Modelling Financial Volatility

Michael McAleer

Econometric Institute
Erasmus School of Economics
Erasmus University Rotterdam
and
Tinbergen Institute
The Netherlands
and
Center for International Research on the Japanese Economy (CIRJE)
Faculty of Economics
University of Tokyo

Course prepared for
Graduate School of Economics
University of Tokyo

Updated: 29 September 2009

Outline: This course is concerned with modelling financial volatility, and provides an econometric analysis of alternative models and techniques for analysing high frequency and ultra high frequency financial data. In each of the three primary areas of volatility modelling, namely Conditional Volatility or Generalised Autoregressive Conditional Heteroskedasticity (GARCH), Stochastic Volatility (SV) and Realized Volatility (RV), univariate volatility models of individual financial assets and multivariate volatility models of portfolios of assets, will be examined critically, the mathematical structural properties of the models will be established, the associated estimation algorithms will be developed, the statistical properties of the estimators will be derived, and the forecasting performance will be evaluated.

Time allocation: Each session will analyse in detail some recent theoretical papers in the financial volatility literature. The course will consist of an examination of recent papers in the GARCH, SV and RV literature, as well as autoregressive conditional duration models proposed for the analysis of ultra high frequency financial tick data. The remaining lectures will focus on important theoretical and empirical issues yet to be analysed in the RV literature, with a view toward suggesting graduate research topics.

Applications: Financial econometrics, agricultural finance, environmental finance, and tourism finance.

Overview: Modelling risk and volatility are crucial ingredients for purposes of forecasting Value-at-Risk (VaR) and minimizing daily capital charges. Sessions on forecasting VaR and minimizing daily capital charges will examine the following papers.

(1) Caporin, M. and M. McAleer (2009), "A scientific classification of volatility models", to appear in *Journal of Economic Surveys*, Available at SSRN: http://ssrn.com/abstract=1314231.

Modeling volatility, or predictable changes over time and space in a variable, is crucial in the natural and social sciences. Life can be volatile, and anything that matters, and which changes over time and space, involves volatility. Without volatility, many temporal and spatial variables would simply be constants. Our purpose is to propose a scientific classification of the alternative volatility models and approaches that are available in the literature, following the Linnaean taxonomy. This scientific classification is used because the literature has evolved as a living organism, with the birth of numerous new species of models.

(2) McAleer, M. (2009), "The Ten Commandments for optimizing value-at-risk and daily capital charges", to appear in *Journal of Economic Surveys*, Available at SSRN: http://ssrn.com/abstract=1354686.

Credit risk is the most important type of risk in terms of monetary value. Another key risk measure is market risk, which is typically concerned with stocks and bonds, and related financial derivatives, as well as exchange rates and interest rates. This paper examines market risk management and monitoring under the Basel II Accord, and presents Ten Commandments for optimizing Va;lue-at-Risk (VaR) and daily capital charges, based on choosing wisely from: (1) conditional, stochastic and realized volatility; (2) symmetry, asymmetry and leverage; (3) dynamic correlations and dynamic covariances; (4) single index and portfolio models; (5) parametric, semiparametric and nonparametric models; (6) estimation, simulation and calibration of parameters; (7) assumptions, regularity conditions and statistical properties; (8) accuracy in calculating moments and forecasts; (9) optimizing threshold violations and economic benefits; and (10) optimizing private and public benefits of risk management. The Basel II Accord would seem to encourage risk taking at the expense of providing accurate measures and forecasts of risk and VaR.

(A) Conditional Volatility – GARCH (60% of course)

Alternative univariate and multivariate, symmetric and asymmetric, GARCH models will be examined, the mathematical structural properties of the models will be established, the associated estimation algorithms will be developed, and the statistical properties of the quasi-maximum likelihood estimators (QMLE) will be derived.

The sessions on Conditional Volatility will examine the following papers.

(3a) Caporin, M. and M. McAleer (2009), "The Ten Commandments for managing investments", to appear in *Journal of Economic Surveys,* Available at SSRN: http://ssrn.com/abstract=1342265.

Stress and distress are unavoidable aspects of dealing with the vagaries of financial markets and financial advisers. The purpose of this paper is to try to reduce the discomfort in dealing with investment advisers, and to make the journey up and down the financial mountain a little less stressful and more satisfying. The commandments deal with defining investment policies precisely, diversifying asset classes, choosing a consistent benchmark for investment policies, structuring precisely the asset allocation process, defining risk and risk management procedures, monitoring the portfolio carefully, matching the allocation and investment horizons, being active or passive according to investment policies, being agnostic about model forecasts, and being aware that, while buy low and sell high is a truism, investors and financial advisers are only human, and therefore make mistakes.

(3b) Jiménez-Martin, J.-A., M. McAleer and T. Perez Amaral (2009), "The Ten Commandments for managing value-at-risk under the Basel II Accord", to appear in *Journal of Economic Surveys*, Available at SSRN: http://ssrn.com/abstract=1356803.

Under the Basel II Accord, banks and other Authorized Deposit-taking Institutions (ADIs) are required to communicate their daily market risk estimates to the relevant national monetary authority at the beginning of each trading day, using one of a variety of Value-at-Risk (VaR) models to measure risk. The purpose of this paper is to provide a simple explanation and a set of prescriptions for managing VaR under the Basel II Accord. The commandments deal with understanding the Basel II colours, understanding the risk model before choosing, varying the choice of risk model, avoiding the green zone and being willing to violate, incurring large violations, stopping before the red zone, avoiding frequent violations, avoiding the estimation of large portfolios, aggregating portfolios into a single index, and interpreting commandments sensibly as guidelines.

(4) Li, W.K., S. Ling and M. McAleer (2002), "Recent theoretical results for time series models with GARCH errors", *Journal of Economic Surveys*, 16, 245-269. Reprinted in M. McAleer and L. Oxley (eds.), *Contributions to Financial Econometrics: Theoretical and Practical Issues*, Blackwell, Oxford, 2002, pp. 9-33 (according to *Essential Science Indicators*, ISI Web of Knowledge, this paper has 64 citations).

The paper reviews the recent theoretical literature on univariate and multivariate GARCH models.

(5) Ling, S. and M. McAleer (2002a), "Stationarity and the existence of moments of a family of GARCH processes", *Journal of Econometrics*, 106, 109-117 (according to *Essential Science Indicators*, ISI Web of Knowledge, this paper has 62 citations).

The paper develops the mathematical structural properties of a family of univariate GARCH processes.

(6) Ling, S. and M. McAleer (2002b), "Necessary and sufficient moment conditions for the GARCH(r,s) and asymmetric power GARCH(r,s) models", *Econometric Theory*, 18, 722-729 (according to *Essential Science Indicators*, ISI Web of Knowledge, this paper has 76 citations).

The paper develops the mathematical structural properties of some univariate GARCH and asymmetric power GARCH processes.

(7) Ling, S. and M. McAleer (2003), "Asymptotic theory for a vector ARMA-GARCH model", *Econometric Theory*, 19, 278-308 (according to *Essential Science Indicators*, ISI Web of Knowledge, this paper has 82 citations).

The paper develops the mathematical structural and asymptotic properties of a new multivariate GARCH process, VARMA-GARCH. This model has been programmed in the RATS econometric software package.

(8) McAleer, M. (2005), "Automated inference and learning in modeling financial volatility", *Econometric Theory*, 21, 232-261 (according to *Essential Science Indicators*, ISI Web of Knowledge, this paper has 68 citations).

The paper reviews a wide range of univariate and multivariate conditional volatility models, and provides a novel automated method for modelling univariate and multivariate conditional volatility.

(9) McAleer, M., S. Hoti and F. Chan (2009), "Structure and asymptotic theory for multivariate asymmetric conditional volatility", *Econometric Reviews*, 28, 422-440.

The paper develops the mathematical structural and asymptotic properties of a new multivariate asymmetric GARCH process, VARMA-AGARCH. This model has been programmed in the RATS econometric software package.

(10) McAleer, M., F. Chan and D. Marinova (2007), "An econometric analysis of asymmetric volatility: theory and application to patents", *Journal of Econometrics*, 139, 259-284 (according to *Essential Science Indicators*, ISI Web of Knowledge, this paper has 25 citations).

The paper develops the mathematical structural and asymptotic properties of the most popular univariate asymmetric GARCH process, the GJR threshold model.

(11) Caporin, M., and M. McAleer (2006), "Dynamic asymmetric GARCH", *Journal of Financial Econometrics,* 4, 385-412.

The paper develops the mathematical structural and asymptotic statistical properties of a new dynamic univariate asymmetric GARCH process with multiple thresholds.

(12) Asai, M. and M. McAleer (2007), "Non-trading day effects in asymmetric conditional and stochastic volatility models", *Econometrics Journal*, 10, 113-123.

The paper develops three new models of non-trading day (or holiday) effects in asymmetric and exponential conditional volatility models.

(13) Caporin, M., and M. McAleer (2008), "Scalar BEKK and indirect DCC", *Journal of Forecasting*, 27, 537-549.

The paper derives the scalar special case of the well known BEKK multivariate GARCH model using a Vector Random Coefficient Autoregressive model, and establishes the structural and asymptotic properties of the scalar BEKK model.

(14) McAleer, M. and B. da Veiga (2008a), "Forecasting Value-at-Risk with a parsimonious portfolio spillover GARCH (PS-GARCH) model", *Journal of Forecasting*, 27, 1-19.

The paper develops a parsimonious portfolio spillover GARCH model to forecast Value-at-Risk (VaR) thresholds.

(15) McAleer, M. and B. da Veiga (2008b), "Single index and portfolio models for forecasting Value-at-Risk thresholds", *Journal of Forecasting*, 27, 217-235.

Using univariate and multivariate conditional volatility models, the paper evaluates the performance of the single index and portfolio models in forecasting Value-at-Risk (VaR) thresholds of a portfolio.

(16) Asai, M. and M. McAleer (2008), "A portfolio index GARCH model", *International Journal of Forecasting*, 24, 449-461.

The paper develops the structure of a parsimonious portfolio index GARCH (PI-GARCH) model which specifies the volatility of a portfolio directly, and examines the effects of symmetric and asymmetric shocks. A portfolio index BEKK model is also developed and evaluated.

(17) McAleer, M., F. Chan. S. Hoti and O. Lieberman (2008), "Generalized autoregressive conditional correlation", *Econometric Theory*, 24, 1554-1583.

The paper develops a generalized autoregressive conditional correlation (GARCC) model when the standardized residuals follow a multivariate random coefficient autoregressive process. The GARCC model provides a motivation for dynamic conditional correlations.

(18) Caporin, M., and M. McAleer (2009), "Thresholds, news impact surfaces, and dynamic asymmetric multivariate GARCH", Available at SSRN: http://ssrn.com/abstract=1198702.

The paper develops the mathematical structural and asymptotic properties of a new dynamic multivariate asymmetric GARCH (DAM-GARCH) process with multiple thresholds, and presents a novel news impact surface to measure the impact of news on volatility deriving from a portfolio of assets.

(19) Caporin, M. and M. McAleer (2009), "Do we really need both BEKK and DCC? A tale of two covariance models", Available at SSRN: http://ssrn.com/abstract=1338190.

Large and very large portfolios of financial assets are routine for many individuals and organizations. The two most widely used models of conditional covariances and correlations are BEKK and DCC. BEKK suffers from the archetypal "curse of dimensionality" whereas DCC does not. This is a misleading interpretation of the suitability of the two models to be used in practice. The primary purposes of the paper are to define targeting as an aid in estimating matrices associated with large numbers of financial assets, analyze the similarities and dissimilarities between BEKK and DCC, both with and without targeting, on the basis of structural derivation, the analytical forms of the sufficient conditions for the existence of moments, and the sufficient conditions for consistency and asymptotic normality, and computational tractability for very large (that is, ultra high) numbers of financial assets, to present a consistent two step estimation method for the DCC model, and to determine whether BEKK or DCC should be preferred in practical applications.

(B) Stochastic Volatility (15% of course)

Alternative univariate and multivariate SV models will be examined, the mathematical structural properties of the models will be established, the associated estimation algorithms will be developed, and the Bayesian Markov Chain Monte Carlo (MCMC), Monte Carlo Likelihood (MCL), Efficient Importance Sampling(EIS) and Efficient Method of Moments (EMM) estimation methods will be discussed.

In addition to papers 8 and 12, the sessions on Stochastic Volatility will examine the following papers.

(20) Asai, M. and M. McAleer (2005), "Dynamic asymmetric leverage in stochastic volatility models", *Econometric Reviews*, 24, 317-332 (according to *Essential Science Indicators*, ISI Web of Knowledge, this paper has 10 citations).

The paper develops alternative new dynamic univariate asymmetric leverage univariate stochastic volatility models and associated estimation algorithms.

(21a) Maasoumi. E. and M. McAleer (2006), "Multivariate stochastic volatility: an overview", *Econometric Reviews*, 25, 139-144.

The paper provides an overview of the multivariate SV literature.

(21b) Asai, M., M. McAleer and J. Yu (2006), "Multivariate stochastic volatility: a review", *Econometric Reviews*, 25, 145-175 (according to *Essential Science Indicators*, ISI Web of Knowledge, this paper has 20 citations).

The paper reviews the rapidly expanding literature on multivariate SV models, and develops a new dynamic correlation matrix exponential multivariate SV model.

(22) Asai, M. and M. McAleer (2006), "Asymmetric multivariate stochastic volatility", *Econometric Reviews*, 25, 453-473 (according to *Essential Science Indicators*, ISI Web of Knowledge, this paper has 9 citations).

The paper develops two new asymmetric multivariate SV models, namely SV with leverage and SV with leverage and size effects, and their associated estimation algorithms.

(23) Asai, M. and M. McAleer (2009), "The structure of dynamic correlations in multivariate stochastic volatility models", *Journal of Econometrics*, 150, 182-192.

The paper develops three new computationally tractable dynamic correlation multivariate SV models, namely the Wishart inverse covariance model, stochastic dynamic correlation Wishart model, and stochastic inverse dynamic correlation Wishart model, and their associated Markov Chain Monte Carlo estimation algorithms.

(24) Asai, M. and M. McAleer (2009), "Multivariate stochastic volatility, leverage and news impact surfaces", *Econometrics Journal*, 12(2), 292-309.

The paper proposes a new MSV with Leverage (MSVL) model in which leverage is defined in terms of the innovations in both financial returns and volatility, such that the leverage effect associated with one financial return is not related to the leverage effect of another return. News impact surfaces are developed for MSV models with leverage based on both log-volatility and volatility, and the corresponding univariate news impact functions are also analysed.

(C) Realized Volatility (15% of course)

The literature on univariate and multivariate RV models will be reviewed, including the theoretical foundations, microstructure noise, consistent estimation of daily realized volatility, independent and dependent noise processes, finite sample properties, asymptotic properties, multivariate models for estimating realized covariances, and modelling and forecasting realized volatilities.

The sessions on Realized Volatility will examine the following papers.

(25a) Maasoumi, E. and M. McAleer (2008), "Realized volatility and long memory: an overview", *Econometric Reviews*, 27, 1-9.

The paper provides an overview of the univariate and multivariate RV and long memory literature.

(25b) McAleer, M. and M. Medeiros (2008), "Realized volatility: a review", *Econometric Reviews*, 27, 10-45 (according to *Essential Science Indicators*, ISI Web of Knowledge, this paper has 12 citations).

The paper critically reviews the theoretical and empirical literature on univariate and multivariate RV models.

(26) McAleer, M. and M. Medeiros (2008), "A multiple regime smooth transition heterogeneous autoregressive model for long memory and asymmetries", *Journal of Econometrics*, 147, 104-119.

The paper develops a flexible model to capture nonlinearities and long-range dependence in time series dynamics. The new model is a multiple regime smooth transition extension of the Heterogenous Autoregressive (HAR) model, which is specifically designed to model the behaviour of the volatility inherent in financial time series. The model is shown to be able to describe simultaneously long memory and sign and size asymmetries.

(27) Asai, M., M. McAleer and M. Medeiros (2009), "Modelling and forecasting noisy realized volatility, Available at SSRN: http://ssrn.com/abstract=1476044.

This paper proposes a new approach for estimating integrated volatility as a bias-corrected and consistent measure of daily volatility with noisy realized volatility for ultra high frequency financial data. The additional noise incorporates the measurement error arising from microstructure noise.

(28) Asai, M., M. McAleer and M. Medeiros (2009), "Asymmetry and leverage in realized volatility", Available at SSRN: http://ssrn.com/abstract=1464350.

This paper develops a new asymmetric model for realized volatility which is based on a correction for measurement errors. The new asymmetric model demonstrates the importance of correcting for measurement errors, and clarifies the various types of asymmetry, leverage and symmetry.

(D) Autoregressive Conditional Duration (ACD) and Log-ACD (5% of course)

An accurate description of the dynamics of duration between stock price changes has important implications and applications for the analysis of financial markets and for testing hypotheses about the market microstructure. The autoregressive conditional duration (ACD) model assumes that the duration between price changes follows a time series process. Numerous extensions to the ACD model have been proposed, including Logarithmic ACD (Log-ACD), Box-Cox ACD, Exponential ACD, Threshold ACD (TACD), and Markov Switching ACD. The literature on ACD models will be reviewed, including the asymptotic and finite sample properties of the Quasi-Maximum Likelihood Estimator (QMLE) for the ACD and Log-ACD models, and forecasting duration and densities.

The sessions on ACD models will examine the following papers.

(29) Allen, D.E., Z. Lazarov and M. McAleer (2007), "Modelling intra-day seasonality and forecasting densities in financial duration data", *Journal of Financial Forecasting*, 1(1), 45-69, Available at SSRN: http://ssrn.com/abstract=993342.

This paper models intra-daily seasonality in the shape of the residual distribution of the standard ACD model, which is estimated using diurnally (seasonally) adjusted duration data. For two of the three companies in the sample, the shapes of the residual distribution for periods corresponding to the mornings and afternoons in a trading day are virtually identical, and are different from the shape of the residual distribution corresponding to the lunch time period. The paper also investigates whether the observed seasonality can explain the bias in density and interval ACD model forecasts, which are popular tools for econometric model evaluation and comparison.

(30) Allen, D.E., F. Chan, M. McAleer and S. Peiris (2008), "Asymptotic and finite sample properties of the QMLE for the Log-ACD model: application to Australian stocks", *Journal of Econometrics*, 147, 163-185.

This paper examines the finite sample properties of the Quasi-Maximum Likelihood Estimator (QMLE) of the Logarithmic Autoregressive Conditional Duration (Log-ACD) model. Proofs of consistency and asymptotic normality of the QMLE for the log-ACD model with a log-normal density are presented. This is an important issue as the Log-ACD is used widely for testing various market microstructure models and effects. Knowledge of the distribution of the QMLE is crucial for purposes of drawing valid inferences and diagnostic checking. The theoretical results developed in the paper are evaluated using Monte Carlo experiments. The experimental results also *provide insight into the finite sample properties of the Log-ACD model under different distributional assumptions. Two extensions to the Log-ACD model are developed to accommodate asymmetric effects. The practical usefulness of the new models is evaluated using empirical data from Australian stocks.*

(31) Allen, D.E., Z. Lazarov, M. McAleer and S. Peiris (2009), "Comparison of alternative ACD models via density and interval forecasts: evidence from the Australian stock market", *Mathematics and Computers in Simulation*, 79(8), 2535-2555.

In this paper a number of alternative ACD models are compared using a sample of data for three major companies traded on the Australian Stock Exchange. The comparison is performed by employing a methodology for evaluating density and interval forecasts. Our main finding is that the generalized gamma and log-normal distributions for the error terms have similar performances, and perform better than the exponential and Weibull distributions. Additionally, there seems to be no substantial difference between the standard ACD and log-ACD specifications.

(E) Extensions of Realized Volatility (5% of course)

In addition to what has already been published in the RV and high frequency finance literature, most of which has been undertaken at the univariate level, the following topics will cover some of the expected important future theoretical and empirical issues in the RV literature.

(a) RV with leverage, asymmetries and thresholds

Few papers to date have considered modelling RV with nonlinear models, including leverage, asymmetries and thresholds. The ARFIMA (or long memory) model will be combined with structural breaks in a simultaneous equations framework, and multiple regime models for RV with leverage and asymmetry will be analysed.

(b) RV with ARFIMA and long memory processes

It is intended to incorporate nonlinearities in the Heterogeneous AutoRegressive Realized Volatility (HAR-RV) model, which is based on Heterogeneous ARCH (HARCH).

(c) GARCH models of RV processes

This is important for modelling the volatility of volatility, that is, the conditional fourth order moment. There are very few papers on this interesting topic.

(d) SV models of RV processes

Barndorff-Nielsen and Shephard (2002, *JRSS B*) provided an econometric analysis of RV in estimating univariate SV models, but did not consider leverage effects. As one of the primary purposes in using SV models is to examine leverage, such leverage will be incorporated into the multivariate model and the associated estimation algorithms will be developed.

(e) Comparison of GARCH and SV models of RV

As GARCH and SV models are based on significantly different assumptions, the forecasting performance of RV processes under GARCH and SV will be compared.

(f) Forecasting VaR thresholds with RV

This will be a novel application of all the models discussed previously. To date there have been very few papers that have considered this issue, even at the univariate level.

(g) Multivariate extensions of (a) to (f) above

(i) This is one of the most important areas of volatility modelling for the future, especially for multivariate RV processes with a large number of assets. Multivariate leverage, asymmetries and thresholds have not yet been considered, or even defined, for multivariate RV processes. These issues have not yet been considered at the multivariate level, primarily due to difficult technical issues.

(ii) Multivariate GARCH and SV models have not yet been compared for multivariate RV processes. Forecasting VaR thresholds is particularly important for portfolios with a large number of assets. A novel approach for a very large portfolio will be adapted for multivariate RV processes.

(iii) In one of the few extensions of univariate RV processes to their multivariate counterpart, Barndorff-Nielsen and Shephard (2004, *Econometrica*) provided an econometric analysis of realized covariation, but did not consider microstructure noise, leverage or asymmetries. These effects will be incorporated in extensions of existing models.

(h) Efficient estimation of RV with many assets

Large portfolios are notoriously difficult to estimate. This has not yet been attempted for multivariate RV processes.

(i) Forecasting VaR thresholds with RV and many assets

This has not yet been attempted for multivariate RV processes.

(j) RV with generated regressors and generated variables

(i) The theoretical developments in the RV literature have assumed that RV is an accurate measure of the true daily integrated variance (IV), and that realized quarticity (RQ) is an accurate measure of the true integrated quarticity (IQ). Both assumptions are incorrect. The effects of the measurement errors in approximating the latent IV and IQ with the observable RV and RQ, respectively, on estimation, testing and forecasting have not yet been analysed.

(ii) A separate measurement error issue has been considered through the introduction of microstructure noise, but this is different from mismeasuring IV and IQ by replacing them with RV and RQ, respectively.

(iii) The presence of measurement error requires an analysis of generated regressors (GR) and generated variables (GV), which has not yet been examined in the RV literature. This source of measurement error will not affect the asymptotic distribution of the estimators of IV and IQ through the use of RV and RQ, respectively, but it will affect the asymptotic covariance matrix, and hence the validity of inferences.

(F) Applications to Financial Econometrics, Finance and Tourism Research

(a) Financial econometrics and empirical finance

(1) Allen, D.E., M. McAleer and B. da Veiga (2009), "Modelling and forecasting dynamic VaR thresholds for risk management and regulation", Available at SSRN: http://ssrn.com/abstract=926270.

(2) Asai, M. and M. McAleer (2009), "Alternative asymmetric stochastic volatility models", Available at SSRN: http://ssrn.com/abstract=1464329.

(3) Asai, M. and M. McAleer (2009), "Dynamic conditional correlations for asymmetric processes", Available at SSRN: http://ssrn.com/abstract=1464325.

(4) Chang, C.-L., M. McAleer, M.-G. Chen and B.-W. Huang (2009), "Modelling the asymmetric volatility in hog prices in Taiwan: the impact of joining the WTO", Available at SSRN: http://ssrn.com/abstract=1355869.

(5) Hammoudeh, S.M., Y. Yuan and M. McAleer (2009), "Exchange rate and industrial commodity volatility transmissions and hedging strategies", Available at SSRN: http://ssrn.com/abstract=1473939.

(6) Huang, B.-W., M.-G. Chen, C.-L. Chang and M. McAleer (2009), "Modelling risk in agricultural finance: application to the poultry industry in Taiwan", *Mathematics and Computers in Simulation*, 79, 1472-1487.

(7) McAleer, M., B. da Veiga and S. Hoti (2009), "Value-at-risk for country risk ratings", to appear in *Mathematics and Computers in Simulation*, Available at SSRN: http://ssrn.com/abstract=1468524.

(8) McAleer, M., J.-A. Jiménez-Martin and T. Perez Amaral (2009), "Has the Basel II Accord encouraged risk management during the 2008-09 financial crisis?", Available at SSRN: http://ssrn.com/abstract=1397239.

(9) McAleer, M., J.-A. Jiménez-Martin and T. Perez Amaral (2009), "What happened to risk management during the 2008-09 financial crisis?", to appear in R.W. Kolb (ed.), *Lessons from the Financial Crisis: Causes, Consequences, and Our Economic Future*, Wiley, New York, 2010, Available at SSRN: http://ssrn.com/abstract=1442034.

(10) McAleer, M., J.-A. Jiménez-Martin and T. Perez Amaral (2009), "Optimal risk management before, during and after the 2008-09 financial crisis", Available at SSRN: http://ssrn.com/abstract=1473191.

(11) McAleer, M., T. Perez Amaral and J.-A. Jiménez-Martin (2009), "A decision rule to minimize daily capital charges in forecasting value-at-risk", to appear in *Journal of Forecasting*, Available at SSRN: http://ssrn.com/abstract=1349844.

(12) Wiphatthananthakul, C. and M. McAleer (2009), "A simple expected volatility (SEV) index: application to SET50 index options", Available at SSRN: http://ssrn.com/abstract=1361906.

(13) Wong, W.-K. and M. McAleer (2009), "Financial astrology: mapping the Presidential Election Cycle in US stock markets", *Mathematics and Computers in Simulation*, 79, 3267-3277, Available at SSRN: http://ssrn.com/abstract=1307643.

(b) Oil spot, forward and futures prices

(1) Chang, C.-L., M. McAleer and R. Tansuchat (2009), "Modelling conditional correlations for risk diversification in crude oil markets", to appear in *Journal of Energy Markets*, Available at SSRN: http://ssrn.com/abstract=1401331.

(2) Chang, C.-L., M. McAleer and R. Tansuchat (2009), "Forecasting volatility and spillovers in crude oil spot, forward and futures markets", Available at SSRN: http://ssrn.com/abstract=1402164.

(3) Chang, C.-L., M. McAleer and R. Tansuchat (2009), "Volatility spillovers between returns on crude oil futures and oil company stocks", Available at SSRN: http://ssrn.com/abstract=1406983.

(4) Lean, H.-H., W.-K. Wong and M. McAleer (2006), "Stochastic dominance test for risk seekers: an application to oil spot and futures markets", Available at SSRN: http://ssrn.com/abstract=916383.

(5) Manera, M., A. Lanza and M. McAleer (2006), "Modelling dynamic conditional correlations in WTI oil forward and futures returns", *Finance Research Letters*, 3(2), 114-132, Available at SSRN: http://ssrn.com/abstract=546484.

(6) Manera, M., M. McAleer and M. Grasso (2006), "Modelling time-varying conditional correlations in the volatility of Tapis oil spot and forward returns", *Applied Financial Economics*, 16, 525-533.

(c) Tourism research

(1) Bartolome, A., M. McAleer, V. Ramos and J. Rey-Maquieira (2009), "A risk map of international tourist regions in Spain", *Mathematics and Computers in Simulation*, 79(9), 2009, 2741-2758.

(2) Bartolome, A., M. McAleer, V. Ramos and J. Rey-Maquieira (2009), "Modelling air passenger arrivals to the Balearic and Canary Islands", *Tourism Economics*, 15(3), 481-500.

(3) Chang, C.-L., M. McAleer and C. Lim (2009), "Modelling short and long haul volatility in Japanese tourist arrivals to New Zealand and Taiwan", Available at SSRN: http://ssrn.com/abstract=1356567.

(4) Chang, C.-L., M. McAleer and D.J. Slottje (2009), "Modelling international tourist arrivals and volatility: an application to Taiwan", in D. Slottje (ed.), *Quantifying Consumer Preferences*, Contributions to Economic Analysis Series, Volume 288, Emerald Group Publishing, pp. 303-320, Available at SSRN: http://ssrn.com/abstract=1355108.

(5) Divino, J.A. and M. McAleer (2009), "Modelling the growth and volatility in daily international mass tourism to Peru", to appear in *Tourism Management*, Available at SSRN: http://ssrn.com/abstract=1361807.

(6) Divino, J.A. and M. McAleer (2009), "Modelling sustainable international tourism demand to the Brazilian Amazon", *Environmental Modelling and Software*, 24, 1411-1419, Available at SSRN: http://ssrn.com/abstract=1361816.

(7) Kuo, H.-I, C.-L. Chang, C.-C. Chen, B.-W. Huang and M. McAleer (2009), "Estimating the impact of Avian Flu on international tourism demand using panel data", *Tourism Economics*, 15(3), 501-511, Available at SSRN: http://ssrn.com/abstract=1365228.

(8) Kuo, H.-I, C.-C. Chen and M. McAleer (2009), "Estimating the impact of whaling on global whale watching", Available at SSRN: http://ssrn.com/abstract=1442444.

(9) McAleer, M., B.-W. Huang, H.-I Kuo, C.-C. Chen and C.-L. Chang (2010), "An econometric analysis of SARS and Avian Flu on international tourist arrivals to Asia", *Environmental Modelling and Software*, 25, 100-106, Available at SSRN: http://ssrn.com/abstract=1355109.

(10) McAleer, M., R. Shareef and B. da Veiga (2009), "Risk management of daily tourist tax revenues for the Maldives", Available at SSRN: http://ssrn.com/abstract=855924.

(11) Medeiros, M., M. McAleer, D. Slottje, V. Ramos and J. Rey-Maquieira (2008), "An alternative approach to estimating demand: neural network regression with conditional volatility for high frequency air passenger arrivals", *Journal of Econometrics*, 147(2), 372-383.

(12) Shareef, R. and M. McAleer (2007), "Modelling the uncertainty in international tourist arrivals to the Maldives", *Tourism Management*, 28, 23-45.