Title: New quantitative techniques for modelling, forecasting, and managing risk in financial markets

Brief introduction

The importance of analyzing financial markets and correctly understanding their complex mechanisms is broadly recognized, see, e.g., Kienitz and Wetterau (2012) and references therein. In particular, the volatility of financial assets has attracted increasing attention in recent years and various different approaches have been developed in order to model it (Ballestra et al., Corsi, 2009, Engle, 1982, Heston, 1993, Kienitz and Wetterau, 2012). From the theoretical standpoint, the volatility of a stock is a statistical quantity expressing the standard deviation of its trading price over a given time period. Nevertheless, empirical measures of volatility do also exist, and, among them, one of the most common is the so-called VIX index.

The VIX index (or, more simply, the VIX) is a real-time index measuring the market's expectations of volatility on the S&P 500 index in the next 30 days, and it is widely employed by investors for quantifying the level of risk, fear, or stress in the market. It was introduced by Whaley (1993), and it is computed based on the implied volatility of a number of put and call options on the S&P 500. Implied volatility reflects the market makers’ point of view about the expected volatility of the futures’ underlying assets. Then, since market makers are often among the most informed agents, implied volatility should outperform the historical one in forecasting the realized volatility of the futures’ underlying asset (Shu and Zhang, 2012). A volatility index that is perfectly analogous to the VIX has also been introduced in the Indian market. This is the NVIX, which is based on the NIFTY index on the (Indian) National Stock Exchange.

The main objective of this research project is to develop new mathematical and statistical methods to accurately forecast the VIX, its future derivatives, and the NVIX. In doing this, we will leverage all the information that is currently available, so that profitable and economically significant trading strategies can be obtained.

Background and statement of the problem

Despite the importance and the common use of VIX as a volatility measure, only little attention has been paid to the problem of forecasting it. The few studies on these subjects, which are largely dominated by autoregressive conditional heteroscedasticity models taking into account non-linearity, long memory features and/or lagged exogenous variables (see, e.g., Ahoniemi (2006), Konstantinidi et al. (2008), Psaradellis and Sermpinis (2016), Shu and Zhang (2012)), show that the VIX is to some extent predictable. This finding is surely interesting for researchers, but not necessarily helpful for traders, because VIX is tradable only as derivative contracts, whose dynamics does not always follow that of the VIX index. For example, Asensio (2013), Degenkakis (2008), Konstantinidi and Skiadopoulos (2011), who are among the few authors focusing on VIX futures (henceforth referred to as VXF s), highlight only a weak evidence of statistical predictability and experience a low level of profitability when implementing trading strategies based on VIX forecasts. The overall picture is not encouraging for investors: even if VIX is to some extent predictable, it seems very hard to successfully trade VXF s.
One of the goals of the research project is to develop suitable statistical and mathematical methods for predicting the VIX and other volatility indices. In Ballestra et al. (2019) we have shown that the VXF can be forecasted, at least to some extent, by employing a suitable (strongly non-linear) neural network architecture (see, for example, Thenmozhi, 2006). In this research project, we plan to extend the above findings along several directions. Specifically, we aim to obtain accurate predictions of both the VIX and VXF. To this aim, we will take into account coincident indicators such as the intraday returns of the Indian NVIX and its futures, which contain overnight information becoming available only few hours before the Chicago Board Options Exchange (CBOE) opening. It is worth noticing that such an approach has interesting theoretical implications, since it allows us to establish if a form of weak efficiency does also hold among markets of different countries.

Moreover, we will tackle the problem of trading volatility. As already observed, the very few works on this subject highlight that even accurate VIX predictions can hardly be exploited for trading VXF. In our project, we will extend the investigation by also considering futures on the NVIX.

**Research questions, objectives, and deliveries**

The research will follow the following four directions, which are intimately connected among themselves and combine both theoretical and practical aspects:

1) Can returns on the VXF derivatives be forecasted accurately? To answer this question, we will employ a neural network model, in order to take into account non-linearities, and we will exploit exogenous and nearly coincident variables that reflect information available only few hours before the Chicago Board Options Exchange (CBOE) opening. In particular, the analysis will include the Indian BSESN and NVIX indices, as well as the futures on the NVIX. Furthermore, instead of using daily returns, we will consider intraday (open to close) returns, which are free of spurious effects related to trading timing and offer the advantage of representing only genuine autocorrelation due to partial price adjustments and time-varying risk premia. This approach will allow us to establish if and to which extent either the VIX or the VXF is affected by the BSESN and the NVIX. Moreover, we expect to obtain accurate predictions of VXF open-to-close returns. In this respect, the neural network model will be tested against more traditional approaches, such as the logistic and the heterogeneous autoregressive specifications. The comparison will be conducted by taking into account the directional accuracy of the models and by employing the tests of superior predictive ability as in Hansen (2005) and Timmerman and Pesaran (1992).

2) Does the most recently available information, even if it comes from a market of a different country, have a significant and sufficient explanatory power in forecasting volatility futures? First, we will test the dependence of the VXF on the BSESN and on the NVIX. Second, if any of these two indices is significant in predicting the VXF, we will test if the futures on the NVIX is affected by the index of a stock market that closes some hours before the Indian market, such as the NIKKEI of Tokyo. Finally, we will directly consider the dependence of the NIKKEI alone on the VXF, so as to check if important variables such as the BSESN or the NVIX are being omitted (a statistical test for omitted variables will be conducted by using instrumental variable regression). All the above procedure will allow us to identify suitable and almost coincident variables that impact the returns of VXF. In doing so, we will establish if a form of weak efficiency does hold among markets of different countries.
3) Can one earn significant profits when trading volatility futures? To answer this question, we will implement suitable trading strategies based on the predictions of the neural network model that we are going to develop. In particular, since we plan to forecast open-to-close returns, we will mainly focus on trading strategies that amount to opening a position of the VXF (or on the futures on the NVIX) and closing it at night.

We shall observe that, by considering intraday returns we can easily connect forecast performances to the profits earned by those investors who open and close a position on the same day, taking advantage of the fact that stock volatility is substantially higher intraday than overnight. Nevertheless, for comparison purposes, strategies based on close-to-close VXF prices will also be considered.

4) Finally, the VXF predictions obtained will also be employed for managing the risk of equity portfolios. As shown by some empirical studies (see, e.g., Moran and Dash, 2007), VXF are negatively correlated with the major US indices, which can be exploited for reducing the risk associated to portfolios of US equities. In our research work, we plan to use the VXF predictions to improve the risk-reduction strategies, and to investigate the extent to which VXF forecasts allow corporate managers to efficiently quantify and reduce portfolio risk.

**Piano di Attività.** The postdoctoral researcher will acquire an in-depth knowledge of the main mathematical and statistical models for volatility forecasting (extended GARCH, heterogeneous autoregressive, CIR, …) and of neural network models. She/he will also learn how to apply these models in either R or Matlab, how to compare them by employing suitable statistical tests and how to use their predictions for trading and managing risk. She/he will also develop models to forecast VXF returns which can include non-lagged exogenous factors in a fashion such that the weak efficiency hypothesis is satisfied. The results obtained will be presented at conferences and will be submitted for the publication in highly qualified journals in quantitative finance and economic statistics.

**Participants in the study and the role they play:** the project will also involve Prof. Andrea Guizzardi, who has a strong expertise in Economic Statistics. He will provide valuable ideas on how to develop some of the quantitative methods described above, and will contribute to the economic interpretation of all the results obtained. The research will also benefit from the international collaboration of Prof. Marcello Mariani, Professor of Management and Entrepreneurship at the Henley Business School (University of Reading, UK). Professor Mariani is an expert of big and open data for decision making, business analytics, digital business models, performance analysis and measurement, make or buy decisions, and he will contribute to identify corporate portfolios, capital allocation strategies and risk management objectives to be improved by means of VXF predictions.

**References**


