Dollar and the Stock Market: An Approach Using Haar Wavelet

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Abstract. This paper presents a methodology to detect significant changes in the price of U.S. dollar in regarding to the stock exchange using the Haar wavelet as well as statistical analyzes of several parameters. The data used arise of information provided by the stock market, both for the U.S. dollar and for the stock market. The results show that the applied methodology through Haar wavelet, are able to inform in advance the trend of the stock market through a single variable, the U.S. dollar.

Keywords: Haar Wavelet, Overreaction, Underreaction, Dollar
PACS: <Replace this text with PACS numbers; choose from this list: `http://www.aip..org/pacs/index.html`>

INTRODUCTION>

The financial market as a whole, has become target of intense research in the last years. Increasingly, tools derived from the engineering and computing, once used only in industrial processes, are being widely applied in the financial market in order to optimize portfolios [7], prediction stock market [8], etc.. Besides these objectives, the research of correlation and dependency between financial market variables is also a field much explored. A study that deserves attention in the financial market is the dynamic behavior of the dollar, since this influences the behavior of the stock market. The processes of import and export between many countries has narrowed considerably in the recent years. In this sense, the changes in the dollar affect directly the economy and have direct influence on the exchange, causing mixed reactions regarding the import and export. Given the importance of the topic, many researches have developed methodologies to analyze the variation of the dollar in relation to some variables: in Coudert [3], by testing for cointegration and causality, is investigate the relationship between the dollar and oil prices, Richards [12] examined through models based on vector auto-regression (VAR), the relationship between stock price and the Australian dollar; Agrawal [1] study the dynamic behavior of the dollar and the volatility of the stock market by statistical tests.Finally, in Rahman [11] is investigated the relationship between stock price and foreign exchange. Such studies have prompted the proposal of a new methodology, based on Haar Wavelets and statistical analysis of detail coefficients produced by time series, allowing detection of significant changes in the exchange rate against the Brazilian stock market. The main objective of this paper is to investigate the dynamic behavior between the foreign exchange and the stock market, which may lead to investors, as well as for the economy, an important information. Thus, here is presented a new methodology that, through the use of wavelets and statistical analysis of detail coefficients produced by time series, to detect the dynamic relationship between the U.S. dollar and the Brazilian stock market, which may be useful as a complementary tool for investors and companies.

THE WAVELETS

The wavelet functions are able to decompose and represent another function hierarchically, allowing a function to be described in terms, producing other forms which have gradually, details, enabling the analysis of the function at different scales of frequency and time. The analysis through of the wavelet has been a promising alternative to replace the classical analysis using the Fourier series, mainly in the treatment of acoustic signals, in the interpretation of seismic signals and also in the solution of numerical methods applied in several areas. A function $\psi(t)$ will be a wavelet, if and only if [4]:

1. $\int_{-\infty}^{\infty} \psi(t)dt = 0$
2. $\int_{-\infty}^{\infty} \|\psi(t)\|^2 dt < 0$

The wavelet algorithms process data at different resolutions or scale, which provides the decomposition of a function in other functions, making it useful in the sense that the characteristics of a signal can be more evident and better exploited. By analogy, looking up a signal through a large window gross characteristics are observed, while if the window is small, there is a higher number of details of the characteristics of the signal [4]. Thus, it is possible to divide a signal at intervals and then subdivided into other ranges allowing refined and extract features of the signal. With the wavelets it's possible to obtain these divisions, refine and explain the detailed features of the signal under study. The analysis using wavelets adopts a function prototype, called mother wavelet, shown in equation 1 and a scaling equation shown in equation 2.

$$\psi_{(s,l)} = 2^{\frac{-s}{2}}\,\psi(2^{-s}x - l) \tag{1}$$

$$W(x) = \sum_{k=-1}^{N-2} (-1)^k c_{k+1}\,\psi(2x+k) \tag{2}$$

The function $W(x)$ is the scaling function to the mother function ψ, c_k are the wavelet coefficients of the function. These coefficients can be viewed as a filter and are put into a transformation matrix that is applied to an array of data (for instance, a signal). These coefficients are ordered in such a way that some of them act to refine the signal and others to show the detailed information of the signal. Briefly, the coefficient matrix is applied to a data vector as follows: the coefficients are arranged in an array as described above and the matrix is applied first to the original data array. Soon after, the vector is smoothed and divided by half and the matrix is applied again. This vector is smoothed and halved again, and the coefficient matrix is applied, this process continues until a trivial number of data remains refined. That is, each application of the coefficient matrix becomes the highest resolution, that is, in each application the detailed characteristics of the signal are evidenced. The wavelets can be applied to many purposes, namely: computer vision, fingerprint compression, recovery of signals, detection of similarity in a series, etc.. In this paper, the fundamental objective is to investigate the similarity between the exchange rate in terms of the price of U.S. dollars and the stock market, which will be represented by the index of the stock exchange in the Sao Paulo State - Ibovespa. The proposal to use a type of wavelets known as Haar wavelets, which can use several types of expansion functions as the pulse function, truncated cosine, etc [9]. The Haar wavelets are formed by a function called mother and another called scale, represented in equations 3 and 4, respectively [6].

$$\psi(t) = \begin{cases} 1 & if 0 \leq t < \frac{1}{2} \\ -1 & if \frac{1}{2} \leq t < 1 \\ 0 & otherwise \end{cases} \tag{3}$$

$$\varphi(t) = \begin{cases} 1 & if 0 \leq t < 1 \\ 0 & otherwise \end{cases} \tag{4}$$

In this paper, using the Haar wavelet, will be proposed a methodology for investigate the dynamic of dollar in a random period.

METHODOLOGY

The data used in this study are the daily price of the Ibovespa index and the U.S. dollar during a period that extends from 02/01/2008 to 30/06/2008. The methodology realizes an analysis of standard deviation, correlation, covariance of maximum, minimum and detail coefficients of the samples after the application of wavelets, besides the waste and the spectra of the signals obtained.

Thus, a set of one hundred twenty-two values of both the U.S. dollar as the stock market in the period from 02/01/2008 to 30/06/2008, were obtained. In the values of the dollar and of the Ibovespa index, which represents the brazilian stock market, was applied the Haar Wavelets using level 6 of resolution, generating the numerical values of the coefficients for the U.S. dollar and for the Ibovespa, [2], [5].

The application of wavelets in the historical data of the U.S. dollar and of the Ibovespa index, resulted in the signals shown in the Figure 1. Note that, after the application of wavelets in the data used, the price of the dollar and the Ibovespa presents a negative correlation, leading to believe that there is between the U.S. dollar and the Bovespa index, a negative correlation. That is, when the dollar have a high, the Ibovespa has a low and vice versa.

For purposes of analysis were chosen few points of change of trajectory of the USD as shown in figure 2.

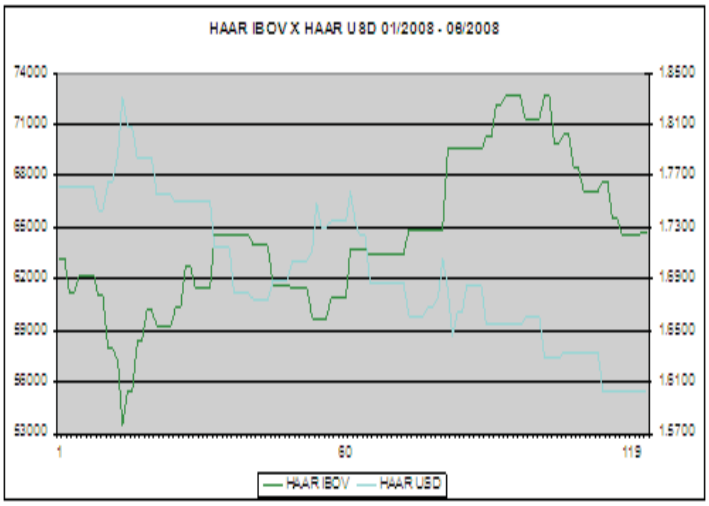

FIGURE 1. Statistical values of USD before and after the application Haar wavelet

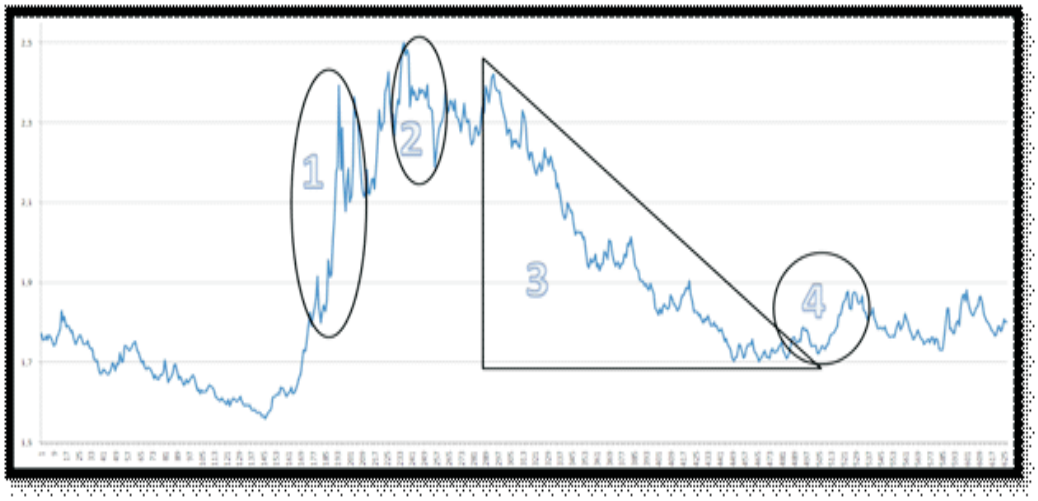

FIGURE 2. Dollar variation

The samples highlighted in Figure 2 show clearly the following characteristics:

a) Sample 1 shows a high trend coming from a low trend.
b) Sample 2 shows a low trend coming from a high trend.
c) Sample 3 shows a low trend coming from a high trend.
d) Sample 4 shows a high trend coming from a low trend.

The table 1 summarizes the results obtained showing the original trend (OT), the linear function after the application of wavelets (LFW), the trend produced by the proposed model (TM), and the original trend that occurs before the original trend of samples (OT-).

It is noted in the results obtained in the table that the original trend of the dollar in a sample 1 is high, and the original tendency before the first sample is low. Interestingly, the model based on Haar wavelets shows, for the sample considered, a downtrend in the price of the dollar and this happens for all samples. In this case, it seems that the proposed model is strongly influenced by heuristics derived from the behavioral finance theory, suggesting overreaction and underreaction effects in the dollar trend. That is, when the results show a fall in the dollar, means that, in fact, the

TABLE 1. Trend values

OT	LFW	TM	OT-
High	$y = -0.00039x + 0.00408$	Possible Low	Low
Low	$y = 0.00032x - 0.00406$	Possible High	High
Low	$y = 0.00023x - 0.01457$	Possible High	High
High	$y = -0.00001x - 0.00294$	Possible Low	Low

dollar will be high and vice versa. Since the Ibovespa and the dollar has a negative correlation, the model proposed by Haar wavelets indicates the true trend of the Ibovespa index.

CONCLUSION

This paper presents the theoretical aspects and a study of the dynamic relationship between the U.S. dollar and the Stock Exchange of São Paulo using the wavelets. The proposed methodology allows to determine the numerical values of the coefficients, depending on the level of resolution, and a detailed statistical analysis of results.Included in the analysis was the method of least squares that allows, through the linear trend and cyclical, and graphs to determine the parameters that indicate trends of graphic samples with great precision. The results point to two important trends:

i. The U.S. dollar and the Bovespa index, in all the period analyzed, it has a negative correlation, ie, when occurs a high in the dollar, the Ibovespa index shows a low and vice versa. Seem to exist between the dollar and the Bovespa index overeaction and undereaction effects arise of behavioral finance theory.

ii. Another interesting aspect is that, when applied the Haar wavelets in subperiods of the behavior of the U.S. dollar, is presented an information always contrary to the trend of the dollar. Since the Ibovespa and the dollar has a negative correlation, the model proposed by wavelets indicates the of the Ibovespa index. Considering that the dynamic behavior of the dollar has a considerable influence on the economy, since the currency appreciation, which is related to the fall of the dollar against the Brazilian currency, can directly stimulate imports, and currency devaluation, which is related with the fall of the Brazilian currency against the dollar may boost exports. In this sense, the proposed methodology proves efficient to inform in advance the investor, the real trend of the dollar, as well as the tendency of the Ibovespa index.

REFERENCES

1. G. Agrawal, and K. A. Srivastav, and A. Srivastavana, A Study of Exchange Rates Movement and Stock Market Volatility, International Journal of Business and Management, v. 5, n.12, 2010.
2. S. J. Chapman, Programação em Matlab para Engenheiros, Thompson, 2009.
3. F. Coudert, and V. Mignon, and A. Penot, Oil Price and the Dollar, Forthcoming in Energy Studies Review, v.15, n.2, 2008.
4. A. Graps, An Introduction to Wavelets, IEEE Computational Science and Engineering, v.2, n. 2, 1995.
5. D. C. Hanselman, and B. C. Littlefield, Matlab 6, Prentice Hall, Brazil, 2008.
6. S. G. Mallat, A Theory for Multiresolution Signal Decomposition: The Wavelet Representation, IEEE Transactions on Pattern Analysis and Machine Intelligence, v.11, n.7, 1989.
7. Z. Mohamed, and D. Mohamad, and O. Samat, A Fuzzy Approach to Portfolio Selection, Sians Malaysiana, v.38, n.6, 2009.
8. B. B. Nair, and others, IEEE Press, in Application of Hybrid Adaptive Filters for Stock Market Prediction, Conference on Communication and Computational Intelligence, p. 443-447, 2010.
9. D. E. Newland, Random Vibrations Spectral and Wavelet Analysis, Addison Wesley Longman, pp. 315-333, 1993.
10. M. C. Pazza, Bem Vindo a Bolsa de Valores, Brazil, Novo Conceito, 2009.
11. L. Rahman, and J. Uddin, Relationship between Stock Prices and Exchange Rates: Evidence from Banglad, International Journal of Business and Management, vol. 3, n. 9, 2008.
12. N. D. Richards, and J. Simpson, and J. Evans, The Interaction between Exchange Rates and Stock Prices: An Australian Context, International Journal of Economics and Finance, vol. 1, n.1, 2009.