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A fuzzy logic control using a differential evolution algorithm aimed at modelling the financial market dynamics

Nizar Hachicha [a], Bassem Jarboui [b], Patrick Siarry [c,*]

[a] COFFIT-FSEGS, route de l'aéroport km 4, Sfax 3018, Tunisia
[b] Institut Supérieur de Commerce et de Comptabilité de Bizerte, Zarzouna 7021, Bizerte, Tunisia
[c] LiSSi, Université Paris-Est Créteil Val-de-Marne, 61 avenue du Général de Gaulle, 94010 Créteil, France

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ABSTRACT

The topic of modelling financial market price movements is in the heart of a wide ranging debate between fundamentalists and behaviourists. Therefore, the difficulty of the prediction is due to several features: the complexity, the non-linearity and the dynamism of the financial market system, as well as the behaviour of two categories of traders. While the irrational traders are known by a shift in their sentiments, the rational ones have a limited capacity of arbitration. While taking into account the fuzzy complementarity between the fundamentalists and the behaviourists in the explanation of financial market dynamics, this study investigates the development of a new modelling technique using fuzzy sets optimized through differential evolution. This new technique provides some applicable results in the explanation of the dynamical emergent and international financial markets.

1. Introduction

There are various social and economic phenomena that lead the financial market system to be more and more complex. With that issue in mind, the field of financial forecasting is characterized by a high degree of uncertainty, and hidden relationships.

Studies of price behaviour following large price dynamics tend to support two contrasting approaches: the traditional one, which sustains the efficiency of the market and the behavioural one, which undergoes the investor sentiment bias. There seems to be no obvious consensus in the literature on which one of these two approaches prevails. The debate is still ongoing on whether the empirical evidence indicates market inefficiency explained by psychological bias or if it can be explained by rational asset pricing theories, dealing with modifications and extensions of the standard theory. This literature has been the crucial point of the debate between proponents of market efficiency and proponents of behavioural finance. On the one hand, proponents of market efficiency mostly argue that these characteristics are proxies for fundamental risk. Nevertheless, proponents of behavioural finance argue that the characteristics reflect mispricing stemming from investor bias, mainly overreaction.

The overview of rational explanations is based on economic fundamentals for the deviations in stock prices in the late 1990s (see [19]). The asset pricing model based on the efficient market hypothesis theoretically contends that systematic risk is measured by the exposure to the market portfolio.

Unfortunately, the empirical record of the asset pricing model based on the efficient market hypothesis is poor – poor enough to invalidate the way it is used in applications. The shortcomings of these models pose challenges that can be

* Corresponding author.
E-mail addresses: hachicha_nizar@yahoo.fr (N. Hachicha), bassem_jarboui@yahoo.fr (B. Jarboui), siarry@univ-paris12.fr (P. Siarry).

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explained by alternative specifications. Therefore, Fama and French [15] updated and synthesized the evidence on the empirical failures of these models. Using the cross-section regression approach, they added two important factors that characterize a firm's risk: the book to market ratio and the firm's size. Chan et al. [10] found a strong relation between book to market equity (B/M) and average return for Japanese stocks. Capaul et al. [8] observed a similar B/M effect in four European stock markets and in Japan. In an attempt to capture the dimensions of risk other than the exposure to the market factor, book to market and size ratios, Pastor and Stambaugh [33] considered a liquidity factor. Acharya and Pedersen [2] provided a unified theoretical framework that can elucidate the empirical findings, namely return sensitivity to market liquidity is priced, average liquidity is priced (see [4]), and liquidity co-moves with market returns and predicts future returns.

The other strand of recent literature has provided empirical evidence on market inefficiencies and proposed a behavioural explanation. Hirshleifer [24] and Barberis and Thaler [6] contain extensive surveys of behavioural finance. Like the early studies on long-term price overreaction (see [13]), empirical studies on short-term price reaction attributed the anomalous pricing to investor behavioural biases, along the lines of the Kahneman and Tversky hypothesis [22]. Indeed, several studies suggested that investor sentiment and trading activities of noise traders influence stock prices (see [11,7,23,16,9]).

In this paper, we seek for an explanation of the price dynamics via the complementary role played by these approaches, i.e., in taking into account the fundamental explanatory variables (market return $r_{m,t}$ and systematic risk), the micro-structural ones (size effect SMB_t and book to market effect HML_t) and the behavioural approach (investor sentiment $sent_t$[18]). Market efficiency is essentially equivalent to considering that market sentiment has no effect. Therefore, the market, even if it is reputed inefficient, will pass through an efficient period. Clearly, the model with a constant volatility based on the market returns data, fails to capture all the anomalies. Thus, the abnormal returns following large price oscillations have been shown to be insensitive to several different specifications. In other words, the model should take into account the uncertainty of presence of the two periods.

Models of financial markets present several weaknesses in the mental representations of the reality. These models are based on Boolean variables (true/false). In reality, the interaction between fundamentalists and behaviourists is uncertain. Modelling the financial markets based on the interacting heterogeneity is a way of reasoning under partial information and, therefore, in presence of uncertainty (see [5]).

Therefore, the intelligent appropriate technique used to satisfy this dynamics is the fuzzy logic [35,31]. This technique has provided fruitful ideas and new tools to statistical methodology. Starting from the late sixties, an increasing flow of contributions has widened the scope of statistical reasoning to comprise fuzzy information and fuzzy uncertainty. The earliest fuzzy systems were constructed using the knowledge provided by human experts and were thus linguistically correct. These techniques initially concentrated on solving a parameter optimization problem based on the numerical performance of the systems, being slightly considered in linguistic aspects. Recently, fuzzy modelling techniques have more concentrated on linguistic issues. However, the construction of fuzzy models of large and complex systems is a hard task demanding the identification of many parameters.

The success of the fuzzy modelling has encouraged research and applications relating to all aspects of the finance in general, and especially to the financial market (see [1,17]). But, this success is sensitive to the choice of parameters. The most important two sets of parameters attributed to this success are those of membership functions and fuzzy rules. One way to solve this problem is to use a nature inspired evolution method.

This method is represented by the evolutionary algorithms, which are based on two powerful evolution principles: variability and selection. A population of individuals, which represent possible solutions to a given problem, evolves in the problem environment, reproduction operations depending on individual fitnesses. This constant competition drives the population towards an individual adaptation to the problem environment. The main purpose of this paper is modelling the price movements through a new approach of fuzzy systems, based on differential evolution regarding the heterogeneous beliefs.

The fuzzy sets optimized through differential evolution are used, for the first time, by designing a hierarchical fuzzy logic controller using the differential evolution approach. This hybrid technique was recently used and proved effective. Thus, we adapted this technique in a financial field, which had not been proposed in the literature until now. This fuzzy logic system proved its prevalence, compared to those existing in the literature.

To validate our technique, we tried to investigate the implication of our modelling under an international market, reputed efficient, and an emergent one, assumed inefficient. For each market, we formed two portfolios, considering the degree of efficiency: a banking sector portfolio (the most efficient one) and a non banking one (the most inefficient one).

This step gave rise to four portfolios for return modelling, namely the banking sector in an emergent market, the non banking sector in an emergent market, the banking sector in an international market and the non banking sector in an international market.

The outline of the paper is as follows: the second section discusses the fuzzy system under its two versions, the traditional presentation and the new one. The third section describes the fuzzy system through its four stages. Section four contains a description of the differential evolution algorithms with their different forms. The coding of the membership functions and fuzzy rules of differential evolution optimization is presented in section five. Experiments and results, as well as the concluding remarks, are provided in the last two sections.