

# Fuzzy logic and investment strategies

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*In this article we focus on the investment strategies towards 25 firms quoted on Tunisian Stock Exchange using a fuzzy logic. We use daily data from January 2001 to December 2008. Despite the debate between efficiency theory and behavioral finance, we find an eventual complementarity on decision making.*

**Keywords:** Fuzzy logic, investment strategy, complementarity

## 1. INTRODUCTION

Decision-making is a complex activity. It can be defined as the process of choosing a particular alternative from a number of alternatives. It is an activity that follows after proper evaluation of all the alternatives. Two principal theories are still on debate according to investment strategies.

The efficiency theory which suggests that investors act rationally and consider all available information in the decision-making process, and hence investment markets are efficient, reflecting all available information in security prices (Fama 1965). It identifies three forms of market efficiency: the weak, semi strong, and strong form. (Fama 1969). The choice of an active or passive investment policy is based on the acceptance concerning the market efficiency. A refusal of the market efficiency hypothesis results logically in an active investment strategy. However, a passive investment strategy is based on the acceptance of efficient markets.

The behavioural finance which has uncovered a surprisingly large amount of evidence of irrationality and repeated errors in judgement. Its field has evolved that attempts to better understand and explain how emotions and cognitive errors influence investors and the decision-making process. Kahneman and Tversky (1979), Shefrin and Statman (1994), Shiller (1995) and Shleifer (2000) are among the leading researchers that have utilised theories of psychology and other social sciences to shed light on the efficiency of financial markets as well as explain many stock market anomalies, bubbles and crashes.

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Between these two theories, some researches, using classical logic, have tried to find an eventual relationship using heterogeneous approach (Henrik 2007). However, the classical logic has been widely critical in the modeling of the association between the fundamental and behavioural data in the investment strategies. The critics concern essentially the representation of each anticipation (so far to the reality), the linearity problem (to ignore the no linearity), the complexity of the parameters (qualitative data)...

So and to overcome those critics, the goal of this paper is to model the investment decision through the fuzzy complementarity between fundamental and behavioural data. In fact, classical (two-valued) logic deals with propositions that are either true or false. In many-valued logic, a generalization of the classical logic, the propositions have more than two truth values. Fuzzy logic is an extension of the many-valued logic in the sense of incorporating fuzzy sets and fuzzy relations as tools into the system of many-valued logic. Fuzzy logic provides a methodology for dealing with linguistic variables and describing modifiers like very, fairly, not, etc. Fuzzy logic facilitates common sense reasoning with imprecise and vague propositions dealing with natural language and serves as a basis for decision analysis and control actions (Bojadziev and Bojadziev (2007)).

The paper is organized as follows. The second section summarizes the main studies in financial literature that deal with investment strategies via the efficiency theory and the behavioural finance. The third section presents our database and the used methodology. The fourth section presents the results. Finally, the last section concludes.

## **2. Literature review**

### ***2.1 investment strategy via efficiency theory***

#### *2.1.1: Empirical Evidence of the weak form efficiency*

According to the weak form efficiency theory, the utilization of technical analysis is deemed void. Canadian evidence of weak form efficiency was seen in a study conducted by Zhang and Kyrzanowksi. Their study proved the “overreaction theory” does not work in Canadian markets. The overreaction theory assumes that knowing past stock returns enables investors to predict future returns. According to Zhang & Kyrzanowski the theory did not replicate similar results when tested with TSX listed stocks over the same time period of 38 years (Zhang and Kyrzanowksi, 1992).

#### *2.1.2: Empirical Evidence of semi-strong form efficiency*

Evidence of semi-strong form efficiency can be seen in examples such as stock splits, dividend announcements, IPOs' and overall reaction to the news and media. A study conducted in 2003 looked at 12,747 stock splits from 1927-1996. The study concluded that although a very small portion of those stock splits allowed investors to yield a substantial return, the overall results suggest that the buyers and sellers of stock splits do not yield extensive gains (Byun & Rozeff 2003). In addition, a study conducted by Fama indicated that markets seem to anticipate any information substantially in advance, and after the news is released the price of securities stabilize and do not experience extraordinary fluctuations (Fama, 1969). The same can be witnessed when a company announces a dividend. Although most dividend announcements coincide with earnings announcements, studies have concluded that the market adjusts accordingly, thus supporting the overall theory of an efficient market (Cleary et al 2005).

### *2.1.3: Empirical Evidence of strong form efficiency*

In order to test strong-form market efficiency the assumption that industry insiders and investing professionals have an advantage should be thoroughly analyzed. In a research study conducted by Jensen, approximately one hundred and fifteen mutual funds were observed from 1955 to 1964. During this ten year period, eighty nine of those funds had average negative returns of -14.6%. If management fees, loading charges and other transactional costs were to be excluded, then fifty eight of the funds posted an average return of -2.5% (Fama, 1969). According to the results found in the research study, it is fair to conclude that evidence for strong-form efficiency exists, and even professional industry insiders are not able to beat the market and post abnormal gains.

In another study conducted on market efficiency called article "Volatility forecasting and the efficiency of the Toronto 35 index options market," Craig Doidge found evidence for efficiency. This study focused on factors that determine option prices in the Toronto 35 option market. The study basically found that no substantial profits could be made after considering transaction costs and other fees thus concluding that the Toronto 35 option market is indeed efficient. Evidence of market efficiency from overseas markets was also observed. In a study conducted on the Nikkei index called, "Market efficiency: Experiences with Nikkei put warrants," by Jason Wei looked at whether abnormal profits could be made by exploiting market lags. Wei concluded that the markets were efficient and that no consistent profits could be derived from utilizing such a strategy (Doidge 1998).

### *2.1.4: Passive investment strategy*

Passive investment makes no attempt to distinguish attractive from unattractive securities, or forecast securities prices, or time markets and market sectors. Passive managers invest in broad sectors of

the market, called asset classes or indexes, and, like active investors, want to make a profit, but accept the average returns various asset classes produce. Passive investors make little or no use of the information active investors seek out. Instead, they allocate assets based upon empirical research delineating probable asset class risks and returns, diversify widely within and across asset classes, and maintain allocations long-term through periodic rebalancing of asset classes.

### *2.1.5: Active investment strategy*

Active investment might best be described as an attempt to apply human intelligence to find "good deals" in the financial markets. Active management is the predominant model for investment strategy today. Active managers try to pick attractive stocks, bonds, mutual funds, time when to move into or out of markets or market sectors, and place leveraged bets on the future direction of securities and markets with options, futures, and other derivatives. Their objective is to make a profit, and, often without intention, to do better than they would have done if they simply accepted average market returns. In pursuing their objectives, active managers search out information they believe to be valuable, and often develop complex or proprietary selection and trading systems. Active management encompasses hundreds of methods, and includes fundamental analysis, technical analysis, and macroeconomic analysis, all having in common an attempt to determine profitable future investment trends.

#### *a. The market timing*

The principal studies which deal with market timing have used the PER, the premium risk and the yield gap (Bleiberg (1989); Jeffrey Gropp (2004)).

#### *b. The Dividend Discount Model*

We find essentially the security market line (SML) and the arbitrage pricing theory (APT)(Blume (1971), Broquet and Capiou-Har (1978), Beaver, Kettler and Scholes (1970), Roll and Ross (1980)).

#### *c. Econometric models*

We can mention the ARMA, GARCH, ARCH, E-GARCH...(Engel (1982), Bollerslev (1986), Nelson (1991), Black (1976)...).

#### *d. The earnings surprises models*

We find the studies of Ball and Brown (1979), Alexander Goff Peterson (1989)...

## **2.2 Investment strategy via Behavioural finance**

### *2.2.1 The safety first theory*

According to the safety-first theory of Roy's (1952), the investors aim to minimize the probability  $\Pr(W < S)$ , that their richness  $W$  passes to a level lower than the minimum level  $S$ .

In order to generalize the safety-first theory, Elton and Gruber (1995) chose to minimize the probability  $\Pr(W < S)$ , under the constraint that this probability does not exceed a level  $\alpha$ ,  $S$  is the minimum level to live and  $\alpha$  is the probability of loss.

According to Arzac and Bawa (1977), the investor must maximize an objective function  $U$  which is defined by the richness average hope and the probability level  $\alpha$ . The pair  $(E(w); \alpha)$  is adapted with a utility function defined by:

$$\begin{aligned} \mu(w) &= w \text{ If } \Pr(W \leq S) \leq \alpha \\ \mu(w) &= w - c \text{ If } \Pr(W \leq S) \geq \alpha \end{aligned}$$

For  $c > 0$ , the utility function becomes:  $E(W) - c \text{PROB}(W \leq S)$

### 2.2.2: The SP /A Theory

Lopes (1987) described that the decisions of the agents are guided by two feelings; the fear and the hope which coexist at any individual.

The fear is noted  $D(s) = P(W = S)$ . The partisans of safety-first were guided by this single feeling.

The hope  $E[w]$  is written:

$$E[W] = D_1 W_1 + \sum_{i=2}^n D_i (W_i - W_{i-1}) = W_i + \sum_{i=2}^n D_i (W_i - W_{i-1})$$

To translate the feeling of fear and hope, Lopes proposes to transform the probabilities, so  $\Phi(D_i) = D_i^{1+a}$

$$p_i^* = \Phi(D_i) - \Phi(D_{i+1}) \text{ For } i < N$$

And  $p_n^* = \Phi(D_n)$

In case of hope, the investor uses a transformation of probabilities as follow  $\varphi(D_i) = 1 - (1 - D_i)^{1+b}$

Finally, Lopes shows that investor can be between fear and hope. The probability transformation which combines  $\Phi$  and  $\varphi$  is written as follow

$$\theta(D_i) = \delta \Phi(D_i) + (1 - \delta) \varphi(D_i)$$

### 2.2.3: The SA theory

The pioneers of this theory are Shefrin and Statman (2000) who part richness on many levels according to their degree of importance.

They constitute a pyramid which are the levels of richness are classified (security, incomes, growth...)

Many researches have study the behavioural portfolio theories.

Pietra nico and Riepe (2002) have describe the behavioural portfolio as "Core and Explore": the low part of the pyramid was constituted of a well diversified portfolio in order to eliminate the risk and to ensure the minimum of income been useful like

foundation to live. Asset Allocation Planner (2003) show that the investors proceed to the behavioural portfolio in their investment rather than the average - variance.

We find also the momentum strategy (Jegadeesh and Titman (1993), Swinkels (2004), Lesmond, Schill and Zhou (2003), Grundy and Martin (2001), Korajczyk and Sadka (2004)...) and the contrarian strategy (Forner and Marhuenda (2003), Balvers, Wu and Gilliland (2000)...).

### 3. Data and Methodology

#### 3.1. Database

In our study, we use daily data for 25 firms quoted on the Tunisian Stock Exchange belonging to the banking and non banking sector. The historical data is obtained from the [www.bvmt.com.tn](http://www.bvmt.com.tn) Website of the Tunisian stock market and covers the period from 2/01/2001 to 31/12/2008. So we have 50025 observations.

#### 3.2. Methodology

We apply a fuzzy logic using software FuzzyTech®, where the model is divided into three main parts (figure 1):

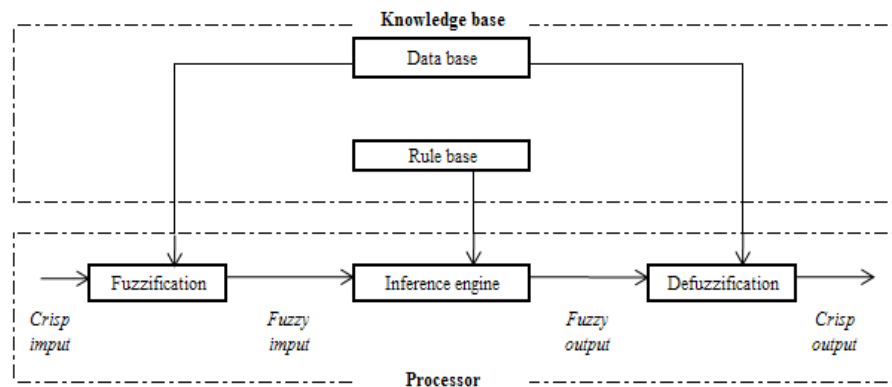


Fig 1. A fuzzy inference system

- Fuzzification: where numerical crisp variables are transformed to linguistic variables, which become a fuzzy input for the inference rules.
- Inference engine: where the fuzzy input is transformed by the rules of inference to fuzzy output.
- Defuzzification: where the linguistic language are changed into numerical value to become the output of the system

#### a Definition of data set for training and testing

Our input variables are:

- Return =  $R_i / E(R_i)$

where  $R_i$  is the observed return and  $E(R_i)$  is the expected return.

- Sent 1=  $ADV_t/DEC_t$

It is a measure of investor sentiment where  $ADV_t$  is the number of securities that know an augmentation of the price at the date  $t$  and  $DEC_t$  is the number of securities that know a diminution of the price at the date  $t$ .

- Sent 2=  $HI/LO$

where  $HI$  is the number of the new augmentations and  $LO$  is the number of the New diminutions.

- Oss= The stochastic oscillator. His measure is as follow:

$$Oss_{(x\text{days})} = 100 * ((C - Lx) / (Hx - Lx))$$

Where  $C$ = The last price,  $Lx$ = the lowest price of the last  $x$  days,  $Hx$ = the highest price of the last  $x$  days.

-Mom: the momentum=  $C_t - C_{t-x}$   
where  $C_t$  is the price of the day  $t$ .

### *b Fuzzification*

All numerical input variables must be converted to linguistic variables. In this work, the input linguistic variables adopted were "low", "high" and "medium". To accomplish this task, membership functions are developed. Figure 2 show these pertinence functions for the variable Sent 1 for example.

This figure shows statistical membership functions which have been based on historical occurrences of the variable defining "low", "high" and "medium". This definition naturally implies the trapezoidal shaped membership functions illustrated.

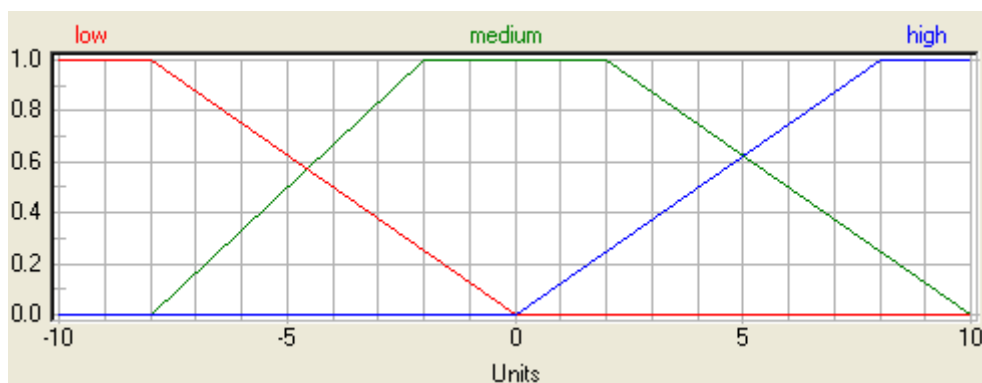


Fig 2: MBF of "sent1"

We define a membership function for each inputs:  
For Return

$$\mu_x(\text{low}) = \begin{cases} 1 & \text{if } x < -16 \\ (17-x)/33 & \text{if } -16 < x < 17 \\ 0 & \text{if } x > 17 \end{cases}$$

$$\mu_x(\text{high}) = \begin{cases} 1 & \text{if } x > 17 \\ (17+x)/33 & \text{if } -16 < x < 17 \\ 0 & \text{if } x < -16 \end{cases}$$

$$\mu_x(\text{medium}) = \begin{cases} 0 & \text{if } x > 17 \text{ M } x < -16 \\ 1 & \text{if } -2 < x < 2 \\ (-2-x)/14 & \text{if } -16 < x < -2 \\ (17+x)/19 & \text{if } 2 < x < 17 \end{cases}$$

For Oss

$$\mu_x(\text{low}) = \begin{cases} 1 & \text{if } x < 42 \\ (56-x)/14 & \text{if } 42 < x < 56 \\ 0 & \text{if } x > 56 \end{cases}$$

$$\mu_x(\text{high}) = \begin{cases} 1 & \text{if } x > 56 \\ (56+x)/98 & \text{if } 42 < x < 56 \end{cases}$$

0 if  $x < 42$

$$\mu_x(\text{medium}) = \begin{cases} 0 & \text{if } x > 56 \text{ or } x < 42 \\ 1 & \text{if } 46 < x < 54 \\ (46-x)/4 & \text{if } 42 < x < 46 \\ (56+x)/110 & \text{if } 54 < x < 56 \end{cases}$$

For Mom

$$\mu_x(\text{low}) = \begin{cases} 1 & \text{if } x < -0.003 \\ (0.003-x)/2 & \text{if } -0.003 < x < 0.003 \\ 0 & \text{if } x > 0.003 \end{cases}$$

$\mu_x(\text{high}) =$

$$\begin{cases} 1 & \text{if } x > 0.003 \\ (0.003+x)/2 & \text{if } -0.003 < x < 0.003 \\ 0 & \text{if } x < -0.003 \end{cases}$$

For Sent1

$$\mu_x(\text{low}) = \begin{cases} 1 & \text{if } x < 0.6 \\ (1.4-x)/0.8 & \text{if } 0.6 < x < 1.4 \\ 0 & \text{if } x > 1.4 \end{cases}$$

$\mu_x(\text{high}) =$

$$\begin{cases} 0 & \text{if } x < 0.6 \\ (1.4+x)/2 & \text{if } 0.6 < x < 1.4 \\ 1 & \text{if } x > 1.4 \end{cases}$$

$$\mu_x(\text{medium}) = \begin{cases} 0 & \text{if } x < 0.6 \text{ M } x > 1.4 \\ 1 & \text{if } 0.8 < x < 1.2 \\ (0.8-x)/0.2 & \text{if } 0.6 < x < 0.8 \\ (1.4+x)/0.6 & \text{if } 0.8 < x < 1.4 \end{cases}$$

For Sent2

$$\mu_x(\text{low}) = \begin{cases} 1 & \text{if } x < 0.5 \\ (1.4-x)/0.9 & \text{if } 0.55 < x < 1.4 \\ 0 & \text{if } x > 1.4 \end{cases}$$

$$\mu_x(\text{high}) = \begin{cases} 0 & \text{if } x < 0.5 \\ (1.4+x)/0.9 & \text{if } 0.5 < x < 1.4 \\ 1 & \text{if } x > 1.4 \end{cases}$$

$$\mu_x(\text{medium}) = \begin{cases} 0 & \text{if } x < 0.5 \text{ M } x > 1. \\ 1 & \text{if } 0.9 < x < 1.1 \\ (0.9-x)/0.4 & \text{if } 0.5 < x < 0.9 \\ (1.4+x)/0.3 & \text{if } 1.1 < x < 1.4 \end{cases}$$

### *C Inference rules*

Once the fuzzification of all input values has been done, the next step involves the establishment of inference rules. These rules represent the manner in which humans make decisions, inferring from linguistics premises. Inference rules were created with the help of the software FuzzyTech®. These rules are logical statements, and to each rule it can be assigned a value from zero to one, called Degree of Support (DoS), that depends on the characteristics of

based sample. When a rule is assigned with a DoS equal to zero (one), the rule is considered insignificant (significant). The DoS also allows for values between zero and one for partial significant rule.

Within FuzzyTech, the DoS can be identified by the user as a fixed value or randomly determined by the software. The program also provides artificial neural networks (ANNs) that can be used to extract data for the rule base. ANNs perform repetitive evaluation of the known results and incrementally strengthen/weaken the influence of the rule on the modeling result; referred to as the 'DoS' in fuzzy models (The DoS is equivalent to rule weightings in an ANN for this application).

Below is an example of one of the used rules in our model.

**If** (Sent 1= 'low' **and** Sent 2= 'low' **and** Rent= 'low' **and** 'Oss'='low'**and** Mom= 'low')  
**Then** Strategy= 'Buy' with DoS= 0.84.

Initially, some difficulties were encountered in calibrating the fuzzy model, because of inconsistencies in the data. To address this problem, fuzzy cluster analysis which is part of FuzzyTech is used to identify discrepancies contained in data. Fuzzy clustering is a method of processing the data to remove redundant or conflicting data to increase the speed of training (Tsoukalas and Uhrig (1996)). For this reason, we remove conflicting data but we reserve them for the model validation.

Based on the probability distribution, the inference rules were developed using FuzzyTech®. Table 1 presents the rules used.

Table 1: Inference rules

IF					THEN	
sent1	sent2	rent	oss	mom	DoS	strategy
low	low	low	low	low	0.84	buy
low	low	low	low	low	0.03	notrade
low	low	low	low	low	0.75	sell
low	low	low	low	high	0.77	buy
low	low	low	low	high	0.26	notrade
low	low	low	low	high	0.22	sell
low	low	low	medium	low	0.42	buy
low	low	low	medium	low	0.17	notrade
low	low	low	medium	low	0.55	sell
low	low	low	medium	high	0.04	buy
low	low	low	medium	high	0.69	notrade
low	low	low	medium	high	0.79	sell
low	low	low	high	low	0.41	buy
low	low	low	high	low	0.09	notrade
low	low	low	high	low	0.01	sell
low	low	low	high	high	0.10	buy
low	low	low	high	high	0.60	notrade

IF					THEN	
low	low	low	high	high	0.25	sell
low	low	medium	low	low	0.91	buy
low	low	medium	low	low	0.45	notrade
low	low	medium	low	low	0.73	sell
low	low	medium	low	high	0.27	buy
low	low	medium	low	high	0.90	notrade
low	low	medium	low	high	0.59	sell
low	low	medium	medium	low	0.28	buy
low	low	medium	medium	low	0.87	notrade
low	low	medium	medium	low	0.77	sell
low	low	medium	medium	high	0.77	buy
low	low	medium	medium	high	0.09	notrade
low	low	medium	medium	high	0.47	sell
low	low	medium	high	low	0.03	buy
low	low	medium	high	low	0.66	notrade
low	low	medium	high	low	1.00	sell
low	low	medium	high	high	0.25	buy
low	low	medium	high	high	0.32	notrade
low	low	medium	high	high	0.20	sell
low	low	high	low	low	0.10	buy
low	low	high	low	low	0.72	notrade
low	low	high	low	low	0.43	sell
low	low	high	low	high	0.67	buy
low	low	high	low	high	0.20	notrade
low	low	high	low	high	0.33	sell
low	low	high	medium	low	0.98	buy
low	low	high	medium	low	0.80	notrade
low	low	high	medium	low	0.84	sell
low	low	high	medium	high	0.45	buy
low	low	high	medium	high	0.16	notrade
low	low	high	medium	high	0.56	sell
low	low	high	high	low	0.79	buy
low	low	high	high	low	0.23	notrade
low	low	high	high	low	0.77	sell
low	low	high	high	high	0.37	buy
low	low	high	high	high	0.05	notrade
low	low	high	high	high	0.58	sell
low	medium	low	low	low	0.87	buy
low	medium	low	low	low	0.10	notrade
low	medium	low	low	low	0.30	sell
low	medium	low	low	high	0.93	buy
low	medium	low	low	high	0.21	notrade
low	medium	low	low	high	0.95	sell
low	medium	low	medium	low	0.09	buy
low	medium	low	medium	low	0.82	notrade
low	medium	low	medium	low	0.98	sell

IF					THEN	
low	medium	low	medium	high	0.35	buy
low	medium	low	medium	high	0.51	notrade
low	medium	low	medium	high	0.14	sell
low	medium	low	high	low	0.80	buy
low	medium	low	high	low	0.18	notrade
low	medium	low	high	low	0.50	sell
low	medium	low	high	high	0.04	buy
low	medium	low	high	high	0.54	notrade
low	medium	low	high	high	0.18	sell
low	medium	medium	low	low	0.90	buy
low	medium	medium	low	low	0.23	notrade
low	medium	medium	low	low	0.13	sell
low	medium	medium	low	high	0.02	buy
low	medium	medium	low	high	0.10	notrade
low	medium	medium	low	high	0.83	sell
low	medium	medium	medium	low	0.62	buy
low	medium	medium	medium	low	0.96	notrade
low	medium	medium	medium	low	0.54	sell
low	medium	medium	medium	high	0.34	buy
low	medium	medium	medium	high	0.73	notrade
low	medium	medium	medium	high	0.40	sell
low	medium	medium	high	low	0.83	buy
low	medium	medium	high	low	0.09	notrade
low	medium	medium	high	low	0.39	sell
low	medium	medium	high	high	0.37	buy
low	medium	medium	high	high	0.74	notrade
low	medium	medium	high	high	0.55	sell
low	medium	high	low	low	0.30	buy
low	medium	high	low	low	0.16	notrade
low	medium	high	low	low	0.09	sell
low	medium	high	low	high	0.87	buy
low	medium	high	low	high	0.85	notrade
low	medium	high	low	high	0.30	sell
low	medium	high	medium	low	0.27	buy
low	medium	high	medium	low	0.23	notrade
low	medium	high	medium	low	0.84	sell
low	medium	high	medium	high	0.96	buy
low	medium	high	medium	high	0.88	notrade
low	medium	high	medium	high	0.16	sell
low	medium	high	high	low	0.09	buy
low	medium	high	high	low	0.95	notrade
low	medium	high	high	low	0.15	sell
low	medium	high	high	high	0.48	buy
low	medium	high	high	high	0.24	notrade
low	medium	high	high	high	0.48	sell
low	high	low	low	low	0.36	buy

IF					THEN	
low	high	low	low	low	0.03	notrade
low	high	low	low	low	0.26	sell
low	high	low	low	high	0.94	buy
low	high	low	low	high	0.20	notrade
low	high	low	low	high	0.78	sell
low	high	low	medium	low	0.51	buy
low	high	low	medium	low	0.58	notrade
low	high	low	medium	low	0.20	sell
low	high	low	medium	high	0.69	buy
low	high	low	medium	high	0.14	notrade
low	high	low	medium	high	0.65	sell
low	high	low	high	low	0.09	buy
low	high	low	high	low	0.61	notrade
low	high	low	high	low	0.66	sell
low	high	low	high	high	0.70	buy
low	high	low	high	high	0.44	notrade
low	high	low	high	high	0.79	sell
low	high	medium	low	low	0.33	buy
low	high	medium	low	low	0.66	notrade
low	high	medium	low	low	0.09	sell
low	high	medium	low	high	0.31	buy
low	high	medium	low	high	0.27	notrade
low	high	medium	low	high	0.37	sell
low	high	medium	medium	low	0.07	buy
low	high	medium	medium	low	0.82	notrade
low	high	medium	medium	low	0.05	sell
low	high	medium	medium	high	0.26	buy
low	high	medium	medium	high	0.38	notrade
low	high	medium	medium	high	0.08	sell
low	high	medium	high	low	0.52	buy
low	high	medium	high	low	0.76	notrade
low	high	medium	high	low	0.17	sell
low	high	medium	high	high	0.61	buy
low	high	medium	high	high	0.61	notrade
low	high	medium	high	high	0.15	sell
low	high	high	low	low	0.05	buy
low	high	high	low	low	0.99	notrade
low	high	high	low	low	0.02	sell
low	high	high	low	high	0.48	buy
low	high	high	low	high	0.70	notrade
low	high	high	low	high	0.99	sell
low	high	high	medium	low	0.43	buy
low	high	high	medium	low	0.24	notrade
low	high	high	medium	low	0.72	sell
low	high	high	medium	high	0.25	buy
low	high	high	medium	high	0.14	notrade

IF					THEN	
low	high	high	medium	high	0.42	sell
low	high	high	high	low	0.89	buy
low	high	high	high	low	0.56	notrade
low	high	high	high	low	0.78	sell
low	high	high	high	high	0.59	buy
low	high	high	high	high	0.70	notrade
low	high	high	high	high	0.51	sell
medium	low	low	low	low	0.06	buy
medium	low	low	low	low	0.73	notrade
medium	low	low	low	low	0.30	sell
medium	low	low	low	high	0.56	buy
medium	low	low	low	high	0.09	notrade
medium	low	low	low	high	0.41	sell
medium	low	low	medium	low	0.89	buy
medium	low	low	medium	low	0.31	notrade
medium	low	low	medium	low	0.37	sell
medium	low	low	medium	high	0.95	buy
medium	low	low	medium	high	0.50	notrade
medium	low	low	medium	high	0.95	sell
medium	low	low	high	low	0.85	buy
medium	low	low	high	low	0.29	notrade
medium	low	low	high	low	0.26	sell
medium	low	low	high	high	0.70	buy
medium	low	low	high	high	0.30	notrade
medium	low	low	high	high	0.21	sell
medium	low	medium	low	low	0.27	buy
medium	low	medium	low	low	0.45	notrade
medium	low	medium	low	low	0.23	sell
medium	low	medium	low	high	0.48	buy
medium	low	medium	low	high	0.88	notrade
medium	low	medium	low	high	0.91	sell
medium	low	medium	medium	low	0.67	buy
medium	low	medium	medium	low	0.67	notrade
medium	low	medium	medium	low	0.62	sell
medium	low	medium	medium	high	0.92	buy
medium	low	medium	medium	high	0.22	notrade
medium	low	medium	medium	high	0.30	sell
medium	low	medium	high	low	0.71	buy
medium	low	medium	high	low	0.18	notrade
medium	low	medium	high	low	0.33	sell
medium	low	medium	high	high	0.93	buy
medium	low	medium	high	high	0.23	notrade
medium	low	medium	high	high	0.71	sell
medium	low	high	low	low	0.50	buy
medium	low	high	low	low	0.75	notrade
medium	low	high	low	low	0.93	sell

IF					THEN	
medium	low	high	low	high	0.75	buy
medium	low	high	low	high	0.30	notrade
medium	low	high	low	high	0.66	sell
medium	low	high	medium	low	0.71	buy
medium	low	high	medium	low	0.15	notrade
medium	low	high	medium	low	0.84	sell
medium	low	high	medium	high	0.08	buy
medium	low	high	medium	high	0.90	notrade
medium	low	high	medium	high	0.93	sell
medium	low	high	high	low	0.56	buy
medium	low	high	high	low	0.41	notrade
medium	low	high	high	low	0.26	sell
medium	low	high	high	high	0.24	buy
medium	low	high	high	high	0.17	notrade
medium	low	high	high	high	0.70	sell
medium	medium	low	low	low	0.76	buy
medium	medium	low	low	low	0.28	notrade
medium	medium	low	low	low	0.39	sell
medium	medium	low	low	high	0.34	buy
medium	medium	low	low	high	0.20	notrade
medium	medium	low	low	high	0.39	sell
medium	medium	low	medium	low	0.31	buy
medium	medium	low	medium	low	0.05	notrade
medium	medium	low	medium	low	0.66	sell
medium	medium	low	medium	high	0.98	buy
medium	medium	low	medium	high	0.37	notrade
medium	medium	low	medium	high	0.34	sell
medium	medium	low	high	low	0.91	buy
medium	medium	low	high	low	0.34	notrade
medium	medium	low	high	low	0.24	sell
medium	medium	low	high	high	0.65	buy
medium	medium	low	high	high	0.62	notrade
medium	medium	low	high	high	0.25	sell
medium	medium	medium	low	low	0.05	buy
medium	medium	medium	low	low	0.08	notrade
medium	medium	medium	low	low	0.59	sell
medium	medium	medium	low	high	0.16	buy
medium	medium	medium	low	high	0.06	notrade
medium	medium	medium	low	high	0.28	sell
medium	medium	medium	medium	low	0.95	buy
medium	medium	medium	medium	low	0.97	notrade
medium	medium	medium	medium	low	0.17	sell
medium	medium	medium	medium	high	0.22	buy
medium	medium	medium	medium	high	0.42	notrade
medium	medium	medium	medium	high	0.38	sell
medium	medium	medium	high	low	0.55	buy

IF					THEN	
medium	medium	medium	high	low	0.31	notrade
medium	medium	medium	high	low	0.45	sell
medium	medium	medium	high	high	0.37	buy
medium	medium	medium	high	high	0.56	notrade
medium	medium	medium	high	high	0.85	sell
medium	medium	high	low	low	0.60	buy
medium	medium	high	low	low	0.29	notrade
medium	medium	high	low	low	0.39	sell
medium	medium	high	low	high	0.09	buy
medium	medium	high	low	high	0.98	notrade
medium	medium	high	low	high	0.84	sell
medium	medium	high	medium	low	0.61	buy
medium	medium	high	medium	low	0.92	notrade
medium	medium	high	medium	low	0.79	sell
medium	medium	high	medium	high	0.35	buy
medium	medium	high	medium	high	0.94	notrade
medium	medium	high	medium	high	0.51	sell
medium	medium	high	high	low	0.99	buy
medium	medium	high	high	low	0.94	notrade
medium	medium	high	high	low	0.45	sell
medium	medium	high	high	high	0.87	buy
medium	medium	high	high	high	0.31	notrade
medium	medium	high	high	high	0.66	sell
medium	high	low	low	low	0.67	buy
medium	high	low	low	low	0.67	notrade
medium	high	low	low	low	0.33	sell
medium	high	low	low	high	0.41	buy
medium	high	low	low	high	0.64	notrade
medium	high	low	low	high	0.36	sell
medium	high	low	medium	low	0.92	buy
medium	high	low	medium	low	0.61	notrade
medium	high	low	medium	low	0.31	sell
medium	high	low	medium	high	0.73	buy
medium	high	low	medium	high	0.93	notrade
medium	high	low	medium	high	0.45	sell
medium	high	low	high	low	0.62	buy
medium	high	low	high	low	0.16	notrade
medium	high	low	high	low	0.23	sell
medium	high	low	high	high	0.70	buy
medium	high	low	high	high	0.44	notrade
medium	high	low	high	high	0.73	sell
medium	high	medium	low	low	0.04	buy
medium	high	medium	low	low	0.99	notrade
medium	high	medium	low	low	0.66	sell
medium	high	medium	low	high	0.12	buy
medium	high	medium	low	high	0.73	notrade

IF					THEN	
medium	high	medium	low	high	0.39	sell
medium	high	medium	medium	low	0.84	buy
medium	high	medium	medium	low	0.77	notrade
medium	high	medium	medium	low	0.00	sell
medium	high	medium	medium	high	0.22	buy
medium	high	medium	medium	high	0.50	notrade
medium	high	medium	medium	high	0.25	sell
medium	high	medium	high	low	0.48	buy
medium	high	medium	high	low	0.13	notrade
medium	high	medium	high	low	0.49	sell
medium	high	medium	high	high	0.09	buy
medium	high	medium	high	high	0.80	notrade
medium	high	medium	high	high	0.09	sell
medium	high	high	low	low	0.64	buy
medium	high	high	low	low	0.05	notrade
medium	high	high	low	low	0.31	sell
medium	high	high	low	high	0.50	buy
medium	high	high	low	high	0.05	notrade
medium	high	high	low	high	0.39	sell
medium	high	high	medium	low	0.12	buy
medium	high	high	medium	low	0.05	notrade
medium	high	high	medium	low	0.16	sell
medium	high	high	medium	high	0.75	buy
medium	high	high	medium	high	0.87	notrade
medium	high	high	medium	high	0.49	sell
medium	high	high	high	low	0.08	buy
medium	high	high	high	low	0.30	notrade
medium	high	high	high	low	0.05	sell
medium	high	high	high	high	0.93	buy
medium	high	high	high	high	0.26	notrade
medium	high	high	high	high	0.92	sell
high	low	low	low	low	0.02	buy
high	low	low	low	low	0.91	notrade
high	low	low	low	low	0.90	sell
high	low	low	low	high	0.89	buy
high	low	low	low	high	0.50	notrade
high	low	low	low	high	0.80	sell
high	low	low	medium	low	0.39	buy
high	low	low	medium	low	0.99	notrade
high	low	low	medium	low	0.07	sell
high	low	low	medium	high	0.84	buy
high	low	low	medium	high	0.98	notrade
high	low	low	medium	high	0.35	sell
high	low	low	high	low	0.09	buy
high	low	low	high	low	0.16	notrade
high	low	low	high	low	0.00	sell

IF					THEN	
high	low	low	high	high	0.04	buy
high	low	low	high	high	0.59	notrade
high	low	low	high	high	0.38	sell
high	low	medium	low	low	0.01	buy
high	low	medium	low	low	0.79	notrade
high	low	medium	low	low	0.80	sell
high	low	medium	low	high	0.05	buy
high	low	medium	low	high	0.91	notrade
high	low	medium	low	high	0.65	sell
high	low	medium	medium	low	0.72	buy
high	low	medium	medium	low	0.32	notrade
high	low	medium	medium	low	0.63	sell
high	low	medium	medium	high	0.17	buy
high	low	medium	medium	high	0.20	notrade
high	low	medium	medium	high	0.43	sell
high	low	medium	high	low	0.32	buy
high	low	medium	high	low	0.87	notrade
high	low	medium	high	low	0.30	sell
high	low	medium	high	high	0.11	buy
high	low	medium	high	high	0.69	notrade
high	low	medium	high	high	0.38	sell
high	low	high	low	low	0.24	buy
high	low	high	low	low	0.66	notrade
high	low	high	low	low	0.43	sell
high	low	high	low	high	0.37	buy
high	low	high	low	high	0.51	notrade
high	low	high	low	high	0.83	sell
high	low	high	medium	low	0.26	buy
high	low	high	medium	low	0.36	notrade
high	low	high	medium	low	0.80	sell
high	low	high	medium	high	0.04	buy
high	low	high	medium	high	0.72	notrade
high	low	high	medium	high	0.64	sell
high	low	high	high	low	0.10	buy
high	low	high	high	low	0.35	notrade
high	low	high	high	low	0.12	sell
high	low	high	high	high	0.43	buy
high	low	high	high	high	0.71	notrade
high	low	high	high	high	0.52	sell
high	medium	low	low	low	0.79	buy
high	medium	low	low	low	0.39	notrade
high	medium	low	low	low	0.38	sell
high	medium	low	low	high	0.62	buy
high	medium	low	low	high	0.02	notrade
high	medium	low	low	high	0.73	sell
high	medium	low	medium	low	0.54	buy

IF					THEN	
high	medium	low	medium	low	0.56	notrade
high	medium	low	medium	low	0.91	sell
high	medium	low	medium	high	0.01	buy
high	medium	low	medium	high	0.69	notrade
high	medium	low	medium	high	0.02	sell
high	medium	low	high	low	0.45	buy
high	medium	low	high	low	0.76	notrade
high	medium	low	high	low	0.90	sell
high	medium	low	high	high	0.05	buy
high	medium	low	high	high	0.09	notrade
high	medium	low	high	high	0.18	sell
high	medium	medium	low	low	0.59	buy
high	medium	medium	low	low	0.91	notrade
high	medium	medium	low	low	0.11	sell
high	medium	medium	low	high	0.02	buy
high	medium	medium	low	high	0.45	notrade
high	medium	medium	low	high	0.44	sell
high	medium	medium	medium	low	0.92	buy
high	medium	medium	medium	low	0.66	notrade
high	medium	medium	medium	low	0.66	sell
high	medium	medium	medium	high	0.32	buy
high	medium	medium	medium	high	0.95	notrade
high	medium	medium	medium	high	0.87	sell
high	medium	medium	high	low	0.45	buy
high	medium	medium	high	low	0.89	notrade
high	medium	medium	high	low	0.84	sell
high	medium	medium	high	high	0.05	buy
high	medium	medium	high	high	0.88	notrade
high	medium	medium	high	high	0.59	sell
high	medium	high	low	low	0.88	buy
high	medium	high	low	low	0.41	notrade
high	medium	high	low	low	0.03	sell
high	medium	high	low	high	0.66	buy
high	medium	high	low	high	0.24	notrade
high	medium	high	low	high	0.92	sell
high	medium	high	medium	low	0.66	buy
high	medium	high	medium	low	0.40	notrade
high	medium	high	medium	low	0.09	sell
high	medium	high	medium	high	0.59	buy
high	medium	high	medium	high	0.04	notrade
high	medium	high	medium	high	0.51	sell
high	medium	high	high	low	0.03	buy
high	medium	high	high	low	0.79	notrade
high	medium	high	high	low	0.54	sell
high	medium	high	high	high	0.71	buy
high	medium	high	high	high	0.97	notrade

IF					THEN	
high	medium	high	high	high	0.27	sell
high	high	low	low	low	0.45	buy
high	high	low	low	low	0.34	notrade
high	high	low	low	low	0.92	sell
high	high	low	low	high	0.45	buy
high	high	low	low	high	0.45	notrade
high	high	low	low	high	0.95	sell
high	high	low	medium	low	0.71	buy
high	high	low	medium	low	0.67	notrade
high	high	low	medium	low	0.54	sell
high	high	low	medium	high	0.83	buy
high	high	low	medium	high	0.30	notrade
high	high	low	medium	high	0.27	sell
high	high	low	high	low	0.62	buy
high	high	low	high	low	0.24	notrade
high	high	low	high	low	0.45	sell
high	high	low	high	high	0.67	buy
high	high	low	high	high	0.56	notrade
high	high	low	high	high	0.35	sell
high	high	medium	low	low	0.70	buy
high	high	medium	low	low	0.74	notrade
high	high	medium	low	low	0.10	sell
high	high	medium	low	high	0.84	buy
high	high	medium	low	high	0.13	notrade
high	high	medium	low	high	0.45	sell
high	high	medium	medium	low	0.13	buy
high	high	medium	medium	low	0.85	notrade
high	high	medium	medium	low	0.02	sell
high	high	medium	medium	high	0.07	buy
high	high	medium	medium	high	0.97	notrade
high	high	medium	medium	high	0.60	sell
high	high	medium	high	low	0.93	buy
high	high	medium	high	low	0.09	notrade
high	high	medium	high	low	0.14	sell
high	high	medium	high	high	0.99	buy
high	high	medium	high	high	0.17	notrade
high	high	medium	high	high	0.89	sell
high	high	high	low	low	0.06	buy
high	high	high	low	low	0.70	notrade
high	high	high	low	low	0.29	sell
high	high	high	low	high	0.45	buy
high	high	high	low	high	0.41	notrade
high	high	high	low	high	0.30	sell
high	high	high	medium	low	0.50	buy
high	high	high	medium	low	0.15	notrade
high	high	high	medium	low	0.42	sell

IF					THEN	
high	high	high	medium	high	0.34	buy
high	high	high	medium	high	0.67	notrade
high	high	high	medium	high	0.00	sell
high	high	high	high	low	0.91	buy
high	high	high	high	low	0.54	notrade
high	high	high	high	low	0.83	sell
high	high	high	high	high	0.11	buy
high	high	high	high	high	0.32	notrade
high	high	high	high	high	0.66	sell

#### d Output variables

The output of our model will be denominated *Strategy*, which represents the decision making of the investor through the period of time. The output of the linguistic values adopted was: buy, sell, no trade.

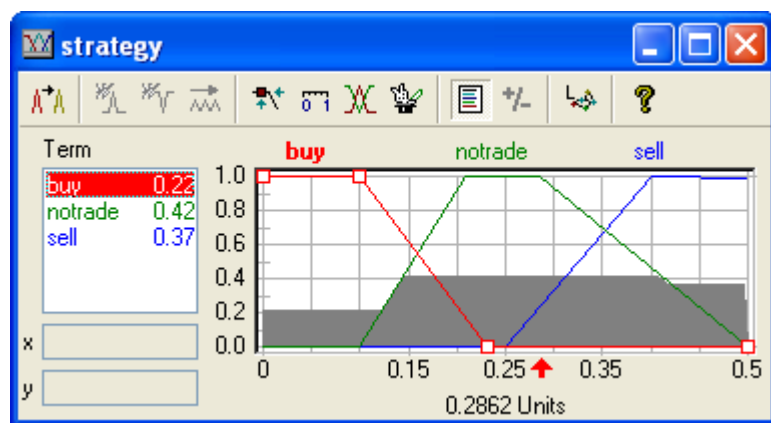


Fig 3. Example of output linguistic value

#### 4. Results

The results show that the fuzzy logic give best results on investment strategies. In fact, there is an interaction between fundamental and behavioral data. The results show that the investor buys and sell according to variations of stocks prices. He no trade when he sent risk and fear from lose. So the use of fundamental data (return, oss, mom) and the behavioral data (sent1 and sent2) lets as conclude that we can have a complementarity between the two types of data on the investment strategies.

#### 5. Conclusion

By using fuzzy logic, we try to model the complementarity between fundamental and behavioral data. Each theory contributes largely to explain investor's decision making. We

have used variables from efficiency theory specifically from the weak efficiency form and variables that are a measure of sentiment. We find that the correlation between the theories let's as conclude that, although the debate between efficiency theory and corporate finance, these theories can converge to explain investors decision making (buy, sell or no trade).

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