Energy 158 (2018) 383–395

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

An interval-based stochastic dominance approach for decision making in forward contracts of electricity market

Movahed Jamshidi [a], Hamed Kebriaei [a, b, *], Mohammad-Kazem Sheikh-El-Eslami [c]

[a] School of Electrical and Computer Engineering, College of Engineering, University of Tehran, Tehran, Iran
[b] School of Computer Science, Institute for Research in Fundamental Sciences (IPM), P.O. Box 19395-5746, Tehran, Iran
[c] School of Electrical and Computer Engineering, Tarbiat Modares University, Tehran, Iran

ARTICLE INFO

Article history:
Received 3 July 2017
Received in revised form
27 May 2018
Accepted 8 June 2018
Available online 9 June 2018

Keywords:
Stochastic dominance
Prospect stochastic dominance
Conditional value at risk

ABSTRACT

virtually, all decisions in financial markets are made in the presence of uncertainty. Stochastic dominance is a well-known concept that is broadly implemented for decision making under uncertainty. Thanks to the advantages of this approach, a decision maker is able to exploit available information related to uncertainties with stochastic nature. In this paper, to cope with the uncertainties in the procedure of decision making for forward contracts in an electricity market, a modified stochastic dominance approach is proposed. In the suggested framework, instead of considering a single value for desirable goal in each scenario of benchmark, a profit interval has been allocated to reflect the economic targets of decision maker. In the next step, the allocated profit interval is utilized for decision making problem in the stochastic dominance framework. In order to find the optimal profit profile in such a setting, a two level optimization structure is suggested. To this end, at the lower level of optimization, three different methods namely the prospect stochastic dominance, conditional value at risk (CvaR) and hypothesis testing are applied to find the optimal profit profiles for a number of benchmarks, those are stochastically generated in an interval around a pre-specified profit benchmark. In the upper level, the optimal profit profile is computed by using the Mean-CvaR method. To show the practical aspects and generalizability of our proposed approach, the methods are applied to two different cases, including a retailer and an electricity producer's decision making problems to determine their involvement in the futures market by maximizing their expected profit over a given planning horizon, while controlling the risk of profit volatility in the electricity market, raised from the uncertainties in the spot market price and the consumer demand. The performance of suggested framework is evaluated through simulation results and relevant conclusions are drawn.

1. Introduction

1.1. Motivation

Risk management is among the most indispensable and efficacious issues which contributes in portfolio selection and decision making problem. Various metrics have been proposed in the literature for risk management in the context of optimization under uncertainty. These metrics have been used in a wide variety of fields. For example, risk management in supply chain has pivotal role. Increased supplier risk vulnerability has led firms to give more weightage to purchasing function and its associated decision makers. To manage decision making problem under uncertainty, an extended approach for order of preference by similarity to ideal solution (TOPSIS) method with interval valued fuzzy numbers has been suggested in Ref. [1].

Apart from that, in carbon market, fluctuations of carbon's price have profound effect on decisions of market players. To deal with this, Authors in Ref. [2] have implemented extreme value theory (EVT) to investigate risk exposure for carbon price and to gauge the Value at Risk (VaR) for the carbon market. The implications of multiscale oil-stock average and tail dependence for portfolio management at different time scales has been investigated in Ref. [3]. Additionally, Ref [3] proposed a flexible wavelet-copula approach to evaluate the risk associated with mixed oil-stock portfolios (compared to a single-stock portfolio) in terms of risk

* Corresponding author.
E-mail address: kebriaei@ut.ac.ir (H. Kebriaei).

https://doi.org/10.1016/j.energy.2018.06.050
0360-5442/

diversification and downside risk gains.

Moreover, there are various types of risks in banking. For example, liquidity creation is a principal task of banks and an economic service of considerable significance to the economy. In reality, although, it is prevalent to evaluate market risk with the consideration that the market is ideal with an insignificant bid-ask spread, spreads can be both broad and floating. By this consideration, a simple liquidity risk framework that can be easily and seamlessly integrated into standard value at risk (VaR) models has been suggested in Ref. [4].

1.2. Litreture survey

In smart grid, demand response (DR) programs can be applied to motivate electricity consumers towards scheduling their controllable demands to off-peak periods [5]. Energy planning is another area that is susceptible to substantial amount of risk. In demand response programs, the responsive load can fluctuate in various time intervals. In Ref. [6], by means of a stochastic programming formulation, the impact of the market and load uncertainties on the scheduling problem is considered. So as to confine the risk of expected profit because of market price and load forecast volatilities, the conditional value-at-risk (CvaR) approach is applied. Also in Ref. [7], CvaR has been used as a risk measure technique in order to control the risk of low profit scenarios for optimal daily operation of a Virtual Power Plant. Besides that, in Ref. [8], in order to evaluate the role of demand response programs in attaining a favorable tradeoff between profit and risk, a mean-risk optimization procedure is suggested for the retailer. A decentralized energy trading framework with considering the integration of renewable energy resources has been proposed in Ref. [9]. In this framework, a penalty term based on the conditional value-at-risk (CVaR) has been applied into the objective function to address the uncertainties in the renewable resources. Ref [10] proposed an optimization procedure to solve the portfolio allocation problem for an electricity retailer using drawdown measure maximizing rate of return. The proposed methodology is based on the modeling of the stochastic evolution of zonal prices that seeks to manage a portfolio of different contracts. In Ref. [11], an interactive multi-objective framework is proposed which considers parametric uncertainty and casts the operational risk as an additional objective function. In addition, in order to cope with the uncertainty, a probabilistic approach via the Sigma Point (SP) method has been applied. Including constraint satisfaction in spite of related uncertainty allows to directly quantify the trade-offs arising when a robust solution is adopted.

Stochastic dominance which is introduced in Ref. [12] is broadly implemented in a wide variety of fields such as risk management, finance, insurance, economics, statistics, medicine and so on. In this context, an optimization criterion is considered to find the profit profiles that dominate a pre-specified benchmark. In this way, instead of searching for optimal profit profile distribution, a set of acceptable profit profiles are selected, those dominate the pre-specified benchmark. Then, the optimal profile that gives the maximum expected profit is chosen from the set. Therefore, a pairwise comparison can be easily conducted on a number of portfolios. In risk management, stochastic dominance is applied to classify risks, determine investors' risk preferences, and access operational losses. In Ref. [13] authors concentrated on optimization problems involving second-order or higher order dominance constraints and evaluated the performance of proposed models on a portfolio optimization problem. Stability of a stochastic optimization problem with stochastic second order dominance constraints is studied in Ref. [14]. Darinka Dentcheva investigated Two-stage stochastic optimization problems when order-constrains exist on the recourse [15]. According to connection between stochastic dominance and expected utility maximization theory, Benjamin Armbruster in Ref. [16] suggested different notion of multivariate stochastic dominance as a constraint in a stochastic optimization model. To examine the efficiency of robust portfolio, a novel approach of second order stochastic dominance is presented in Ref. [17]. In the case of finite probability spaces, authors in Ref. [18] proposed a decomposition algorithm for stochastic programs with first order dominance constrains. In Ref. [19], a method for determining the trading strategies of a virtual power plant (VPP) in cooperation with its neighboring VPPs is presented. To handle the market price uncertainties, an efficient risk management approach based on the concept of first-order stochastic dominance constraints (FSD) is used to enable informed decision making under different levels of uncertainty. The inclusion of FSD in the VPP's cooperation problem allows the VPP manager to impose its preferences on the resulting profit, and thereby, identify its risk-hedging strategy against uncertain market prices. Moreover, it flexibly controls the resulting profit and guarantees a minimum acceptable profit and bilateral contracts fulfilment. Authors in Ref. [20] proposed a two-stage stochastic optimization model for maximizing the profit of a price-taker power producer who wants to determine the optimal planning for investment in power generation capacity in a long term horizon with the respect to the uncertainties. To this end, authors used two different approaches for risk management, namely Conditional Value at Risk (CVaR) and first order Stochastic Dominance constraints (FSD). Four benchmarks has been used to test the FSD risk aversion strategy and the authors draw an analogy between these two approaches for risk management and concluded that with tolerating higher computational time with the standard MIP solver, FSD risk measure gives a more complete description of the investor's aversion to risk.

To reduce the risk suffering from low profits in the problem faced by an electricity retailer, authors in Ref. [21], applied stochastic dominance constraints. In this paper, sum of the selling prices has been took into the account as the objective and second order stochastic dominance criterion was applied to find profit profiles that dominate a pre-specified profit benchmark profile that is just acceptable to the decision maker. The difference between FSD and Second order Stochastic Dominance (SSD) strategies is that the former considers bounds on the probability of failure that the objective function value reaches the thresholds, and the latter considers bounds on the expected shortfall on reaching them. In Ref. [22] a new multistage risk averse strategy is proposed as a mixture of FSD and SSD, induced by mixed integer-linear recourses. In addition, the expansion of the Branch-and-Fix Coordination (BFC) algorithm is also proposed to counter the group constraints of the cross-scenario.

1.3. Contribution

Most of the articles reviewed, only used SSD and FSD criteria to evaluate dominance condition in stochastic dominance approach for risk management. These criteria do not have desirable flexibility and have some restrictions to model decision maker's priorities. For example, these criteria do not allow decision maker to treat differently with gains and losses. Moreover, all studies do not regard uncertainties exist in determining profit profile that is supposed to model decision maker's risk preferences.

In this paper, we introduce a novel procedure for risk management via stochastic dominance approach whereby we cope with uncertainties exist in the pre-specified benchmark. A benchmark is actually an estimation of the profitability of investing in other economic fields. To obtain a better realization of decision maker's economic goals, we consider the uncertainties in a benchmark by