETNs offered by the South African institution ABSA, a member of the Barclays Group. These three are (1) NewWave USD Currency Dollar ETN; NewWave GBP Currency ETN; and NewWave EUR Currency ETN. These funds will, of course, behave differently from each other due to the currency relationship of each noted currency and the Rand. The appendix has information on the NewWave USD Currency Dollar ETN which would represent an excellent alternative to currency trading for individual South African investors employing this paper's or other currency trading strategies.

(F) ZA:NEWUSD. This paper is exclusively dealing with the relationship of the South African Rand and the United States Dollar. The data feed for this relationship comes from 2004-2015. This could be different than the quoted price of the NewWave Currency USD ETN for those periods when this fund existed. We deemed the difference to be minor especially after taking into account foreign currency transaction costs to an individual investor.

(G) USD/ZAR Relationships and Currency Movements. It should be fully noted that the selection of a currency relationship involves complex relationships between each of the involved parties. It is not our purpose to analyze either the United States economy or that of South Africa as well. However, investors should note the impact the United States has on the South African Rand. Noube et al. (2012) find that the U.S. monetary policies have a powerful impact on the rand exchange rate. The U.S.

monetary easing leads to rand appreciation and lower bond yields. Thus, US interest rates could be one of the ways to time the rand exchange rate.

(H) South Africa Monetary Policy. It is well beyond the scope of this paper to discuss the monetary policy of the South African Reserve Bank. Needless to say, it has a signal relationship to exchange rates. There are numerous papers dealing with this topic. Mtonga (2011) documents relationship between monetary policy regime and exchange rate dynamics in South Africa. Dawie Roodt (2013) notes that as long as the inflation rate of South Africa is higher than the inflation rate of the US the rand will lose value over the long-run to the dollar.

(I) Market Timing of South African Exchange Rate. This paper is centered on the rand exchange rate. There have been a number of papers on the topic from a wide range of different perspectives on this topic such as de Bruyn, et. al (2015), but we focus on exploring effectiveness of entropy based uncertainty measure as a risk indicator for the timing of the exchange rate.

3. Entropy

The concept of Entropy was first applied to the study of thermodynamics in the late 1850s. In that context it was used to characterize the amount of energy in a system that was no longer available for doing work. Subsequently, the definition has been expanded to a measure of randomness and disorder. In more modern times, entropy has been applied to the study of financial markets (Pincus 2008, Maasoumi 2002, Molgedey 2000). The basic idea is that more volatile securities have a greater entropy state than more stable securities. Two fundamentally different phenomena exist in which the time series securities data deviate from constancy. These two phenomena are that series (1) exhibit larger standard deviations and (2) appear highly irregular.

These two phenomena are not mutually exclusive and as such can be used to characterize the uncertainty associated with the fluctuations in security data. The standard deviation measures the extent of deviation from centrality while entropy provides a useful metric for categorizing the extent of irregularity or complexity of the data set. Evaluating the subtle but complex shifts in data series is a primary prerequisite for exploring the potential information contained therein.

Entropy as utilized in this study is part of a wider discipline called Econophysics. Econophysics is an interdisciplinary research field that applies the problem solving methods of physics to economics. It was a discipline founded by physicists who believed that economic analysis often prioritized simplified approaches for the sake of soluble theoretical models over agreement with empirical data. Econophysicists often cite Irving Fisher, the famed Yale economist, as one of the “founders” having been trained in physics at Yale before turning to economics. They imply his thought processes on economics were a carry-over from physics.

Econophysicists believe that the traditional methods of analysis in economics are insufficient. In their opinion, standard economics methods dealt with homogeneous agents and equilibrium while many of the more interesting phenomena in financial markets fundamentally depended on heterogeneous agents and far-from-the-equilibrium situations.

One driving force for this new discipline was the sudden availability of large amounts of financial data and the computing power to analyze it. Thus, an increasing number of researchers began to employ models adapted from physics to this large amount of available financial data. One example of the successful application of econophysics dealing with pragmatic economic issues is the work of Harvard economist Ricardo Hausmann and MIT physicist Cesar Hidalgo dealing with the concept of economic complexity. They and their subsequent associates have developed a predictive tool for economic growth. Their Economic Complexity Index (ECI) is far more accurate, in their estimate, in predicting GDP growth than the traditional measures of the World Bank.[1] There are also known physics applications in finance as well. One of the more notable examples is the Black-Scholes Option Pricing Model which comes from diffusion theory.

Financial literature has begun to apply physics concepts to finance. Pincus (2008) found that approximate entropy (ApEn) is both robust to outliers and can be applied to time series with 50 observations or more with good reproduction. A second measure of system complexity that is often used in this regard is called sample entropy (SaEn). In this paper we use sample entropy as it has shown better results than approximate entropy in previous studies (Efremidze et al. 2013). The literature is replete with detailed discussions of these alternative measures of entropy (Sharma 2010, Thuraisingham 2005, and Richman 2000). A more detailed discussion of the entropy metric employed in this study is noted in a following section.

4. Capital Market Theory, Dis-equilibrium, Chaos, and Entropy Analytics

Capital Market Theory is built upon the key assumption of equilibrium. There is no need to signally change the composition of a portfolio. This is in essence the “buy and hold” orientation of a rational economic mean-variance analysis. The Life Cycle (investment portfolio purpose) does imply a change, but a gradual one as one moves the utility curve down the Capital Market Line (CML) or the Security Market Line (SML). Recent evidence suggests that markets deviate from efficiency. De Bruyn et al. (2015) find that the gains from there dynamic model relative to the random-walk model are substantial and statistically consistent. Neuhierl and Schlusche (2012) focused on a comprehensive set of simple and complex market timing rules and found favorable results that beat benchmarks.

Thus, Capital Market Theory does not incorporate well the concept of either dis-equilibrium or chaos. Dis-equilibrium occurs when stocks do not plot on the CML or SML. Thus, there are periods when dis-equilibrium exists between expected returns and required returns. Dis-equilibrium is not contemplated by Capital Market Theory nor is the concept of Chaos. Chaos occurs in the capital markets when the rational economic risk-reward paradigm no longer exists. Thus, returns or volatility, or both combine to make rational economic behavior meaningless.

Entropy analytics may provide the additional information embedded in the asset market prices, which may signal shifts from normal market behavior to dis-equilibrium or Chaos type market behavior. High levels of entropy mean that there is high level of randomness and irregularity in the recent data.

5. Empirical Methods and Results

The Entropy Metric Employed in This Study

By employing the parameters listed in Table 1, we calculated sample entropy (SaEn) values. We follow the same model as Efremidze et al. (2014).

[1] See http://atlas.media.mit,edu, The Atlas of Economic Complexity: Mapping Paths to Prosperity.

Table 1. Entropy model inputs

Time Series (TS)	Matching Template Length (M)	Matching Tolerance Level (R)
Running 120 days of daily series based on a sample from **Jan 1, 2004 to Aug 17, 2015**	2	20% of the standard deviation of the times series (TS)

Implementation of Market Timing

We use daily data of the Rand/USD exchange rate from January 1, 2004 to August 17, 2015. Data is divided into two year (2) periods. The returns are estimated on the portfolio values in U.S. dollars. We use sample entropy as an indicator for selling or buying the Rand. *The theoretical hypothesis is that when uncertainty is high the currency will likely depreciate, and when uncertainty is low the currency will appreciate*. Low sample entropy numbers indicate low uncertainty; high numbers indicate a higher level of uncertainty. *In each two year investment period the best strategy is based on the previous two year estimation window results.* The estimation period results are calculated for seven (7) different buy or sell signal thresholds of sample entropy. The general model for the buy and sell thresholds are as follows:

*Buy signal threshold = mean (30 days of SaEn) - multiple * standard deviation (30 days of SaEn)* (1)

*Sell signal threshold = mean (30 days of SaEn) + multiple * standard deviation (30 days of SaEn)* (2)

where *multiple* is a variable that takes seven different values: 0.5, 0.75, 1, 1.25, 1.5, 1.75, and 2.

Thus, in our sample we have five (5) estimation periods and five (5) investment periods, each with two years of data (except for the last investment testing period which has about a year and a half of data). In each estimation period, we select the best performing threshold (based on the above mentioned standard deviation *multiple*) *with the highest Sharpe ratio*. This threshold is then used for the next trading strategy for a two year investment period. *Thus we dynamically update the strategy parameters after every two years.*

Results

Table 2 shows the results of each estimation and investment periods. The best performing trading threshold portfolios in estimation periods are in bold, while the subsequent investment testing period performance of that strategy is in bold italics.

Table 2. Results of Estimation and Investment Periods

		1 (0.50)	*2 (0.75)*	*3 (1.00)*	*4 (1.25)*	*5 (1.50)*	*6 (1.75)*	*7 (2.00)*	*Buy&Hold*
2004-2005							**Best Estimate**		
Annualized	Return	0.01	0.03	0.05	0.14	0.11	**0.13**	0.06	0.00
Annualized	Standard Deviation	0.15	0.14	0.12	0.11	0.10	**0.08**	0.06	0.15
Annualized	Sharpe	-0.12	0.01	0.21	0.97	0.86	**1.34**	0.68	-0.17
Maximum	Drawdown	0.16	0.16	0.10	0.07	0.07	**0.03**	0.05	0.19
2006-2007			**Best Estimate**				**Invested**		
Annualized	Return	0.00	**0.01**	-0.02	-0.06	-0.07	***-0.06***	-0.04	-0.04
Annualized	Standard Deviation	0.14	**0.13**	0.12	0.10	0.09	***0.07***	0.06	0.15
Annualized	Sharpe	-0.15	**-0.09**	-0.41	-0.81	-1.02	***-1.18***	-1.02	-0.39
Maximum	Drawdown	0.26	**0.26**	0.26	0.25	0.21	***0.20***	0.15	0.25
2008-2009		**Best Estimate**	**Invested**						
Annualized	Return	**0.12**	***0.05***	-0.01	0.04	0.00	-0.05	-0.03	-0.04
Annualized	Standard Deviation	**0.26**	***0.23***	0.21	0.19	0.16	0.13	0.11	0.26
Annualized	Sharpe	**0.34**	***0.12***	-0.18	0.06	-0.17	-0.57	-0.54	-0.24
Maximum	Drawdown	**0.24**	***0.26***	0.25	0.15	0.17	0.15	0.12	0.41
2010-2011		**Invested**				**Best Estimate**			
Annualized	Return	***0.13***	0.15	0.14	0.13	**0.15**	0.10	0.07	-0.05
Annualized	Standard Deviation	***0.15***	0.15	0.14	0.12	**0.10**	0.08	0.06	0.16
Annualized	Sharpe	***0.69***	0.84	0.80	0.83	**1.26**	0.93	0.75	-0.44
Maximum	Drawdown	***0.12***	0.10	0.11	0.09	**0.05**	0.04	0.06	0.23
2012-2013						**Invested**		**Best Estimate**	
Annualized	Return	0.00	0.02	0.03	0.01	***-0.01***	0.03	**0.05**	-0.11
Annualized	Standard Deviation	0.12	0.11	0.11	0.10	***0.09***	0.07	**0.06**	0.14
Annualized	Sharpe	-0.22	-0.04	0.03	-0.17	***-0.37***	0.08	**0.33**	-0.98
Maximum	Drawdown	0.17	0.13	0.13	0.12	***0.11***	0.08	**0.05**	0.29
2014-2015								**Invested**	
Annualized	Return	-0.08	-0.06	-0.08	-0.02	-0.04	0.00	***0.00***	-0.12
Annualized	Standard Deviation	0.11	0.11	0.10	0.09	0.07	0.06	***0.05***	0.12
Annualized	Sharpe	-0.88	-0.74	-1.03	-0.50	-0.88	-0.40	***-0.50***	-1.19
Maximum	Drawdown	0.20	0.18	0.18	0.14	0.15	0.07	***0.04***	0.20

Note: Risk free rate is assumed to be 2.5% in the Sharpe ratio calculation. “Best Estimate” means the strategy with the best performance during estimation period. “Invested” means the results of the strategy that was used during the investment test period. Numbers in parentheses are values used for a *multiple* of standard deviation used in buy and sell signal threshold calculations.

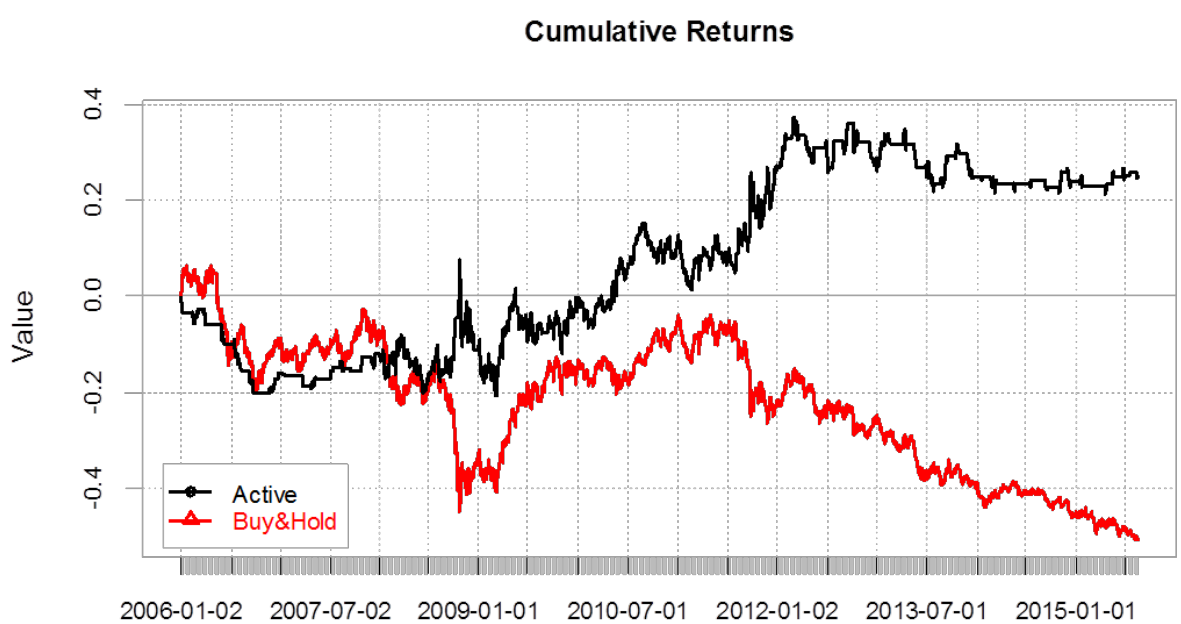
To clarify further, during the 2004-2005 estimation period the threshold of number 6 strategy (*multiple* of standard deviation here equals 1.75) had the highest Sharpe ratio. Thus in the investment period of 2006-2007 buy and sell signals are based on this value of *multiple*. Similarly, in the estimation period of 2006-2007, best performance comes from strategy 2, thus this strategy threshold is used in subsequent 2008-2009 investment period. This algorithm continues all the way through the other periods too.

Table 3. Results of Dynamic Investment Portfolio (Active) Strategy, 2006-2015

		Active	*Buy&Hold*
2006-2015			
Annualized	Return	0.02	-0.07
Annualized	Standard Deviation	0.14	0.17
Annualized	Sharpe	-0.02	-0.53
Maximum	Drawdown	0.26	0.54

The end result is that in different investment periods (5 periods within 2006-2015) we use different strategy thresholds. We calculate the performance of this dynamically rebalanced portfolio (Active) and compare it to buy and hold strategy. Table 3 shows that this active portfolio substantially outperforms buy and hold method on a risk adjusted bases, using levels of Sharpe ratios and also maximum drawdown. Cumulative returns of the active and buy and hold are presented in Figure 1.

Figure 1. Cumulative Returns of Active and Buy&Hold Strategies, 2006-2015



Note: Values are cumulative returns in decimals.

These results are preliminary and need to account for reasonable transactions costs, which could be very small in liquid currency markets. There were approximately 100 round trip transactions. We will explore this in the next revision of this paper.

6. Conclusion

We investigated the predictability of the South African Rand to US Dollar exchange rate with sample entropy analytics for the period of 2004-2015. We utilized sample entropy (SaEn) as a non-linear indicator of uncertainty, in other words a degree of randomness. We calculated sample entropy based on the daily data of the exchange rate and conduct empirical implementation of several market timing rules based on these entropy signals. The dynamic investment portfolio based on entropy signals produces better risk adjusted performance than buy and hold strategy. The returns are calculated on the portfolio values in terms of U.S. dollars. These results point toward currency market inefficiencies in the South African Rand market, which can be exploited using entropy analytics. These results are preliminary and do not yet account for reasonable transactions costs, although these can very small in currency markets.

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Appendix:

NewWave USD Currency ETN

Valuation Date 31 December 2014

NewWave Exchange Traded Notes (ETNs) constitute unconditional, unsecured and unsubordinated obligations of Absa Bank Limited listed on the JSE Limited.

The NewWave USD Currency ETN is designed to provide investors with cost-effective exposure to the USD/ZAR spot price in a listed instrument trading in South African rand. Each NewWave USD Currency ETN is equivalent to 1 US Dollar.

Note Details

Inception date	12/03/2012
Maturity date	12/03/2042
Bloomberg Code	NEWUSD SJ
ISIN Code	ZAE000162608
Exchange	JSE Limited
Yearly Fee	0.00%
Interest Rate Spread	0.10%
Number of notes outstanding	2,335,177
Market Capitilisation*	27,019,399
Principal Amount (USD)	1
Indicative Redemption Value	11.57
Spread/Redemption Fee	1%
Subscription and Redemption to Issuer**	Daily
Issuer early redemption	Applicable
Block	1 000 000 notes

Issuer Details

Absa Bank Limited - National long term credit rating

Moody's rating	**Aa2.za**
Fitch rating	**AA+ (zaf)***
* Outlook stable	

Source: Fitch/Moody's

NewWave ETNs have not been assigned a security credit rating but are backed by the credit of Absa Bank Limited. The NewWave ETNs rely on the rating of the issuer, Absa Bank Limited.

This note is inwardly listed on the JSE and as such does not require an individual to utilise their offshore allowance of R4 million per annum.

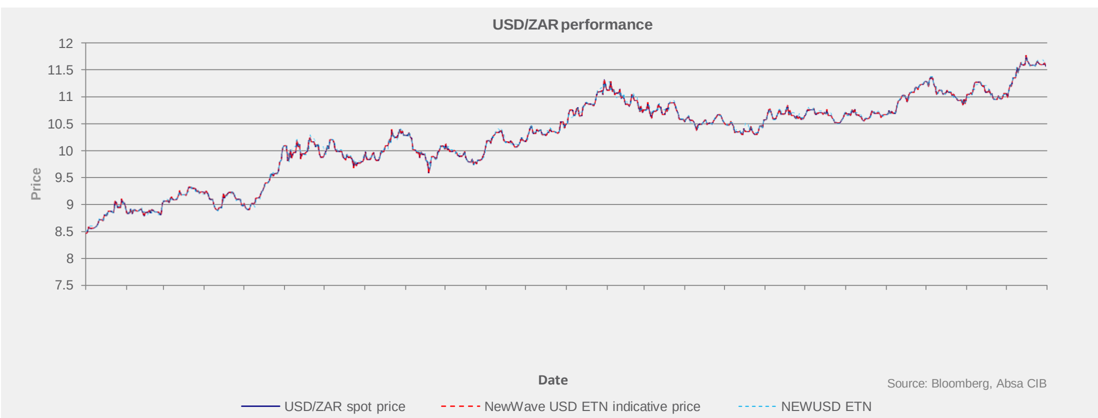
*Market Capitalisation = Number of notes outstanding x Indicative Redemption Value

**Subscriptions and Redemption to Issuer subject to a minimum block size and redemption fee.

USD Currency ETN

USD Currency ETN is designed to provide investors with exposure to USD Currency. The USD Currency ETN will distribute interest (if there is) on a semi-annual basis calculated at Overnight LIBOR - spread and will charge no management fee.

USD/ZAR performance



Corporate and Investment Banking

NewWave USD Currency ETN

USD/ZAR Returns

	USD/ZAR spot price	NewWave USD ETN indicative price (Absa CIB)	NEWUSD ETN
Cumulative return since inception	53.33%	53.33%	52.90%
Annualised return since inception	16.46%	16.46%	16.34%
Annualised 1 year return	10.27%	10.27%	10.33%
Annualised 2 years return	16.85%	16.84%	16.74%

returns as of 31/12/2014

Source:Bloomberg, Absa CIB

USD/ZAR spot returns are derived from closing price data sourced from Bloomberg. This does not include any fees or charges. Where there have been no trades, the closing prices may not represent the indicative fair value of the ETN. Therefore, the returns derived for the NewWave USD ETN is derived from indicative prices calculated by Absa CIB. Past performance does not guarantee future results.

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