Editorial

Econometric analysis of financial derivatives: An overview☆

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ABSTRACT

One of the fastest growing areas in empirical finance, and also one of the least rigorously analyzed, especially from a financial econometrics perspective, is the econometric analysis of financial derivatives, which are typically complicated and difficult to analyze. The purpose of this special issue of the journal on "Econometric Analysis of Financial Derivatives" is to highlight several areas of research by leading academics in which novel econometric, financial econometric, mathematical finance and empirical finance methods have contributed significantly to the econometric analysis of financial derivatives, including market-based estimation of stochastic volatility models, the fine structure of equity-index option dynamics, leverage and feedback effects in multifactor Wishart stochastic volatility for option pricing, option pricing with non-Gaussian scaling and infinite-state switching volatility, stock return and cash flow predictability: the role of volatility risk, the long and the short of the risk–return trade-off, what's beneath the surface? option pricing with multifrequency latent states, bootstrap score tests for fractional integration in heteroskedastic ARFIMA models, with an application to price dynamics in commodity spot and futures markets, a stochastic dominance approach to financial risk management strategies, empirical evidence on the importance of aggregation, asymmetry, and jumps for volatility prediction, non-linear dynamic model of the variance risk premium, pricing with finite dimensional dependence, quanto option pricing in the presence of fat tails and asymmetric dependence, smile from the past: a general option pricing framework with multiple volatility and leverage components, COMFORT: A common market factor non-Gaussian returns model, divided governments and futures prices, and model-based pricing for financial derivatives.

1. Introduction

According to the International Monetary Fund, "Financial derivatives are financial instruments that are linked to a specific financial instrument or indicator or commodity, and through which specific financial risks can be traded in financial markets in their own right…. Financial derivatives are used for a number of purposes including risk management, hedging, arbitrage between markets, and speculation". Derivatives are associated with numerous types of financial contracts, including the widely-used and analyzed futures, options and forward prices, credit default swaps, and mortgage backed securities. Together with stocks and bonds, derivatives comprise the third main category of financial instruments, and are typically exchange traded or over-the-counter.

One of the fastest growing areas in empirical finance, and also one of the least rigorously analyzed, especially from a financial econometrics perspective, is the econometric analysis of financial derivatives. Risk management is crucial for optimal portfolio management. While some of the key issues underlying risk and portfolio management are reasonably well understood, many of

the technical issues underlying the creation and movements in financial derivatives are less well understood.

Derivatives can be very complex, as evidenced by the massive losses incurred by J.P. Morgan in 2012, which seem to have combined various measures of incompetence, ignorance, failure to comply with financial regulations, and corruption. Senator Carl Levin, Chairman of the Senate Subcommittee on Investigations, summarized the pervasive cynicism and concern when he stated: "Derivative values that cannot be trusted are a serious risk to our financial system" (14 March 2013).

The purpose of the special issue is to bring together the leading specialists in financial econometrics, statistics and mathematics to provide a rigorous theoretical approach to "Econometric Analysis of Financial Derivatives". Mathematical finance will be combined with rigorous theoretical and empirical econometric and statistical analyses of ultra high and high frequency data, using continuous time and discrete time models to analyze realized, stochastic and conditional volatility, as well as higher moments, for univariate and multivariate processes.

Financial derivatives are typically complicated and difficult to analyze. The special issue presents an extensive range of papers by the leading scholars in the field on "Econometric Analysis of Financial Derivatives". The purpose of the special issue is to highlight a number of areas of research in which novel econometric, financial econometric and empirical finance methods have contributed significantly to the econometric analysis of financial derivatives, specifically market-based estimation of stochastic volatility models (Aït-Sahalia et al., in this issue), the fine structure of equity-index option dynamics (Andersen et al., in this issue), leverage and feedback effects in multifactor Wishart stochastic volatility for option pricing (Asai and McAleer, in this issue), option pricing with non-Gaussian scaling and infinite-state switching volatility (Baldovin et al., in this issue), stock return and cash flow predictability: the role of volatility risk (Bollerslev et al., in this issue), the long and the short of the risk-return trade-off (Bonomo et al., in this issue), What's beneath the surface? option pricing with multifrequency latent states (Calvet et al., in this issue), bootstrap score tests for fractional integration in heteroskedastic ARFIMA models, with an application to price dynamics in commodity spot and futures markets (Cavaliere et al., in this issue), a stochastic dominance approach to financial risk management strategies (Chang et al., in this issue), empirical evidence on the importance of aggregation, asymmetry, and jumps for volatility prediction (Duong and Swanson, in this issue), non-linear dynamic model of the variance risk premium (Eraker and Wang, in this issue), pricing with finite dimensional dependence (Gourieroux and Monfort, in this issue), quanto option pricing in the presence of fat tails and asymmetric dependence (Kim et al., in this issue), smile from the past: a general option pricing framework with multiple volatility and leverage components (Majewski et al., in this issue), COMFORT: A common market factor non-Gaussian returns model (Paolella and Polak, in this issue), divided governments and futures prices (Sojli and Tham, in this issue), and model-based pricing for financial derivatives (Zhu and Ling, in this issue).

The interesting, timely and novel contributions to this special issue should highlight and encourage innovative research in a variety of challenging areas associated with the topical and rapidly expanding areas of financial derivatives. It is exciting that the leading international leaders in the field have agreed to contribute to an innovative special issue on "Econometric Analysis of Financial Derivatives".

The plan of the remainder of the paper is as follows. An overview of the 17 papers is presented in Section 2, and some final remarks are given in Section 3.

2. Overview

The first paper is "Pricing with finite dimensional dependence" by Christian Gourieroux (CREST, France, University of Toronto, Canada) and Alain Monfort (CREST, France, Banque de France, France). The authors consider derivative pricing in factor models, where the factor is Markov with Finite Dimensional Dependence (FDD). The FDD condition allows for explicit formulae for derivative prices and their term structures. In this respect, the FDD models are serious competitors for models with affine dynamic factors, especially as they are numerically less demanding. The approach is illustrated by a comparison of the prices of realized and integrated volatility swaps. The authors show that the usual practice of replacing a payoff written on the realized volatility by a payoff written on the integrated volatility can imply pricing errors which are not negligible when the volatility of the volatility is large.

In the second paper, "Market-based estimation of stochastic volatility models", by Yacine Aït-Sahalia (Department of Economics, Princeton University and NBER, USA), Dante Amengual (Centro de Estudios Monetarios y Financieros (CEMFI), Madrid, Spain), and Elena Manresa (Centro de Estudios Monetarios y Financieros (CEMFI), Madrid, Spain), the authors propose a method for estimating stochastic volatility models by adapting the HJM approach to the case of volatility derivatives. They characterize restrictions that observed variance swap dynamics have to satisfy to prevent arbitrage opportunities. When the drift-of-variance swap rates are affine under the pricing measure, they obtain closed-form expressions for the restrictions and formulae for forward variance curves. Using data on the S&P500 index and variance swap rates on different times to maturities, the authors find that linear mean-reverting one factor models provide an inaccurate representation of the dynamics of the variance swap rates, while two-factor models significantly outperform one factor models, both in and out of sample.

The third paper by Manabu Asai (Faculty of Economics, Soka University, Tokyo, Japan) and Michael McAleer (National Tsing Hua University, Taiwan) is on "Leverage and feedback effects on multifactor Wishart stochastic volatility for option pricing". The authors propose a general asymmetric multifactor Wishart stochastic volatility (AMWSV) diffusion process which accommodates leverage, feedback effects and multifactor for the covariance process. The paper provides the closed-form solution for the conditional and unconditional Laplace transform of the AMWSV models. In addition, the paper suggests estimating the AMWSV model by the generalized method of moments using information not only from stock prices but also from the realized volatilities and co-volatilities. The empirical results for the bivariate data of the NASDAQ 100 and S&P 500 indices show that the general AMWSV model is preferred from among several nested models.

"Model-based pricing for financial derivatives", the fourth paper, is by Ke Zhu (Chinese Academy of Sciences, China) and Shiqing Ling (Department of Mathematics, Hong Kong University of Science and Technology, China). The authors consider a stock price process and a bond price process with a constant continuously compounded risk-free interest rate, where both are defined on an appropriate probability space. The returns on the stock price can generally be decomposed into a conditional mean component and a noise component with volatility, but the discounted stock price is not a martingale under the probability space. In a general framework, the authors obtain a risk-neutralized measure under which the discounted stock price is a martingale. Using this measure, the authors show how to derive the risk neutralized price for the derivatives. Special examples of pricing models based on symmetric and asymmetric conditional volatility are given. A simulation

study reveals that these pricing models can capture the 'volatility skew' of implied volatilities on European options. A small application highlights the importance of the new model-based pricing procedure.

The fifth paper by Tim Bollerslev (Department of Economics, Duke University, USA, NBER, USA, CREATES, Denmark), Lai Xu (Department of Economics, Duke University, USA), and Hao Zhou (Division of Research and Statistics, Federal Reserve Board, Washington DC, USA) is on "Stock return and cash flow predictability: The role of volatility risk". The authors examine the joint predictability of return and cash flow within a present value framework by imposing the implications from a long-run risk model that allow for both time-varying volatility and volatility uncertainty. They provide new evidence that the expected return variation and the variance risk premium positively forecast both short-horizon returns and dividend growth rates, and also confirm that dividend yield positively forecasts long-horizon returns, but that it cannot forecast dividend growth rates. The equilibrium-based "structural" factor GARCH model permits much more accurate inference than univariate regression procedures that are traditionally employed in the literature. The model also allows for the direct estimation of the underlying economic mechanisms, including a new volatility leverage effect, the persistence of the latent long-run growth component and the two latent volatility factors, as well as the contemporaneous impacts of the underlying "structural" shocks.

"A stochastic dominance approach to financial risk management strategies" is the sixth paper, by Chia-Lin Chang (Department of Applied Economics and Department of Finance, National Chung Hsing University, Taiwan), Juan-Angel Jiménez-Martín (Department of Quantitative Economics, Complutense University of Madrid, Spain), Esfandiar Maasoumi (Department of Economics, Emory University, USA), and Teodosio Pérez-Amaral (Department of Quantitative Economics, Complutense University of Madrid, Spain). The Basel III Accord requires that banks and other Authorized Deposit-taking Institutions (ADIs) communicate their daily risk forecasts to the appropriate monetary authorities at the beginning of each trading day, using one of a range of alternative risk models to forecast Value-at-Risk (VaR). The risk estimates from these models are used to determine the daily capital charges (DCC) and associated capital costs of ADIs, depending in part on the number of previous violations, whereby realized losses exceed the estimated VaR. In this paper the authors define risk management in terms of choosing sensibly from a variety of risk models and discuss the optimal selection of financial risk models. Previous approaches to model selection for predicting VaR proposed combining alternative risk models and ranking such models on the basis of average DCC, or other quantiles of its distribution. These methods are based on the first moment, or specific quantiles, of the DCC distribution, and supported by restrictive evaluation functions. The authors consider robust uniform rankings of models over large classes of loss functions that may reflect different weights and concerns over different intervals of the distribution of losses and DCC. The uniform rankings are based on recently developed statistical tests of stochastic dominance (SD), which are illustrated using the prices and returns of VIX futures. The empirical findings show that the tests of SD can rank different pairs of models to a statistical degree of confidence, and that the alternative (recentered) SD tests are in general agreement.

Fulvio Baldovin ("Galileo Galilei" Department of Physics, University of Padova, Italy), Massimiliano Caporin ("Marco Fanno" Department of Economics and Management, University of Padova, Italy), Michele Caraglio ("Galileo Galilei" Department of Physics, University of Padova, Italy), Attilio Stella ("Galileo Galilei"

Department of Physics, University of Padova, Italy), and Marco Zamparo (Department of Applied Science and Technology, Politecnico di Torino, Italy, and Human Genetics Foundation, Torino, Italy) present the seventh paper, namely "Option pricing with non-Gaussian scaling and infinite-state switching volatility". Volatility clustering, long-range dependence, and non-Gaussian scaling are stylized facts of financial assets dynamics. These elements are ignored in the Black and Scholes framework, but have a relevant impact on the pricing of options written on financial assets. Using a recent model for market dynamics which adequately captures the above stylized facts, the authors derive closed-form equations for option pricing, obtaining the Black and Scholes formula as a special case. By applying the pricing equations to a major equity index option data set, it is shown that inclusion of stylized features in financial modeling moves derivative prices about 30% closer to the market values without the need of calibrating the model parameters on available derivative prices.

The eighth paper, "What's beneath the surface? Option pricing with multifrequency latent states", is by Laurent E. Calvet (Department of Finance, HEC Paris, France), Marcus Fearnley (Department of Finance, HEC Paris, France), Adlai J. Fisher (Sauder School of Business, University of British Columbia, Canada), and Markus Leippold (Department of Banking and Finance, University of Zurich, Switzerland). The authors introduce a tractable class of multi-factor price processes with regime-switching stochastic volatility and jumps, which can flexibly adapt to changing market conditions and permits fast option pricing. The joint dynamics of the underlying asset and options implied volatility surface are fully specified by a small set of fixed parameters, whose dimension is invariant to the number of factors. The authors develop a novel particle filter for efficiently extracting the latent state from joint S&P 500 returns and options data. The model performs well relative to standard benchmarks in-sample and out-of-sample, and remains robust even in the wake of seemingly large discontinuities, such as the recent global financial crisis.

"Quanto option pricing in the presence of fat tails and asymmetric dependence" is the ninth paper, by Young Shin Kim (College of Business, Stony Brook University, New York, USA), Jaesung Lee (Department of Mathematics, Sogang University, Korea), Stefan Mittnik (Center for Quantitive Risk Analysis, Department of Statistics, Ludwig Maximilians University, Munich, Germany), and Jiho Park (Department of Mathematics, Sogang University, Korea). The authors propose an approach to pricing European quanto options assuming that the underlying instruments follow a multivariate normal tempered stable (NTS) process. This allows both fat-tailedness and asymmetric dependence between the returns on the underlying asset and the exchange rate to be accommodated. In an empirical illustration, the authors estimate the market and risk-neutral parameters for a quanto construction involving the Nikkei 225 index, as the underlying asset, and the Japanese yen and US dollar exchange rate. While the Gaussian model is clearly rejected by the data, the NTS model cannot be rejected at any reasonable level. A calibration exercise for both the estimated NTS and the conventional Gaussian models demonstrates that the resulting prices differ substantially, with the NTS model yielding a superior performance as it reflects more accurately the tail behavior of the instruments involved.

Adam A. Majewski (Scuola Normale Superiore, Pisa, Italy), Giacomo Bormetti (Scuola Normale Superiore, Pisa, and QUANTLab, Pisa, Italy), and Fulvio Corsi (Ca' Foscari University of Venice, Italy, and City University London, United Kingdom) present the tenth paper on "Smile from the past: A general option pricing framework with multiple volatility and leverage components". The analytical tractability of discrete time option pricing models is presently guaranteed only for specific types of models and pricing

kernels. The authors propose a general and fully analytical option pricing framework that encompasses a wide class of discrete time models, and which features a multiple components structure in both volatility and leverage, and a flexible pricing kernel with multiple risk premia. Although the proposed framework is sufficiently general to include GARCH-type volatility, Realized Volatility (RV), or both, the authors focus on RV option pricing models by extending the Heterogeneous Autoregressive Gamma (HARG) model to incorporate heterogeneous leverage structures with multiple components, while preserving closed-form solutions for option prices. Applying the analytically tractable asymmetric HARG model to a large sample of S&P 500 index options, the authors show its superiority in pricing out-of-the-money options compared with existing benchmarks.

The eleventh paper on "The fine structure of equity-index option dynamics", is by Torben G. Andersen (Department of Finance, Kellogg School, Northwestern University, USA, NBER, USA, CREATES, Aarhus University, Denmark), Oleg Bondarenko (Department of Finance, University of Illinois at Chicago, USA), Viktor Todorov (Department of Finance, Kellogg School, Northwestern University, USA), and George Tauchen (Department of Economics, Duke University, USA). The authors analyze the high-frequency dynamics of S&P 500 equity-index option prices by constructing an assortment of implied volatility measures. This allows inference on the underlying fine structure behind the innovations in the latent state variables driving the evolution of the volatility surface. In particular, the authors focus attention on implied volatilities that cover a wide range of moneyness (such as strike/underlying stock price), which load differentially on the different latent state variables. The authors conduct a similar analysis for high frequency observations on the VIX spot index, as well as on VIX futures. They find that the innovations over small time scales in the risk-neutral intensity of the negative jumps in the S&P 500 index, which is the dominant component of the short-maturity out-of-the-money put implied volatility dynamics, are best described via non-Gaussian shocks, that is, jumps. On the other hand, the innovations over small time scales of the diffusive volatility, which is the dominant component in the short-maturity at-the-money option implied volatility dynamics, are best modeled as Gaussian with occasional jumps.

Bjorn Eraker (Department of Finance, Investment and Banking, University of Wisconsin—Madison) and Jiakou Wang (Department of Finance, Investment and Banking, University of Wisconsin—Madison) analyze "A non-linear dynamic model of the variance risk premium" in the twelfth paper. The authors propose a new class of non-linear diffusion processes for pricing and estimation of financial asset prices. The non-linear diffusions are obtained as transformations of affine processes. The authors show that asset pricing and estimation are possible and that likelihood estimation is straightforward. They estimate a non-linear diffusion model for the VIX index under both the objective measure and the risk-neutral measure, where the latter is obtained from futures prices. Under both measures, they find that VIX exhibits significant non-linearities. The authors define the difference between the P and Q drift as a measure of the variance risk premium, and show that it has strong predictive power for stock returns.

The thirteenth paper, "Bootstrap score tests for fractional integration in heteroskedastic ARFIMA models, with an application to price dynamics in commodity spot and futures markets", is by Giuseppe Cavaliere (Department of Statistical Sciences, University of Bologna, Italy), Morten Ørregaard Nielsen (Department of Economics, Queen's University, Canada and CREATES, Denmark), and A.M. Robert Taylor (School of Business, University of Essex, UK). Empirical evidence from time series methods which assume the usual I(0)/I(1) paradigm suggests that the efficient markets hypothesis, stating that spot and futures prices of a commodity

should cointegrate with a unit slope on futures prices, does not hold. However, these statistical methods are known to be unreliable if the data are fractionally integrated. Moreover, spot and futures price data tend to display clear patterns of time-varying volatility which also has the potential to invalidate the use of these methods. Using new tests constructed within a more general heteroskedastic fractionally integrated model, the authors find evidence in support of the efficient markets hypothesis for a number of commodities. The new tests are wild bootstrap implementations of score-based tests for the order of integration of a fractionally integrated time series. These tests are designed to be robust to both conditional and unconditional heteroskedasticity of a quite general and unknown form in the shocks. The authors show that the asymptotic tests do not admit pivotal asymptotic null distributions in the presence of heteroskedasticity, but that the corresponding tests based on the wild bootstrap principle do admit pivotal asymptotic null distributions. A Monte Carlo simulation study demonstrates that very significant improvements in finite sample behavior can be obtained by the bootstrap vis-à-vis the corresponding asymptotic tests in both heteroskedastic and homoskedastic environments.

"The long and the short of the risk-return trade-off" is the fourteenth paper, by Marco Bonomo (Insper Institute of Education and Research, Brazil), Rene Garcia (Edhec Business School, Nice, France), Nour Meddahi (Toulouse School of Economics, GREMAQ, IDEI, France), and Romeo Tedongap (Stockholm School of Economics and Swedish House of Finance, Sweden). The relationship between conditional volatility and expected stock market returns, the so-called risk-return trade-off, has been studied at high- and low-frequencies. The authors propose an asset pricing model with generalized disappointment aversion preferences and short- and long-run volatility risks that captures several stylized facts associated with the risk-return trade-off at both short and long horizons. Using a model at the daily frequency, the authors reproduce the moments of the variance premium and realized volatility, the long-run predictability of cumulative returns by the past cumulative variance, the short-run predictability of returns by the variance premium, the daily autocorrelation patterns at many lags of the VIX and of the variance premium, and the daily cross-correlations of these two measures with leads and lags of daily returns. By retaining the same calibration as in previous research in the literature, they ensure that the model captures the first and second moments of the equity premium and the risk-free rate, and the predictability of returns by the dividend ratio. Overall, adding generalized disappointment aversion to the Kreps–Porteus specification improves the fit for both the short- and long-run risk-return trade-offs.

Marc S. Paolella (Department of Banking and Finance, University of Zurich, Switzerland and Swiss Finance Institute) and Pawel Polak (Department of Banking and Finance, University of Zurich, Switzerland and Swiss Finance Institute) present "COMFORT: A common market factor non-Gaussian returns model" in the fifteenth paper. A new multivariate returns model with various attractive properties is motivated and analyzed. By extending the well-known CCC model in several ways, the new model accommodates all of the primary stylized facts of asset returns, including volatility clustering, nonnormality of asset returns (excess kurtosis and asymmetry), and also dynamics in the dependency between assets over time. A fast EM-algorithm is developed for estimation. Each element of the return vector at time t is endowed with a common univariate shock, interpretable as a common market factor. This leads to the new model being a hybrid of GARCH and stochastic volatility, but without the estimation problems associated with the latter, and being applicable in the multivariate setting for potentially large portfolios of assets. A feasible technique which allows for multivariate option pricing is presented, along with an

empirical illustration of the daily returns of 30 components of the Dow Jones Industrial Index from 2001 to 2011.

The sixteenth and penultimate paper by Diep Duong (Utica College, USA) and Norman R. Swanson (Department of Economics, Rutgers University, USA) is entitled "Empirical evidence on the importance of aggregation, asymmetry, and jumps for volatility prediction". Many recent modeling advances in finance topics ranging from the pricing of volatility-based derivative products to asset management are predicated on the importance of jumps, or discontinuous movements in asset returns. In light of this, a number of recent papers have addressed volatility predictability, some from the perspective of the usefulness of jumps in forecasting volatility. In this paper, the authors review the extant literature and present new empirical evidence on the predictive content of realized measures of jump power variations (including upside and downside risk, jump asymmetry, and truncated jump variables), constructed using instantaneous returns. They also present new empirical evidence on the predictive content of realized measures of truncated large jump variations, constructed using truncated squared instantaneous returns. Their prediction experiments use high frequency price returns constructed using S&P 500 futures data, as well as stocks in the Dow 30. The empirical implementation involves estimating linear and nonlinear heterogeneous autoregressive realized volatility (HAR-RV)-type models. The authors find that past "large" jump power variations help less in the prediction of future realized volatility than do past "small" jump power variations. In addition, they find evidence that past realized signed jump power variations, which have not previously been examined in this literature, are strongly correlated with future volatility, and that past downside jump variations matter in prediction. Finally, the incorporation of downside and upside jump power variations is found to improve predictability, albeit to a limited extent.

The seventeenth and final paper, entitled "Divided governments and futures prices", is by Elvira Sojli (Rotterdam School of Management, Erasmus University Rotterdam, The Netherlands, and Duisenberg School of Finance, The Netherlands) and Wing Wah Tham (Econometrics Institute, Erasmus School of Economics, Erasmus University Rotterdam, The Netherlands, and Tinbergen Institute, The Netherlands). The authors investigate the effect of divided governments on asset prices. For identification purposes, the authors use changes in the implied probability of a divided government while votes are being counted. Using ultra-high frequency data from the betting market and the U.S. overnight futures market, the authors estimate a 1.4% decrease in the S&P500 index in the election event of a divided government. The empirical results are similar for the 2010 U.K. election. Further analysis shows that a divided government affects the expected stock returns through the mechanism of policy uncertainty.

3. Final remarks

The collection of interesting, topical, technical and novel papers in this special issue by the leading experts in the field of "Econometric Analysis of Financial Derivatives" should highlight and encourage further innovative research in a variety of challenging areas associated with the rapidly expanding area of econometric analysis of financial derivatives.

High frequency and ultra high frequency data frequently require analytical techniques that are not standard in econometrics and statistics. Therefore, it is not surprising that novel financial econometrics, statistics and mathematical techniques are constantly being developed, used in empirical analyses, and also widely cited. This special issue should contribute significantly to the constantly changing world of the econometric analysis of financial derivatives.

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