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AUTOMATIC DATA PROCESSING SYSTEM OF RENEWABLE ELECTRIC POWER PRICES IN END-USE RESIDENTIAL SECTOR OF USA

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ABSTRACT

We propose a computer-based automatic system of electric power prices processing and finding an optimal price level for renewable electric energy produced in USA. We implement classical Markowitz portfolio theory to electric energy prices in all regions of USA. For given margin volatility we find shares of electric power that should be bought in different US regions for making K.W.H. as cheap as possible for US residents.

Keywords: data processing system, renewable energy price, residential US sector, Markowitz portfolio theory.

1. INTRODUCTION

The most significant factor of modern world economy growth is the rise of energy consumption. Low-capacity renewable energy (sunlight, wind, and geothermal heat) production in end-use residential sectors is also shooting up, reaches up to 19% of global energy consumed. However, sources of renewable energy usually spread so vast and they so weak that some major electric supply network companies should optimize their capacities and prices in an optimal way, especially if they permit of giving back excess electricity to the grid.

This phenomenon, in recent years, has been observed in the Russian Federation, which is a consequence of the transition of the economy to a new level.

In the world IT-market there is an enormous quantity of automatic detecting or managing systems, e.g. systems described in [1,2]. Nevertheless, in the same time we need to extract the data to be processed from gigantic amount of daily - weekly - monthly reports so that the new class of automated systems should be built. It is a primary part of our investigation.

The second part of the investigation is as follows: we should solve to the problem of energy pricing optimization. It has the same mathematical solution as investment portfolio problem whose solution was proposed by Markowitz portfolio theory [3-5]. It gives us a set of shares of some instruments integrated for implementation of purposes, profit growth etc.

The constructing of the portfolio of shares or securities, originated around the time when securities were themselves, and is a consequence of the natural reluctance of investors to fully link their financial well-being with the fate of only one company. Portfolio investment allows us to plan, assess, and monitor outcomes throughout the investment activities in various sectors of the stock market.

The constructing of portfolio investment is an allocation of investment money between various groups of assets, since it is impossible to predict fulfillment of two conditions at the same time: high reliability and maximum yield. Depending on the tasks and objectives, investors analyze the stock market situation and reasons that influence the stock price. The process of portfolio construction implies indicating the most appropriate portfolio structure for a certain type of securities; the percentage ratio of financial instruments is defined as well. In turn, the output of the bidders on the stock market through brokerage firms and financial groups. In addition, the choice of a management company investor occurs because of advertising, the advice of friends, the size of commission fees, etc. However, these factors are not always objective.

For example, high fees are not indicative of fair labor control and further high-yield investments, and advertising often only serves as a means of attracting attention, justifying the company entrusted to investor confidence. Therefore, there is a need for a study of the relationship between the amount of fees received income, the level of investor risk aversion and the degree of trust to the management company as the fundamental indicators of interaction between investors and management companies. As a rule, the portfolio represents a specific set of shares, bonds or other securities with varying returns and risks, and fixed income securities, guaranteed by the state, that is, with minimal risk of loss of principal and current income.

In the making of portfolio should be guided by the following considerations:

a) the safety of investments, i.e. investments invulnerability from shocks in the market of investment capital;

b) the stability of income - in each time we should know a value of capital we get;

c) the liquidity of investments, i.e., ability to engage in immediate purchase of goods (works, services), or quickly and without loss in price converted into cash.

This work covers extracting of the data to be processed from monthly reports and constructing an optimal portfolio using Markowitz portfolio theory for huge amount of small renewable energy production companies (or non-commercial houses) all around USA with prices, given by U.S. Energy Information

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Administration (EIA). We propose a computer-based system for finding an optimal price level for renewable electric energy produced in USA. We implement classical Markowitz portfolio theory to electric energy prices in all major regions of USA. For given margin volatility we find shares of electric power that should be bought in different US regions for making K.W.H. as cheap as possible for residential US sector.

2. THE MODEL

The modern theory of portfolio investment was laid down in the works of Markowitz, the Nobel Prize winner in economics, is based on the concept of systematic (market) risk and unsystematic security [3]. He also acquaints us with bases and the most important questions of market operation of securities with the point of world practice. Markowitz considers questions of management of securities portfolio, basic concepts and financial strategies used in the branch of stock market. The main index of effectiveness of the financial instrument is a profitability, which depends of quality of portfolio management. Connection between portfolio management and company itself depends of the level of risk aversion. Author considers methods, which helps us to understand behavior patterns of economic facilities, list of variables, and specification of his model for its evaluation, given the basic principles of building and analyses of different econometric models.

Markowitz also paid a great attention to the optimal choice of the assets based on the desired ratio profitability risk and gave the advices of successful portfolio investment, financing companies.

Yield can be described as average slope of the line plotted on the graph in asset prices, and the level of risk describes how the amplitude of fluctuations in the real price in relation to the level of profitability. Furthermore, Markowitz noted that the greater the oscillation amplitude, the less predictable the behavior of prices. Prices influence on investors' behavior very strong [1,2], especially for high-frequency 'hidden' trading on futures and options market with informed professionals.

One can consider the problem of finding the optimal portfolio from two different aspects: ensuring minimum risk, which will be provided at a certain level of income, and getting maximum return for a given level of risk.

For the portfolio construction, optimal proportions between available assets were calculated in such the way that the portfolio's risk reaches minimum with the set rate of yield. The foundation of Markowitz portfolio is the investor's preference principle. According to this one, investor prefer the lowest risk portfolios under other equal conditions.

Consider a portfolio of prices on renewable energy from different suppliers

$$X_\pi = \sum_{k=1}^{n} \alpha_k x_k \ , \qquad (1)$$

where α_k – share of k^{th} supplier in all energy delivered, x_k – energy price of this one.

Let expected value of stochastic price $E(x_k) = a_k$ and dispersion $D(x_k) = \sigma_k^2$ with covariancies $\operatorname{cov}(x_k, x_j) = \sigma_{kj}$, k=1, 2,…, n.

So, variance of our portfolio is as follows:

$$\sigma_\pi^2 = \operatorname{var}\left(\sum_{k=1}^{n} \alpha_k x_k\right) = \sum_{k=1}^{n}\sum_{j=1}^{n} \alpha_k \alpha_j \rho_{kj} \sigma_k \sigma_j \ , \qquad (2)$$

where $\rho_{kj} = corr(x_k, x_j)$.

To construct the optimal price portfolio we should limit a sum (1) of shares of all suppliers who deliver us energy by unit: $\sum_{k=1}^{n} \alpha_k = 1$. After that we must minimize expected value of stochastic price X_π of the portfolio constructed to offer the most competitive price in the market:

$$E(X_\pi) = \sum_{k=1}^{n} \alpha_k E(x_k) = \sum_{k=1}^{n} \alpha_k a_k \to \min.$$

To complete our model we should constrain a variance level σ_π^2 in (2) by some predefined and given variance, say, σ^2:

$$\sum_{k=1}^{n}\sum_{j=1}^{n} \alpha_k \alpha_j \rho_{kj} \sigma_k \sigma_j < \sigma^2 .$$

This inequality completes our problem:

$$\begin{aligned} & E(X_\pi) \to \min, \\ & \sum_{k=1}^{n} \alpha_k = 1, \\ & \sigma_\pi^2 < \sigma^2. \end{aligned} \qquad (3)$$

To solve (3) one can use any numerical package like Excel Solver. In addition, it can be derived analytically by Lagrange multipliers method.

For clarity let examine the optimization problem in case of just two suppliers. Expression (1) should be rewritten as

$$X_\pi = \alpha_1 x_1 + (1-\alpha_1) x_2 \ ,$$

with expected value

$$E(X_\pi) = \alpha_1 a_1 + (1-\alpha_1) a_2$$

and variance

$$\sigma_\pi^2 = \alpha_1^2 \sigma_1^2 + (1-\alpha_1)^2 \sigma_2^2 + 2\sigma_{12}\alpha_1(1-\alpha_1) =$$
$$= \alpha_1^2 \sigma_1^2 + (1-\alpha_1)^2 \sigma_2^2 + 2\rho_{12}\sigma_1\sigma_2\alpha_1(1-\alpha_1).$$

If we constrain expected value $E(X_\pi)$ at some unknown level r, we can find the share α_1:

$$\alpha_1 a_1 + (1-\alpha_1) a_2 = r \ ,$$

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$$\alpha_1 = \frac{r - a_2}{a_1 - a_2}.$$

It allows us to find functional dependence $\sigma = \sigma(r)$ for variance. Actually, substitute α_1 in (2) we get

$$\sigma_\pi^2 = \sigma_1^2 \left(\frac{r - a_2}{a_1 - a_2} \right)^2 + \left(\frac{a_1 - r}{a_1 - a_2} \right)^2 \sigma_2^2 +$$
$$+ 2\rho_{12}\sigma_1\sigma_2 \left(\frac{r - a_2}{a_1 - a_2} \right)\left(\frac{a_1 - r}{a_1 - a_2} \right),$$

from which

$$\sigma_\pi^2 = Ar^2 + Br + C, \tag{4}$$

where

$$A = \frac{\sigma_1^2 + \sigma_2^2 - 2\sigma_{12}}{(a_1 - a_2)^2}, C = \frac{\sigma_1^2 a_2^2 + \sigma_2^2 a_1^2 - 2\sigma_{12} a_1 a_2}{(a_1 - a_2)^2},$$
$$B = \frac{2\sigma_{12}(a_1 + a_2) - 2\sigma_1^2 a_2 - 2\sigma_2^2 a_1}{(a_1 - a_2)^2}.$$

So, in (4) we have parabola with minimum

$$r = \frac{\sigma_1^2 a_2 + \sigma_2^2 a_1 - \sigma_{12}(a_1 + a_2)}{\sigma_1^2 + \sigma_2^2 - 2\sigma_{12}},$$

that solves our problem (3) completely.

If we consider problem (3) for n energy suppliers we can find the solution by Lagrange multipliers method with Lagrange function

$$L = \sum_{k=1}^{n} \sum_{j=1}^{n} \alpha_k \alpha_j \sigma_{kj} - \lambda \left(\sum_{k=1}^{n} \alpha_k a_k - r \right) - \mu \left(\sum_{k=1}^{n} \alpha_k - 1 \right).$$

Setting partial derivative from L to zero for each α_k, k=1, 2,…,n, we get linear system from n equations:

$$2\sum_{j=1}^{n} \alpha_j \sigma_{kj} - \lambda a_k - \mu = 0.$$

Its solution also defines unknown α_k in expression (1).

3. AUTOMATIC DATA ANALYSIS AND NUMERICAL RESULTS

Review all results we got.

First of all, we collected all the energy price statistics data since Jan 2012 till June 2016. After that, we built the automatic computer-based system as a program, which converts pdf files of all monthly reports into one Excel file with combined same-named Tables from different reports. Each Table is situated on a separate Excel sheet. Further we used monthly kilowatt-hour price dynamics for different US regions with follow notations: x_1='Residential area price in New England', x_2='Residential area price in Middle Atlantic', x_3='Residential area price in East North Central', x_4='Residential area price in West North Central', x_5='Residential area price in South Atlantic', x_6='Residential area price in East South Central', x_7='Residential area price in West South Central', x_8='Residential area price in Mountain', x_9='Residential area price in Pacific Contiguous', x_{10}='Residential area price in Pacific Noncontiguous'. For example, in June 2016 there were such prices (US cents per K.W.H): x_1=18.90, x_2=15.98, x_3=13.01, x_4=12.75, x_5=11.84, x_6=10.93, x_7=10.61, x_8=12.05, x_9=15.49, x_{10}=25.04.

Secondly, we estimated covariance matrix for time series x_1–x_{10} and chose marginal volatility as σ^2=0.3 (or 30%, because prices change significantly).

So, standard deviations for each region are: σ_1=19.12%, σ_2=18.35%, σ_3=18.17%, σ_4=17.92%, σ_5=17.61%, σ_6=34.64%, σ_7=31.62%, σ_8=21%, σ_9=14.14%, σ_{10}=31.62%.

At last, we computed shares and constructed energy portfolio as

$$X_\pi = 0.12x_4 + 0.88x_6.$$

So, the margin price level r is 11.15 cents for K.W.H. in June 2016.

4. CONCLUSIONS

We built automatic computer-based data processing system and suggested mathematical technique of finding marginal price r for renewable electric energy produced in residential sector of USA in different regions since Jan 2012 till June 2016. We implemented Markowitz portfolio theory to sustainable electric energy monthly prices in all major regions of USA. For given margin volatility equal to 30% we compute that K.W.H. costs 11.15 cents in June 2016 if we buy 12% electricity power in West North Central region and 88% - in East South Central region of USA.

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