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Fuzzy logic, trading uncertainty and technical trading

Nikola Gradojevic [a,c,*], Ramazan Gençay [b,c]

[a] Faculty of Business Administration, Lakehead University, 955 Oliver Road, Thunder Bay, ON, Canada P7B 5E1
[b] Department of Economics, Simon Fraser University, 8888 University Drive, Burnaby, BC, Canada V5A 1S6
[c] The Rimini Center for Economic Analysis, Via Patara, 3, 47900 Rimini (RN), Italy

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ABSTRACT

From the market microstructure perspective, technical analysis can be profitable when informed traders make systematic mistakes or when uninformed traders have predictable impacts on price. However, chartists face a considerable degree of trading uncertainty because technical indicators such as moving averages are essentially imperfect filters with a nonzero *phase shift*. Consequently, technical trading may result in erroneous trading recommendations and substantial losses. This paper presents an uncertainty reduction approach based on fuzzy logic that addresses two problems related to the uncertainty embedded in technical trading strategies: market timing and order size. The results of our high-frequency exercises show that 'fuzzy technical indicators' dominate standard moving average technical indicators and filter rules for the Euro-US dollar (EUR-USD) exchange rates, especially on high-volatility days.
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1. Introduction

Technical trading models typically rely on technical indicators constructed from past price and volume information that generate discrete (buy or sell) trading recommendations. Such models are atheoretic and ignore fundamental information about the price; however, they have been shown to result in trading profitability. Specifically, the success of technical trading violates the weak form of the efficient market hypothesis, which states that past prices should not assist traders in earning unusually high returns. In general, the literature examines the practical value of two types of analysis: *charting*, which identifies geometric patterns in the history of prices, and *technical indicators approach*, which mechanically applies mathematical trading rules constructed from past and present prices. Studies that find charting profitable include Chang and Osler (1999), Lo et al. (2000) and Savin et al. (2007), whereas evidence for the profitability of technical indicators can be found in Neftci (1991), Levich and Thomas (1993), Brock et al. (1992), Neely et al. (1997), Allen and Karjalainen (1999) and Gençay (1992).

Some of the above contributions combine technical analysis with other statistical methodologies. For example, Lo et al. (2000) show that charting based on automatic pattern recognition with kernel regressions adds value to the investment process. In a related study, Savin et al. (2007) produce similar results for price patterns. Gençay (1992) uses technical indicators to feed an artificial neural network model and thereby demonstrates that trading signals produced by such a combination outperform a simple buy-and-hold strategy. Allen and Karjalainen (1999) apply genetic programming to search for ex-ante "optimal" trading rules. In summary, several papers present evidence that technical analysis can be informative for the price, although its profitability can vary over time, which is in line with the adaptive markets hypothesis (Lo, 2004).[1]

In light of the market microstructure theory, technical trading may be profitable when informed traders make systematic mistakes or when uninformed traders have a predictable impact on price (Harris, 2003). When technical traders reveal and trade on mistakes made by informed traders, they in turn themselves become informed traders. The trading of these so-called *information-oriented technical traders* corrects prices and improves market efficiency. Information-oriented technical trading is,

* Corresponding author at: Faculty of Business Administration, Lakehead University, 955 Oliver Road, Thunder Bay, ON, Canada P7B 5E1. Tel.: +1 807 343 8419; fax: +1 807 343 8443.

E-mail addresses: ngradoje@lakeheadu.ca (N. Gradojevic), rgencay@sfu.ca (R. Gençay).

[1] See Irwin and Park (2007) and Menkhoff and Taylor (2007) or, more recently, Neely and Weller (2012) for extensive surveys on the application of technical analysis in the foreign exchange and equity markets.

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however, quite difficult in practice because informed traders correct their mistakes and learn from their past actions. This process diminishes profitable information-oriented technical trading opportunities. In contrast to technical trading on the informed traders' actions, *sentiment-oriented technical traders* exploit predictable price patterns caused by uninformed traders. Such an order-anticipating approach attempts to front-run the uninformed traders and trade before they trade. Sentiment-oriented technical trading can be useful when it correctly anticipates the impacts that uninformed traders will have on prices. In this paper, we extend the activity of sentiment-oriented technical traders (or order anticipators) to 'uncertainty reduction', whereas the uninformed traders are considered to be pure technical traders who employ simple technical indicators.

The practice of mechanically applying technical indicators in investment management without any uncertainty considerations could potentially be dangerous. Uncertainties in foreign exchange (FX) and equity markets can originate from, for example, market regime shifts, the impact of large trades on price, short-sale restrictions, incomplete data or behavioral issues. Recently, Lo and Mueller (2010) have argued that the presence of inappropriately identified uncertainties in a quantitative investment strategy can adversely affect risk management efforts. They introduce five levels of uncertainty: perfect certainty (e.g., direct trading costs), risk (e.g., probability distributions of trading volumes), fully reducible uncertainty (e.g., statistical framework for time series analysis), partially reducible uncertainty (e.g., multiple market regimes) and irreducible uncertainty (e.g., tail risk). Each of these levels is to be addressed with an appropriate set of skills and methodologies. For instance, the application of time series or linear regression analysis to tail events rather than extreme value theory could be disastrous for an investment strategy. In the same vein, utilizing technical indicators in trading while neglecting the uncertainty aspect of such actions would probably result in a series of unnecessarily risky trading recommendations.

Our analysis addresses the issue of trading model uncertainty (or trading uncertainty) that belongs to the partially reducible uncertainty domain, as defined above. This situation involves the uncertainty in decision making that arises if there is insufficient knowledge regarding the appropriateness of the trading model. Trading uncertainty represents a refinement of the economic uncertainty concept also known as model uncertainty. Model uncertainty generally arises from the potential incorrectness of the choice of the model that is generating the data. In this context, Pesaran and Timmermann (2002) link model uncertainty to an investor facing many competing forecasting models.[2] This problem is the reason why predictability and profitable opportunities in financial markets are short-lived (Timmermann and Granger, 2004).[3]

This paper introduces fuzzy logic as a tool that can help traders to control for the trading uncertainty aspect of employing technical indicators. The information generated by technical indicators is possibly imprecise, incomplete or unreliable. Fuzzy logic by its very nature tolerates uncertainty by defining variables, i.e., technical indicators, as imprecise linguistic terms that cover a broad fuzzy variable range; for example, trading signals can be expressed in a more sophisticated fashion as a 'strong buy', 'hold' or 'very strong sell.' Furthermore, technical indicators such as moving averages are prone to indicating a turning point later than the it actually occurs, as they are essentially imperfect filters with a nonzero *phase shift* (Gençay et al., 2001). Management of uncertainty in such situations is of the utmost importance. Fuzzy logic involves more continuous and conservative decision making than buy or sell recommendations, and it thereby partially reduces trading uncertainty in volatile markets. In addition, fuzzy logic can reduce trading costs by controlling for the order size, whereas pure technical indicators commit all available funds to a trading position. By using fuzzy logic, we attempt to resolve two problems related to the uncertainty embedded in investment strategies based solely on technical trading rules: market timing ("when to trade") and order size ("how to trade").

Studies on the application of fuzzy logic in financial economics have been scarce (Bekiros and Georgoutsos, 2007) and usually are considered mostly in tandem with other methodologies such as artificial neural networks (Gradojevic, 2007) or reinforced learning of agent-based systems (Bekiros, 2010; Tay and Linn, 2001). Additionally, Bojadziev and Bojadziev (1997) uses fuzzy logic to evaluate a client's risk tolerance based on the annual income and total net worth, whereas Serguieva and Hunter (2004) evaluate the risk associated with investing in 35 UK companies traded on the London Stock Exchange. With regard to technical trading, research efforts have centered on fuzzy logic-assisted charting (Zhou and Dong, 2004) but not on technical indicators. The fact that charting is primarily visual, whereas the technical indicators approach is essentially mathematical, suggests that the latter is more amenable to statistical methodologies such as fuzzy logic.

In this paper, our goal is to reduce the trading uncertainty of the standard technical indicators approach by utilizing fuzzy logic technical trading rules that are more robust with respect to errors in decision-making (trading). We directly compare the efficacy of standard technical indicators with that of fuzzy technical indicators for high-frequency (1-min) EUR-USD exchange rates in 2005. Furthermore, we develop five testable hypotheses that involve the relationship between high-frequency profitability and volatility (Hypotheses 1–3) and the ranking of the trading strategies (Hypotheses 4 and 5). We find that the extension of standard technical trading strategies with the fuzzy control methodology results in improved profitability. Our results show that fuzzy technical indicators are particularly useful for reducing trading losses on highly volatile days of the week. On such days, profits from pure technical trading strategies decrease and profits from fuzzy technical trading strategies increase. Overall, higher volatility leads to greater excess returns of fuzzy technical trading strategies relative to pure technical trading strategies. The documented gains in conditional mean returns are, in general, statistically significant over 50 weeks of 1-min EUR-USD exchange rates, whereas the buy-and-hold strategy performs poorly, irrespective of volatility. Finally, we link our results to market microstructure in the sense that the profitability of fuzzy logic-based technical trading might be used to explain the motivation for pursuing sentiment-oriented technical trading strategies. Such strategies are devised by order anticipators who front-run uninformed traders who apply simple technical trading rules. In accordance with Bekiros (2010), we argue that fuzzy control acts as a learning mechanism through which it is possible to better predict turning points and to thus react before uninformed technical traders trade. Hence, we conclude that the profitability of sentiment-oriented technical trading is particularly pronounced during high-volatility trading sessions.

In Section 2, we provide a brief overview of fuzzy logic, including an illustrative example for the S&P-500 Index. The data are described in Section 3. This section also develops testable economic and ranking hypotheses for the competing trading strategies. The construction of our fuzzy technical indicators and our results are reported in Section 4. We conclude and offer some potential future research avenues in Section 5.

[2] This type of uncertainty is also used to denote heteroskedasticity in the conditional variance of asset returns (Easley and O'Hara, 2010).

[3] Model averaging techniques are typically used to reduce model uncertainty. Such approaches can be found when model uncertainty is present in the shaping of monetary policy (Cogley et al., 2011), hedge fund pricing (Vrontos et al., 2008) and investment management (Avramov, 2002; Pesaran et al., 2009).

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