TRADING SYSTEM FOR AUSTRALIAN DOLLAR USING MULTIPLE MOVING AVERAGES AND AUTO-REGRESSIVE MODELS.

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Abstract: This paper tested two of the simplest and most popular trading rules – Auto-Regressive Models and Moving Averages – by utilising the Australian Dollar relative to US Dollar from 1 Jan 1986 to 9 June 1999. This data set was used by Tan [1995, 1997] in his study in comparing the profitability of systems based on Artificial Neural Networks and ARIMA models.

Similar works were done earlier [LeBaron et al. 1995] which utilised Dow Jones index from 1897 to 1986. This paper did not utilise any index data due to the inconsistency of its composite stocks from time to time. The main reason for using the techniques was that they were simple to interpret and calculate, and seemed to work quite well in trending markets.

Trading rules were derived from the short and long-term moving averages with the trading signals based on the differences between the two. Combination of relatively longer period moving averages generally outperformed the shorter period moving averages. This was probably the result of eliminating unprofitable whipsaw trades. Buying (selling) signals were generated if the short (long) period moving average crossed above (below) the long (short) period moving average. Certain bands or filters were introduced to reduce the number of unnecessary trades that signals were only generated if the differences between the moving averages exceeded the interest rate differentials and foreign exchange spreads. Periods used were 5, 10, 15, 20 and 25 days for the short-term and 50 to 100 days for the long-term periods. Extensive tests to compare each and every moving average periods to find the best profit were carried out and the highest percentage of winning trades over the test period.

The work was extended to utilising support and resistance line as a filter to the buying or selling signals. Trading signals were generated only if the period tested was at the local minimum or maximum, or in other words, identifying key reversal areas. Results confirmed that the use of two-period moving averages with auto-regressive models outperform the simple single-period moving averages. The use of support and resistance lines as part of the filter rules will help a trading system to eliminate unnecessary trading, even though the overall performance does not outperform the previous two models.

Keywords: Moving Averages, Short and Long Term Moving Averages, Auto-Regressive Models, Trading Systems, Foreign Exchange, Australian Dollar Market, Random Walk Theory, Technical Analysis, Support and Resistance, Trading Break-out Rules.

JEL Classification Number: F47 - Forecasting and Simulation

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1 Introduction

Forecasting foreign exchange rates or profiting from trading foreign exchange has been an extremely difficult task and most previous studies have shown little or no success in their attempts to predict foreign exchange market. Recently, this has been changing in both academic communities and financial industries. This paper presents the main features of one model or trading system being developed to generate profits out of trading foreign exchange. Traders considered these exchange rates to have persistent trends that permitted mechanical trading systems (systematic methods of repeatedly buying and selling on the basis of past prices and technical indicators) to consistently generate net profits with relative acceptable amount of countable risk. On the other hand, some other researchers presented evidence supporting the random walk hypothesis, which implies that rate changes are independent and have identical statistical distributions. When prices follow random walk, the only relevant information in the historical series of prices, for traders, is the most recent price. The presence of a random walk in a currency market is a sufficient condition to the existence of a weak form of the efficient market hypothesis, i.e. that historical price movements could not be used to predict future prices.

While there is no final word agreed between traders and academicians about the efficiency of the foreign exchange market, the old fashioned view in economic books that exchange rates follow a random walk has been dismissed by many research works [Tenti 1996]. There is however strong evidence indicating the returns are not independent of past changes.

The term ***"Technical Analysis"*** is believed to be the original form of investment analysis [LeBaron 1995]. Technical Analysis attempts to forecast prices by studying the historical prices and a few related summary statistics about trading securities. From the Technical Analysis literature, works by LeBaron et al. [1995], provided strong support for the technical analysis being able to predict some variability on the financial markets. They tested the two most popular trading rules – Moving Averages and Trading Range Break by utilising the Dow Jones Index from 1897 to 1986.

The standard statistical analysis is extended through the use of bootstrap techniques and still found the techniques to be worth considering. The results of their research are consistent with the popular belief that technical rules have predictive power and outperform some other techniques. It shows that the rule-generating process of stocks is probably more complicated than suggested by the various other studies using linear models.

It is quite possible that technical rules are able to identify some of the patterns otherwise hidden. This seems to be the case as the authors emphasise that their successful systems were based on the simplest trading rules such as moving average techniques.

However, other factors that need to be carefully considered were overlooked in their research. Transaction and brokerage costs should be included in the trading system calculation before they would be practically implemented.

In this paper, similar test will be performed using foreign exchange data, since indices change their composite stocks from time to time, therefore distorting the forecasting

outcomes. Further more, in real life, one would be interested not only in efforts in forecasting but also in practical trading strategies with possibility of taking positions in the market. Tsoi, Tan and Lawrence [1993] in their earlier studies have shown that the direction of the forecast is more important than the actual forecast itself in determining the profitability of a model.

Thus, the effort is always on to beat the market by superior techniques. For that reason, the work was further extended to build a trading system based on the rule-generating process over thirteen-year period. Again, this cannot go on forever as the market can 'learn' and adapt to such techniques and strategies and can start following them. This confirms the economic theory of Efficient Market Hypothesis, which in its weakest form states that future prices cannot be predicted based on the past.

One of the limitations to this test is that Technical Analysis or Time Series Analysis techniques do not include or take into account a number of factors such as macro-economical or political effects, whether it be national or international, which may seriously influence the foreign currency market. Technical Analysis as its name suggests does not study the cause of the price move; it is the studies of the pattern of the price movements.

1.1 Data

In this exercise the time series data being used are as follows:

- Closing price of Australian Dollar quoted on weekly basis relative to US Dollar between 1st January 1986 and 23rd June, 1999, obtained from the Reserve Bank of Australia,
- The weekly Australian closing cash rate in Sydney from 1st January 1986 to 23rd June 1999 and obtained from the Reserve Bank of Australia,
- The weekly closing US Fed Fund rate in New York from 1st January 1986 to 23rd June 1999 and obtained from Federal Reserve Bank of Chicago, USA.

The optimum technical model is built using the in-sample data, starting from 1st January 1986 to 25th July 1998. The model is then tested on out-sample data from 2nd August 1998 to 23rd June 1999 and profits were calculated from the trades on those dates.

2 Research Methodology and Results

Two of the simplest and most widely used technical rules are investigated: Moving-Average Oscillator and Auto-Regressive Models. Moving averages have been the subject of more discussion in most technical analysis than any other technical indicators and are widely used by financial trading institutions.

At a later stage of the paper, the use of basic trading tools such as Support and Resistance lines to indicate key reversal areas is examined.

In its simplest form, the moving average is a very traditional way of smoothing cyclical fluctuations. The basic analysis consists of two parts:

- the data in the time series is smoothed by calculating an arithmetic moving average series of the data
- each number from the original series is divided by an average from the moving average series.

In this exercise, popular short and long-period, 5 (five), 10 (ten), 15 (fifteen) and 50 (fifty) week moving-averages are utilised. Buying and selling signals are generated when the short period moving average rises above (or falls below), the long period moving averages. When the short-period moving average penetrates the long-period moving averages, a trend is considered to exist, and theoretically traders can generate profits from trading the market.

The moving average rules are often modified by the introduction of a band around the moving averages. The objective of the band, which in this case is the funding cost, is to reduce the number of buy (sell) signals by eliminating weak signals when the short and long-period moving averages are very close. Buying and selling signals are generated only when the differences between prices and moving averages (for single moving average) or between long and short moving averages (in the case of two-period moving averages) are greater than the foreign exchange and interest rate spreads.

Mathematically the trading rules in their simplest form can be expressed as follows:

Rule 1: If (PMA(n period) < Pt) then "Sell"

Rule 2: If (PMA(n period) > Pt) then "Buy"

where PMA(n period): the moving average price of n period, and

Pt : the current price.

When including the funding costs as bands then the trading rules can be modified to:

Rule 1: If PMA(n period) - Pt >Funding Costs then "Sell"

Rule 2: If Pt - PMA(n period) > Funding Costs then "Buy"

where PMA(n period): the moving average price of n period, and

Pt : the current price.

The rules were extended so that the signals were generated only if the differences cover the costs of funding, in this case the Foreign Exchange and Interest Rate Spreads.

Foreign Exchange spread in this research is 14 (seven) basis point or 0.0014 for each buying (selling) and reselling (re-buying) on the basis of Australian Dollar which represents foreign exchange transaction cost, while the interest rate spread is 2 basis point or 0.02% which represent the money market transaction costs.

Profit or Loss of the trading is computed as realisation of the foreign exchange prices differences and the interest cost/gain (or referred to as Net Funding Cost) associated with buying/selling the currencies.

The formula used for profit/loss computation in terms of Australian Dollar is as follows [Tan, 1997]:

$$\textit{Profit/Loss = [Foreign Exchange Profit/Loss]-[Net Funding Cost]}$$

$$\Rightarrow \left[Io - \left(\frac{Io \times (fx - fxspr)}{fx + fxspr} \right) \right] - \left[\left(\frac{ilocal + ispr}{52 \times 100} \times Io \right) - \left(\frac{iforeign - ispr}{52 \times 100} \times (Io \times (fx - fxspr)) \right) \right]$$

where:

Io:	Initial Outlay, or the Amount of Investment in terms of Local Currency, in this case Australian Dollars
fx:	Foreign Exchange Rates
fxspr:	Foreign Exchange Rate bid/ask spread
ilocal:	Local Interest Rate
iforeign:	Foreign Interest Rate
ispr:	Interest Rate bid/ask spread

Additional filter rules are introduced to eliminate whipsaws or unnecessary trading signals. In this paper, initial experiments are performed without any filter, with subsequent filters of 0.5, 1.0 and 1.5 percent being used. The filter eliminates any signals where the differences between current week and previous week are less than the filter values.

The initial test is to examine the statistical properties of the Australian Dollar data time series. It is important to see if any unusual pattern existed from time to time, or in other words, do trends in Australian Dollar market change from time to time. Since the period used for the test is from 1st January 1986 to 23rd June 1999, then the whole series are arbitrarily divided into 3 (three) different sub-periods as follows:

- First sub-period, weekly time series, which starts from 1st January 1986 to 20th June 1990.
- Second sub-period, weekly time series, which starts from 27th June 1990 to 14th December 1994.

- Third sub-period, weekly time series which starts from 21st December 1994 to 23rd June 1999.

Table 1 contains summary statistic results and the auto-correlation coefficients for the entire series and three sub-samples prices of the Australian Dollar market over the tested period.

	Full Series	*First*	*Second*	*Third*
Mean	1.376243	1.360691	1.358505	1.409534
Standard Error	0.004331	0.007577	0.005375	0.008708
Standard Deviation	0.114741	0.115902	0.082227	0.133204
Sample Variance	0.013166	0.013433	0.006761	0.017743
Kurtosis	0.011443	-0.241599	-0.836687	-0.858845
Skewness	0.688411	0.382855	0.343447	0.651385
Range	0.654779	0.524755	0.347567	0.540177
Minimum	1.118900	1.118900	1.200900	1.233502
Maximum	1.773679	1.643655	1.548467	1.773679
Count	702	234	234	234
ρ (1)	0.986598	0.983219	0.984414	0.988786
ρ (2)	0.975080	0.969702	0.971132	0.978543
ρ (3)	0.963127	0.955020	0.954074	0.969730
ρ (4)	0.951212	0.939624	0.938323	0.961141

Table 1: Statistic Summary
Results are presented for the full sample and 3 non-overlapping sub-periods as relative comparison. ρ(i) is the estimated auto-correlation at lag i for each series.

The results showed that volatility was the highest during the third sub-period which started from 21st December 1994 to 23rd June 1999, measured in terms of 'Sample Variance' or 'Standard Deviation', as seen in Chart 1. It was contributed from the fact that Australian Dollar had been depreciating against US Dollars during the third sub-period. The triggering event that reversed the up-trend was Australia's biggest share market loss of $13 billion in a single day as the weight of the Asian slumps hit world markets on 27th October 1997. Later on 8th June, 1998, international speculators sold Australian Dollars below 60 US cents (more than A$ 1.67 per US $1), a level not seen since July 1986 [Colebatch, 1998].

Other than that, the table shows that generally there should not be any material difference in time series among the sub-periods, which means that it is possible to build a profitable trading system for the entire period.

The research methods of the paper are performed in three stages:

- Comparison of Single and Two Moving Averages, and ARMA Model – with and without filter rules – using in-sample and out-of-sample data.
- Single and Two Moving Averages – with and without filters.
- Single Moving Averages using Support and Resistance as Filter Rules

2.1 Single and Two Moving Averages – In and out-of-sample data

In this part of the experiment, certain tests were performed as follows:

Single Moving Averages – period used are between 5 (five) to 100 (one hundred) weeks and filters used are 0.0, 0.5, 1.0 and 1.5 percent.

Two Moving Averages – period used are between 5 (five) to 30 (thirty) weeks for short moving averages and between 15 (fifteen) and 100 (one hundred) weeks for long moving averages. Same filters used are 0.5, 1.0 and 1.5 percent for each possible combination.

Moving Average with Auto-Regression – In this part of the test, an auto-regression forecast and moving average are computed. Moving average periods used are between 5 (five) to 30 (thirty) weeks and filters used are 0.5, 1.0 and 1.5 percent for each possible combination.

The period used for building the model, as in-sample data is from 1st January 1986 to 29th July 1998 and period used for testing the model or out-of-sample data is from 5th August 1998 to 23rd June 1999.

The results of the tests are presented in Table 2 (only those combinations generating relatively higher profits are displayed).

Type	Filter	Period MA	Total Profit	Best Profit	WorstLoss	%Win Trade	AvgPrft/ Trd
Single	0.005	15	0.251211	0.071916	-0.10638	0.300314	0.000395
Single	0.005	65	0.223663	0.047979	-0.07247	0.322526	0.000382
Two	**0.005**	**05 and 50**	**0.435254**	**0.104389**	**-0.08576**	**0.546917**	**0.000724**
Two	**0.005**	**05 and 55**	**0.424306**	**0.104389**	**-0.08576**	**0.54717**	**0.000712**
Two	0.005	05 and 60	0.381712	0.104389	-0.08576	0.542466	0.000646
Two	0.005	05 and 45	0.337536	0.104389	-0.08576	0.537234	0.000557
Two	0.005	05 and 35	0.314907	0.104389	-0.08576	0.536649	0.000511
Two	0.005	05 and 40	0.278794	0.104389	-0.08576	0.534392	0.000456
Two	0.01	15 and 35	0.257813	0.104389	-0.08576	0.570732	0.000419
Two	0.005	05 and 65	0.241049	0.047979	-0.07247	0.537604	0.000411
Two	0.005	10 and 55	0.222009	0.104389	-0.08576	0.524324	0.000372
ARMA	**0.005**	**55**	**0.441666**	**0.104389**	**-0.08576**	**0.540761**	**0.000741**
ARMA	**0.005**	**10**	**0.414165**	**0.104389**	**-0.08576**	**0.502618**	**0.000646**
ARMA	0.005	15	0.341932	0.104389	-0.08576	0.502577	0.000538
ARMA	0.01	55	0.258460	0.104389	-0.08576	0.564356	0.000434

Table 2: Result Summaries for Different Moving Averages with and without filters for in-sample data.

The data used is from 1st January 1986 to 29th July 1998 (in-sample data). The performance of the system is measured in terms of Total Profit, those lines in bold represent the highest profits. Moving Average with Auto regression (ARMA) seems to outperform two moving averages and single moving average.

As presented in the table above, the use of single moving average alone does not seem to generate substantial profits over time. The main reason is that the system generates too many unnecessary buying and selling signals to trade, which do not generate enough profits and due to the transaction costs, may result in lower prices or higher losses.

Generally the profitability results are closely linked to the number of trades the system generates. Large number of trades may cause overtrading which reduces the profit by substantial amount, mainly due to high transaction and funding costs.

The results confirm the fact that the overall performance of the system improves with the use of filters around the moving averages. With the single moving average strategy, 15 (fifteen) and 65 (sixty-five) week perform best. To see the relationship among the closing price and moving averages (of 15 and 65 weeks), a line graph is presented in Chart 1.

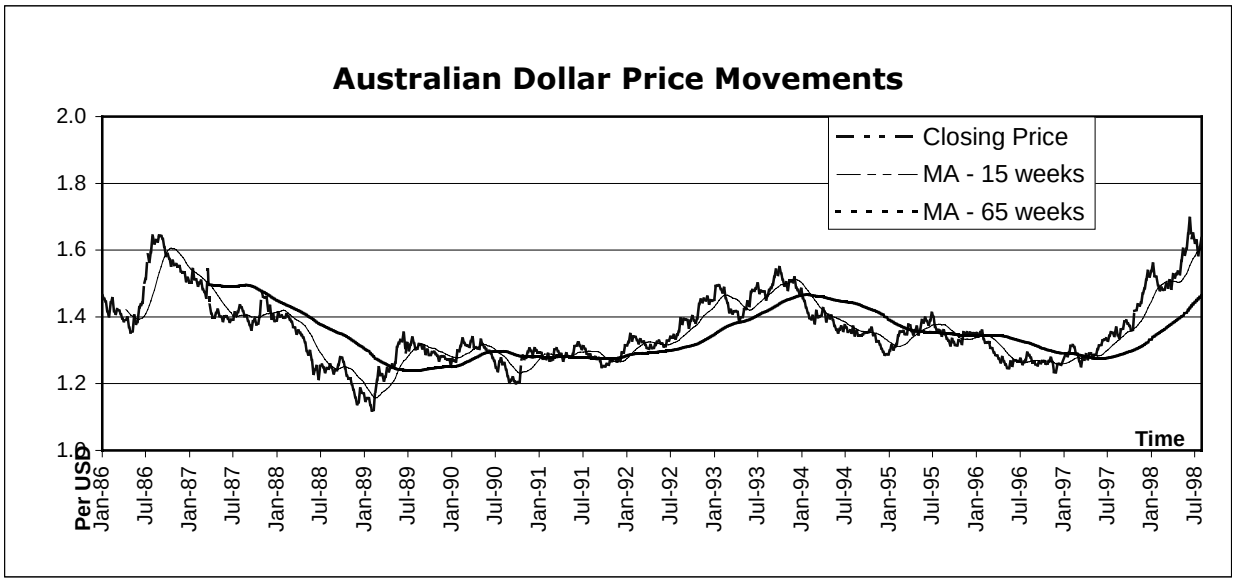

Chart 1: Moving Averages 15 and 65 week and closing price of Australian Dollar from 1 January 1986 to 29 July 1998.

MA 15 week seems to perform better when the trend is not very obvious while MA 65 will outperform if market is trending upward.

In general, while shorter period averages generate more false signals, it has the advantage of giving trend signals earlier in the move [Murphy, 1986]. It stands to reason that the more sensitive the average, the earlier the signals will be generated. The optimisation simulation is to find the optimum average that is sensitive enough to generate early signals, but insensitive enough to avoid most of the random noise.

The second method, which uses two moving averages, generally performs better results than the first one. When two moving averages are employed, the longer one is used for trend identification (for a longer term) and the shorter one for timing purposes or indicator. The purpose of this method is to use both shorter and longer period moving averages to better generate trading signals. The best moving averages used for the test are 5 (five) and 50 (fifty) weeks.

In every case, the introduction of the filter rules seemed to improve the profitability of the system over time. For each trading rule, the number of buy signals is always greater than sell signals, which is consistent with the upward-trending market in the Australian Dollar over time period.

Among the tests performed, the use of ARMA (Auto Regression Moving Average) seemed to generate the highest profit. This is consistent with random walk theory that the best predictor of today's price is yesterday's.

The test finds that 'Total Profit' of the trades simulated from 1st January 1986 to 29th July 1998 exceeded that from 1st January 1986 to 23rd June 1999 (next test). In other words, the model developed using data from 1st January 1986 to 29th July 1998 should not be used to trade for the period of 6th August 1999 to 23rd July 1999. The main reason for this is the fact that the trend differed during the period of 5th August 1998 to 23rd June 1999 compared to the previous 12 (twelve) years (Chart 1). According to O'Loughlin [1999], one of the reasons for Australian Dollar's depreciation is due to the fact that 15.5% of the Australian Gross National Product is vulnerable to export shocks with Asian countries.

For out-of-sample data, which starts from 5th August 1998 to 23rd June 1999, another optimisation was performed with the best moving average and filter are as follows:

Type	Filter	Period MA	TotalProfit	Best Profit	Worst Loss	% WinTrade	Av Prft/Trd
Two	0.05	5 and 25	0.097929	0.05344	-0.03543	0.571429	0.004451

Table 3: Result Summary for Different Moving Averages with and without Filters.
The data used is from 5th August 1998 to 23rd June 1999 and another optimisation was employed to obtain best profitability.

The optimised combination for out-of-sample data and in-sample data are different. Using the out-of-sample data, the best long moving average is 25 (twenty-five) instead of 50 (fifty) or 55 (fifty-five) week which is the case for in-sample data. The main factors that influence the result are the fact that the out-of-sample data only has 46 (forty-six) data points and also the fact that Australian Dollar has continued to depreciate in the past two years.

2.2 Single and Two Moving Averages – Full Series

Similar methodology is employed in this part of the test, and the data used starts from 1st January 1986 to 23rd June 1999. The total number of data in the sample is 702 weeks and the best comparative results are presented in the following table:

Type	Filter	Period MA	Net Profit	Max Profit	Max Loss	% WinTrade	Av Prft/Trd
Two	**0.01**	**5 and 50**	**0.355072**	**0.104389**	**-0.08576**	**0.571429**	**0.000553**
Two	**0.005**	**5 and 35**	**0.351229**	**0.104389**	**-0.08576**	**0.53271**	**0.000527**
Two	**0.005**	**5 and 50**	**0.350846**	**0.104389**	**-0.08576**	**0.538462**	**0.000538**
Two	0.005	5 and 60	0.338183	0.104389	-0.08576	0.541463	0.000527
Two	0.01	5 and 60	0.290103	0.07246	-0.077	0.561404	0.000452
Single	0.005	15	0.246556	0.071916	-0.10638	0.297052	0.000559
Single	0	30	0.201364	0.07246	-0.08576	0.321429	0.0003
Two	0	35 and 50	0.185177	0.083734	-0.10638	0.506066	0.000284

Table 4: Result Summaries for Different Moving Averages with and without Filters.
The data used is from 1st January 1986 to 23rd June 1999. The performance of the system is measured in terms of Net Profit, those lines in bold represent the highest profits. The results confirm the previous study that the best moving average combination is 5 and 50.

The results presented in the above table seem to confirm the previous test that the use of two moving averages outperforms the single moving average strategy. The use of filters improves the profitability in both cases, as it helps to remove any unprofitable trading signal. The best long moving averages used are 35 (thirty-five) and 50 (fifty) weeks, as anything shorter than that will be too sensitive for Australian Dollar market which has not been 'trend-less' over time.

2.3 Support and Resistance – Full Series

The final technical rule is the trading range break out, where a buy signal is generated when the price break through the resistance level, which is defined as local maximum. Consequently, a sell signal is generated when the price breaks through the support level, which is the local minimum price.

Fundamentally, the term support level refers to the price at which buyers are willing to step in and buy enough shares of stock to temporarily stop or possibly reverse a downtrend. Conversely, a resistance level is the price at which sellers are willing to sell enough quantity to temporarily stop and possibly reverse an uptrend.

In this exercise, a support and resistance is used as a 'filter' on the conventional moving average oscillator. The measure of significance and future reliability of the support and resistance lines in technical analysis are directly related to the number of times that prices touch the lines and then reverse back.

In this exercise, the single moving average trading system is utilised to generate buying and trading signals. Signals are then generated only when the foreign exchange price of the particular week is the local maximum or minimum of the period (the same period used for calculating moving average). For example, in 5 (five) week moving average, buying (selling) signal is generated only when the prices of the week is greater than the maximum (minimum) price over the past 5 (five) weeks. In this part of the test the same moving average periods as the previous section are used.

The results of the trading system using both moving averages and support and resistance are presented in the Table 5.

MA	*Net Profit*	*Nothing*	*Buy*	*Sell*
10	***0.075852***	***433***	***123***	***137***
15	***0.054752***	***477***	***100***	***111***
9	0.046608	420	130	144
8	0.02176	400	144	151
12	0.016717	455	111	125
20	0.012358	507	82	94
30	-0.01803	538	64	71
25	-0.01937	524	73	81
7	-0.03919	384	153	159
35	-0.0528	545	58	65
6	-0.14058	364	159	174
3	-0.29279	186	244	267
5	-0.3325	326	178	193
11	-0.4379	488	84	120
4	-0.53156	282	197	218

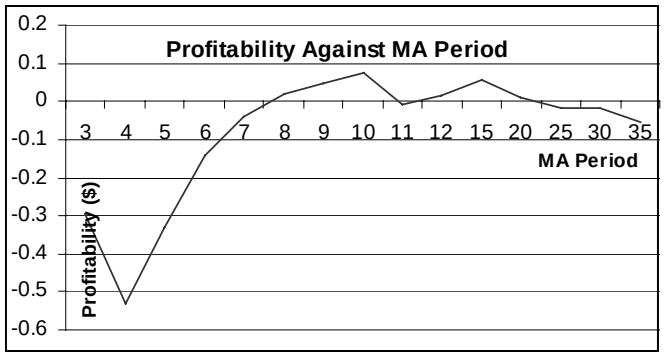

Table 5 and Chart 2: Result Summaries for Different Moving Averages with Support and Resistance measured in terms of Profitability

The data used is from 1st January 1986 to 23rd June 1999. The performance of the system is measured in terms of Net Profit, those lines in bold represent the highest profits. The next columns represent the number of signals (Buy, Sell or Do Nothing) generated by the system Chart 3 represents profitability using different moving average periods.

The table shows that the profitability is highest when the periods used are 10 (ten) and 15 (fifteen) weeks. Unfortunately, the profitability of the trading system using this method does not exceed the previous methods explored. Chart 3 next to the Table 4 shows the profitability against moving average period used. The outlook of the chart only applies for the case of Australian Dollar, and has not been tested on any other foreign exchange markets. Even within the Australian Dollar itself, the trends may be entirely different for quotation on other basis like monthly or daily.

3 Conclusion

The findings of this research indicates that profits from Foreign Exchange trades can be generated from utilising one of the simplest form of technical analysis, single and two-period moving averages, ARIMA or Moving Average with Support and Resistance lines. The finding of the research confirms that technical analysis is a useful tool to create a trading system that is profitable even after accounting for funding cost. It is especially true in trending markets (upward or downward) where moving average method proves to be one of the best simple methods available.

The best Moving Average period in terms of highest 'Total Profit' varied from one time series data to another. When volatility is higher or trend is more apparent, then the longer period moving average is desirable. The use of two moving averages seems to outperform that of single moving average, due to its ability to eliminate unnecessary trades and capture the existing trends.

The introduction of a filter, which is used to eliminate less profitable trading signals, of 0.5% outperforms other techniques where no filters or higher percentage use of filters are utilised. The reasons for the higher percentage i.e. 1.0% or 1.5% used tend to eliminate many profitable trades. This is particularly true in the foreign exchange market where the movement of the rates can be relatively small and the volatility is higher.

The model that produces the highest Total Profit of $0.4417 is ARIMA with filter of 0.5% being used. The next best model that produces second highest Total Profit of $0.4352 is the Two Moving Averages with filter of 0.5%.

Support and Resistance used in the model seem to contribute profitability to the single moving average model even though the overall profitability does not outperform the previous two moving averages and ARIMA models. Support and Resistance lines are not very accurate predictors of when and where prices will reverse, but rather these lines are tools that can be used to alert traders to areas that need a closer examination.

The optimisation model used for the above test recognises some limitation, which does not guarantee success. The main problem with optimisation is the need to constantly re-optimise every so often. Changing market conditions may cause these optimised numbers to change over time. Another limitation is the fact that these methods have not been used in other instruments such as securities and commodities.

4 Future Research

The trading system created in the research suggested continuous buying and selling every time certain conditions are satisfied and the system does not facilitate any trader to hold the foreign currency for more than one period unit at any given time. Another limitation is that system allows buying and selling only one unit of foreign currency. In real life, profit can be maximised by holding the foreign currencies for more than one period unit (which can be daily, weekly or monthly) and ideally a system should encourage more units to buy or sell when the signals appear to be very strong. In other words, this research does not look at any money management technique.

Money management technique or strategy that is worth considering is 'Optimal f', introduced by Ralph Vince [1990]. Optimal f is a money management strategy that can be used to improve and maximise system performance by finding the best percentage of capital to invest in each trade.

The 'optimal f' can also be extended to optimise the timing of the investment. Future research will be conducted to investigate how long traders should hold their foreign currency exposure and how much he or she should buy or sell every time a signal is generated.

Another possibility of future works will be to use the same or similar models and optimisation techniques using other historical time series data or other financial instruments, such as securities and commodities.

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