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Real-Time Pricing and Hedging of Options on Currency Futures with Artificial Neural Networks

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ABSTRACT

High-frequency trading and automated algorithm impose high requirements on computational methods. We provide a model-free option pricing approach with neural networks, which can be applied to real-time pricing and hedging of FX options. In contrast to well-known theoretical models, an essential advantage of our approach is the simultaneous pricing across different strike prices and parsimonious use of real-time input variables. To test its ability for the purpose of high-frequency trading, we perform an empirical run-time trading simulation with a tick dataset of EUR/USD options on currency futures of 4 weeks. In very short non-overlapping 15-minute out-of-sample intervals, theoretical option prices derived from the Black model compete against nonparametric option prices through two different neural network topologies. We show that the approximated pricing function of learning networks is suitable for generating fast run-time option pricing evaluation as their performance is slightly better in comparison to theoretical prices. The derivation of the network function is also useful for performing hedging strategies. We conclude that the performance of closed-form pricing models depends highly on the volatility estimator, whereas neural networks can avoid this estimation problem but require market liquidity for training. Nevertheless, we also have to take particular enhancements into account, which give us useful hints for further research and steps.

KEY WORDS option pricing; delta-hedging; high-frequency data; neural networks; black model

INTRODUCTION

Since the introduction of electronic brokers in the foreign exchange (FX) interbank market, the FX options market has gained enormously in importance. Advances in computer technology and automated algorithm trading have supercharged the transmission and execution of orders, making use of big data, and established a new phenomenon: 'high-frequency trading' (HFT). Today, market participants need access to the speed, liquidity and pricing accuracy of FX option products for hedging or speculative purposes. Thus an accurate real-time market valuation of option products in the HFT FX market is still difficult and requires appropriate models and techniques.

Option pricing is based on theoretical models developed by Black and Scholes (1973), Merton (1973) and Cox *et al.* (1979), with several extensions. In each case, the derivation of the pricing formula intimately depends on the particular parametric form of the underlying asset's price dynamics $F(t)$. A misspecification of the stochastic process for $F(t)$ will lead to systematic pricing and hedging errors for derivatives. Therefore, the success or failure of the traditional approach to pricing and hedging options is closely tied to the ability to capture the dynamics of the underlying asset's price process. Despite the usefulness of closed-form type models, Black (1975), Rubinstein (1985) and Bakshi *et al.* (2000) emphasized that some models primarily address perceived weaknesses. Unfortunately, theoretical pricing models are based on several unrealistic assumptions: markets are efficient, underlying prices follow a memoryless continuous-time or discrete-time stochastic process and the future volatility σ of the underlying price can be estimated accurately and is a priori known to the seller and the buyer of an option. An unsatisfactory and quite artificial adaptation to the true market conditions is permanently necessary.

Nonparametric or model-free pricing methods for pricing and hedging derivatives attempt to overcome the mentioned restrictions in theoretical models. As option pricing theory typically derives nonlinear relations between an option price and the variables determining it, neural networks (NN) are well suited for this purpose due to their ability to approximate any measurable function up to an arbitrary degree of accuracy; see Hornik (1989) and Hornik *et al.* (1990) for a theoretical explanation. Rather than starting from a price process of the underlying security and subsequently deriving the corresponding option value, the option market's pricing mechanism is estimated by means of observed prices via an NN. When properly trained, the network synthesizes the option pricing formula, which may be used in the same way that formulas obtained from the parametric pricing method are used.

The first attempts at market price approximation with NNs were made in the early 1990s. Many of these studies maintain the view that NN models are capable of generating better results in comparison to closed-form models like

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