2010 RECENT ADVANCES IN FINANCIAL ENGINEERING

editors
Masaaki Kijima • Chiaki Hara
Yukio Muromachi • Hidetaka Nakaoka
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World Scientific

2010
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Proceedings of the KIER-TMU International Workshop on Financial Engineering 2010

Akihabara Daibiru, Tokyo

2 – 3 August 2010

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NEW JERSEY · LONDON · SINGAPORE · BEIJING · SHANGHAI · HONG KONG · TAIPEI · CHENNAI

Published by

World Scientific Publishing Co. Pte. Ltd.
5 Toh Tuck Link, Singapore 596224
USA office: 27 Warren Street, Suite 401-402, Hackensack, NJ 07601
UK office: 57 Shelton Street, Covent Garden, London WC2H 9HE

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

RECENT ADVANCES IN FINANCIAL ENGINEERING 2010
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ISBN-13 978-981-4366-02-1
ISBN-10 981-4366-02-1

Printed in Singapore by B & Jo Enterprise Pte Ltd

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PREFACE

This book is the Proceedings of the *KIER-TMU International Workshop on Financial Engineering 2010* which was held in Tokyo in the summer of 2010 in order to exchange new ideas in financial engineering among researchers from various countries, not only from academia but also from industry.

The KIER-TMU workshop is held for two consecutive years from 2009 as a successor to "Daiwa International Workshop on Financial Engineering," which was held from 2004 to 2008, and is jointly organized by the Institute of Economic Research, Kyoto University (KIER) and the Graduate School of Social Sciences, Tokyo Metropolitan University (TMU). Financial supports from Life Risk Research Center, Doshisha University, Japan Society for Promotion of Science's Program for Grants-in Aid for Scientific Research (A) #21241040, TMU Program for Enhancing the Quality of University Education, Selective Research Fund of Tokyo Metropolitan University and Credit Pricing Corporation are greatly appreciated.

The KIER-TMU workshop serves as a bridge between academic researchers and practitioners. We invited global leading scholars, including four keynote speakers, and various kinds of active and productive discussions were made during the workshop. Main features of the presentations at the workshop are (1) wide coverage of the research themes, (2) reporting of the most up-to-date research results, and (3) active and friendly discussions between the speakers and the audiences from academia and industry.

This book consists of eleven papers, all refereed, representing or related to the presentations at the KIER-TMU workshop. These papers are addressing state-of-the-art techniques and concepts in financial engineering. This book will be of value to the readers for the most up-to-date information about the hot topics in financial engineering and brief surveys on such topics as the basic to the forefront.

We would like to express our utmost gratitude to those who contributed their papers to the proceedings and those who kindly helped us by refereeing these papers. We would also like to thank Mr. Satoshi Kanai for editing manuscripts, and Ms. Alisha Nguyen and the editorial committee members of World Scientific Publishing Co. for their kind assistance in publishing this book.

March, 2011

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KIER-TMU International Workshop on Financial Engineering 2010

Date

August 2–3, 2010

Place

Akihabara Daibiru, Tokyo, Japan

Organizer

Institute of Economic Research, Kyoto University
Graduate School of Social Sciences, Tokyo Metropolitan University

Supported by

Life Risk Research Center, Doshisha University
Japan Society for Promotion of Science's Program for Grants-in Aid for Scientific Research (A) #21241040
TMU Program for Enhancing the Quality of University Education
Selective Research Fund of Tokyo Metropolitan University
Credit Pricing Corporation

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Hidetaka Nakaoka, Tokyo Metropolitan University
Katsumasa Nishide, Yokohama National University
Tadashi Yagi, Doshisha University

PROGRAM

August, 2 (Monday)

Chair: Masaaki Kijima

10:00–10:10 Fumio Harashima, President, Tokyo Metropolitan University
Opening Address

Chair: Katsumasa Nishide

10:10–10:55 Ernst Eberlein, University of Freiburg
Plenary talk: Unlimited Liabilities, Reserve Capital Requirements and the Taxpayer Put (with Dilip Madan)

10:55–11:25 Kazutoshi Yamazaki, Osaka University
On Scale Functions of Spectrally Negative Lévy Processes with Phase-Type Jumps (with Masahiko Egami)

11:25–13:00 Lunch

Chair: Yuan Tian

13:00–13:45 Arturo Kohatsu Higa, Osaka University
Plenary talk: Approximations for SDE Driven by Lévy Processes

13:45–14:15 Yuji Yamada, University of Tsukuba
Robust Hedging of Multivariate Derivatives Using Additive Models

14:15–14:35 Afternoon Coffee I

Chair: Yuji Yamada

14:35–15:05 Yuri Kabanov, Université de Besançon
Small Transaction Costs, Absence of Arbitrage and Consistent Price Systems (with Julien Grépat)

15:05–15:35 Hideatsu Tsukahara, Seijo University
Estimation of Distortion Risk Measures

15:35–16:05 Chi Chung Siu, Tokyo Metropolitan University
First Passage Time under Regime Switching Jump-Diffusion Process (with Masaaki Kijima)

16:05–16:25 Afternoon Coffee II

Chair: Kazutoshi Yamazaki

16:25–16:55 Luz Rocío Sotomayor, Georgia State University
A Regime Switching Model for the Optimal Intervention of a Central Bank in the Exchange Rate Market (with Abel Cadenillas)

16:55–17:25 Naoya Takezawa, Nanzan University
Investor Characteristics and Portfolio Value

August, 3 (Tuesday)

Chair: Yukio Muromachi

10:00–10:45 Jean-Paul Laurent, University of Lyon
Plenary talk: Pricing CDOs with State Dependent Stochastic Recovery Rates (with Salah Amraoui, Laurent Cousot, Sébastien Hitier)

10:45–11:15 Shoji Kamimura, Reitaku University
On the State Variables for Optimal Portfolio Strategies in the Japanese Market

11:15-11:45 Yoshihiko Sugihara, Bank of Japan
An Empirical Analysis of Equity Market Expectations in the Recent Financial Turmoil Using Implied Moments and Jump Diffusion Processes (with Nobuyuki Oda)

11:45–13:00 Lunch

Chair: Emmanuel Denis

13:00–13:45 Rama Cont, CNRS & Columbia University
Plenary talk: Measuring Contagion and Systemic Risk: Insights from Network Models

13:45–14:15 Masaaki Fukasawa, Osaka University
Model-Free Implied Volatility: From Surface to Index (with I. Ishida, N. Maghrebi, K. Oya, M. Ubukata, and K. Yamazaki)

14:15–14:45 Taro Kanatani, Shiga University
Subsampling Cumulative Covariance Estimator

14:45–15:05 Afternoon Coffee I

Chair: Chiaki Hara

15:05–15:35 James Huang, Lancaster University
Are We Extracting the True Risk Neutral Densities from Option Prices? A Question with No Easy Answer

15:35–16:05 Satoshi Kawanishi, Sophia University
The Diversity of Information Acquisition Strategies in a Noisy REE Model with a Common Signal and Independent Signals

16:05–16:25 Afternoon Coffee II

Chair: Hidetaka Nakaoka

16:25–16:55 Emmanuel Denis, Paris-Dauphine University
Vector Valued Risk Measure Processes (with Imen Ben Tahar)

16:55–17:25 Masaaki Fujii, The University of Tokyo
Collateral Posting and Choice of Collateral Currency - Implications for Derivative Pricing and Risk Management - (with Yasufumi Shimada, Akihiko Takahashi)

Chair: Hidetaka Nakaoka

17:25–17:35 Makoto Yano, Director, Institute of Economic Research, Kyoto University
Closing Address

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The Distribution of Returns at Longer Horizons

Ernst Eberlein[1] and Dilip B. Madan[2*]

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Longer horizon returns are constructed from data on daily returns. Observed drawbacks of a Lévy process are a sharp decrease in skewness and excess kurtosis. Drawbacks to scaling are a flat term structure of skewness and excess kurtosis. A strategy that combines some exposure to independent increments and some exposure to scaling is developed in the context of self decomposable daily return distributions. Estimations are conducted on 400 stocks and we report that a good strategy for constructing longer horizon returns can be that of accumulating as i.i.d. half the daily return while scaling the remainder at rate one half.

Keywords: Lévy processes, Scaling, time consistency, return distribution

1. Introduction

A statistical analysis of data on daily returns can provide some assessment of the centered daily return distribution but many questions of financial interest require a knowledge of distributional properties at a longer horizon like a week, a month, a quarter or even a year. This is particularly true when considering investment decisions in stocks or options thereof as the typical investment horizon or rebalancing period is more than just a day. One could in principle estimate on daily data a fully dynamic return generating process reflecting time varying conditional moments and including mean reversion in drifts and volatilities, that can then be simulated to the horizon of interest. However, such an approach is time consuming and considerably hampered by the many questions that need to be answered in building dynamic models. A more direct and simpler alternative is the construction of the long horizon return directly from the short horizon return.

* Dilip Madan acknowledges support from the Humboldt foundation as a Research Award Winner.

Such an approach is investigated in Eberlein and Özkan (2003) where a Lévy process distribution is estimated at the shorter horizon and the independent and identically distributed (i.i.d.) returns are accumulated to the longer horizon to get the latter distribution. An implication of the independent increment property of Lévy processes is that volatilities should scale with the square root of the return horizon. These principles are widely adopted and noted in Diebold, Hickman, Inoue and Schuermann (1998) as advocated by Basel II documents, though they warn against the wide spread use of square root scaling for volatilities. The objections are consistent with the wide spread rejection of the hypothesis of independent and identically distributed increments in empirical work (Lo and MacKinlay (1988), and Lo (2002)). We note however, that this hypothesis may be accepted after a devolatilization procedure has been implemented as described in Eberlein, Kallsen, and Kristen (2003).

Apart from employing an infinitely divisible distribution to model log returns at the longer option maturity, numerous authors have entertained the hypothesis of self similarity and scaling and we cite Peters (1991, 1999), Mantegna and Stanley (1995), Cont, Bouchaud and Potters (1997), Mandelbrot (1963, 1997), Heyde (1999), Shiryaev (1999) and Cont (2001). Our interest here is not in Lévy processes with such a property, but just with the suggestion of generating the longer horizon return by scaling the shorter horizon return without saying anything about the process. Hence we consider scaling an arbitrary probability density at unit time, say the day, to construct the longer horizon density from it. Such scaling principles were employed in Bakshi and Madan (2006) and the scaling coefficient was estimated to lie just under one half. On the hypothesis of such a self similarity one supposes that the distribution of returns at the longer horizon is equal in law to h^{γ} times the lower horizon return where h is the ratio of the two horizons. A convenient choice for the coefficient γ, in line with the square root scaling of volatilities, is the value 0.5. Our focus is entirely on the construction of the longer horizon density and we make no statement about any stochastic processes that may or may not be involved.

The two approaches of accumulating i.i.d. innovations and scaling a unit time variate are widely differentiated with respect to their effects on the term structure of skewness and kurtosis. For example, it is known that for a Lévy process skewness falls like the reciprocal of the square root of the horizon while excess kurtosis falls like the reciprocal of the horizon itself. On the other hand, with scaling both skewness and kurtosis are constant for all horizons. In this paper we present evidence in support of both hypotheses, demonstrating that scaling tends to dominate the alternative of a Lévy process, when we consider Kolmogorov-Smirnov (KS) statistics at longer horizons. However, we also observe that skewness and kurtosis do appear to fall at longer horizons and these observations are not consistent with the constancy implied by scaling. They just do not fall as fast as predicated by accumulating i.i.d. variates. This set of observations leads us to formulate a mixed approach that allows for both aspects to be present. We proceed to decompose the return into two components, one of which we accumulate as i.i.d. returns while we scale the other component. The mixed approach of partially accumulating i.i.d. returns and scaling the remaining component, is shown to yield superior KS statistics and also provides for a slower decline in skewness and kurtosis. There are two parameters to be estimated in the mixed approach, and this is the proportion that is accumulated as i.i.d. returns and the scaling coefficient of the portion that is scaled. We find that an adequate and superior performance to accumulating i.i.d. returns or scaling is delivered by just accumulating half the return and scaling the remainder with a scaling coefficient of one half. Hence, in the absence of estimation opportunities for the longer horizon we advocate accumulating half the return as i.i.d. and scaling the remainder at a scaling coefficient of one half.

The mixed approach we suggest for constructing the longer horizon return, at this writing, does not have associated with it any process consistent with the distributions being generated for the entire continuum of longer horizons. An additive process consistent with these densities has subsequently been constructed in Madan and Schoutens (2009) when the unit time density is further restricted to be in the class L^1, in the hierarchy introduced by Urbanik (1972, 1973) and studied in detail by Sato (1980). We note in passing that the distributions generated by any Lévy process (the CGMY class included) with finite moments of order 4 will display a term structure for skewness and excess kurtosis that possibly falls too rapidly while the Sato process associated with a self decomposable law at unit time as constructed in Carr, Geman, Madan and Yor (2007) will display a term structure for these entities that is flat.

Our method for combining the accumulation of independent shocks with scaling or self similarity over the longer horizon employs self-decomposable daily return distributions. By the definition of self-decomposability one may split the daily return into a fraction of itself plus an independent component. We then accumulate in an i.i.d. fashion the fraction and scale the residual independent component using a scaling coefficient. The longer horizon return then requires the estimation of the fraction and the scaling coefficient. Maximum likelihood procedures are used to estimate these two parameters.

The outline of the paper is as follows. Section 1 presents preliminary evidence in support to some degree for both hypotheses that also addresses why a strict adherence to either hypothesis is questionable. In Section 2 we develop our mixed approach that accomodates both ideas at some level. Estimation strategies and results for the combined model are described in Section 3. Section 4 describes the improvement attained by the mixed model, along with what is possible without estimation, by accumulating half the return as i.i.d. and scaling by one half the remainder. Section 5 concludes.

2. Preliminary Evidence on Scaling and Accumulating i.i.d. Variates

We obtained from CRSP (Chicago Center for Research in Security Prices) data on stock prices for 477 stocks with 3000 observations starting on Jan. 31, 1996 and finishing on December 31, 2007. We shall use this data to construct from daily returns 10 and 20 day returns by simulating both operations of accumulating i.i.d. variates and scaling the daily return. We then ask how well the simulated long horizon returns describe the properties of the actual 10 and 20 day nonoverlapping returns in the data.

The first step is then to build the empirical distribution function for daily returns for each of the 477 stocks. This was done by binning the data in the interquantile range of a tenth of a percent to the 99.9 percentile into 100 regularly sized bins. For purposes of comparison to actual long horizon returns we also extracted data on 10 and 20 day nonoverlapping returns.

For simulating the accumulation of i.i.d. variates for 10 or 20 days, we draw from the empirical daily return distribution 10000 paths of length 10 and 20 respectively. The long horizon return is then built by merely summing these draws over the length of the paths.

For simulating the scaling operation we draw from the daily return distribution just once and scale the outcome by the square root of 10 or 20 to build the sample for the scaled long horizon returns.

Our first comparison between the simulated long horizon returns and the actual ones is to perform a *KS* test for whether the actual non-overlapping 10 and 20 day return outcomes come from the two candidate distributions that we call Lévy for accumulating i.i.d. variates, and Scaling for just scaling the daily return. We record the 477 p-values for each of the two methods, Lévy and Scaling, at each of the two horizons, 10 and 20 days. We graph in figure (1) the proportion of stocks with a p-value exceeding a particular level.

This graph supports the superiority of scaling over accumulating i.i.d. variates. At both horizons the proportion of stocks with high p-values is greater under scaling though we note that almost 70% of the stocks fail to make a 10% p-value in all the cases. The support for scaling is therefore not that strong and there appears to be a substantial room for improvement in performance.

Our second comparison focuses attention on skewness and kurtosis for daily returns and the same for the set of nonoverlapping 10 and 20 day returns. Under a finite moment Lévy process construction we know that long horizon skewness decreases at a rate proportional to the square root of the number of periods while excess kurtosis decreases like the reciprocal of the number of periods (Konikov and Madan (2000)). On the other hand under scaling the term structure of skewness and excess kurtosis is flat. To evaluate these properties we regressed the 10 and 20 days skewness and excess kurtosis across the 477 stocks on the daily skewness and excess kurtosis. We recognize that it has been argued that return kurtosis and even variance could be infinite. We clearly do not subscribe to this view and

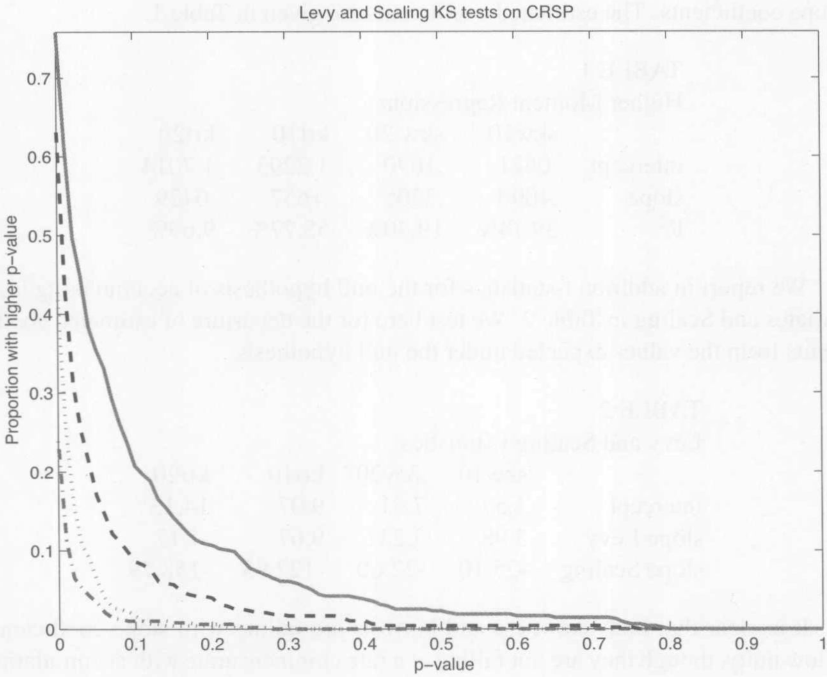

Figure 1. Independent draws for 10 and 20 days in dot dashed and dotted lines respectively. Scaling for 10 and 20 days in dashed and solid lines.

in fact view actual returns to be bounded random variables with finite moments of all orders. The analytical difficulties of dealing with bounded random variables prompt us to use models with a support on the real line. Infinite moments are then a theoretical possibility, but only as a consequence of our inability to analytically model the reality.

For the validity of the approach of accumulating i.i.d. variates we expect, in this regression, a zero intercept with slope coefficients equal to $\frac{1}{\sqrt{10}} = .3162$ and $\frac{1}{\sqrt{20}} = .2236$ for the skewness regression. For the excess kurtosis regression the expected slope coefficients are .1 and .05 while the intercepts are zero. On the other hand for the validity of scaling, as skewness and kurtosis are constant in term structure, they are at longer horizons equal to their value at the daily horizon. Hence we should observe in the cross sectional regression zero intercepts and unit slope coefficients. The estimated coefficients are given in Table 1.

TABLE 1

Higher Moment Regressions

	skw10	skw 20	krt10	krt20
intercept	.0621	.1670	1.2293	1.7014
slope	.4098	.3205	.1657	.0429
R^2	39.14%	19.40%	55.77%	9.69%

We report in addition t-statistics for the null hypothesis of accumulating i.i.d. variates and Scaling in Table 2. We test here for the departure of estimated coefficients from the values expected under the null hypothesis.

TABLE 2

Lévy and Scaling t-statistics

	skw10	skw20	krt10	krt20
intercept	3.57	7.51	9.07	14.13
slope Lévy	3.98	3.23	9.67	-1.17
slope Scaling	-25.10	-22.60	-122.93	-158.79

It is clear that both skewness and kurtosis are falling with slope coefficients below unity, though they are not falling at a rate commensurate with accumulating i.i.d. variates. The fact that they are falling is also evidenced by the large and highly significant t-statistics (Mood and Graybill (1963)) associated with scaling. That the rate is lower than that of a Lévy process is evidenced by the positive and significant Lévy t-statistics. We take this evidence of declining skewness and kurtosis to be in favor of the hypothesis of independent increments being present in some form.

A preliminary investigation of the relationship between daily return distributions and the distribution of longer horizon returns provides partial support for both operations of scaling and accumulating i.i.d. variates. The latter accumulates the effects of independent shocks while the former reflects the attributes of self similarity that preserve distributional structure but recognize that the longer horizon is a scaled version of the shorter horizon. The next section considers combining these properties.

3. Combining the Accumulation of i.i.d. Variates with Scaling

The arguments in favor of accumulating i.i.d. variates relate to the arrival of sequences of independent news shocks that get incorporated into stock price revisions in markets. The arguments in favor of scaling relate to issues of self similarity whereby we recognize the occurence of a change of scale but no change in the structure of the underlying probability law. A natural approach to synthesize these two ideas is to attempt to split the random variable at unit time into