February 2012 - March 2012

The use of Nonparametric Models in Derivatives Pricing

By Efstathia D. Korkou, Doctoral Candidate

This paper reviews the use of nonparametric models in derivatives pricing focusing on the use of artificial neural networks in option pricing. It consists of a summary of the paper entitled «Literature Review of the Use of Nonparametric Models in Derivatives Pricing» by the same author (MSL WP 08/11).

The pricing of financial derivatives and more particularly of options constitutes a classic problem in the area of financial engineering. Many algorithms have been developed attempting to capture and simulate the nonlinear behavior of financial derivatives and calculate accurately their price.

In 1973, Black, Scholes and Merton (B-S-M) developed an efficient computational algorithm for option pricing that is till today a standard technique for financial traders in the way they price and hedge options.

Empirical research shows that B-S-M model produces reasonable fair prices for options which are close to their observed prices. Nevertheless, the B-S-M model is based on a series of critical assumptions: the model assumes no dividends, no taxes or transaction costs, constant interest rates, no penalties for short sales, continuous market operation, continuous share price and lognormal terminal stock price return. Furthermore, the B-S-M model assumes continuous diffusion of the underlying asset, normal distribution of returns, constant volatility and no effect on option prices from supply/demand.

In practice, several of these assumptions do not hold. For instance, stock returns exhibit non-normality as well as stochastic volatility and jumps that come in contrast with the B-S-M assumptions.

In practice, the B-S-M model is sufficient in the analytical valuation of European call and put options on a non-dividend paying stock. For the valuation of other financial derivatives, analytical solutions do not exist and hence numerical techniques are necessary.

In empirical option pricing literature, nevertheless, nonparametric models such as neural networks (NN) have been more successful in relaxing the assumptions of the B-S-M model and in providing us with alternative, efficient, accurate and competitive pricing algorithms.

A very popular class of NNs is the artificial neural networks (ANNs) that are capable of "learning". Due to this property, a significant amount of research has been devoted in examining, the ability of NNs to learn the B-S-M model.

A substantial bulk of research has been dedicated to the study of ANNs in the pricing of financial derivatives. A plethora of researchers has examined the ability of ANNs in pricing options by comparing the produced by the ANNs prices to the ones produced by parametric pricing models, such as the B-S-M model. There is a great variety of studied indices, from equity indices –S&P 500, FTSE 100, DAX, OMX, CAC40- to individual equity options, currency options, interest rate options as well as stock index futures.

Garcia and Gençay (1998, 2000) presented a study of how pricing accuracy can be improved by the use of a homogeneity hint. They considered an option pricing formula homogeneous of degree one with respect to the underlying asset price and the strike price. Instead of setting up a learning network mapping moneyness and maturity directly into the derivative pricing, they broke down the price function into two parts: one with moneyness and the other with time to maturity. The results of their study showed that the homogeneity hint always reduced the out-of-sample performance.

Qi and Maddala (1996), Gençay and Qi (2001), Gençay and Salih (2001), Ghaziri et al (2000) and Andreou et al (2005) studied the performance of ANNs in pricing European call options on the S&P 500 Index and concluded that ANNs outperform the B-S-M model.

Gençay and Qi (2001) studied the effectiveness of cross validation, Bayesian regularization, early stopping and bagging to mitigate overfitting and improving generalization for pricing and hedging derivative securities.

Malliaris and Salchenberger (1993) compared ANN option prices with the B-S-M prices by using S&P 100 call options. Approximately for half of the cases they had examined, mean square error for the ANN proved smaller than that of the B-S-M model, testifying the ANN's superiority.

Hutchinson, Lo and Poggi (1993) compared the prices derived by three ANNs to the ones produced by B-S-M model for American-style options on S&P 500 futures and proved without generalizing the superiority of ANNs for the problem at hand.

Boek et al. in 1995 performed a hybrid approach of combining the B-S-M model and NN. They introduce a new method of pricing options based on the augmentation of a conventional model with an ANN trained on the difference between the standard model and actual options data. They demonstrated the pricing accuracy using the actual All Ordinaries Share Price Index options on futures. Their hybrid approach was shown to provide greater accuracy than either the standard model or the ANN used alone.

Mishra, Kumar et al. in 2011 used a hybrid approach to forecast value of the option in the future. They combined time delay NN and Genetic algorithm to get more accurate forecast of European option prices of NIFTY index. By using parameters like time to expiry, previous day closing price and underlying value as inputs, they showed that after training the NN and optimizing them with genetic algorithm, the results they got were more accurate and significant than the previous work done.

Saxena (2008) investigated the pricing accuracy of a hybrid model combining the B-S-M model and ANNs to price European-style equity index options and more specifically S&P CNX Nifty index options and proved that ANN is clearly superior to B-S-M for both in-the-money and out-of-the-money options. The study also showed that the use of the homogeneity hint and moneyness were of key performance for the ANN to outperform the B-S-M model.

Gradojevic, Kukolj and Gençay in 2011 investigated how clustering and classification can assist option pricing models. For this purpose, they used nonparametric modular NN (MNN) to price S&P-500 European call options. They propose the fuzzy learning vector quantization (FLVQ) algorithm combining a Kohonen unsupervised NN and fuzzy logic c-means clustering that generates decision regions, i.e. option classes, divided by "intelligent" classification boundaries, an approach that improves the generalization properties of the MNN model and consequently its pricing accuracy.

In conclusion, we could infer from the previous literature review, the superiority, accuracy and competitiveness of ANNs and other nonparametric models in pricing of a plethora of financial derivatives in comparison to the pricing performed by parametric models. Furthermore, we could also refer to the fact that hybrid methodologies and fuzzy logic neural networks seem to gain more and more ground in the pricing methodologies of nonparametric models.

References

Black, F., Scholes, M., "The Pricing of Options and Corporate Liabilities", Journal of Political Economy, 81 (May-June 1973):637-59.

Merton, R., "Theory of Rational Option Pricing", Bell Journal of Economics and Management Science, 4 (Spring 1973): 141:83.

Bakshi, G., Cao, C., Chen, Z., "Empirical Performance of Alternative Option Pricing Models", Journal of Finance 52(5), (1997), 2003-2049.

Hull, J., Options, Futures and Other Derivatives, 6th Edition, Pearson Prentice-Hall, Upper Saddle River, NJ, (2006).

Gençay, R., Gibson, R., "Model Risk for European-Style Stock Index Options", IEEE Transactions on Neural Networks 18(1), (2009), 193-202.

Haykin, S., Neural Networks: A Comprehensive Foundation, Prentice-Hall, Englewood Cliffs, NJ, (1999).

Bishop, C., Neural Networks for Pattern Recognition, Clarendon Press, Oxford, (1995).

Gradojevic, N., Kukolj, D., Gençay, R., "Clustering and Classification in Option Pricing", Review of Economic Analysis 3 (2011) 109-128.

Garcia, R., Gençay, R., "Option Pricing with Neural Networks and a Homogeneity Hint", In Decision Technologies for Computational Finance: Proceedings of the Fifth International Conference Computational Finance, edited by A.P.N. Refenes, A.N. Burgess and J.E. Moody, Advances in Computational Management Science, (1998), vol. 2, pp. 195-205.

Garcia, R., Gençay, R., "Pricing and Hedging Derivative Securities with Neural Networks and a Homogeneity Hint", Journal of Econometrics 94(1/2),(2000), 93-115.

Qi, M., Maddala, G.," Option Pricing Using Artificial Neural Networks: The Case of S&P 500 Index Call Options", (1996) In Neural Networks in Financial Engineering: Proceedings of the Third International Conference on Neural Networks in the Capital Markets, edited by A.P.N. Refenes, Y. Abu-Mostafa, J. Moody and A. Weigend, World Scientific, New York, 78-91.

Gençay, R, Qi, M., "Pricing and Hedging Derivative Securities with Neural Networks: Bayesian Regularization, Early Stopping and Bagging", IEEE Transactions on Neural Networks, vol. 12, no. 4, (July 2001) , 726-734.

Gençay, R., Salih, A., "Degree of Mispricing with the Black-Scholes Model and Non Parametric Cures", Annals of Economics and Finance, (2003), vol. 4, no. 1, 73-101.

Ghaziri, H., Elfakhani, S., Assi, J., "Neural Networks Approach to Pricing Options", Neural Network World, (2000), vol. 10, no. 1-2, 271-277.

Andreou, P.C., Charalambous, C., Martzoukos, S., "Robust Artificial Neural Networks for Pricing of European Options", Computational Economics, (2006), vol. 27, no. 2-3, 329-351.

Malliaris, M., Salchenberger, L., "A Neural Network Model for Estimating Option Prices", Journal of Applied Intelligence, (1993) vol. 3, no. 3 193-206.

Hutchinson, J., Lo, A., Poggio, T., "A Nonparameric Approach to Pricing and Hedging Derivative Securities via Learning Networks", Journal of Finance 49(3), (1994), 851-889.

Amilon, H., "A Neural Network Versus Black-Scholes: A Comparison of Pricing and Hedging Performances", Journal of Forecasting, vol 22, no. 4. (July 2003), 317-335.

Mishra, P., Kumar, P., Sharma, V., Dhar, J., "Option Pricing Using Hybrid Neuro Evolution Approach", International Research Journal of Finance and Economics, 64 (2011).

Saxena, A., "Valuation of S&P CNX Nifty Options: Comparison of Black-Scholes and Hybrid ANN Model", SAS Global Forum 2008.

print out this page