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Handbook of Recent Advances in Commodity and Financial Modeling

Quantitative Methods in Banking, Finance, Insurance, Energy and Commodity Markets

Springer

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Preface

A widespread liberalization process in commodity and energy markets has led over the last 15 years or so to a fruitful and rich methodological spreading of techniques and quantitative approaches previously proposed in financial markets into a wider global market area. At the same time, the increasing volatility of international prices and the introduction of regulatory frameworks on banking and insurance institutions enhanced the research on risk theory and risk management inducing new, practically relevant, theoretical developments. This handbook, at the time it was proposed to Springer, aimed at elaborating on such evidence to include contributions related to optimization, pricing and valuation problems, risk modeling, and decision-making problems arising in nowadays global financial and commodity markets from the perspective of operations research and management science.

The volume is structured in three parts, emphasizing common methodological approaches arising in the areas of interest:

1. Risk modeling
2. Pricing and valuation
3. Optimization techniques

Our original aspiration, as volume editors, was to collect within such structure a comprehensive set of recent state-of-the-art and original works addressing a variety of management and valuation problems arising in modern financial and commodity markets, such as:

- Risk measurement methodologies, including model risk assessment, currently applied to energy spot and future markets and new risk measures recently proposed to evaluate risk-reward trade-offs in global financial and commodity markets.
- Decision paradigms, in the framework of behavioral finance or factor-based or more classical stochastic optimization techniques, applied to portfolio selection problems including new asset classes such as alternative investments.

- Derivative portfolio hedging and pricing methods recently put forward in the professional community in the presence of increasing instability in financial as well as commodity markets.
- The adoption of multi-criteria and dynamic optimization approaches in financial and insurance markets in the presence of market stress and growing systemic risk.

Upon volume completion, we may say that most of the original research objectives have been reached and the 14 chapters included in this volume span a large and diversified variety of modeling and decision-making problems with a range of underlying methodological implications. We eventually decided to structure the content putting first the chapters primarily concerned with risk modeling and risk assessment issues, then those proposing (risk) pricing techniques, and finally those focusing on optimal risk control and decision-making paradigms.

Part I of this volume, on *risk modeling*, includes five chapters. The first chapter by Malliaris–Malliaris focuses on the market dynamics of gold and silver as commodities and analyzes in particular the directional predictability of their daily returns. The authors propose an interesting application of cluster analysis leading to the identification over a 15-year period of six important clusters, whose evaluation allows the definition of strategies within this market of precious metals. Three strategies in particular are evaluated which establish a relevant evidence for directional strategies in commodity markets, based on their lagged negative correlation: gold appears leading silver movements with a stable anti-correlated dynamics. The role of commodities in global financial portfolios has been advocated for their importance in enhancing real, inflation-adjusted returns and also due to their diversification gain relative to fixed-income and equity investments. Here the authors emphasize that indeed, also within commodity markets, investors and financial agents can profit from the commodity diversified market dynamics and their relationship with the business and economic cycle.

Sarwar et al. focus in Chap. 2 on credit-rated stocks and analyze how indeed a different approach to investment-grade rather than speculative-grade equities may generate significant momentum returns across business cycles with evidence of anti-cyclical patterns. During the period 1985–2011, the authors analyze in detail the US market and report that momentum returns from speculative-grade stocks amount on average to 1.27% per month and are more prevailing during contraction periods, in which they earn 1.61% per month. Furthermore investment-grade stocks are found to earn, on average, momentum returns of 0.85% per month and 1.14% per month during contractions. Momentum returns are in general associated with trading strategies based on canonical buy/sell signals associated with recent past winners vs. past losers, respectively. Interestingly, during the 2008 crisis, higher momentum returns are not explained by macroeconomic variables. The authors' overall conclusion is that positive momentum returns are due to high uncertainty associated with the increased credit risk of stocks and across business cycles. Such conclusion provides evidence of a persistent excess risk premium in speculative markets, with companies that in trouble periods either consolidate their business or go bankrupt.

In the third chapter, Sannajust–Chevalier analyze from a different perspective a developing equity market such as the emerging Asian private (rather than exchange-based or public) one, focusing on leveraged buyout (LBO) operations and their correlation with the target companies' performance over short and long term. The research spans a large set of candidate drivers (financial, governance, macroeconomic, cultural, microeconomic, and industry variables), and the authors base their analysis on the Capital IQ database. They focus in particular on the impact of macroeconomic factors on the performance of LBOs in Asia during the first decade of this century. The study, thus extending previous evidence on developed markets, shows that GDP growth, industry growth, and market return are important drivers that significantly contribute to create value in LBOs. It is worth recalling that, over the last 15 years, the private equity market attracted increasing interest due to the stable excess performance produced in the long term by this market and its increasing role as vehicle to attract equity investors at a time in which fixed-income returns were decreasing in developed as well as developing markets and financial instability and systemic risk were increasing.

D'Ecclesia–Kondi in the following Chap. 4 provide an interesting and in-depth methodological survey of the state of the art on correlation assessment methods across financial and commodity markets: as is well known, correlations between different asset returns represent a crucial element in asset allocation decisions as well as exotic derivative pricing. In commodity markets where prices are reported to be mostly nonstationary and returns are only mean stationary, a time-varying measure of correlation is needed, and indeed it is such assumption that in the first place leads to the emergence of correlation clustering phenomena during turbulent market phases. According to the prevailing literature, correlations among different markets are known to be higher during recessions than during expansion periods. When applied to portfolio management, with an investment universe including both financial and real assets, in order to shield investors from equity declines, portfolio managers historically used to invest in commodities deemed poorly correlated with stock markets. The authors clarify in their study, with an extensive data analysis, that during the last decade, also due to an increasing speculative role of many commodities, correlations between commodities and stock returns have dramatically changed and an accurate risk assessment may no longer be attained without introducing a correlation model assuming nonstationary data and structural breaks in market variables. The authors compare the historical rolling correlation and the dynamic conditional correlation methods and show how each estimator can provide useful information given a specific data structure and that information provided by the correlation measures can be used to identify structural breaks in the original variables. The analysis performed by D'Ecclesia and Kondi contributes, albeit indirectly, to underline the relevance of the adopted correlation model in the solution of a generic allocation problem.

In the fifth chapter, Gianfreda–Scandolo address directly the issue of measuring the cost generated by a wrong model. Indeed it has been shown that model risk has an important effect on any risk measurement procedures; therefore, its proper quantification is becoming crucial in several application domains. The authors

analyze in particular the case of energy markets, where traders and market participants face several kinds of risks including market, liquidity, and, more importantly, operational risk. The authors propose the assessment of model risk in the German wholesale electricity market, looking at daily spot prices and comparing several models presented in the literature with their possible variations. Gianfreda and Scandolo propose a quantitative measure of model risk, namely, the relative measure of model risk, as proposed by Barrieu and Scandolo (2015). They quantify the model risk by studying day-ahead electricity prices in the European Energy Exchange (EEX). Germany, indeed, decided to exit from nuclear power by 2020 focusing on renewable energy sources and energy efficiency. This market is characterized by a high wind penetration which has increased the complexity of the electricity price dynamics given that wind (and solar) energy is highly variable and partially predictable. Model risk assessment is in this study applied to a specific energy market, but the research over possible quantitative methods to measure the impact of inaccurate or even wrong model assumptions on pricing, as well as risk management and decision models, is ongoing and attracting increasing interest, also through the so-called model sensitivity analysis as well as counterfactual analysis in commodity and financial markets. The topic is indeed becoming a specific task of many risk management units in global financial institutions and investment banks.

Part II on *pricing and valuation* collects contributions in which new and valuable techniques are introduced and described for pricing and evaluating financial products. This part includes four chapters in which the prevailing research focus is on pricing and calibration methods mainly in derivative markets with again as in Part I a variety of underlying assets, commodity or financial.

Noparumpa et al. provide in Chap. 6 a thorough analysis of the market of wine (mainly US) futures and the determinants of price formation and decision-making by wine producers taking into account spot vs. future price dynamics (their basis risk). The authors move from a detailed study of the determinants of wine prices and their dependence on seasonal and quality uncertainty to consider the drivers of price settlements in spot and future markets. This agricultural market represents a large and growing share of agri-markets primarily in developed but increasingly in selected developing markets. The study takes into account wines with different aging and production methods to infer the producer's decisions on (1) the sale price of her/his wine futures, (2) the quantity of wine futures to be sold in advance, and (3) the amount of wine to be kept for retail and distribution. The study makes two contributions to the optimization of pricing and quantity decisions by wine managers. A stochastic optimization model that integrates uncertain consumer valuations of wine both in the form of futures and in bottle and the uncertainty associated with bottle scores is also proposed with a detailed empirical analysis based on data collected from Bordeaux wineries engaging in wine futures.

In a rather different setting, Hitaj et al. discuss in Chap. 7 the important (methodological thus general) problem of describing log return dynamics in option pricing problems. It is well known that financial time series, increasingly in the recent past, exhibit heavy tails, asymmetric distribution, and persistence and clustering of volatility. The authors propose a class of discrete-time stochastic

volatility models, starting from the affine GARCH model and assuming that the conditional distribution of log returns is a normal variance–mean mixture. They develop a discrete-time stochastic volatility model in a simple way, obtaining a recursive procedure for the computation of the log price characteristic function at option maturity. Finally, option prices are obtained via Fourier transforms. The authors are able to extrapolate information from the VIX data and find a linear relationship between the variance dynamics and the VIX^2. Moreover, this model is able to generate time-varying skewness and kurtosis that standard GARCH models cannot reproduce. Again, the issue of model risk assessment and the implications brought about by model selection are considered as in Chaps. 4 and 5 of this volume. The signaling power of the VIX is confirmed in the research. The authors also investigate the ability of the proposed modeling approach to reproduce the behavior of European option prices on SPX index. The dynamic normal inverse Gaussian-based model provides more flexibility in capturing market dynamics especially in turbulent periods.

Under more general assumptions, linking to the previous chapter, the important problem of finding a sound calibration method for pricing purposes is also discussed in Chap. 8 by Lindström–Åkerlindh. Indeed, while there is an abundance of good option valuation models, far less attention has been given in the literature to the key statistical problem of calibrating those models to market data and thus validate the proposed approaches. Local volatility models fit often perfectly with in-sample data, but the performance with out-of-sample data is less satisfactory. It is widely acknowledged that often practical calibration methods adopted in the financial industry reduce to some kind of least squares minimization of the difference between the fitted and observed data. Several studies have shown however that the weighted least squares (WLS) technique is practically infeasible when the model complexity grows, while nonlinear filters or penalized WLS work much better. A recent approach, proposed by one of the two authors, is based on using a nonlinear filter with time-varying model parameters, leading to more robust estimates and better out-of-sample forecasts. However, some tuning matrices were introduced that had to be tuned manually. The contribution in this volume extends the proposed methodology in two different directions: first by deriving a statistical framework for the tuning matrices and second by extending the dynamics of the original method from one to three different types of parameter dynamics. The proposed methodology, applied to European call options, is evaluated on several sets of simulated data as well as on S&P 500 index options from 2004 to 2008. The results are encouraging and capture well the structure of the underlying process. This may lead to improved and more effective hedging and risk management.

LIBOR-based derivatives (swaps, caps, swaptions) are the most liquid derivatives traded in global financial markets. Due to their importance and popularity, swaption market quotations are often used for calibration of interest rate models. However, the calibration procedure involves the pricing of a large number of swaptions (different option maturities, swap tenors, and strikes); then an efficient algorithm is required here. Since a closed-form formula of swaption prices does not exist for many popular interest rate models, then several approximate pricing methods have

been developed in literature especially for affine interest rate models. In Chap. 9, extending previous results, Gambaro et al. establish a lower bound which is based on an approximation of the exercise region via an event set defined through a function of the model factors. The resulting formula consists in the valuation of the option on the approximate exercise region and requires a single Fourier transform performed through the appropriate parameter. The proposed approximation has several advantages. Indeed, by providing a lower bound, the direction of the error is known a priori; it is very general and involves the computation of only one Fourier inversion, independently of the number of cash flows of the underlying swap. Finally, it can be used as a control variate to improve the accuracy of the Monte Carlo simulation method.

Part III on *optimization* includes contributions in which maximization or minimization approaches take a prominent role in order to establish the best investment policies based on specific concave utility or convex risk functions, respectively. This part includes five chapters addressing different decision problems, from canonical one-period portfolio selection to multi-period institutional asset-liability management and hedging problems.

Hitaj–Zambruno discuss in Chap. 10 the effects of diversification constraints on the optimal portfolio choices by using the Herfindahl concentration index. In order to determine the optimal investment strategies, they use the third-order Taylor expansion of the exponential utility function to account for skewness. In the empirical analysis, these strategies are compared with others in the "smart beta" class and for various values of the risk aversion coefficient. The authors' contribution extends the domain of static portfolio selection methods, allowing an interesting comparison analysis.

In Chap. 11, Sbuelz investigates the joint effect of default risk and systemic risk on the dynamic asset allocation strategies in a no-arbitrage continuous time setting. This is accomplished by describing the dynamics of two representative assets as diffusion–jump processes, one of which is exposed to systemic risk only and the other also to default risk: the problem is formulated as a maximization problem of the expected power utility of terminal wealth. A numerical example shows the viability of the proposed model in the presence of systemic risk and interestingly highlights, under the given assumptions, the influence of an agent's time horizon.

In the following Chap. 12, Benazzoli–Di Persio focus on the implications of market liquidity in stock markets. They determine the optimal sequence of transactions required to sell a given amount of stock in an illiquid market, in which the trading rate affects prices. Such market impact is modeled by combining two effects: a permanent one, assumed linear in the trading rate, and a temporary one, represented through a negative exponential. The objective is to minimize the risk-adjusted expected costs of the strategy, where the control variable is represented by the transaction flow through time: a closed-form solution is obtained using the Lambert W function.

The issue of liquidity is also considered as a key strategy driver by Consigli et al. in Chap. 13, in which the elements of a real-world asset-liability management model of an occupational pension fund are considered. By adopting a multistage stochastic

programming approach, the authors report how, from an initial underfunded status, a pension fund manager brings the fund to a fully funded status under different perspective scenarios over a 20-year planning horizon. The authors extend previous methodological approaches based on scenario trees to an interesting combination of decision stages distributed over time to annual liquidity assessments in which however investment rebalancing is not allowed. The presence of liquid as well as illiquid instruments in the investment universe has become a characterizing feature of global portfolios in the quest of excess returns at a time of unprecedented poor fixed-income returns. This chapter describes also in detail the adopted methodological and modeling steps leading to the completion of an advanced decision support tool for asset-liability management purposes.

In the final Chap. 14, Kallio et al. also adopt a stochastic programming approach, which in this case is applied to a currency hedging problem familiar to companies operating at an international scale. After an extensive review of the exchange rate dynamic models and the formulation of hedging techniques, the authors employ a multistage stochastic programming technique to determine the optimal hedging policy, the one providing at the end of the planning horizon the best risk-reward trade-off: working on actual data, they show not only that in general the model is effective in limiting downside risk but also that in specific periods the optimized policy can indeed improve profits from currency management by as much as 20%, particularly when leverage strategies are adopted.

This volume, in this reflecting the wide spectrum implied by its title, includes a variety of valuation and methodological problems emerging in different operational contexts, from developing private equity markets in Asia to liquid derivative markets either on commodities or on equity stocks as underlyings to again commodity futures in precious metals or global portfolios by pension fund managers. The volume also includes a set of dedicated contributions, primarily methodological, focusing on model risk, correlations, and stochastic volatilities, whose role in jeopardizing long-established results in mainstream finance has been remarked by many authors in recent times.

Upon completion of the editorial work, the editors would like to acknowledge the cooperation of the contributing authors and the continuing and productive assistance of Springer to achieve and complete the work.

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