**Bogdanova, Boryana**; **Ivanov, Ivan**

**A wavelet-based approach to the analysis and modelling of financial time series exhibiting strong long-range dependence: the case of southeast Europe.** (English) Zbl 07281518

J. Appl. Stat. 43, No. 4, 655-673 (2016)

Summary: This paper demonstrates the utilization of wavelet-based tools for the analysis and prediction of financial time series exhibiting strong long-range dependence (LRD). Commonly emerging markets' stock returns are characterized by LRD. Therefore, we track the LRD evolvement for the return series of six Southeast European stock indices through the application of a wavelet-based semi-parametric method. We further engage the á trous wavelet transform in order to extract deeper knowledge on the returns term structure and utilize it for prediction purposes. In particular, a multiscale autoregressive (MAR) model is fitted and its out-of-sample forecast performance is benchmarked to that of ARMA. Additionally, a data-driven MAR feature selection procedure is outlined. We find that the wavelet-based method captures adequately LRD dynamics both in calm as well as in turmoil periods detecting the presence of transitional changes. At the same time, the MAR model handles with the complicated autocorrelation structure implied by the LRD in a parsimonious way achieving better performance.

**MSC:**

62-XX Statistics

**Keywords:**

long-range dependence; wavelet transform; multiscale autoregressive (MAR) model; southeast European stock markets

**Full Text:** DOI

**References:**

[1] L. Aguiar-Conraria and M. Soares, \textit{The continuous wavelet transform: A primer}, NIPE Working Papers from NIPE - Universidade do Minho, WP 16/2011, 2011.

[2] L. Aguiar-Conrara and M. Soares, \textit{The continuous wavelet transform: Moving beyond uni-and bivariate analysis}, J. Econ. Surv. 28(2) (2014), pp. 344-375. doi: 10.1111/joes.12012· doi:10.1111/joes.12012

[3] P. Arby, P. Flandrin, M. Taqqu, and D. Vietch, Theory and applications of long-range dependence, in Self-similarity and long-range dependence through the wavelet lens, P. Doukhan, G. Oppenheim, and M.S. Taqqu, eds., Birkhäuser Basel, Boston, 2003, pp. 527-556. · Zbl 1029.60028

[4] P. Arby and D. Veitch, \textit{Wavelet analysis of long-range-dependent traffic}, IEEE Trans Inf. Theory 44(1) (1998), pp. 2-15. doi: 10.1109/18.650984 · Zbl 0905.94006 · doi:10.1109/18.650984

[5] G. Aye, M. Balcilar, R. Gupta, N. Kilimani, A. Nakumuryango, and S. Redford, \textit{Predicting BRICS stock returns using ARFIMA models}, Appl. Financ. Econ. 24(17) (2014), pp. 1159-1166. doi: 10.1080/09603107.2014.924297

[6] R. Baillie, \textit{Long memory processes and fractional integration in econometrics}, J. Econ. 73 (1996), pp. 5-59. doi: 10.1016/0304-4076(95)01732-1 · Zbl 0854.62099 · doi:10.1016/0304-4076(95)01732-1

[7] J. Barkoulas, C. Baum, and N. Travolos, \textit{Long memory in the Greek stock market}, Appl. Financ. Econ. 10 (2000), pp. 177-184. doi: 10.1080/096031000331815

[8] G. Bhardwaj and N. Swanson, \textit{An empirical investigation of the usefulness of ARFIMA models for predicting macroeconomic and financial time series}, J. Econ. 131(1-2) (2006), pp. 539-578. doi: 10.1016/j.jeconom.2005.01.016 · Zbl 1337.62344 · doi:10.1016/j.jeconom.2005.01.016

[9] B. Bogdanova, \textit{A wavelet-based discussion on the Greek stock market integration during the last decade}, J. Eng. Sci. Technol. Rev. 8(1, Special Issue on Econophysics) (2015), pp. 8-11.

[10] D. Cajueiro, P. Gogas, and B. Tabak, \textit{Does financial market liberalization increase the degree of market efficiency? The case of the Athens stock exchange}, Int. Rev. Financ. Anal. 18 (2009), pp. 50-57. doi: 10.1016/j.irfa.2008.11.004· doi:10.1016/j.irfa.2008.11.004

[11] D. Cajueiro and B. Tabak, \textit{The Hurst exponent over time: Testing the assertion that emerging markets are becoming more efficient}, Phys. A 336 (2004), pp. 521-537. doi: 10.1016/j.physa.2003.12.031· doi:10.1016/j.physa.2003.12.031

[12] D. Cajueiro and B. Tabak, \textit{Testing for predictability in equity returns for European transition markets}, Econ. Syst. 30 (2006), pp. 56-78. doi: 10.1016/j.ecosys.2005.09.003· doi:10.1016/j.ecosys.2005.09.003

[13] D. Cajueiro and B. Tabak, \textit{Testing for long-range dependence in world stock markets}, Chaos Solutions Fractals 37(3) (2008), pp. 918-927. doi: 10.1016/j.chaos.2006.09.090 · Zbl 1136.91557 · doi:10.1016/j.chaos.2006.09.090

[14] C. Christodoulou-Volos and F. Siokis, \textit{Long range dependence in stock market returns}, Appl. Financ. Econ. 16(18) (2006), pp. 1331-1338. doi: 10.1080/09603100600829519

[15] A. Conejo, M. Plazas, R. Espinola, and A. Molina, \textit{Day-ahead electricity price forecasting using the wavelet transform and ARIMA models}, IEEE Trans. Power Syst. 20(2) (2005), pp. 1035-1042. doi: 10.1109/TPWRS.2005.846054· doi:10.1109/TPWRS.2005.846054

[16] S. Dajcman, M. Festic, and A. Kavkler, \textit{Comovement dynamics between Central and Eastern European and developed European stock markets during European integration and amid financial crises – a wavelet analysis}, Inzinerine Ekonomika - Eng. Econ. 23(1) (2012), pp. 22-32.

[17] C. Eom, S. Choi, G. Oh, and W. Jung, \textit{Hurst exponent and prediction based on weak-form efficient market hypothesis of stock markets}, Phys. A 387(18) (2008), pp. 4630-4636. doi: 10.1016/j.physa.2008.03.035· doi:10.1016/j.physa.2008.03.035

[18] F. Ernst, R. Dürichen, A. Schlaefer, and A. Schweikard, \textit{Evaluating and comparing algorithms for respiratory motion prediction}, Phys. Med. Biol. 58(11) (2013), pp. 3911-3929. doi: 10.1088/0031-9155/58/11/3911· doi:10.1088/0031-9155/58/11/3911

[19] F. Ernst, A. Schlaefer, and A. Schweikard, \textit{Prediction of respiratory motion with wavelet-based multiscale autoregression}, Med. Image Comput. Comput. Assist. Intervent. 4792 (2007), pp. 668-675.

[20] G. Faÿ, E. Moulines, F. Roueff, and M. Taqqu, \textit{Estimators of long-memory: Fourier versus wavelets}, J. Econ. 151(2) (2009), pp. 159-177. doi: 10.1016/j.jeconom.2009.03.005 · Zbl 1431.62367 · doi:10.1016/j.jeconom.2009.03.005

[21] R. Fox and M. Taqqu, \textit{Large-sample properties of parameter estimates for strongly dependent stationary Gaussian time series}, Ann. Statist. 14 (1986), pp. 517-532. doi: 10.1214/aos/1176349936 · Zbl 0606.62096 · doi:10.1214/aos/1176349936

[22] C. Franzke, T. Graves, N. Watkins, R. Gramacy, and C. Hughes, \textit{Robustness of estimators of long range dependence and self-similarity under the non-Gaussianity}, Philos. Trans. R. Soc. Lond. Ser. A Math. Phys. Eng. Sci. 370 (2012), pp. 1250-1267. doi: 10.1098/rsta.2011.0349· doi:10.1098/rsta.2011.0349

[23] M. Gallegati, M. Gallegati, J. Ramsey, and W. Semmler, \textit{The US wage Phillips curve across frequencies and over time}, Oxford Bull. Econ. Stat. 73(4) (2011), pp. 489-508. doi: 10.1111/j.1468-0084.2010.00624.x· doi:10.1111/j.1468-0084.2010.00624.x

[24] R. Gençay, F. Selçuk, and B. Whitcher, \textit{An Introduction to Wavelets and Other Filtering Methods in Finance and Economics}, Academic Press, New York, 2001. · Zbl 1068.42029

[25] J. Geweke and S. Porter-Hudak, \textit{The estimation and application of long memory time series models}, J. Time Ser. Anal. 4 (1983), pp. 221-238. doi: 10.1111/j.1467-9892.1983.tb00371.x · Zbl 0534.62062 · doi:10.1111/j.1467-9892.1983.tb00371.x

[26] C. Granger and R. Joyeux, \textit{An introduction to long-memory time series models and fractional differencing}, J. Time Ser. Anal. 1(1) (1980), pp. 15-29. doi: 10.1111/j.1467-9892.1980.tb00297.x · Zbl 0503.62079 · doi:10.1111/j.1467-9892.1980.tb00297.x

[27] A. Grinsted, J. Moore, and S. Jevrejeva, \textit{Application of the cross wavelet transform and wavelet coherence to geophysical time series}, Nonlinear Process Geophysics 11 (2004), pp. 561-566. doi: 10.5194/npg-11-561-2004· doi:10.5194/npg-11-561-2004

[28] O. Henry, \textit{Long memory in stock returns: Some international evidence}, Appl. Financial Econ. 12 (2002), pp. 725-729. doi: 10.1080/09603100010025733

[29] J. Hosking, \textit{Fractional differencing}, Biometrika 68(1) (1981), pp. 165-176. doi: 10.1093/biomet/68.1.165 · Zbl 0464.62088 · doi:10.1093/biomet/68.1.165

[30] E. Hurst, \textit{Long term storage capacity of reservoirs}, Trans. Am. Soc. Civ. Eng. 116 (1951), pp. 770-779.

[31] I. Ivanov, B. Lomev, and B. Bogdanova, \textit{Investigation of the market efficiency of emerging stock markets in the East-European region}, Int. J. Appl. Oper. Res. 2(2) (2012), pp. 13-24.

[32] T. Jagric, B. Podobnik, and M. Kolanovic, \textit{Does the efficient market hypothesis hold? Evidence from six transition economies}, Eastern Eur. Econ. 43(4) (2005), pp. 79-103.

[33] M. Jensen, \textit{Using wavelets to obtain a consistent ordinary least squares estimator of the long-memory parameter}, J. Forecast. 18 (1999), pp. 17-32. doi: 10.1002/(SICI)1099-131X(199901)18:1<17::AID-FOR686>3.0.CO;2-M· doi:10.1002/(SICI)1099-131X(199901)18:1<17::AID-FOR686>3.0.CO;2-M

[34] A. Lo, \textit{Long-term memory in stock market prices}, Econometrica 59 (1991), pp. 1279-1313. doi: 10.2307/2938368 · Zbl 0781.90023 · doi:10.2307/2938368

[35] A. Lo, \textit{Adaptive markets and the new world order}, Financ. Anal. J. 68(2) (2012), pp. 18-29. doi: 10.2469/faj.v68.n2.6

[36] L. Loh, \textit{Co-movement of Asia-Pacific with European and US stock market returns: A cross-time-frequency analysis}, Res. Int. Bus. Financ. 29 (2013), pp. 1-13. doi: 10.1016/j.ribaf.2013.01.001· doi:10.1016/j.ribaf.2013.01.001

[37] B. Lomev, I. Ivanov, and B. Bogdanova, \textit{What can wavelets reveal about SOFIX?} J. Eng. Sci. Tech. Rev. 4(3) (2011), pp. 233-236.

[38] M. Madaleno and C. Pinho, \textit{International stock market indices comovements: A new look}, Int. J. Financ. Econ. 17(1) (2012), pp. 89-102. doi: 10.1002/ijfe.448· doi:10.1002/ijfe.448

[39] S. Makridakis, A. Andersen, R. Carbone, R. Fildes, M. Hibon, R. Lewandowski, J. Newton, E. Parzen, and R. Winkler, \textit{The accuracy of extrapolation (time series) methods: Results of a forecasting competition}, J. Forecast. 1 (1982), pp. 111-153. doi: 10.1002/for.3980010202· doi:10.1002/for.3980010202

[40] S. Mallat, \textit{A theory for multiresolution signal decomposition: The wavelet representation}, IEEE Trans. Pattern Anal. Mach. Intell. 11 (1989), pp. 674-693. doi: 10.1109/34.192463 · Zbl 0709.94650 · doi:10.1109/34.192463

[41] B. Mandelbrot, \textit{A statistical methodology for non-parametric cycles: From the covariance to R/S analysis}, Ann. Econ. Soc. Measur. 1 (1972), pp. 259-290.

[42] B. Mandelbrot and J. Van Ness, \textit{Fractional Brownian motions, fractional noises and applications}, SIAM Rev. 10 (1968), pp. 422-437. doi: 10.1137/1010093 · Zbl 0179.47801 · doi:10.1137/1010093

[43] B. Mandelbrot and J. Willis, \textit{Some long-run properties of geophysical records}, Water Resour. Res. 5 (1969), pp. 321-340. doi: 10.1029/WR005i002p00321· doi:10.1029/WR005i002p00321

[44] B. Mohamed, V. Marimoutou, and L. Nouria, \textit{Estimation methods of the long memory parameter: Monte Carlo analysis and application}, J. Appl. Stat. 34(3) (2007), pp. 261-301. doi: 10.1080/02664760601004874 · Zbl 1157.62059

[45] N. Netov and B. Lomev, \textit{Balkans Capital Markets and Market Risk Forecasting Under Long Memory in Returns}, \textit{Economic Development and Entrepreneurship in Transition Economies}, Banja Luka, 2014.

[46] J. Ramsey, \textit{The contribution of wavelets to the analysis of economic and financial data}, Philos. Trans. R. Soc. Lond. Ser. A Math. Phys. Eng. Sci. 357 (1999), pp. 2593-2606. doi: 10.1098/rsta.1999.0450 · Zbl 0963.91506 · doi:10.1098/rsta.1999.0450

[47] M. Ranta, \textit{Wavelet Multiresolution Analysis of Financial Time Series}, Universitas Wasaenis, Vaasa, 2010.

[48] M. Ranta, \textit{Contagion among major world markets: A wavelet approach}, Int. J. Manag. Financ. 9(2) (2013), pp. 133-149.

[49] W. Rea, L. Oxley, M. Reale, and J. Brown, \textit{Estimators for long range dependence: An empirical study}, Electron. J. Stat. (2009). Available at http://arxiv.org/pdf/0901.0762.pdf.

[50] O. Renaud, J. Starck, and F. Murtagh, \textit{Wavelet-based forecasting of short and long memory time series}, 2002.

[51] O. Renaud, J. Starck, and F. Murtagh, \textit{Wavelet-based combined signal filtering and prediction}, IEEE Trans. Syst. Man Cybern B (Cybern) 35(6) (2005), pp. 1241-1251. doi: 10.1109/TSMCB.2005.850182· doi:10.1109/TSMCB.2005.850182

[52] A. Rua and L. Nunes, \textit{International comovement of stock market returns: A wavelet analysis}, J. Empir. Financ. 16 (2009), pp. 632-639. doi: 10.1016/j.jempfin.2009.02.002· doi:10.1016/j.jempfin.2009.02.002

[53] S. Schlüter and C. Deuschle, \textit{Using wavelets for time series forecasting: Does it pay off?} IWQW discussion paper series, No.04/2010, 2010.

[54] R. Tsay, \textit{Analysis of Financial Time Series}, 3rd ed., Wiley Series in Probability and Statistics, John Wiley \& Sons, New Jersey, 2010.· doi:10.1002/9780470644560

[55] L. Vacha and J. Barunik, \textit{Co-movement of energy commodities revisited: Evidence from wavelet coherence analysis}, Energy Econ. 34(1) (2012), pp. 241-247. doi: 10.1016/j.eneco.2011.10.007· doi:10.1016/j.eneco.2011.10.007

[56] J. Wang, J. Zhu, and F. Dou, \textit{Who plays the key role among Shanghai, Shenzhen and Hong Kong stock markets?} China World Econ. 20(6) (2012), pp. 102-120. doi: 10.1111/j.1749-124X.2012.12004.x· doi:10.1111/j.1749-124X.2012.12004.x

[57] H. Wong, W. Ip, Z. Xie, and X. Lui, \textit{Modelling and forecasting by wavelets, and the application to exchange rates}, J. Appl. Stat. 30(5) (2003), pp. 537-553. doi: 10.1080/0266476032000053664 · Zbl 1121.62516

[58] S. Yousefi, I. Weinreich, and D. Reinarz, \textit{Wavelet-based prediction of oil prices}, Chaos, Soliton. Fract. 25(2) (2005), pp. 265-275. doi: 10.1016/j.chaos.2004.11.015 · Zbl 1136.91571 · doi:10.1016/j.chaos.2004.11.015

[59] G. Zheng, J. Starck, J. Campbell, and F. Murtagh, \textit{Multiscale transforms for filtering financial data streams}, J. Comput. Intell. Financ. 7 (1999), pp. 18-35.

[60] D. Zhou, S. Chen, and S. Dong, \textit{Network traffic prediction based on ARFIMA model} (2013). Available at http://arxiv.org/abs/1302.6324.