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Applying portfolio theory-based modified ABC to electricity generation mix

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ABSTRACT

Portfolio theory has found its model in numerous engineering applications for optimizing the electrical generation mix of an electricity area. However, to have better performance of this theory, this paper presents a new heuristic method as known modified artificial bee colony (MABC) to portfolio optimization problem. Moreover, we consider both dis-patchable and non-dis-patchable constrains variables and energy sources. Note that the proposed MABC method uses a Chaotic Local Search (CLS) to enhance the self searching ability of the original ABC algorithm. Resulting, in this paper a portfolio theory-based MABC model that explicitly distinguishes between electricity generation (energy), installed capacity (power) and actual instantaneous power delivery is proposed. Therefore, in this model, the uncertainties of wind power and ramp-up/down constrains of traditional power plants are correctly considered in the investment cost. The numerical results show the great potential of proposed model with lowest risk on generation cost. Also, they are show that MABC approach is successful in portfolio optimization.

Introduction

Electricity energy plays a critical task in electricity system, underpinning all zones of economic activity. The economic impact of price fluctuations or supply disruptions can thus be important and wide-ranging. This makes an incentive for governments to guarantee that reliable, secure, and competitively priced energy sources are readily available. There is astonishingly little in the way of specific indicators modified for security of energy supply on a national basis. This is in branch due to the diversity and complexity of the area under discussion. These properties to regard one aspect of the energy sector using portfolio theory. Note that it is significant to understand the assumptions of mean–variance analysis in order to use it effectively. Firstly, mean–variance analysis is according to a single period form of investment. At the start of it, the investor allocates his prosperity among different asset models, assigning a positive weight to each asset model. In general, maximizing expected utility of ending period wealth by choosing portfolio weights is a complicated stochastic nonlinear programming problem. To summarize the assumptions [1–5]:

1. Investors seek to maximize the expected return of total wealth.
2. All investors have the same expected single period investment horizon.
3. All investors are risk-adverse, that is they will just agree to larger risk if they are compensated with a higher expected return.
4. Investors base their investment decisions on the expected return and risk.
5. All markets are perfectly efficient (e.g. no taxes and no transaction cost).

The utility function is assumed to be increasing and concave. Therefore, this interprets into expected utility being rising in expected return and decreasing in variance. Therefore, of all possible portfolios, the investor must just consider those that minimize variance or maximize expected return for a given level of estimated return. They form the mean–variance efficient set. There are related papers will be review as follows:

In [7] firstly introduced the application of mean–variance portfolio (MVP) model to fossil fuel procurement in the United States electricity sector. Nevertheless, their analysis was consistent with the prevailing "cost-plus" regulatory regime. In [8–10] thought that energy planning must not only follow the lowest investment cost, but must also pay more concentration to developing an

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effective generating portfolio to achieve risk diversification. They applied portfolio theory to study the optimal energy mix, and their numerical results demonstrated that renewable energy had its own particular benefits in energy price organization, but these were always ignored by conventional energy-assessment systems. In [11] proposed that fuel price risk might have a great impact on domestic economic improvement; an efficient energy portfolio could decrease ensure energy security and fuel price risk. In [6] also pointed out that according to portfolio theory, given a positive combination of generating models, adding renewable plant to a generating portfolio can surely decrease the generating-cost risk for the portfolio. In [12] suggested that portfolio theory could help policy-makers in developing an efficient generating portfolio under their preferred level of energy security. Also, in [13–16] demonstrated that renewable plant with high fixed costs can hedge fossil fuel price risk in a cost-effective way. In [17,18] utilized Monte Carlo method to take the return from gas-fired, coal-fired, and nuclear power investments and then used the simulation results as portfolio model inputs to study the efficient generating portfolio for large-scale power generation enterprises in liberalism electricity market. However, these approaches have some shortcomings in solving the portfolio selection problem. In order to conquer these shortages, MABC algorithm is proposed to solve the portfolio selection and optimization problem. MABC is a population based stochastic optimization method developed in this paper. In comparison with the dynamic programming, MABC permits the designers to get the sub-optimal solution while dynamic programming cannot. It is very significant for the optimization problem and portfolio selection.

The portfolio opportunities and its constraint

Portfolio theory is a set of different methods of assets belonging to any of individual or institutions, which principles of formation are redirected to the employment of different types of assets and collection proportions seeking for the efficacy by the owner of portfolio. Generally, if the portfolio consists of $A_1, A_2, \ldots, A_n$ assets, we assume that the structure of portfolio is $w_1, w_2, \ldots, w_n$ ($w_i > 0$, $w_1 + w_2 + \cdots + w_n = 1$) and its value $v = w_1a_1 + w_2a_2 + w_na_n$, when a_i is the value of ith asset. To understand the solution of arisen problems more easily it is essential to concentrate on the geometry surface of those problems reflecting their criteria of decisions in order to find better solution. Usually, fix the average meaning of portfolio profitability on the ordinate axis, while the instability (risk) measure of the same profitability i.e., average standard deviation – on the abscissa. Therefore, the average and deviation of the same probability distribution are set on separate organizes. Having selected the set of assets though meaningful of their standard deviation and profitability, and assuming that each of assets might take the part altering in the range $(0, 1)$, we'll achieve the set of possible portfolios (as shown in Fig. 1). This is the way to identify the whole complex of available portfolios or the set of investor's choices. Mathematical random variables and characteristics of their weighted sums influence such form of available portfolios. YB is named effectiveness line and is the part of curve AB. Those lines are shown to be of acceptable meaning while analyzing separate characteristics of portfolio. Efficiency lines, the highest profit average line of available portfolios possessing the proper level of risks.

Risk and return

It is essential to discuss the basic characteristics of the return and its dispersion of an asset as well as a portfolio before we proceed to the discussion of portfolio selection models. For each asset,

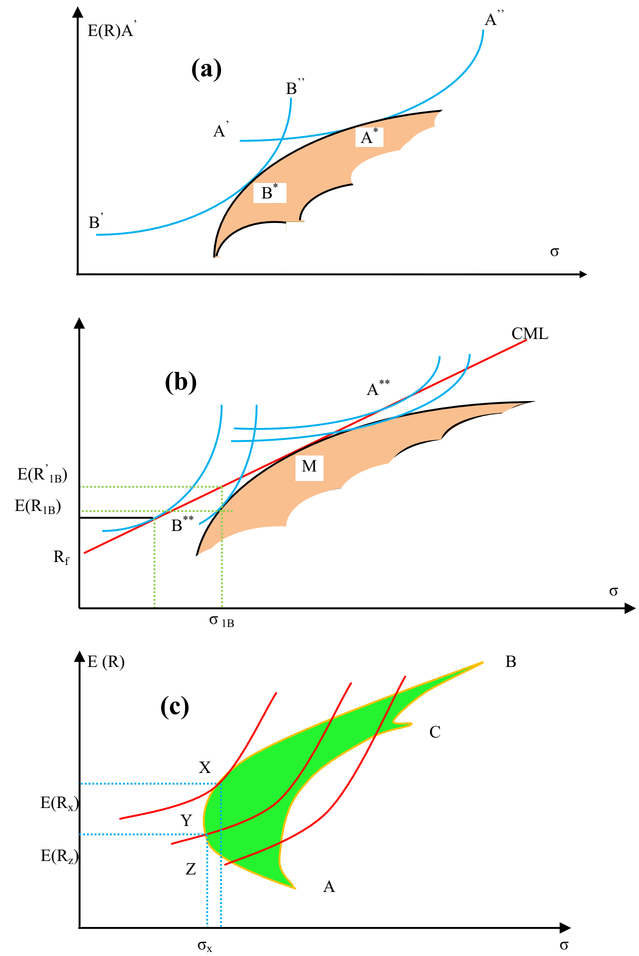

Fig. 1. Variants of the search for portfolio decision, (a) selection of the best alternative from available variants, (b) envelope curve with two investors' indifference curves, and (c) capital market line (CML).

variance, the expected return, and covariance are expressed as follows:

$$\begin{cases} \overline{R}_i = \sum_{t=1}^{N} \frac{R_{it}}{N} \\ \sigma_i^2 = \sum_{t=1}^{N} \frac{(R_{it} - \overline{R}_i)^2}{N-1} \\ \operatorname{cov}(R_i, R_j) = \sigma_{ij} = \sum_{t=1}^{N} \frac{(R_{it} - \overline{R}_i)(R_{jt} - \overline{R}_j)}{N-1} \end{cases} \quad (1)$$

where N is the numbers of observed returns of asset i, and R_{it} denotes the tth observed return of asset i. Further, the correlation coefficient between assets A and B is always between -1 and 1 and is expressed as follows:

$$\rho = \frac{\operatorname{cov}(R_A, R_B)}{\sigma_A \sigma_B} \quad (2)$$

For a portfolio with assets that are linear combinations of one another, the expected return and variance are expressed as follows:

$$\overline{R}_P = E(R_P) = \sum_{i=1}^{N} x_i \overline{R}_i \quad (3)$$

$$\sigma_P^2 = \sum_{j=1}^{N} x_j^2 \sigma_j^2 + \sum_{j=1}^{N} \sum_{k=1}^{N} x_j x_k \sigma_{jk} \quad (4)$$

where x_i denotes the proportion of asset i held in the portfolio. Now we are convinced that diversification is beneficial in reducing risks, we go into the discussion of short sales. As talked earlier, x_i shows