Profitability of Elliott Waves and Fibonacci Retracement Levels in the Foreign Exchange Market

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Abstract

This thesis investigates the use of technical analysis in the foreign exchange market. It researches the profitability of a combination of two different technical analysis techniques, namely Elliott wave pattern formations and Fibonacci retracement levels. These techniques are developed into three trading strategies, two to investigate historical significance of the techniques and one to study whether real life trading of the strategy is significantly profitable. The trading strategies applied to four different exchange rates. The replicable mean profits per position obtained were tested for significance using a bootstrap technique. This thesis did not result in finding significant profitability for the technical analysis techniques used in this research.

JEL classification: G11; G12; G14; G15; G020
Keywords: Efficient market theory; Technical analysis; Foreign exchange rates

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1. Introduction

In order to predict price movements in financial markets, financial traders mainly use two different approaches. These are fundamental analysis and technical analysis. In this paper, the focus is on the latter. Technical analysis involves the use of historical prices to forecast future price movements. It is based on the notion that investor behavior is patterned and therefore price action must repeat itself. (Plummer, 1993) This is in contrast to another popular theory in finance, the efficient market theory. This theory pertains that securities' prices reflect all relevant information available. Therefore, historical prices cannot be used to predict future prices (Samuelson, 1965). The focus of this thesis is to examine the profitability of the technical analysis technique of Elliott waves in combination with Fibonacci levels, thereby, possibly refuting the efficient market hypothesis.

There is currently no major consensus on the use of technical analysis. Research on the subject shows inconclusive results. However, based on surveys by Allen & Taylor (1992), Menkhoff (1998, 2010), and Cheung & Chinn (1999) it seems that technical analysis has obtained a solid ground in professional traders' strategies in the past few decades. Since then, increasingly more literature seems to be corroborating their notion that it does have its usefulness as a trading instrument. There are numerous studies that claim technical analysis does have its merit (Menkhoff-Schlumberger, 1995; Levich-Thomas, 1993; Sweeney, 1986; Ng, 2008; Neely & Weller, 2011). Yet, there are also still studies that find no value in technical analysis as opposed to for instance a simple buy and hold strategy (Papadamou & Tsopoglou, 2001)

Two particular technical analysis techniques are Elliott waves and Fibonacci retracement levels. These techniques are often used in concurrence (Elliott, 1946). Elliott waves are certain pattern formations in financial securities, while Fibonacci levels are support and resistance levels that are plotted by utilizing Fibonacci ratios. The challenge in this paper lies in the combined use of Elliott wave theory and Fibonacci retracement levels. More precisely, this research focuses on the profitability of a trading strategy that uses Elliott waves in combination with Fibonacci retracement levels. Thus, a null hypothesis is formed that states that the combination of Elliott waves and Fibonacci retracement levels is not profitable. This hypothesis is tested by a comparison of mean profits between actual security movements and a random walk.

1.1. Motivation and contribution

The motivation behind this thesis is that research on the subject of technical analysis shows inconclusive results. There are numerous studies that do not find any value or rationality in the use of technical analysis (Gupta, 2011;Malkiel, 1990; Papadamou & Tsopoglou, 2001; Yamamoto, 2012). However, there are also various studies that oppose this notion (Levich-Thomas, 1993; Menkhoff-Schlumberger, 1995; Neely & Weller, 2011; Sweeney, 1986).

On the use of Elliott waves, and in combination with Fibonacci levels in specific, literature is scarce. Furthermore, research on technical analysis in trading financial markets primarily focuses on simple indicators rather than pattern formations. Although the research on those particular subjects does seem to indicate that these technical instruments have predicting power (Chong & Ng, 2008; Reitz, 2006).

This thesis will contribute to existing literature by employing the combination of both Elliott wave theory and Fibonacci levels as a trading strategy. Furthermore, this supposed profitability is tested in the foreign exchange market. Current literature in technical analysis mainly focusses on stock markets. Altogether, this research tries to add to a growing body of studies on technical analysis and might contribute support to the efficient market hypothesis and thus oppose the use of technical analysis, or vice versa.

1.2. Approach

First, a literature review is outlined. Related research is discussed and analyzed here. Thereafter, the application of Elliott waves and Fibonacci levels in trading is reviewed.

After this, a sample was chosen that consists of the following currency pairs. The Australian Dollar with the US dollar (aud/usd), the Euro with the US dollar (eur/usd), the Canadian Dollar with the US dollar (usd/cad), and the Japanese Yen with the US Dollar (usd/jpy). These are some of the most traded, yet some of the lesser correlated currency pairs (Lien, 2010). The time period in the sample is 2005-2013 and the currency pairs will be investigated at the weekly, daily, and hourly time frame. Further motivation behind the use of this particular sample is given in chapter 4.

After this, objective rules for Elliott wave formation are determined. A breakdown of Fibonacci level calculation is also presented. These will be combined into a trading strategy. This trading strategy is then translated into an algorithm. The algorithm produces returns once it is administered to the sample data.

A total of three tests for the trading strategy are used, all with their own specific conditions for Elliott wave formation and with their own separate algorithms.
Two of these tests are ex-post tests to analyze two distinct types of Elliott wave patterns, and whether these have any significance in historical data. Furthermore, one of the tests is an ex-ante test. This test will simulate how a real life trader would be trading Elliott waves and Fibonacci levels, and if this strategy is significantly profitable.

The obtained mean profits of these tests are compared to mean profits obtained from a random walk exchange rate series. This is because an exchange rates' profit distribution does not strictly follow a normal distribution (Chang & Osler, 1999).To account for this, an artificial random walk exchange rate was created, and then the algorithms were applied to this simulated exchange rate series. Obtained returns from technical analysis trading in a random walk are arbitrary and should hold no value. Therefore, interest is in the question whether mean profits from the real exchange rates significantly outperformed the mean profits from the simulated exchange rate.

1.3. Conclusions and recommendations

The two ex-post tests did not return enough significant mean profits to reject the null hypothesis. However, the ex-ante test did produce a fair amount of significant returns. Therefore, these returns were checked further for several factors that might have contributed to their significance. The profits were corrected by three basis points to compensate for average transaction costs (Ramadorai, 2008). This did not affect the significance of the results. Furthermore, for each of the significant returns of the currency pairs and their given time frame, Sharpe ratios were calculated to control for risk compensation. All of the Sharpe ratios dominated the S&P500's Sharpe ratio, and thus the significant returns do not appear to be a result of risk compensation.

Furthermore, the returns were annualized and compared to a simple buy-and-hold strategy in the different currency pairs, a portfolio of these currency pairs, and the S&P500. All but one of the significant annualized profits outperformed the simple buy-and-hold strategy.

This all provides some evidence to support the notion of profitability of Elliott wave and Fibonacci level trading. However, considering all the results combined, the author feels the null hypothesis cannot be rejected. Further research is necessary, especially on practical real life trading of the Elliott wave and Fibonacci level trading strategy. Furthermore, a sample of different currency pairs, stocks, commodities, or indices might be researched and may provide very different results.

2. Literature review and Historical background

2.1. Efficient market theory and Technical analysis

2.1.1. Efficient market theory

Since technical analysis' premise is to use past price information to produce excess risk-adjusted returns when trading in financial markets, it would violate the form efficient market theory.

The efficient market theory states that market prices instantaneously and fully reflect all relevant information available. In other words, past prices should not provide any information about future prices. The efficient market theory originated from Paul Samuelson's influential paper "Proof that Properly Anticipated Prices Fluctuate Randomly" (1965). The theory was further corroborated by Eugene Fama (1970) when he reviewed the theoretical and empirical literature on the efficient market hypothesis to that date. Fama concluded that evidence supporting the theory was prevalent, and evidence contradicting the theory was scarce.
From then on, the efficient market theory became one of the standards of financial economics.

2.1.2. Technical analysis

Technical analysis is based on the notion that historical performance of financial markets is a strong indicator for future performance of those markets. Supporters of technical analysis believe that behavior of investors tends to move in patterns and therefore security price moves are repeating over time. Thus historical price patterns can be identified and used for trading (Plummer, 1993). The origins of technical analysis lie in the Dow Theory. The Dow Theory was pieced together from a series of writings from Charles Dow. He was the originator of the Wall Street Journal, and the Dow Jones Index was named after him. The theory was formalized by William Peter Hamilton in his book "The Stock Market Barometer" (1922), and further popularized by Robert Rhea with his book "The Dow Theory" (1932).
Further important studies that followed were that of Alexander (1961) on the use of filter techniques in technical analysis, and by Levy (1971), the first examination of chart patterns.

Hereafter, little research was done in the 1970's due to the general acceptance of the efficient market theory. However, research on technical analysis had a revival in the 1980's when Banz (1981), Keim (1983), and Reinganum et al. (1983) found that anomalies in the efficient market theory could not be explained by the capital asset pricing model.

2.2. Current state of technical analysis

2.2.1. Technical analysis in practice.

Despite the general acceptance of the efficient market hypothesis in the early seventies, it seems that technical analysis has made a comeback in the last few decades. Numerous studies show that professional traders use technical analysis in their trading strategies. Surveys by Allen & Taylor (1992), Menkhoff (1998), and Cheung & Chinn (1999) indicated that traders use technical analysis in their trade decisions quite extensively.

Furthermore, Murphy (1999) mentions that technical analysis is extensively applied by practitioners. The paper by Allen & Taylor (1992) indicates that at least 90% of chief foreign exchange dealers based in London place some weight on technical analysis.

Additionally, a study by Menkhoff (2010) researched the use of technical analysis in fund management. It found that 87% of fund managers give some importance to technical analysis. Moreover, a group of 18% used technical analysis as their preferred method of financial market analysis. Furthermore, they stated that “At a forecasting horizon of weeks, technical analysis is the most important form of analysis and up to this horizon it is thus more important than fundamental analysis. Technicians are as experienced, as educated, as successful in their career and largely just as overconfident in decision-making as others.”
Moreover, a study by Naveen & Sanjay (2013) shows that stock brokers in India relied heavily on technical analysis in their trading on shorter forecasting horizons, and more on fundamental analysis in longer forecasting horizons.

2.2.2. Elliott waves

The focus of this paper is on the use of Elliot wave theory in combination with Fibonacci retracement levels. Elliott wave theory was developed by R.N. Elliott, although the theory was published by Collins (1938). Elliott later published his definitive work on the theory himself in 1946, in his book “Nature’s Law - The Secret of the Universe”. Elliott describes certain price movement patterns in financial markets which he calls waves. These patterns are fractals, i.e. the patterns consist of smaller versions of the same patterns, or vice versa. The patterns describe a five step price movement, and after each step the price finds support or resistance at a certain price level.
In order to find these support and resistance levels in Elliott waves, some traders believe in the use of Fibonacci ratios (Gupta, 2001). Elliot acknowledged this relationship himself, after his theory was published (Prechter, 2005).

2.2.3. Fibonacci ratios

Leonardo Pisano Fibonacci was a twelfth century mathematician and is known for describing the mathematical Fibonacci sequence. This is a sequence of numbers that consists of two numbers being added to form the consecutive number, starting at zero. For example:

0,1,1,2,3,5,8,13,21,34, etc. From this sequence, Fibonacci ratios can be obtained. The sequence and ratios can be found in nature, music, architecture, and are also used in trading the financial markets[1].

The object of the Fibonacci ratios is to find retracement levels, also known as support and resistance levels. The most common of these ratios are 61.8%, 50%, 38.2%, and 23.6%. These are the levels in an Elliott wave where support and resistance lie and thus traders enter long or short positions (Poser, 2003). In section 3.1.2 it is explained how these ratios are obtained and applied to Elliott wave theory.

2.3. Approaches to the subject

In current literature, there are many different approaches to research technical analysis. These approaches not only differ in the various technical analysis techniques they investigate, but in the sort of sample they investigate as well.

Most of the research on technical analysis focuses on techniques such as moving averages which uses average prices as an indicator to go long or short, stochastic oscillators which uses closing prices to price range over a certain time period, chart patterns which are pattern formations in the price of a security, or Japanese candlestick analysis, which looks for pattern formations in Japanese candlesticks. Japanese candlesticks are a certain way to display high, low, closing, and opening prices of a security.

According to Atmeh & Dobbs (2006) the moving average trading rules are “extremely popular amongst practitioners”. This form of technical analysis has been previously researched thoroughly by LeBaron (1990), Brock et al. (1992), and Fama & Blume (1966).

Furthermore, the study by Yamamoto (2012) also investigates moving averages by utilizing data from transactions in individual stocks on the Tokyo Stock Exchange.

Additionally, the paper by Papadamou & Tsopoglou (2001) focuses on moving averages as well. It also focusses on momentum and moving average convergence/divergence or MACD.

Research by Chong & Ng (2008), Liu & Zheng (2011) and by Reitz (2006) studies the use of oscillators in technical analysis. Furthermore, the research of Marshall et al. (2006) studies the use of Japanese candlesticks in technical analysis.

Research on the technical analysis technique of pattern recognition is scarcer. This is most likely due to the more complicated nature of testing technical patterns.

When looking at the sample studies on technical analysis’ use, it can be concluded that a major part of the research in technical analysis focusses on stocks. Their research obtains price information on for instance the New York stock exchange (Watson, 2009), the London stock exchange (Chong & Ng, 2008), Tokyo (Yamamoto, 2012), and Brazil (Penteado, 2013). A minority of the research found focusses on foreign exchange rates (Neely & Weller, 2011) and even less research was found on derivatives markets (Eng, 1997).

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[1] http://www.investopedia.com/articles/technical/04/033104.asp

2.4. Current state of literature

2.4.1. Literature in favor of technical analysis

Even though technical analysis has been denounced in the past (Malkiel, 1990) and seems to violate the efficient market hypotheses, there is a fair amount of research that seems to validate the use of technical analysis as a profitable technique in predicting the financial markets. There are several papers that corroborate the notion that technical analysis can help to predict market movements.

For instance, research by Menkhoff-Schlumberger (1995), Levich-Thomas (1993), and Sweeney (1986) shows that technical analysis has been extremely profitable over previous years. Chong & Ng (2008) find that the oscillator indicators and moving average convergence/divergence or MACD indicator outperform a simple buy and hold strategy.

Furthermore, Menkhoff & Taylor (2007) state that “It is beyond question that, for major flexible exchange rates and over longer time periods, the use of technical analysis may be used to provide very high returns.” However, they question the fact if this will hold true if returns are risk adjusted. Whereas Neely & Weller's (2011) research claims that use of technical analysis produced risk adjusted profits, and that their research provides evidence for market inefficiency.

Moreover, Liu & Zheng (2011) find that their researched technical analysis models can “successfully explain the rationality of technical analysis and could be widely used in financial area.” Reitz’s (2006) research provides support for his oscillator model to not only forecast direction but magnitude of movements as well. Penteado’s (2013) study of technical analysis in the Brazilian stock market provides support for the use of technical analysis to predict the trend of security prices. The study focusses on price patterns such as head and shoulders pattern, bullish pennants, flags, and many more.

Moreover, Bettman et al. (2009) researched the use of fundamental and technical analysis as complements to each other. It states that fundamental analysis and technical analysis each perform well in isolation. However, the model where fundamental and technical analysis was integrated had superior explanatory power.

Lastly, Reszat (1987) found that chart formations are even used by central banks in exchange rate interventions. They state “The central bank can consider reinforcing certain chart formations that coincide with its intentions. It is also conceivable, however, that it will use intervention in an attempt to breach or defend resistance or support lines and thus exert a lasting influence.” Furthermore, a study by Chang & Osler (1999) tests the profitability if head-and-shoulders patterns on exchange rates. They found the pattern to be profitable for the Deutsche Mark and the Japanese Yen. They also conclude however, that the pattern is outperformed by simpler trading techniques.

2.4.2. Literature opposing technical analysis

Even though research exists that gives some merit to the use of technical analysis, there are studies that oppose the notion of technical analysis as a viable instrument for market movement prediction as well.
For instance, Papadamou & Tsopoglou (2001) conclude that “technical systems over the period of investigation were profitable but there was evidence that these profits were statistically insignificant compared to a "buy and hold" strategy.” Furthermore, Yamamoto (2012) concludes that “all technical trading strategies fail to outperform the buy-and-hold strategy, indicating that information on past prices and on demand/supply imbalances in the order book are not related to superior technical trading profitability.” Moreover, Gupta (2011) concludes that “the evidence suggests that Fibonacci retracements exert little to no predictive power over exchange rates, and that, at least for this trading phenomenon, the efficient market hypothesis remains the best explanation of the data observed.”

In addition to that, there is the issue whether the studies in favor of technical analysis might have been poorly tested. Case in point, Irwin & Park (2004) state that “early studies indicate that technical trading strategies are profitable in foreign exchange markets and futures markets, but not in stock markets. Modern studies indicate that technical trading strategies consistently generate economic profits in a variety of speculative markets at least until the early 1990s. Among a total of 95 modern studies, 56 studies find positive results regarding technical trading strategies, 20 studies obtain negative results, and 19 studies indicate mixed results.” However, they move on by stating that the studies they researched were subject to various testing problems. They mention data snooping, ex post selection of trading rules, and difficulties in estimation of risk and transaction costs as possible faults in the studies.

2.4.3. Literature on Elliot waves and Fibonacci levels

Literature that investigates the combined use of Elliott waves and Fibonacci retracement levels is scarce. A study by Balasundram et al. (2002), states that when trading these two techniques a carefully constructed strategy can generate profits.

However, studies on Elliot waves and on Fibonacci levels in isolation are more numerous.
For instance a study by Dash & Patil (2009) on Elliot waves in the Indian stock market provides support for the Elliot wave theory. Furthermore, Magazzino et al. (2012) state that: “Elliott’s wave theory, as all the instruments of technical analysis, is proposed as a tool for analysis, able to seize opportunities for profit even in turmoil phases.” Also, Blackledge & Murphy’s (2011) research uses a model called the fractal market hypothesis which is very similar to the Elliott wave theory’s model. The study concludes that “the system can generate a profitable portfolio over a range of currency exchange rates”.

Various studies have been done on the use of Fibonacci levels in trading as well. Eng (1997), Fischer (1993), Hartle (1997), Krausz (1998), and Plummer (1989, 1997), all concluded the Fibonacci ratios could be useful in some way when trading financial markets. Furthermore, Chen et al. (2007) stated that their Fibonacci model improved forecasting accuracy in Taiwanese stock markets. However, a study by Gupta (2011) resulted in support for the efficient market hypotheses and against Fibonacci ratios as a viable trading instrument.

2.5. Research relevance

In conclusion, as mentioned in the introduction, there is currently no major consensus on the use of technical analysis. Research on the subject shows inconclusive results. There are studies that find no value in technical analysis as opposed to for instance a simple buy and hold strategy. Yet, there are numerous studies that claim technical analysis does have merit.

The contribution of this paper to existing literature will be the combination of both Elliott wave theory and Fibonacci levels as a possible risk-adjusted profitable trading strategy. This is predominantly because literature on technical analysis thus far focuses only on simple indicators, as opposed to chart pattern formations. Additionally, this paper will collect its sample from foreign exchange rates; current research in this area has not yet been exhausted.

3. Trading strategy

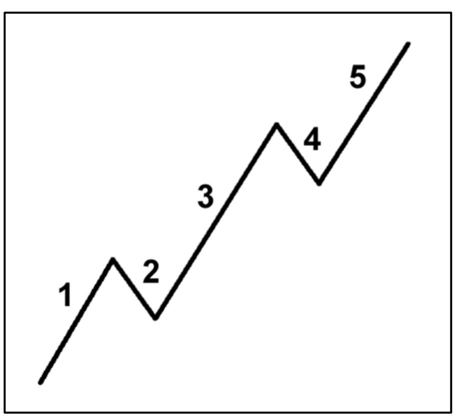
3.1. Elliott wave and Fibonacci retracement levels trading strategy

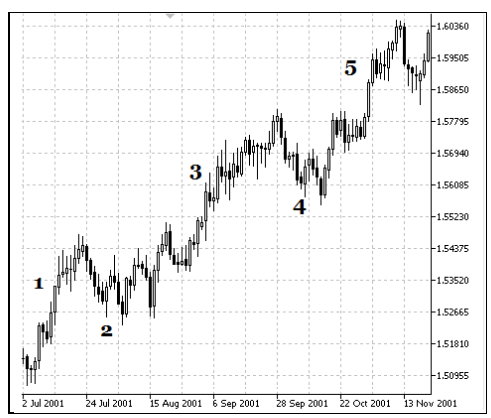
This segment describes the trading strategies that will be investigated, also, a brief overview of the theory behind Elliott wave patterns and Fibonacci retracement levels is given. The study by Chang and Osler (1999) says that: "Since the goal of technical trading is profitability, the best technical forecast is not necessarily the one which is most numerically accurate. Instead, the best technical forecast is the most profitable one, and profitability must replace unbiasedness as the first criterion by which to judge the price forecasts implicit in any technical trading rule. This difference is elaborated in Leitch and Tanner (1991)."

In this case, the profitability of Elliott waves in combination with Fibonacci retracement levels is researched.

3.1.1. Elliott wave theory

The Elliott wave pattern is a five wave pattern, where the five waves are called impulse waves. The impulse waves are separated in two segments. Wave 1, 3, and 5 are called motive waves and in these waves the price ascends for regular Elliott waves and descends for inverted Elliott waves. Wave 2 and 4 are called corrective waves and in these waves the price descends for regular Elliott waves and ascends for inverted Elliott waves (see Figure 3.1 and Figure 3.2).





According to Collins (1938) in his book "The Wave principle" the theory behind the Elliott wave pattern goes as following. The initial move upwards, or Wave 1, is caused by a minority of investors who feel that the price of an asset is undervalued and thus they buy this asset sufficiently for the price to rise. Then, this group of first buyers sells their assets to take profits which cause the price to drop. In the Elliott wave pattern this is called Wave 2. The second climb of the price, or Wave 3, is caused by the undervaluation of the asset becoming "common knowledge" among investors. Thus, an even larger group of investors than in Wave 1 go long on the asset. This causes the price to move beyond the top price of Wave 1. Wave 4 is again caused by investors taking profits. The final move up, or Wave 5, is caused by hysteria and late entrants causing the price to eventually be overvalued and thus ending the impulse wave pattern. For inverted Elliott wave patterns, the theory assumes the price is overvalued at the start and investors go short. Due to the fractal nature of Elliott waves, the size of the Elliott wave pattern can be broken down in to several categories. The biggest Elliott waves can be found when looking at larger time frames. If a trader looks at the same Elliott wave pattern in a smaller time frame, the pattern disappears and according to theory breaks down into smaller Elliott waves. See figure 3.3.

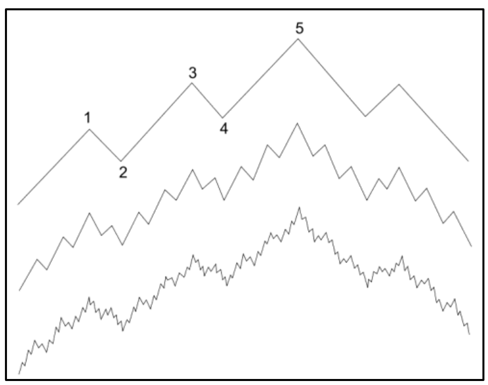


Figure 3.3 The fractal nature of the Elliott wave pattern.
I.e. each Elliott wave pattern consists of smaller Elliott wave patterns.
This figure was retrieved from
http://www.bigtrends.com/trading-education/basics-of-elliott-wave/

Thus Elliott wave patterns can be categorized in size. The categories in order from largest to smallest are the "Grand Super cycle", the "Super cycle", the "Cycle", "Primary", "Intermediate", "Minor", "Minute", "Minuette", and finally "Sub-Minuette". The "Grand Super cycle" and the "Super cycle" have a range of several decades. The "Intermediate", ranges from weeks to months. The "Minor", can last several weeks. The "Minute" cycle lasts several days and finally the "Minuette" and "Subminuette" which respectively last hours and minutes. Since the focus of this paper is in the weekly, daily, and hourly time frames, the Elliott wave patterns that will be identified most likely are the "Intermediate", the "Minor", the "Minute", and the "Minuette" and "Subminuette".

3.1.2. Fibonacci retracement levels

Fibonacci retracement is a tool used by technical traders in order to identify support and resistance levels in financial asset pricing.

Fibonacci retracement levels can be calculated quite easily. The retracement levels are created from the most common Fibonacci ratios, namely 23.6%, 38.2%, 50%, 61.8% and 100%. The 23.6%, 38.2%, 50% and 61.8% ratios are obtained from the Fibonacci sequence in the following manner[2]. The key Fibonacci ratio is the 61.8% ratio, also called the golden mean. It is obtained by dividing any higher number of the Fibonacci sequence with the number that follows it. For instance: — . The 38.2% ratio is found by dividing a number of the Fibonacci sequence with the number in the sequence two places to the right of the initial number. For instance: — . The 23.6% ratio is found by dividing a number in the Fibonacci sequence by the number in the sequence three places to the right of it. For instance: — . The 50% ratio is obtained by the dividing the second number (1) in the Fibonacci sequence, by the third number (2) in the sequence: – .

Although the 50% is not one of the most common ratios, it is widely used in financial trading. This is due to the belief of technical traders that securities tend to move in the original direction after it retraces half of the security's original move[2].
There seems to be no real fundamental reason behind the use of Fibonacci ratios in trading, other than the fact that the ratios appear to be abundant in nature, music, architecture, and might therefore also apply to financial markets. The theory entails that markets retrace a predictable proportion of a move, the Fibonacci ratio, and then continue to move in the initial direction[2].
However, the ratios and their retracement levels are widely used in financial markets, and the inventor of the Elliott wave theory even suggests doing so. Elliott claims that when he researched Elliott waves he discovered the retracements of the waves reflected the Fibonacci ratios (Elliott, 1946). Furthermore, the widespread use of the Fibonacci retracements might be attributed to confirmation biases and/or self-fulfilling prophecies of investors using Fibonacci.
To identify the Fibonacci retracement levels in a chart, first two extreme points (peak and trough, or valley) must be obtained. The retracement levels are obtained by dividing the vertical price distance of the peak and valley by the aforementioned Fibonacci ratios. Then these numbers have to be subtracted from the peak, to obtain the retracement levels. Horizontal lines are drawn on these Fibonacci retracement levels to identify support and resistance levels.
The following is the formula for calculating the retracement levels for the different Fibonacci ratios:

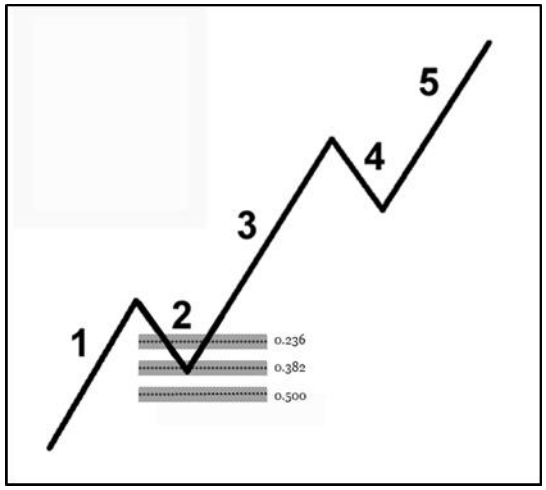
[2] http://www.investopedia.com/ask/answers/05/fibonacciretracement.asp

Where "*Fibonacci ratio*" is one of the Fibonacci ratios mentioned in section 3.1 (0.236, 0.381, 0.5, 0.618), *"Peak"* is the level at a peak in a security's price, and lastly *"Valley"* is the level at a valley in a security's price.

Fibonacci retracement levels give the trader entry signals once the exchange rate hits any of these retracement levels. According to consulted trading manuals[1] Fibonacci levels are not strict, and should be viewed as more of an area the price could bounce of, rather than a strict price point. Therefore, price of a security is viewed as bouncing of a Fibonacci level if it ends within a certain range of a Fibonacci level. (See figure 3.4)

Therefore, to account for this range, if the price is within 0.001% of a Fibonacci retracement level, we identify this as an entry signal (Osler, 2000). The formula for the Fibonacci retracement levels then becomes the following:

The signs will be adjusted to whether a position is long or short.



3.1.3. Trading strategy

Several technical trading manuals[3] were consulted. Their opinion on the use of Elliott waves and Fibonacci levels were approximately the same, and conveyed the following.

A trader begins his or her wave count when a rise (fall) in the exchange rate is identified after a trough (peak), and subsequently the exchange rate reverses and bottoms (tops) out. This is called a retracement. Then, the exchange rate starts to begin a move in the same direction as the initial move. The initial move is labeled as Wave 1 and the retracement as Wave 2. The entry signal for the trader is at the start of Wave 2 and can be found using Fibonacci retracement levels (see figure 3.4).

To sum up, the trading strategy entails identifying Elliott waves. After Wave 1 is identified, Fibonacci retracement levels are obtained from this wave. If Wave 2 retraces on any of the Fibonacci levels, this constitutes as a signal to go long or short depending on whether the Elliott wave is regular or inverted.

In section 5.1 algorithms will be described in order to objectively identify the Elliott waves and the entry and exit signals by using Fibonacci retracement levels.

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3 Collins, C.J., Frost, A.J., and Prechter Jr, R.R. (2001). *Elliott Wave Principle: Key to Market Behavior*. Wiley.

Gorman, W. and Kennedy, J. (2013).*Visual Guide to Elliott Wave Trading*. Bloomberg Financial.

Weis, D.H. (1998). *Trading with the Elliott Wave principle: a practical guide*. Tape Readers Press.

Online manuals retrieved from:
http://www.babypips.com/school/elementary/fibonacci/
http://www.babypips.com/school/test-school/elliott-wave-theory/
http://www.actionforex.com/education/free-training-courses/free-elliott-wave-tutorial-from-ewi-200411145694/
http://www.daytradersbulletin.com/html/elliottwave.html
http://www.investopedia.com/articles/technical/111401.asp
http://www.tradingfives.com/articles/elliott-wave-guide.htm

4. Data sample

The research will be conducted in the foreign exchange market. The foreign exchange market is chosen due to the fact that it is the largest financial market in the world, which makes it highly liquid. It has low bid-ask spreads which minimize the effect of transaction costs on profitability. It is traded 24 hours, and five days a week, thus a lot of trading data is available. Furthermore, due to the sheer size of the forex market, it is nearly immune to insider trading; therefore data is not distorted by individual major trading institutions.

Data will be obtained from the Metatrader 5 trading platform, Yahoo finance, and Bloomberg.com. This will be used to back track foreign exchange prices for different timeframes. For the sample weekly, daily, and hourly time frames will be used from four major currency pairs. The sample's time horizon will consist of the years 2005-2012. This way, pre-crisis data, mid-crisis data, and post-crisis data will be available for testing. The currency pairs will be the, the eur/usd, the aud/usd, the usd/jpy, and the usd/cad. These pairs are chosen because they rank among the most traded in global forex markets. Furthermore, they do not have the same high correlation to each other as some other pairs have (Lien, 2010).

The data that will be used are time series of the eur/usd, aud/usd, and usd/jpy currencies. They show, daily, hourly, and 30 minute closing prices, starting at January 3rd, 2005, and going to June 6th, 2013. In table 4.1, descriptive characteristics are portrayed of the currencies used in the sample period.

	Minimum	Maximum	Mean	Std. Deviation of returns
aud/usd	.6031	1.1022	.881677	,0088354
eur/usd	1.1669	1.5995	1.340556	,0065537
usd/cad	.9161	1.2993	1.076558	,0060355
usd/jpy	75.730	123.780	98.41316	,0065961

Table 4.1 Descriptive Statistics of currencies**.** Minimum, maximum, mean, and standard deviation of returns of the aud/usd, eur/usd, usd/cad, and usd/jpy currency pairs for January 3rd 2005 to June 6th 2013.

As depicted in table 4.1, the usd/jpy, usd/cad, and aud/usd are more volatile than the eur/usd currency pair.

Figures 4.1, 4.2, 4.3, and 4.4, show the time series' plots of the different currency pairs. As can be seen in these plots the aud/usd and the eur/usd show a steep drop around the start of the sub-prime mortgage crisis in 2008. The usd/cad shows a steep rise around this period. This suggests that the US dollar appreciated at the start of the crisis, or at least remained stable while the other currencies depreciated. This might be due to the fact that the US dollar is the world's reserve currency and investors were highly uncertain at the time. As Dadush & Eidelman (2010) say, "In the first phase [of the crisis], which lasted roughly from September 2008 to March 2009, most currencies depreciated against the dollar as investors sought a safe haven, and the dollar appreciated 13.6 percent in nominal effective terms". The usd/jpy drops around the start of the crises. However, it appears to be already in descent quite some years before that.

Figure 4.1 *The aud/usd exchange rate from 2002 to 2013. The horizontal line depicts the exchange rate at August 29th 2013. The data was extracted from Metatrader 5.* This software is available at http://www.metatrader5.com

Figure 4.2 *The eur/usd exchange rate from 2002 to 2013. The horizontal line depicts the exchange rate at August 29th 2013. The data was extracted from Metatrader 5.* This software is available at http://www.metatrader5.com

Figure 4.3 *The usd/cad exchange rate from 2002 to 2013. The horizontal line depicts the exchange rate at August 29th 2013. The data was extracted from Metatrader 5.* This software is available at http://www.metatrader5.com

Figure 4.4 *The usd/jpy exchange rate from 2002 to 2013. The horizontal line depicts the exchange rate at August 29th 2013. The data was extracted from Metatrader 5.* This software is available at http://www.metatrader5.com

4.1. Smoothing

In order to filter out noise in the form of short term volatility that tends to exist in currency prices, the data will be smoothed. This is also useful for detecting the Elliott wave patterns more easily. The data will be smoothed by using the simple moving average method. This technique smooth the data by averaging a data point with historical data points. The simple moving average formula is the following:

Here, is the smoothed data point, is the original data point, and is the number of time periods used in the averaging technique. In most cases, is three, four, or five. Here, three time periods are used to smooth the data[4].

The obtained data is going to be tested against the random walk hypothesis. The random walk hypothesis states that financial asset prices follow a random and unpredictable walk. The theory implies that prices fluctuate randomly, that they do this independently from one another, and with the same probability distribution. Therefore, it would be impossible to beat the market without taking on additional risk.

The theory directly opposes the theory of technical analysis profitability, which is under investigation in this paper. Consequently, the random walk hypothesis is in agreement with the efficient market hypothesis. The exact manner of testing is clarified in section 5.3.

[4] http://www.dallasfed.org/research/basics/moving.cfm

5. Methodology

The following section describes the methods for objectively identifying Elliott wave patterns by means of a replicable pattern-recognition strategy. Furthermore, exact rules for entry and exit signals are defined. Additionally, the methods for evaluating the results for statistical significance are described.

5.1. Identifying Elliott waves

There are three ways the trading strategy in section 3.1 will be examined. Two ex-post analyses of different versions of the Elliott wave pattern will be conducted. In addition, one ex-ante analysis of a practical, real-time trading, version of the Elliott wave pattern will be conducted.

5.1.1. Alternative Elliott wave pattern ex-post analysis

First, the Elliott wave pattern formulated by Dash and Patil (2009) and a minority of technical trading manuals[5] will be described. This alternative form of Elliott wave patterns will be abbreviated as the EWALT pattern from now on. The difference between this form of Elliott wave patterns and the traditional Elliott wave pattern is that it has rules for the retracement waves to lie in certain time intervals. Wave 1 lies in the time interval . The retracement Wave 2 lies in the time interval , where cannot be larger than 0.382* and retracement Wave 3 lies in time interval , where cannot be larger than 1.618* . As mentioned in section 3.1.2, the ratios 0.382 and 0.618 are important Fibonacci ratios. The same rule applies to the time interval of Wave 4 and 5, i.e., retracement Wave 4 lies in time interval , where cannot be larger than 0.382* and Wave 5 lies in time interval , where cannot be larger than 1.618* (See Figure 5.1).

There really is no underlying theory behind the use of these time intervals, other than that it is simply, according to technical trading manuals[5], a classic relationship seen in Elliott waves and the patterns often conform to this time interval condition. No further underlying rationale seems existent and this condition for Elliott waves is rarely used.

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[5] Online manuals retrieved from:
http://financeandtradingmadeeasy.blogspot.com/2010/03/download-elliot-wave-calculator.html
http://www.smartfinancein.com/elliot-wave-calculator-manual.html
http://www.tradingfives.com/articles/elliott-wave-guide.htm
http://ta.mql4.com/elliott_wave_theory

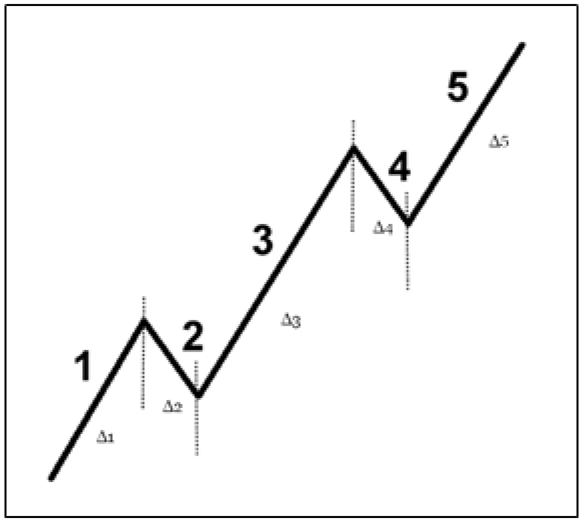

Figure 5.1 *The alternative Elliott wave pattern investigated in this study. The deltas in the figure refer to time intervals waves 2 to 5 have to end in for the pattern to constitute as an Elliott wave pattern.*

Since this paper investigates the combined use of Elliott wave patterns and Fibonacci retracement levels, the following criterion for a valid pattern is added to the criteria found in the technical trading manuals. Wave 2 must retrace on a Fibonacci level.

The following criteria are set in the EWALT algorithm to identify EWALT patterns.

- The pattern starts with a climb in exchange rate (Wave 1), followed by a retracement (Wave 2), followed by another climb (Wave 3), followed by a retracement (Wave 4), and then followed by the final climb (Wave 5).
- Wave 1 starts at a valley
- Wave 2 can never drop lower in price than the start of Wave 1
- Wave 2 lies in time interval , where =0.382*
- Wave 2 bounces of a Fibonacci retracement level
- Wave 3 can never be the shortest impulse wave
- Wave 3 lies in time interval , where =1.618*
- Wave 4 can never drop lower in price than the end of Wave 1
- Wave 4 lies in time interval , where =0.382*
- Wave 5 lies in time interval , where =1.618*
- Wave 5 is not obliged to peak beyond the end of Wave 3 in price, this is called truncation
- Inverted criteria apply to inverted Elliott wave patterns.

The algorithm used to identify the alternative Elliott wave patterns in the data was constructed in MATLAB, and can be found in appendix I.

The algorithm designed from these criteria works in the following fashion. The algorithm starts at the beginning of the data. The following step of the algorithm entails the search for peaks and valleys in the data, if no valley is found for the current data point, the algorithm moves on to the following point.

Elliott wave patterns always start at a major through or valley (or at a major peak for inverted Elliott waves). In this research, a peak is defined as a local price point, where the previous closing price and the following closing price are lower. A valley is defined as a local price point where the previous closing price and the following closing price are higher. As hourly, daily, and weekly time frames, are used, closing prices are defined as hourly closing prices, daily closing prices, and weekly closing prices. Thus, after the algorithm has identified peaks and valleys in the data it puts the peaks and valleys in a new matrix.

The algorithm then proceeds to search the peak and valley matrix for peaks and valleys that conform to the criteria described before, and thereby forming an Elliot wave pattern. This entails that after an initial valley, the second valley must be higher than this initial valley. The second peak must be higher than the initial peak, and the third valley must also be higher than the initial peak (See example figure 5.2).

aud/usd	0,568733	0,570767	0,570633	0,5714	0,571233	0,571267

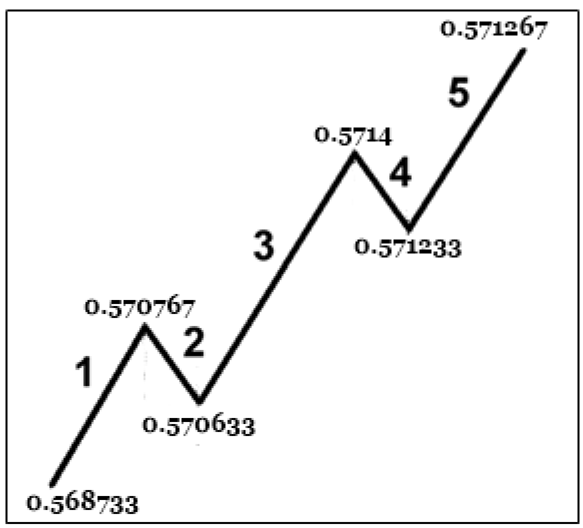

Figure 5.2 *An example of maxima and minima in the aud/usd exchange rate. These maxima and minima are obtained by the algorithm used in this research. The pictured example shows how these maxima and minima conform to an Elliott wave pattern.*

Then the algorithm checks if Wave 3 is not the shortest impulse wave. It then checks whether Wave 2, 3, 4, and 5 lie in the time intervals specified in the criteria above.

Finally the algorithm checks if Wave 2 bounces of a Fibonacci retracement level, and then displays returns calculated from entry en exit signals further specified in section 5.2.1 and 5.2.2. The algorithm then ends the wave count, and begins to search for another Elliott wave pattern.

5.1.2. Traditional Elliott wave pattern ex-post analysis

The second ex-post analysis is about the traditional concept of the Elliott wave pattern. Several technical trading manuals[6] were consulted in order to create an algorithm to objectively identify the traditional Elliott wave patterns in the exchange rate data. This pattern will be referred to as the EWTRAD pattern from now on. The EWTRAD pattern is similar to the EWALT pattern, except that it releases the conditions that the retracement waves must end in certain time intervals. Again, this paper researches the combined use of Elliott wave patterns and Fibonacci retracement levels. Therefore, the following criterion for a valid pattern is added. Wave 2 must retrace on a Fibonacci level.

The following are the criteria set in the algorithm to identify the EWTRAD patterns.

- The pattern starts with a climb in exchange rate (Wave 1), followed by a retracement (Wave 2), followed by another climb (Wave 3), followed by a retracement (Wave 4), and then followed by the final climb (Wave 5).
- Wave 1 starts at a valley
- Wave 2 can never drop lower in price than the start of Wave 1
- Wave 2 bounces of a Fibonacci retracement level
- Wave 3 can never be the shortest impulse wave
- Wave 4 can never drop lower in price than the end of Wave 1
- Wave 5 is not obliged to peak beyond the end of Wave 3 in price, this is called truncation
- Inverted criteria apply to inverted patterns.

The MATLAB algorithm used to identify the traditional Elliott wave patterns in the data can be found in appendix II.

The algorithm for the EWTRAD pattern functions in the same manner as that of the EWALT pattern. The explanation can be found in section 5.1.1. However, EWTRAD pattern has no conditions for time intervals. Therefore, after checking if Wave 3 is not the shortest impulse wave, the algorithm checks for Fibonacci retracement bounces and displays returns.

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[6] Collins, C.J., Frost, A.J., and Prechter Jr, R.R. (2001). *Elliott Wave Principle: Key to Market Behavior*. Wiley.

Gorman, W. and Kennedy, J. (2013).*Visual Guide to Elliott Wave Trading*. Bloomberg Financial.

Weis, D.H. (1998). *Trading with the Elliott Wave principle: a practical guide*. Tape Readers Press.

Online manuals retrieved from:
http://www.babypips.com/school/elementary/fibonacci/
http://www.babypips.com/school/test-school/elliott-wave-theory/
http://www.actionforex.com/education/free-training-courses/free-elliott-wave-tutorial-from-ewi-200411145694/
http://www.daytradersbulletin.com/html/elliottwave.html
http://www.investopedia.com/articles/technical/111401.asp
http://www.tradingfives.com/articles/elliott-wave-guide.htm

5.1.3. Practical Elliott wave pattern ex-ante analysis

Finally, an ex-ante analysis will be performed to check for a "real-time" application of the Elliott wave pattern. After real life traders start their wave count, they have no certainty that their position will eventually develop into a proper Elliott wave pattern. To account for this, a practical pattern will be described and analyzed in order to see whether it is profitable to trade Elliott wave patterns in real time. As mentioned in section 3.1.2, entry signals for Elliott wave patterns are set up by Fibonacci retracement levels at the end of Wave 2.

Thus, a real life trader identifies a valley or peak in the exchange rate. The trader labels this as the start of Wave 1. If Wave 1 is completed and the price is retracing, the trader opens a long position (or short position for inverted patterns) if the price retracement stops and reverses at a Fibonacci level. These first two waves will be labeled as the practical pattern, and abbreviated as PRAC (See figure 5.3).

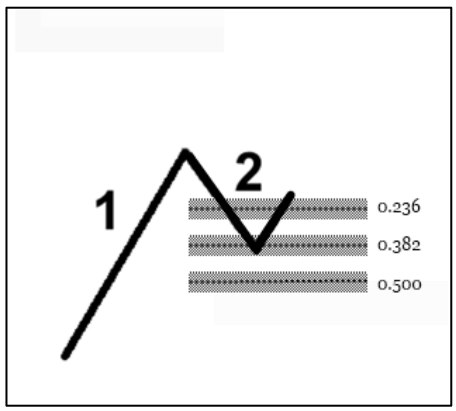

Figure 5.3 *The practical pattern investigated in this thesis. The figure shows the pattern labeled as the PRAC pattern in this case. It is the first part of a full Elliott wave pattern. Traders place their trades at the end of this PRAC pattern, believing it signals the formation of an Elliott wave pattern.*

The following are the criteria set in the algorithm to identify the PRAC patterns.

- The pattern starts with a climb in exchange rate (Wave 1), followed by a retracement (Wave 2)
- Wave 1 starts at a valley
- Wave 2 can never drop lower in price than the start of Wave 1
- Wave 2 bounces of a Fibonacci retracement level
- Inverted criteria apply to inverted patterns.

The MATLAB algorithm used to identify the practical Elliott wave patterns in the data can be found in appendix III.

The algorithm for the PRAC pattern works similarly as the other algorithms. However, criteria for time intervals and for the wave formation after Wave 2 have been omitted. The practical pattern searches for peaks and valleys in the data, and only has specific criteria for Wave 1 and

Wave 2, i.e., the algorithm searches for Wave 1 and Wave 2, and checks if these comply with the same conditions as in the other Elliott wave pattern algorithms. Since entry lies after Wave 2, the further completion of the pattern is unknown to a real trader. The trader would only know that it has to exit at the top of Wave 5, the third peak in the data, or if the price drops below 0.001% of the entry price, a stop loss (described further in section 5.2.2). Thus, the algorithm searches for peaks and valleys and after it has found Wave 1 and Wave 2, it looks for a Fibonacci retracement level bounce. It then identifies the exit at the second peak after initial entry.

5.2. Entry and Exit signals

5.2.1. Entry signal

When an Elliott wave has been identified, profits are calculated from entry and exit. Technical manuals[7] describe the corrective waves in an Elliott wave pattern as bouncing off Fibonacci retracement levels. For traders, this bounce is the signal to enter a trade.

Therefore, if the start of Wave 3 (or end of Wave 2) is within 0.001% of a Fibonacci retracement level, as mentioned in section 3.1.2 and section 3.1.3, we identify this as an entry signal (Osler, 2000). The signs will be adjusted to whether a position is long or short. The formula for the Fibonacci formula that accounts for the 0.001% range can be found in section 3.1.2 as well.

To realistically recreate the entry signal, it is defined as one of the Fibonacci levels, plus 0.001%. Because a trader will look at the bounce of a Fibonacci level, the entry cannot lie exactly on the Fibonacci level. As explained in section 3.1.2, the Fibonacci levels should be viewed as areas. Thus, the entry signal here is defined as the price leaving the Fibonacci retracement area.

5.2.2. Exit signal

Technical trading manuals[7] suggest that exits should be located at the top of wave 5. They describe that the Elliott 5-wave pattern is followed by a corrective pattern, which starts with the price descending. The corrective pattern is of no importance to this paper, except that it makes the end of wave 5 a peak or trough for inverted waves. The peak or trough is identified similarly as described in section 5.1.1. The end of Wave 5 is the third maximum of an Elliot wave pattern. Therefore, the exit signal is defined as the third maximum after the initial wave pattern count. A

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[7]Collins, C.J., Frost, A.J., and Prechter Jr, R.R. (2001). *Elliott Wave Principle: Key to Market Behavior*. Wiley.

Gorman, W. and Kennedy, J. (2013).*Visual Guide to Elliott Wave Trading*. Bloomberg Financial.

Weis, D.H. (1998). *Trading with the Elliott Wave principle: a practical guide*. Tape Readers Press.

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http://www.babypips.com/school/test-school/elliott-wave-theory/
http://www.actionforex.com/education/free-training-courses/free-elliott-wave-tutorial-from-ewi-200411145694/
http://www.daytradersbulletin.com/html/elliottwave.html
http://www.investopedia.com/articles/technical/111401.asp
http://www.tradingfives.com/articles/elliott-wave-guide.htm

trader cannot identify the third maximum, until after the price has dropped. Therefore, the exit signal cannot lie exactly at the end of Wave 5. It has to lie slightly below that level. Therefore, to realistically recreate the exit signal, the exit signal is the third maximum minus 0.001%.

A second exit rule is in place which is common practice in trading. A stop loss is set to limit potential losses in a trade. If the price drops more by a certain percentage below the entry point, the stop loss automatically exits the trade. As in Chang and Osler (1999), the stop loss is set at 1% of the original entry point price. In other words, if the price drops more than 1% below the Fibonacci level used as an entry point, the trade is closed out. In this case, this entails that any returns lower than -1% are converted to the stop loss level of -1%.

The stop loss is only relevant for the practical pattern. Because in the PRAC pattern, the criterion that Wave 5 must be higher in price than the end Wave 2 is not imbedded in the algorithm. Thus, it could potentially produce very negative returns. This is not the case in the other patterns. There, the nature of the pattern identification algorithms inhibits the production of large negative returns.

Profits will be calculated as in Chang and Osler (1999), where profits are the cumulative change of the exchange rate between the entry and exit signal.

5.3. Statistical tests

5.3.1. Bootstrapped simulations

In order to test the statistical significance of the obtained profits, the method used by Chang and Osler (1999) is followed. According to them, the profit distribution of exchange rates is disputed. Therefore, in accordance with Chang and Osler (1999), Levich and Thomas (1993), Brock et al. (1992), and Allen & Karjalainen (1993) an appropriate statistical distribution is derived by means of a bootstrap methodology.

The Chang and Osler (1999) bootstrap methodology pertains a simulation of profits via a random walk model. The obtained profit distribution is then compared to the actual profits obtained from the trade strategy. The simulations are constructed as an artificial exchange rate series similar in length, variance, skewness, and kurtosis, in order to be representative of the entire population of the exchange rate series.

However, due to the fact that price movements in the simulated series are random, Elliot wave patterns should hold no value, i.e., in a random walk prices cannot be predicted, thus Technical (or Fundamental analysis for that matter) should have no predicting power.

The Elliott wave pattern identification algorithm is run on the simulated series. This provides a distribution of profits. Actual Elliott wave profits must outperform those of the simulated series for them to be significant.

More accurately, if the mean profits of the actual exchange rates are significantly higher than the mean profits of the simulated exchange rate series, the null hypothesis is rejected. The significance level is set at 5% or 0.05. This analysis is done by performing an one sample t-test.

5.3.2. Measuring transaction costs

To check if the Elliott wave profits will hold in a real time trading situation, the profits will be corrected with transaction costs. Here, the transaction costs are measured by the bid-ask spreads set by brokers. According to Ramadorai (2008), the average spreads for Major currencies are 2 to 3 basis points. This average will be used as a proxy for transaction costs on all exchange rates researched in this paper.

5.3.3. Measuring annual profitability

Besides using the bootstrap method for testing the statistical significance of profits, annualized profits will also be compared to a buy and hold strategy. This is because, if the market moves randomly (i.e. random walk model) actively trading financial assets have no incremental value. The man who popularized the Random Walk model, Malkiel (1990) claims that the buy and hold strategy is always preferable and that individuals should not attempt to time the market. Thus, if the buy and hold strategy outperforms the Elliott wave profits this would be in support for the random walk hypothesis, the efficient market hypothesis, and our null hypothesis (see section 5.4).

5.3.4. Risk

In order to check if any significant profits in Elliott waves are not a result of risk compensation, a measure of risk is needed. As Chang and Osler (1999) state, currently “there is no consensus on appropriate risk adjustment of excess returns to foreign exchange speculation, one approach is to calculate the Sharpe ratio of annualized excess returns to their annualized standard deviation.” This notion is corroborated by Neely (1997) in “Technical analysis in the foreign exchange market: A layman's guide”.

5.4. Hypotheses

The main research of this paper is whether a trading strategy of Elliott wave pattern recognition combined with the use of Fibonacci retracement levels is profitable once adjusted for risk and other variables. If this were to be true, it would provide evidence against the efficient market hypothesis. The mean profits of trading the different Fibonacci levels in Elliott waves will be researched. This has led to the following hypotheses.

Elliott wave trading with the use of Fibonacci levels is not profitable

Elliott wave trading with the use of Fibonacci levels is profitable

If the obtained profits of Elliott wave patterns are significantly higher than the profits obtained from the simulated series (via the random walk model), the null hypothesis is rejected.
The hypotheses above are quantified for the two ex-post analyses and the ex-ante analysis in the following manner.

Here, is the mean profit per position (hypothetical trade) for the actual exchange rates, and is the mean profit per position for the simulated exchange rate series.

To test the hypotheses, two-tailed t-tests will be performed. This is to check whether the means from the trading strategy in the actual exchange rate series and the means from the trading strategy in the simulated exchange rate series are from different populations.
In other words, if the means are from the same population, exchange rates must be following a random walk and technical analysis techniques have no predicting power and thus cannot be utilized for a profitable trading strategy. However, if these means are from different populations, significance of the actual exchange rate Elliott wave trading means can only be established if they outperformed those means of the simulated exchange rate series. Therefore, in this case, if any of the algorithms produce mean returns that seem to be significant it will be verified whether it also outperforms the mean returns obtained from the simulated series.

6. Results

The following section contains the results of the statistical tests described in section 5.3 for the two ex-post tests and the ex-ante test. First, frequency statistics of the obtained data will be described. Then, the general results of the profit tests are portrayed. After this, any significant obtained profits will be scrutinized for transaction costs, risks.

In the profit tests, average profits are described. These are the average profits of a hypothetical trade entered or a trade position opened according to the rules of the algorithm. The average profits per position of the EWALT pattern will be described first. After this, the average profits per position of the EWTRAD pattern will be described. Finally, the average profits per trade of the PRAC pattern will be discussed.

6.1. EWALT pattern ex-post test

6.1.1. Frequency statistics

A total number of 3,128 EWALT patterns were found. As can be seen in frequency table 6.1, 1,178 patterns had wave 2 landing on the first Fibonacci level. 823 times wave 2 of the EWALT pattern landed on the second Fibonacci level. Furthermore, 646 times wave 2 landed on the third Fibonacci level and 481 times it landed on the fourth Fibonacci retracement level. This is as expected, because the price has to move deeper if it were to hit the Fibonacci levels beyond the first retracement level, though, the price does not have to retrace that much to hit the first Fibonacci level. Therefore, the lower a Fibonacci level, the more often it will be missed. This was further explained in section 3.1.1.

Table 6.1 further shows the number of EWALT patterns found per currency pair. The usd/cad produced the most patterns. The algorithm observed 28% of all EWALT patterns found in this currency pair. The aud/usd pair generated 720 patterns which amount to about 23.03% of all EWALT patterns. The eur/usd and the usd/jpy currency pairs generated approximately the same amount of patterns, which entails 24% of all EWALT patterns were observed in these currency pairs.

Furthermore, it can be seen that the hourly time frame produces the most patterns by far. About 99% of all the patterns found were in the hourly time frame. It produced 3,102 patterns. The daily time frame showed 23 EWALT patterns, which amounts to 0.74% of all the patterns. Finally, the algorithm hardly produced any patterns in the weekly time frame. About 0.06% of all patterns found were in this time frame. This makes sense, since this time frame consists of more data points in the sample period. Also, according to the theory that Elliott waves are fractals, smaller Elliott waves are observed in the lower time frames. This is precisely the situation here. This provides some initial evidence on the historical existence of Elliott wave patterns, since the results do show signs of the fractal nature of Elliott waves.

	Fibo 1	Fibo 2	Fibo 3	Fibo 4	Cumulative
aud/usd	300	196	137	87	720
hour	297	195	136	86	714
day	3	1	1	1	6
week	-	-	-	-	-
eur/usd	288	197	158	120	763
hour	284	195	157	120	756
day	4	2	1	-	7
week	-	-	-	-	-
usd/cad	319	235	188	148	890
hour	315	234	188	148	885
day	2	1	-	-	3
week	2	-	-	-	2
usd/jpy	271	195	163	126	755
hour	266	193	163	126	748
day	5	2	-	-	7
week	-	-	-	-	
Currency portfolio	1178	823	646	481	3128
hour	1162	817	644	480	3102
day	14	6	2	1	23
week	2				2

Table 6.1 Frequencies of EWALT patterns found by the algorithm for the hourly, daily, and weekly time frames of the aud/usd, eur/usd, usd/cad, and usd/jpy currency pairs and an equally weighted currency portfolio of those pairs.

6.1.2. Mean profits

Table 6.2 depicts the obtained average profits per position for the EWALT pattern. The p-values or significance levels of the profits are in parentheses. If the algorithm did not find any patterns or there were too few patterns to perform a statistical test, this is indicated by a dash.

	Fibo 1 profits	Fibo 2 profits	Fibo 3 profits	Fibo 4 profits
aud/usd	0.004	0.004	0.004	0.003
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0.004	0.004	0.004	0.003
	(.999)	*(.999)*	*(.889)*	*(.999)*
day	0.008	0.003	0.004	0.004
	(.972)	-	-	-
week	-	-	-	-
	-	-	-	-
eur/usd	0.003	0.003	0.003	0.003
	(.999)	*(.999)*	*(.999*	*(.999*
hour	0.003	0.003	0.003	0.003
	(.619)	*(.999)*	*(.138)*	*(.268)*
day	0.014	0.010	0.028	-
	(.112)	*(.749)*	-	-
week	-	-	-	-
	-	-	-	-
usd/cad	0.003	0.002	0.002	0.002
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0.002	0.002	0.002	0.002
	(.999)	(.999)	(.999)	(.999)
day	0.004	0.003	-	-
	(.247)	-	-	-
week	0.038	-	-	-
	(.977)	-	-	-
usd/jpy	0.003	0.003	0.003	0.003
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0.003	0.003	0.003	0.003
	(.999)	*(.999)*	*(.999)*	*(.999)*
day	0.019	0.015	-	-
	(.922)	*(.778)*	-	-
week	-	-	-	-
	-	-	-	-
Currency portfolio	0.003	0.003	0.003	0.003
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0,003	0,003	0,003	0,003
	(.999)	*(.999)*	*(.999)*	*(.999)*
day	0,013	0,010	0,010	0,004
	(.990)	*(.991)*	*(.380)*	-
week	0,038	-	-	-
	(.899)	-	-	-

Table 6.2 describes the mean profits per position of all the sample exchange rates for all their time frames, mean profits for the exchange rates per time frame, plus mean profits for all the exchange rate combined called the “currency portfolio”. The profits per position per time frame for the currency portfolio are depicted as well.

The profits are shown per Fibonacci level. As described in section 3.1.2, a pattern is identified if in the Elliott wave count, Wave 2 hits a Fibonacci level. Thus the profits for the different Fibonacci levels describe the average profits of the patterns that hit a certain Fibonacci level. I.e. if there was a hit at Fibonacci level 1 (the 23.6% level) in an Elliott wave the profit per trade averaged at about 3.1% for the aud/usd currency pair for all the time frames. If Fibonacci level 2 (the 38.2% level) produced an entry signal, the average profit per position was 0.3% for the eur/usd pair. For Fibonacci level 3 (the 50.0% level) and 4 (the 61.8% level), the average profits per position opened were 0.3% for the usd/jpy pair.

As can be seen, all the obtained profits are positive but small. These profits range from 0.28% for several currency pairs, to 3.8% for the first Fibonacci level of the currency portfolio in the weekly time frame.

6.1.3. Profits of currency portfolio

The currency portfolio is essentially all the currency pairs in our sample combined. The currency pairs are equally weighted. As can be seen in table 6.2 for every Fibonacci level the average profits per position were about 0.3%.

Table 6.2 depicts mean profits for the hourly, daily, and weekly time frame for the currency portfolio as well. The daily time frame produces the largest profits. They are about 1% per position, except for the fourth Fibonacci level which averages only 0.4% per position. The hourly time frame shows profits per position of about 0.3% for all Fibonacci levels. The weekly time frame shows a profit per position of almost 4% for only the first Fibonacci level. However, this time frame only produced two EWALT patterns, and therefore not much can be deduced for EWALT profits on a weekly time frame.

6.*1.4. Statistical significance of the currency portfolio*

None of the obtained profit means in table 6.2 are higher than the EWALT profit means obtained from the simulated exchange rate series for any Fibonacci level. Therefore, for all the currency pairs combined, using the EWALT model for obtaining Elliott wave patterns is in support for the null hypothesis. The EWALT pattern appears to not be significantly profitable.

If we look at average profits per time frame none produced an average profit per position opened that outperformed the simulated exchange rate series average profits. This is concurrent with EWALT results per currency pair and for the currency portfolio with all the time frames combined. This supports the notion that the EWALT pattern is not significantly profitable.

6.1.5. *Profits per currency*

In table 6.2, the profit means per Fibonacci level for each currency pair are shown. Again, the profits are all positive. The aud/usd and the eur/usd pair show the largest profits ranging from 0.30% to 0.37%. The usd/jpy and especially the usd/cad pair report smaller profits that range from 0.2% to 0.29%. The profits do not differ much between Fibonacci levels for a given currency pair.

6.1.6. *Statistical significance of profits per currency*

Each currency pair failed to outperform the average profits per position obtained from the random walk exchange rate series. This is further support for the null hypothesis that the EWALT pattern is not significantly profitable.

6.1.7. *Profits per currency per time frame*

For the daily and weekly time frames there are several instances where the algorithm failed to produce any patterns. For instance, only the usd/cad pair for the first Fibonacci level did the algorithm produce patterns. For every currency pair, the hourly time frame generally shows mean profits from 0.2% to 0.4%. These profits are similar to the daily time frames in the aud/usd pair and the usd/cad pair. For the eur/usd and the usd/jpy pairs the daily average profits ranged from 1% to 2.8%.

6.1.8. *Statistical significance of profits per currency per time frame*

For none of the time frame for each currency pair did the mean profits per position significantly outperform the simulated series. This is in support for the null-hypothesis of non-profitability of the trading strategy.

6.2. EWTRAD pattern ex-post test

In this subsection the results for the EWTRAD tests are discussed. The EWTRAD pattern is similar to the EWALT pattern, yet some of the conditions that make up a EWALT pattern are released as is described in section 5.1.2.

6.2.1. *Frequency statistics*

An aggregate of 31,473 EWTRAD patterns were found across all the currencies in the sample period. Table 6.3 depicts the number of times a pattern was observed per each Fibonacci Level. This table further shows the number of Elliott wave patterns found per currency pair and for the currency portfolio. The fewest patterns were found in the aud/usd currency pair. The aud/usd pair generated 7,461 patterns which amounts to about 23.7% of all EWTRAD patterns found. The rest of the currency pair generated approximately the same amount of patterns. The rest of the currency pairs average around 8,000 patterns per pair, which is about 25% of all EWTRAD patterns found by the algorithm.

	Fibo 1	Fibo 2	Fibo 3	Fibo 4	Cumulative
aud/usd	2276	1938	1722	1525	7461
hour	2247	1917	1700	1510	7374
day	27	19	21	15	82
week	2	2	1	0	5
eur/usd	2321	2076	1876	1694	7967
hour	2268	2037	1847	1672	7824
day	50	37	28	20	135
week	3	2	1	2	8
usd/cad	2279	2052	1879	1711	7921
hour	2237	2018	1853	1689	7797
day	38	33	25	21	117
week	5	1	1	1	8
usd/jpy	2359	2107	1911	1747	8124
hour	2314	2071	1881	1719	7985
day	44	36	30	26	136
week	1	-	-	2	3
Currency portfolio	9235	8173	7388	6677	31473
hour	9066	8043	7281	6590	30980
day	159	125	104	82	470
week	11	5	3	5	24

Table 6.3 Frequencies of EWTRAD patterns found by the algorithm for the hourly, daily, and weekly time frames of the aud/usd, eur/usd, usd/cad, and usd/jpy currency pairs and an equally weighted currency portfolio of those pairs.

Table 6.3 further shows the number of patterns the algorithm identified per time frame. Again, the hourly time frame produces the most patterns. About 98% of all the patterns found were in the hourly time frame. For the daily time frame 470 patterns were found, which sums to about 1.5% of all the patterns found. Lastly, the weekly time frame produced the fewest patterns. 0.08% of all patterns found were found here. Again, this was explained in section 3.1.1. Again, this supports the notion of Elliott waves being fractals.

6.2.2. Mean profits

In table 6.4, the mean profits per position for the EWTRAD pattern ex-ante test are shown. As can be seen, all the obtained profits are positive. The returns range from 0.3% for several currency pairs, to 7.6% for the first Fibonacci level of the eur/usd pair in the weekly time frame.

The EWTRAD pattern produced more returns for the weekly time frames than in the EWALT pattern test.

	Fibo 1 profits	Fibo 2 profits	Fibo 3 profits	Fibo 3 profits
aud/usd	0.005	0.005	0.005	0.005
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0.005	0.004	0.005	0.005
	(.998)	*(.000)*	*(.999)*	*(.999)*
day	0.022	0.019	0.018	0.018
	(.437)	*(.538)*	*(.703)*	*(.909)*
week	0.069	0.037	0.035	-
	(.101)	*(.344)*	-	-
eur/usd	0.004	0.004	0.004	0.004
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0.003	0.003	0.004	0.004
	(.999)	*(.999)*	*(.326)*	*(.570)*
day	0.022	0.022	0.026	0.028
	(.286)	*(.665)*	*(.102)*	*(.154)*
week	0.076	0.027	0.047	0.031
	(.563)	*(.943)*	-	(.688)
usd/cad	0.003	0.003	0.003	0.003
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0.003	0.003	0.003	0.003
	(.579)	*(.008)*	*(.000)*	*(.305)*
day	0.017	0.018	0.018	0.018
	(.906)	*(.578)*	*(.485)*	*(.832)*
week	0.035	0.044	0.045	0.045
	(.910)	-	-	-
usd/jpy	0.003	0.004	0.004	0.004
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0.003	0.003	0.003	0.004
	(.836)	*(.000)*	*(.565)*	*(.999)*
day	0.017	0.019	0.018	0.016
	(.216)	*(.466)*	*(.915)*	*(.769)*
week	0.067	0.000	0.000	0.062
	-	-	-	*(.341)*
Currency portfolio	0.004	0.004	0.004	0.004
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0.003	0.004	0.004	0.004
	(.549)	*(.000)*	*(.000)*	*(.239)*
day	0.019	0.020	0.020	0.020
	(.904)	*(.207)*	*(.374)*	*(.866)*
week	0.055	0.034	0.042	0.046
	(.959)	*(.666)*	*(.482)*	*(.954)*

6.2.3. Profits of the currency portfolio

Portrayed in table 6.4 are all the obtained profits for the currency portfolio. The average profits are very similar for each Fibonacci level, spreading from 0.38% for the first Fibonacci level, to 0.39% for the fourth Fibonacci level.

Looking at the time frames of the currency portfolio, profits for the daily and weekly time frame are positive and higher than the EWALT pattern results. The highest average profits were generated in the weekly time frames. Mean profits per position of the weekly time frame are about 3.5% for the second Fibonacci level, to 5.5% for the first Fibonacci level. The average profits per trade for the daily time frame are quite high as well. These are about 2% for all Fibonacci levels. The average profits for the hourly time frames are the lowest. They are about 0.35% for the first and second Fibonacci level, 0.36 for the third Fibonacci level, and 0.37 for the fourth Fibonacci level. The high mean profits in the weekly and daily time frame are probably due to the fact that the larger time frame consists of larger Elliott wave patterns as explained in section 3.1.1. This means that when entering a trade in this larger pattern, the subsequent move will be far larger, and thus the profits will be far larger.

6.2.4. Statistical significance of the currency portfolio

The average percent returns were for none of the Fibonacci levels significantly higher than those from the simulated exchange rate series. Thus, for all the four currency pairs and the time frames combined, the Elliott wave trading strategy is not significantly profitable. This supports the null-hypothesis of non-profitability of the trading strategy, and it supports the notion that exchange rate series follow a random walk.

If we look at the average profits per time frame of the currency portfolio, we see that these results are the first time the simulated series is significantly outperformed by the EWTRAD trading strategy. In the hourly time frame, the mean profits per position are significantly higher for the second and third Fibonacci level. The significant profits per position are in support for the alternative hypothesis, which states that Elliott wave trading in combination with Fibonacci levels is profitable.

6.2.5. Profits per currency

Furthermore, the profits per currency pair are described in table 6.4. These are the mean profits per currency pairs for all the time frames combined. The highest profits are generated in the aud/usd pair. These profits span from 0.46% to 0.49%. In the eur/usd and usd/jpy pair the profits range from 0.35% to almost 0.4%. The usd/cad pair produced the lowest profits. They are between 0.3% and almost 0.33%. These results suggest that Elliott wave trading in combination with Fibonacci levels is less suited for usd/cad pair.

6.2.6. Statistical significance of profits per currency

Not any of the currency pairs show significantly higher profits for any of the Fibonacci retracement levels than the simulated series. All of the currency pairs showed less average profit per trade position than in the random walk exchange rate series. Therefore, the null hypothesis of non-profitability for Elliott wave trading cannot be rejected.

6.2.7. Profits per currency per time frame

For the EWTRAD pattern, mean profits for the hourly time frame for each of the currency pairs are similar to those found for the EWALT pattern. They range from 0.3% to 0.5%. For any of the currency pairs, the daily time frame the profits are quite a bit higher. They are about 1.7% to 2.8%.The EWTRAD pattern algorithm found more patterns in the weekly time frame than the EWALT pattern did, however for some currency pairs not enough patterns were found to perform the statistical tests. For the weekly patterns were this was possible, the average profits per position are the largest for any of the currency pairs or time frames.

6.2.8. Statistical significance of profits per currency per time frame

Again, for the EWTRAD pattern none of the mean profits per position in any time frame of any currency pair significantly outperformed the simulated series for any of the Fibonacci levels. These results fail to reject the null hypothesis.

6.3. PRAC pattern ex ante test

Here the obtained results from the PRAC pattern are recounted. The PRAC pattern only consists of a Wave 1 and a Wave 2 similar to a regular Elliot wave pattern. Besides, Wave 2 bounces of a Fibonacci level. As described in section 5.1.3 this is typically the point where a real time trader would place his or her trade in Elliott wave and Fibonacci trading.

6.3.1. Frequency statistics

The total number PRAC patterns were found amounted to 132,369. Because it is a less complex pattern than the general Elliott wave pattern, it was expected that the PRAC pattern would appear more frequently. In the frequency table can be seen that in 33504 patterns, Wave 2 retraced on the first Fibonacci level and 35,623 patterns on the second Fibonacci levels. Furthermore the second wave retraced 32,945 times on the third Fibonacci level and 30,206 times on the fourth Fibonacci level. As was explained in section 5.1.1, the lower the Fibonacci retracement level, the fewer patterns can be found.
Table 6.5 shows the number of PRAC patterns found for each currency pair investigated in the sample. The usd/cad pair again produced the most patterns. The algorithm observed 27.5% of all EWALT patterns found in this currency pair. The aud/usd pair produced 30,602 patterns which amounts to about 23.18% of all EW pairs found. The eur/usd currency pair generated the fewest patterns. About 22% of all EWALT patterns were observed for the eur/usd. The usd/jpy

pair generated approximately the same amount of patterns as the usd/cad pair did. About 27% of all PRAC patterns were found in this pair.

	Fibo 1	Fibo 2	Fibo 3	Fibo 4	Cumulative
aud/usd	8711	7965	7307	6619	30602
hour	8585	7860	7204	6536	30185
day	126	97	99	77	399
week	-	8	4	6	18
eur/usd	4834	8886	8212	7570	29502
hour	4706	8746	8100	7476	29028
day	126	136	108	90	460
week	2	4	4	4	14
usd/cad	10043	9495	8862	8232	36632
hour	9874	9361	8748	8139	36122
day	149	126	110	91	476
week	20	8	4	2	34
usd/jpy	9916	9277	8564	7876	35633
hour	9746	9139	8429	7770	35084
day	160	132	123	98	513
week	10	6	12	8	36
Currency portfolio	33504	35623	32945	30297	132369
hour	32911	35106	32481	29921	130419
day	561	491	440	356	1848
week	32	26	24	20	102

Table 6.5 Frequencies of PRAC patterns found by the algorithm for the hourly, daily, and weekly time frames of the aud/usd, eur/usd, usd/cad, and usd/jpy currency pairs and an equally weighted currency portfolio of those pairs.

Table 6.5 also shows the number of patterns the algorithm identified per time frame. Again, the hourly time frame produces the most patterns. About 98.6% of all the patterns found were in this time frame or about 130,419 patterns. For the daily time frame, the total number of patterns found is 1,848, or 1.33%. Unsurprisingly, the fewest patterns were observed in the weekly time frame. This again shows support for the notion of Elliott wave patterns being fractals.

6.3.2. Mean profits

In table 6.6, the mean profits per position for the PRAC pattern ex-post test is construed.
As can be seen, again all the obtained profits are positive yet very small. The mean profits per trade positioned opened range from 0.01% for several of the currency pairs, to 8% for the third Fibonacci level of the usd/cad pair in the weekly time frame.

	Fibo 1 profits	Fibo 2 profits	Fibo 3 profits	Fibo 3 profits

aud/usd	0.001	0.001	0.001	0.002
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0.001	0.001	0.002	0.001
	(.160)	*(.003)*	*(.894)*	*(.998)*
day	0.012	0.010	0.011	0.011
	(.679)	*(.519)*	*(.974)*	*(.470)*
week	0.000	0.028	0.002	0.042
	-	*(.713)*	*(.999)*	*(.839)*
eur/usd	0.001	0.001	0.001	0.001
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0.001	0.001	0.001	0.001
	(.999)	*(.128)*	*(.023)*	*(.000)*
day	0.003	0.011	0.102	0.011
	(.999)	*(.484)*	*(.355)*	*(.175)*
week	0.006	0.036	0.031	0.003
	-	*(.864)*	*(.849)*	*(.921)*
usd/cad	0.001	0.001	0.001	0.001
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0.000	0.001	0.001	0.001
	(.021)	*(.000)*	*(.000)*	*(.000)*
day	0.009	0.010	0.009	0.009
	(.196)	*(.062)*	*(.199)*	*(.094)*
week	0.021	0.017	0.080	0.023
	(.347)	*(.615)*	*(.328)*	-
usd/jpy	0.001	0.001	0.001	0.001
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0.001	0.001	0.001	0.001
	(.000)	*(.000)*	*(.000)*	*(.000)*
day	0.012	0.012	0.011	0.010
	(.032)	*(.089)*	*(.156)*	*(.218)*
week	0.023	0.008	0.041	0.037
	(.721)	*(.780)*	*(.385)*	*(.598)*
Currency portfolio	0.001	0.001	0.001	0.001
	(.999)	*(.999)*	*(.999)*	*(.999)*
hour	0.001	0.001	0.001	0.001
	(.106)	*(.000)*	*(.000)*	*(.000)*
day	0.010	0.011	0.010	0.010
	(.531)	*(.013)*	*(.084)*	*(.095)*
week	0.021	0.021	0.039	0.030
	(.853)	*(.457)*	*(.485)*	*(.626)*

6.3.3. Profits of the currency portfolio

The first Fibonacci level shows average position profits of 0.086%. For the second, third, and fourth Fibonacci levels the average profit per position is about 0.1%.

For the currency portfolio profits per trade position for the daily and weekly time frame are far higher than those of the hourly time frame. This might be because the hourly time produces more patterns. Thus it also produces more false Elliott wave pattern signals as explained in section 3.1.1. The positions rack up more losses, therefore the average profit per position drops. Mean profits per trade in the hourly time frame range from about 0.07% to 0.088% for all the Fibonacci levels. The profits per trade in the daily time frame averages at about 1% for all the Fibonacci levels. Moreover, in the weekly time frame the profits per trade position averages at about 2% for the first, and second Fibonacci level, 3% for the fourth Fibonacci level, and almost 4% for the third Fibonacci level.

6.3.4. Statistical significance of the currency portfolio

For the combined currency pairs, none of the average profits per trade outperformed the simulated exchange rate series' average profits per trade. This means that for the combination of the aud/usd, eur/usd, usd/cad, and the usd/jpy, on all the researched time frames, profits per position are insignificant. This is in support for the null hypothesis of non-profitability.

For all the separate time frames in the currency portfolio, the average profit per position did outperform those obtained from the simulated exchange rate series. However, for the weekly time frame, the outperformance was insignificant. The daily and hourly time frames do show significance, however. For the daily time frame, mean profits per trade for the second Fibonacci level are significantly higher than those obtained from a random walk. Furthermore, for the hourly time frame, mean profits per position for the second, third, and fourth Fibonacci levels are significant. This is in support for the alternative hypothesis, which states that Elliott wave trading in combination with Fibonacci levels is profitable.

6.3.5. Profits per currency

In table 6.6 mean profits per trade position, for each currency pair in the sample, are depicted. For all Fibonacci levels, the aud/usd pair produced the highest average profits per position. The aud/usd profits averages about 0.14% to 0.15% per position. The usd/jpy mean profits approaches the aud/usd pair for the third and fourth Fibonacci level. These are approximately 0.1%. For the first and second Fibonacci level, the means are similar to those of the eur/usd pair and the usd/cad pair. These range from 0.06% to 0.08%. All-in-all the average profits per position, are all positive for the different currency pairs, yet they are quite small.

6.3.6. Statistical significance of profits per currency

None of the mean profits per trade are higher than those obtained from the simulated exchange rate series. This entails that the profits per currency pair, for all the researched time frames, are all insignificant in comparison to those from a random walk. This supports the null hypothesis of non-profitability.

6.3.7. Profits per currency per time frame

All mean profits per currency per time frame are very similar to those of the currency pairs for the time frames combined. The largest mean profits per position are found are in the weekly time frame of the usd/cad pair. Here, the PRAC patterns that bounced on the third Fibonacci level produced an average profit of 8%. Lowest mean profits are found in the hourly time frames for any of the currency pairs. They hover around the 0.1% level per position.

6.3.8. Statistical significance of profits per currency per time frame

Looking at the different time frames for a given currency pair, several times the average profits per position significantly outperform the simulated series. Average profits are significant for the aud/usd pair for the second Fibonacci level in the hourly time frame and for the third and fourth Fibonacci level in the hourly time frame of the eur/usd pair. Furthermore, for any of the Fibonacci levels in the usd/cad and usd/jpy hourly time frame and for the first Fibonacci level in the usd/jpy daily time frame mean profits are significant as well.

7. Discussion

This section discusses the mean profits obtained and their significance. They will be put into perspective by methods described in sections 5.3. First, the mean profits will be compensated for transaction costs. Then, any remaining significant profits will be checked for risk compensation buy comparing Sharpe ratios. Finally, the profits will be compared to an annual buy-and-hold strategy.

7.1. Transaction costs

In order to check if the obtained profits hold up in a real time trading, the profits will be compensated for transaction costs. The transaction costs are the 3 basis point bid-ask spread, as explained in section 5.3.2. I.e. the significant profits are deducted 0.0003 or 0.03%. For only some of the mean profits per position, the transaction costs slightly reduced these mean profits. This was especially the case in the hourly time frames. In the daily and weekly time frames, where mean profits are higher, the correction of transaction costs had even less influence. Moreover, after accounting for transaction costs, the obtained significant mean profits all remained significant.

7.2. Risk

As explained in section 5.3.4, in order to check if the obtained significant profits are not a result of risk compensation, the Sharpe ratio of the annualized profits will be calculated. For the PRAC pattern, mean profits are significant for the daily time frame for the currency portfolio and the usd/jpy currency pair.
Furthermore, mean profits are significant in the hourly time frames for all the currency pairs and the currency portfolio as well. The Sharpe ratios of these returns are compared to that of the S&P500, which is 0.25 for the sample period.
As a proxy for the risk free rate, the three month US Treasury bill rate was used. This 0.03% on July 24^{th} 2013. The Sharpe ratios of the daily and hourly time frames for the PACT pattern are depicted in table 7.1 and 7.2.

	fibo 1	fibo 2	fibo 3	fibo 4
aud/usd	-	3,50	-	-
eur/usd	-	-	2,18	2,31
usd/cad	1,72	2,13	2,27	2,38
usd/jpy	2,37	2,65	2,82	2,96
currency portfolio	-	2,57	2,70	2,80

Table 7.1 The Sharpe ratios for actively trading the PRAC pattern in the daily time frame. The Sharpe ratios per Fibonacci retracement level for the aud/usd, eur/usd, usd/cad, and usd/jpy the currency pairs and the currency portfolio are depicted.

	fibo 1	fibo 2
aud/usd	-	-
eur/usd	-	-
usd/cad	-	-
usd/jpy	0,42	-
currency portfolio	-	2,83

Table 7.2 The Sharpe ratio for actively trading the PRAC pattern in the hourly time frame. The Sharpe ratios for first and second Fibonacci level for the usd/jpy currency pair and the currency portfolio are depicted.

Looking at the Sharpe ratios for the PRAC pattern they all dominate the S&P500. Thus, the significant returns are not compensating for extra risk taken. This is in support for the alternative hypothesis. However, this measure does not provide information on statistical significance. It should also be noted, that Sharpe ratios can be overstated when underlying returns are not normally distributed.

7.3. Buy-and-hold

As mentioned in section 5.3.3, Malkiel (1990) states that a buy and hold strategy is always preferable to actively trading financial assets. Therefore, for support of the null hypothesis of non-profitability of Elliott wave and Fibonacci trading, an annualized buy and hold strategy must outperform the annualized obtained significant profits.

The average annual buy and hold return for S&P500 is 4.57%. The annualized buy and hold return for the aud/usd is 7%, and 4.8%, for the eur/usd the usd/cad has a negative buy and hold return of -4.8%. The usd/jpy has a negative buy and hold return as well, which amounts to -1.8% The average annual buy hold return for the equally weighted currency portfolio of the aud/usd, eur/usd, usd/cad, and usd/jpy currency pairs is 1.30% over the sample period.

Here, the pattern of interest is in the PRAC pattern, since we are comparing a live and active trading strategy to a simple buy-and-hold strategy. Since the Elliott wave strategy is an active investment strategy, non-trading hours need to be accounted for. If a trader wants to trade the Elliott wave trading strategy, he or she cannot hold an open Elliott wave position for a year nor can he or she be actively trading 24/7 for a year. Therefore, an active trading period per year for a trader is assumed. Outside of this time period, the traders' money is in a risk free savings account.

The first assumption is that there are 250 trading days a year, and the trader is trading 8 hours per day. This amounts to 2,000 trading hours. There are 8,766 hours per year. This leads to 6,766 hours the investors' money is in a risk free savings account that has an annualized return of 1.76%[8]. Furthermore, the second assumption is that the trader invests his or hers entire capital when entering a trade, thus the trader cannot hold more than one open position at a time. For hourly frames there were enough patterns found that it is assumed the trader is practically able to enter a PRAC whenever he or she is actively trading. The daily time frame showed a pattern every other day. Therefore, the trader can enter a trade once every two days.
In table 7.3, the average trading days, average significant profits per position, and annualized buy and hold returns are depicted, for each of the different currency pairs in the hourly time frame. Table 7.4 shows these for the daily time frame.

		fibo 1	fibo 2	fibo 3	fibo 4
aud/usd	*mean holding period per position*	-	15.855	-	-

8 http://www.federalreserve.gov/releases/h15/data.htm

	mean profits per position	-	0.001	-	-
	annualized buy and hold return	-	0.196	-	-
eur/usd	*mean holding period per position*	-	-	15.585	15.440
	mean profits per position	-	-	0.001	0.001
	annualized buy and hold return	-	-	0.100	0.105
usd/cad	*mean holding period per position*	15.725	15.579	15.457	15.332
	mean profits per position	0.000	0.001	0.001	0.001
	annualized buy and hold return	0.072	0.103	0.109	0.114
usd/jpy	*mean holding period per position*	15.761	15.680	15.522	15.387
	mean profits per position	0.001	0.001	0.001	0.001
	annualized buy and hold return	0.107	0.121	0.130	0.137
currency portfolio	*mean holding period per position*	-	15.702	15.587	15.462
	mean profits per position	-	0.001	0.001	0.001
	annualized buy and hold return	-	0.122	0.128	0.134

Table 7.3 The mean holding period per position, mean profits per position, and the annualized buy and hold returns for actively trading the PRAC pattern in the daily time frame for the aud/usd, eur/usd, usd/cad, and usd/jpy currency pairs and the currency portfolio for all Fibonacci retracement levels.

		fibo 1	fibo 2	fibo 3	fibo 4
usd/jpy	*mean holding period per position*	15.414	-	-	-
	mean profits per position	0.001	-	-	-
	annualized buy and hold return	0.023	-	-	-
currency portfolio	*mean holding period per position*	-	15.298	-	-
	mean profits per position	-	0.011	-	-
	annualized buy and hold return	-	0.106	-	-

Table 7.4 The mean holding period per position, mean profits per position, and the annualized buy and hold returns for actively trading the PRAC pattern in the hourly time frame for the usd/jpy currency pair and the currency portfolio for the first and second Fibonacci retracement level.

For the hourly time frame, all the buy and hold returns from actively trading Elliott waves are substantially higher than those of the S&P500, the different currency pairs, and the currency portfolio. For the daily time frame, the usd/jpy Fibonacci level 1 patterns show a substantially lower buy and hold return than the S&P500. Yet, it is higher than the currency portfolio and the usd/jpy passive buy and hold returns. Furthermore, the Elliott wave trading in the combined currency portfolio also shows substantially higher buy and hold returns. These results support the alternative hypothesis of Elliott wave trading profitability.

7.4. Statistically significant profits

Even though some of the mean profits obtained seem to be statistically significant and still hold up after adjusting for transaction costs and risk, the null hypothesis cannot be rejected on basis of this alone. There is always a chance of the significant results occurring randomly. Due to the sheer number of statistical tests performed, a fair amount of results has to be significant in order to avoid type I errors. In this case, 14 significant mean profits are obtained form 240 hypothesis tests. Thus, about 6% of all tests performed returned a significant result.

For the EWALT ex-post tests not one test showed a significantly higher result than the simulated series. Of all the EWTRAD ex-post tests performed, a mere 2.5% of the tests returned a significantly higher profit than the simulated series.
The PRAC ex ante test returned the most significant results. Of all PRAC tests executed, 20% returned a significant higher mean profit per position than the simulated series. Given the 5% significance level, the total of 6% of significant results is a number too weak to reject the null hypothesis with a high degree of certainty. This is especially the case for the two ex-post tests performed. The number of significant results did not break the 5% level, and thus the null hypothesis can definitely not be rejected on the basis of these significant results.

For the PRAC pattern however, the 20% of significant results does exceed the 5% level quite a bit. These results have been analyzed further for several factors that could have led to their significance. The profits were compensated for transaction costs by deducting 3 basis points, the average transaction costs in foreign exchange markets as explained in section 5.3.2. Compensating for transaction costs had little effect on the significance.

After this, Sharpe ratios of the significant mean profits were calculated. This was done in order to check if the significant profits are not the results of risk compensation. The Sharpe ratios were compared to the S&P500. All of them exceeded the S&P500 Sharpe ratio. This implies the significant returns are not compensation for extra risk taken on.

Finally, in order to check if actively investing using the Elliott wave trading strategy is rational, the significant profits were transformed to an annual return and then compared to an annual buy-and-hold strategy in the foreign exchange market. Actively trading the Elliott wave strategy outperformed a simple buy-and-hold strategy in the S&P500, the individual currency pairs, and the currency portfolio. Only the usd/jpy Fibonacci level 1 mean profit in the daily time frame was outperformed by a buy and hold in the S&P500, yet it outperformed the currency portfolio and the usd/jpy buy and hold returns.

Thus, actively trading the PRAC pattern does seem to be significant for all the currency pairs under investigation. However, given the fact that both of the ex-post tests of Elliott wave profitability barely showed any significance, concluding that Elliott wave trading in combination with Fibonacci retracement levels is profitable is equivocal at best. Therefore, given all the results of this thesis, the null hypothesis cannot be rejected with absolute certainty.

8. Conclusion

This thesis has investigated a specific technical analysis technique in the foreign exchange market. Technical analysis directly opposes the efficient market hypothesis, a theory that has a solid basis in financial literature. Yet, many practices in the financial world are not in line with this theory. One of them is technical analysis in trading financial assets. The use of Elliott waves and that of Fibonacci retracement levels are a common technical analysis technique. However, research on these techniques, especially the combined use of them is scarce. This study set out to determine the profitability of the combined use of Elliott waves and Fibonacci levels.

Since Elliott wave trading employs the use of pattern recognition, a technique that can be very subjective, an objective and replicable trading strategy was defined. This strategy was applied to four different currency pairs, namely the Australian and US dollar, the Euro and the US dollar, the US dollar and the Canadian dollar, and the US dollar and the Japanese Yen. These were chosen because they rank among the most trader currencies in the world, yet are not substantially correlated to one another. The sample period used was 2005-2013, thus including pre-crisis, mid-crisis, and post-crisis data.

The trading strategy was broken down into three different tests. Two ex-post tests were performed to investigate whether the Elliott wave and Fibonacci retracement theory had any rational and valid basis in reality. Additionally, an ex-ante test was performed to simulate and test if a real trader employing the trading strategy would have been profitable if he used the strategy in the sample period. For all tests algorithms were constructed and applied to the data. The algorithms produced profits, which were tested for statistical significance. Profits in foreign exchange rate markets do not appear to follow a normal distribution. Therefore, testing for statistical significance was done by comparing the obtained profits to a simulated random walk exchange rate series. Any Elliott wave and Fibonacci retracement profits in a random walk series are arbitrary and should hold no value.. Therefore, in order for trading strategy to be profitable, the actual obtained profits have to be significantly higher than the profits obtained from the random walk series.

The results show no conclusive evidence of significant profitability of the Elliott wave and Fibonacci retracement level trading strategy in the currency pairs under investigation. In some cases, profits did show some significance. The profits were adjusted for transaction costs and risks. Furthermore, to check for rationality in actively trading the strategy posed by this thesis, significant profits were compared to simple buy-and-hold strategies. However, there were not enough significant profits obtained, compared to the number of statistical tests that were performed, to dismiss the notion that these significant profits arose randomly. For the PRAC pattern however, enough significant profits were obtained. Even after accounting for transaction costs and risks, these profits showed no signs of faltering. Furthermore, these mean profits also outperformed the buy-and-holds returns. However, considering the results altogether, not enough substantial and conclusive evidence was found to reject the null hypothesis with certainty. Thus, the null hypothesis which states that Elliott wave and Fibonacci retracement level trading is not profitable, is not rejected. The results of this research do not reject the idea of the efficient market theory with certitude.

A number of caveats need to be noted regarding this research. First, returns on currencies are not regarded as following a normal distribution. In order to counter this, the bootstrap simulated series were used to account for statistical significance of profits. Yet, the statistical t-tests that were employed do assume a normal distribution. Although, this does not have to be problem for large sample sizes which this study utilizes. However, it might have distorted the results. Secondly, the data used was smoothed by a three period moving average. Data might still show too much noise, and thus a moving average with larger periods should be used. This might enable the algorithm to identify patterns better. Furthermore, for this research one-tailed t-tests might have been more appropriate. However, in the author's opinion, the two-tailed tests failed to produce enough significant returns to reject the null hypothesis. If one-tailed tests would have been used, fewer significant returns would have been obtained, and thus the same conclusion would have been drawn.
Finally, appropriately adjusting for risk in excess returns in foreign exchange speculation is ambiguous. In this research the Sharpe ratio was chosen to account for risk. Yet Sharpe ratios can be distorted when returns are not normally distributed. Furthermore, they do not provide information statistical significance. A more pertinent risk accounting measure might be available.

The present study does not reject the weak form efficient market theory. On the other hand, the trading strategy of Elliott wave and Fibonacci retracement levels did not generate any significant profit for the currency pairs used in the sample and for the time-period used in the sample. Further research should be done on trading the Elliott wave pattern and Fibonacci levels in practice, since this section of this thesis did appear to show significant risk-adjusted profits. Moreover, further research on Elliott wave theory could select a different sample period, different currency pairs, or even a different financial asset category such as stocks. To conclude, results of this study are ambivalent, and considerably more work will need to be done to determine effectiveness of technical analysis and the effectiveness Elliott waves and Fibonacci retracement levels in particular.

9. References

Allen, F. and Karjalainen, R. (1993). *Using genetic algorithms to find technical trading rules,* Wharton School Rodney L. White Working Paper, pp.20-93.

Allen, H. and Taylor, M.P. (1992), *The use of technical analysis in the foreign exchange market,* Journal of International Money and Finance vol. 11, pp. 304-314.

Alexander, S.S. (1961), *Price Movements in Speculative Markets: Trends or Random Walks,* Industrial Management Review, vol. 2, pp. 7-26.

Atmeh, M.A. and Dobbs, I.M. (2006), *Technical analysis and the stochastic properties of the Jordanian stock market index return,* Studies in Economics and Finance vol. 23, pp. 119-140.

Balasundram, S., Chatterjee, A., and Ayadi, F., (2002), *The Applications of the Fibonacci sequence and Elliott Wave Theory in predicting the security price movements: a survey*. Journal of Commercial Banking and Finance, vol. 1, pp. 65-76

Banz, R.W. (1981), *The Relationship Between Return and Market Value of Common Stocks,* Journal of Financial Economics, pp. 93-18.

Bettman, J.L., Sault, S.J., and Schultz, E.L. (2009), *Fundamental and technical analysis: substitutes or complements?,* Accounting and Finance vol. 49, pp. 21–36.

Blackledge, J., Murphy, K. (2011), *Forex trading using MetaTrader 4 with the fractal market hypothesis*, The Third International Conference on Resource Intensive Applications and Services, vol: 978-1-61208-006-2, pp.1-9.

Brock, W., Lakonishok, J. and Lebanon, B. (1992), *Simple technical trading rules and the stochastic properties of stock returns*, Journal of Finance, vol. 47, pp. 1731-64.

Chang, P.H.K. and Osler, C.L. (1999), *Methodical Madness: Technical Analysis and the Irrationality of Exchange Rate Forecasts,* The Economic Journal vol. 109 pp. 636-661.

Chen, T., Cheng, C., and Teoh, H.J. (2007), *Fuzzy time-series based on Fibonacci sequence for stock price forecasting,* Physica A: Statistical Mechanics and its Applications, vol. 380. pp. 377-390.

Cheol-Ho Park, C. and Irwin, S.H. (2007), *What do we know about the profitablity of technical analysis?,* Journal of Economic Surveys vol. 21, pp. 786–826.

Cheung, Y., Chinn, M.D. (1999), *Macroeconomic Implications of the Beliefs and Behavior of Foreign Exchange Traders,* NBER working paper 7417.

Chong, T.T. and Ng, W. (2008). *Technical analysis and the London stock exchange: testing the MACD and RSI rules using the FT30,* Applied Economics Letters. vol. 15, pp. 1111–1114.

Collins, C.J. (1938), *The Wave Principle.*

Dadush, U. and Eidelman, V. (2010), *Exchange Rates and the Crisis: The Dog That Didn't Bark,* Retrieved from http://carnegieendowment.org/2010/02/10/exchange-rates-and-crisis-dog-that-didn-t-bark/36u9

Dash, M., and Patil, A. (2009), *An Exploratory study of Elliot Wave Theory in Indian Stock Markets,* Available at SSRN: http://ssrn.com/abstract=1412733.

Elliott, R.N. (1946), *Nature's Law - The Secret of the Universe.*

Eng, W. F. (1997), *Technical Analysis of Stocks, Options & Futures.* Homewood, IL, Irwin Professional Publishing Inc.

Fama, E. and Blume, M. (1966), "Filter rules and stock market trading", Journal of Business, vol. 39, pp. 226-41.

Fama, E.F. (1970), *Efficient Capital Markets: A Review of Theory and Empirical Work,* Journal of Finance vol. 25, pp. 383-417.

Fischer, R. (1993), *Fibonacci Applications & Strategies for Traders: Unveiling the Secret of the Logarithmic Spiral.* New York, NY, J. Wiley & Sons, Inc.

Gupta, N. (2011), *Fibonacci Retracements and Self-Fulfilling Prophecy.* Honors Projects, Paper 41, http://digitalcommons.macalester.edu/economics_honors_projects/41

Hamilton, W.P. (1922), *The Stock Market Barometer.*
Hartle, T. (1997), *Fibonacci Trader Product Review.* Stock & Commodities Magazine, November, pp. 1-15.

Irwin, S.H. and Park, C.H. (2004), *The Profitability of Technical Analysis: A Review.* AgMAS Project Research Report vol. 2004-04. Available at SSRN: http://ssrn.com/abstract=603481

Keim, D. (1983), *Size-Related Anomalies and Stock Return Seasonality: Further Empirical Evidence,* Journal of financial economics, vol. 12, pp. 13-32.

Krausz, R. (1998), *New Gann Swing Charist Dynamic Fibonacci Channels.* Fibonacci Trader Journal, vol. 1, pp. 1-8.

LeBaron, B. (1990), "Technical trading rules and regime shifts in foreign exchange", working paper, University of Wisconsin-Madison.

Leitch, G. and Tanner, J. E. (1991). *Economic forecast evaluation: profits versus the conventional error measures,* American Economic Review, vol. 81, pp. 580-670.

Levich, R. M., and Thomas, L. R. (1993), *The significance of technical trading rule profits in the foreign exchange market: a bootstrap approach.,* Journal of International Money and Finance vol. 12, pp. 451-474.

Levy, R.A. (1971), *The Predictive Significance of Five-Point Chart Patterns,* The Journal of Business, vol. 44, pp. 316-323.

Lien, K. (2010) *Using Currency Correlations To Your Advantage.* Retrieved from http://www.investopedia.com/articles/forex/05/051905.asp

Liu, W. and Zheng, W.A. (2011), *Stochastic volatility model and technical analysis of stock price.* Acta Mathematica Sinica, English Series. vol. 27, pp. 1283–1296.

Lui, Y.-H., Mole, D., (1998), *The use of fundamental and technical analysis by foreign exchange dealers: Hong Kong evidence,* Journal of International Money and Finance vol. 17, pp. 535–545.

Magazzino, C., Mele, M., and Prisco, G. (2012), *The Elliott's Wave Theory: Is It True during the Financial Crisis?,* Journal of Money, Investment and Banking, vol. 24.

Malkiel B. G. (1990), *A Random Walk Down Wall Street*, Fifth Edition, New York: W.W. Norton & Co.

Marshall, B.R., Rose, L.C., and Young, M.R. (2006), *Candlestick technical trading strategies: Can they create value for investors?,* Journal of Banking & Finance vol. 30, pp. 2303-2323.

Menkhoff, L. and Schlumberger, M. 1995. Persistent Profitability of Technical Analysis on Foreign Exchange Markets?, BNL Quarterly Review vol. 193, pp. 189-216.

Menkhoff, L. (1998), *The noise trading approach - questionnaire evidence from foreign exchange,* Journal of International Money and Finance vol. 17, pp. 547-564.

Menkhoff, L. and Taylor, M.P. (2007), *The Obstinate Passion of Foreign Exchange Professionals: Technical Analysis.* Journal of Economic Literature vol. 45, pp. 936-972.

Menkhoff, L. (2010), *The use of technical analysis by fund managers: International evidence,* Journal of Banking & Finance vol. 34, pp. 2573-2586.

Murphy, J. (1999), *Technical analysis of financial markets.* New York: Prentice Hall.

Neely, C. J. (1997) *Technical analysis in the foreign exchange market: A layman's guide*, Federal Reserve Bank of St. Louis Review, vol. 79, no. 5, pp. 23-38.

Neely, C.J. and Weller, P.A. (2011), *Technical Analysis in the Foreign Exchange Market,* Retrieved from http://research.stlouisfed.org/wp/2011/2011-001.pdf

Osler, C.L. (2000) *Support for Resistance: Technical Analysis and Intraday Exchange Rates*. Federal Reserve Bank of New York Economic Policy Review, vol. July.

Papadamou, S. & Tsopoglou, S. (2001), *Investigating the profitability of technical analysis systems on foreign exchange markets,* Managerial Finance vol. 27, pp. 63-78.

Penteado, M.A. (2013), *Efficient Markets, Behavioral Finance and a Statistical Evidence of the Validity of Technical Analysis*. Cornell University Library.

Plummer, T. (1989), *Forecasting Financial Markets: The Psychological Dynamics of Successful Investing*. 3rd Edition. Boston, MA, Kogan Page Inc.

Plummer, T.(1993), *The Psychology of Technical Analysis; Profiting from Crowd Behavior and the Dynamics of Price*. Boston, MA, McGraw Hill, Inc.

Poser, S.W. (2003), *Applying Elliot Wave Theory Profitably*. John Wiley & Sons.

Prechter, R.R, Jr. (2005), *R.N. Elliott's Masterworks The Definitive Collection,* Second Edition, New Classics Library.

Ramadorai, T. (2008), *What Determines Transaction Costs in the Foreign Exchange Markets?*, International Journal of Finance and Economics, vol. 13, pp. 14-25.

Reinganum, M. R. and J. K. Smith, (1983), *Investor preference for large firms: New evidence on economies of size,* Journal of Industrial economics, vol. 32, pp. 231-227.

Reitz, S. (2006). *On the predictive content of technical analysis*. North American Journal of Economics and Finance, vol. 17, pp. 121–137.

Reszat, B. (1987). *Technical analysis and computer trading*. Intereconomics, vol. May/June.

Rhea, R. (1932), *The Dow Theory*.

Naveen, K. and Sanjay, M. (2013), *The use of technical and fundamental tools and techniques in the Indian stock exchange,* Asian Journal of Research in Business Economics and Management. vol. 3, pp. 269-297.

Samuelson, Paul A. (1965) *Proof That Properly Anticipated Prices Fluctuate Randomly*. Industrial Management Review, vol. 6:2 pp. 41.

Sweeney, R. (1986), *Beating the foreign exchange market*. Journal of Finance vol. 41, pp.163-182.

Allen, H. and Taylor, M.P. (1992), *The use of technical analysis in the foreign exchange market,* Journal of International Money and Finance, vol. 11, pp. 304-314.

Watson, T.D, (2009), *On the protability of technical trading,* Durham theses, Durham University. Available at Durham E-Theses Online:http://etheses.dur.ac.uk/198/

Yamamoto, R. (2012), *Intraday technical analysis of individual stocks on the Tokyo Stock Exchange*, Journal of Banking & Finance vol. 36, pp.3033–3047.

Appendix I

```
%variable list%
v = input('enter vector of exchange rates')
j = 1:length(v);
x = [  ];
z = [  ];
b=[x;z];
profits = [  ];

%set counter i = start:stepsize:finish%
for i=2:1:length(v)-1;

    %finding peaks and valleys%
    if v(i) <= v(i+1)&& v(i-1) >= v(i)||v(i) >= v(i+1)&& v(i-1)  <=
     v(i);

        %putting the peaks and valleys in a new matrix b%
        x = [x v(i)];
        z = [z j(i)];

        x=x([1,diff(x)]~=0);
        z=z([1,diff(x)]~=0);

        b=[x;z];

    end

end

%set new counter n = start:stepsize:finish%
for n=3:1:length(x)-4;

      %check for Elliott wave pattern
      if x(n)< x(n-1) && x(n)>=x(n-2)&& x(n+1)>x(n-1)&& x(n+2)>x (n-1);

            if x(n+1)-x(n)>= x(n-1) - x(n-2) ||  x(n+1)-x(n)>= x
            (n+3) - x(n+2);

                 %check for time intervals%
                 if z(n)-z(n-1)<=(0.382*(z(n-1)-z(n-2))) && z(n+
                  1)-z(n)<=(1.618*(z(n-1)-z(n-2))) && z(n+2)-z(n+1)
                  <=(0.382*(z(n+1)-z(n))) && z(n+3)-z(n+2)<=(1.618*
                  (z(n+1)-z(n)));

                 %check for Fibo retracement 1 hits, for other Fibo
                  levels replace 0.236 with other fibo ratios%
                 if x(n)<= (x(n-1)-((x(n-1)-x(n-2))*0.236))*1.001
                  && x(n)>= (x(n-1)-((x(n-1)-x(n-2))*0.236))*0.999;
```

```
                %profits after exit signal and entry is price
                exiting top of Fibonacci range, for other Fibo
                levels replace 0.236 with other fibo ratios%%
                disp(((0.999*x(n+3))-((x(n-1)-((x(n-1)-x(n-2))*
                0.236))*1.001))/((x(n-1)-((x(n-1)-x(n-2))*0.236))
                *1.001))

                end

                end

            end

        end

    end
```

Appendix II

```
%variable list%
v = input('enter vector of exchange rates')
j = 1:length(v);
x = [  ];
z = [  ];
b=[x;z];
profits = [  ];

%set counter i = start:stepsize:finish%
for i=2:1:length(v)-1;

    %finding peaks and valleys%
    if v(i) <= v(i+1)&& v(i-1) >= v(i)||v(i) >= v(i+1)&& v(i-1)   <=
     v(i);

        %putting the peaks and valleys in a new matrix b
        x = [x v(i)];
        z = [z j(i)];

        x=x([1,diff(x)]~=0);
        z=z([1,diff(x)]~=0);

        b=[x;z];

    end

end



%set new counter n = start:stepsize:finish%
for n=3:1:length(x)-4;

     %check for Elliott wave pattern
     if x(n)< x(n-1) && x(n)>=x(n-2)&& x(n+1)>x(n-1)&& x(n+2)>x  (n-1);

          if x(n+1)-x(n)>= x(n-1) - x(n-2) ||  x(n+1)-x(n)>= x
          (n+3) - x(n+2);

               %check for Fibo retracement 1 hits, for other Fibo
               levels replace 0.236 with other fibo ratios%
               if x(n)<= (x(n-1)-((x(n-1)-x(n-2))*0.236))*1.001
               && x(n)>= (x(n-1)-((x(n-1)-x(n-2))*0.236))*0.999;
```

```
                %profits after exit signal and entry is price exiting
                top of Fibonacci range, for other Fibo levels replace
                0.236 with other fibo ratios%%
                disp(((0.999*x(n+3))-((x(n-1)-((x(n-1)-x(n-2))*
                0.236))*1.001))/((x(n-1)-((x(n-1)-x(n-2))*0.236))
                *1.001))

                end

           end

      end

end
```

Appendix III

```
%variable list%
v = input('enter vector of exchange rates')
j = 1:length(v);
z = [  ];
profits = [  ];

%set counter i = start:stepsize:finish%
for i=2:1:length(v)-1;

    %finding peaks and valleys%
    if v(i) <= v(i+1)&& v(i-1) >= v(i)||v(i) >= v(i+1)&& v(i-1)   <=
     v(i);

        %putting the peaks and valleys in a new matrix b%
        x = [x v(i)];
        z = [z j(i)];

        x=x([1,diff(x)]~=0);


    end

end

%set new counter n = start:stepsize:finish%
for n=3:1:length(x)-4;

     %check for Elliott wave pattern
     if x(n)< x(n-1) && x(n)>=x(n-2)

           %check for Fibo retracement 1 hits, for other Fibo
           levels replace 0.236 with other fibo ratios%
           if x(n)<= (x(n-1)-((x(n-1)-x(n-2))*0.236))*1.001 && x
           (n)>= (x(n-1)-((x(n-1)-x(n-2))*0.236))*0.999;

           %profits after exit signal and entry is price
           exiting top of Fibonacci range, for other Fibo
           levels replace 0.236 with other fibo ratios%%
           disp(((0.999*x(n+3))-((x(n-1)-((x(n-1)-x(n-2))*0.236))
           *1.001))/((x(n-1)-((x(n-1)-x(n-2))*0.236))*1.001))

           end

     end

end
```