Research on the Portfolio of Chinese Photovoltaic Enterprises

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Abstract. Two models to reduce potential risks in photovoltaic enterprises are introduced in this paper to demonstrate the problem that the price of silicon is dropping sharply today. Based on the portfolio theories, the first model is created by the use of Mean-variance model which is traditional and functional. As an improvement, the second model, the Mean-semivariance model takes not only the financial marketing risks but also the background risks into consideration. The data is collected by iFind from three different enterprises. Despite having a large production scale, each enterprise is separated from each other. The calculations indicate that the paper contains a figure that contains the weights of two stocks from two different enterprises. The figure displays the distinction between the effective and inefficient portfolios. Among the efficient portfolios, some of them own a high level of Sharpe ratio while having a low level of deviation, indicating that upstream industries could invest in both upstream industries, and midstream industries in order to weaken the risks brought by the price drop of silicon. This paper will assist investors in making better investment decisions using portfolio theories.

Keywords: Photovoltaic enterprises, portfolio theories, Mean-variance model, Mean-semivariance model, background risks.

1. Introduction

Chinese photovoltaic industry has grown steadily and is now ranked first worldwide for its installed photovoltaic power generation capacity. For eight consecutive years, the total installed capacity of new capacity has ranked first in the world, and this year's new installed capacity reached 78.42 million kilowatts [1]. The industrial chain is made up of three parts: upstream for silicon wafer processing, midstream for cell and module synthesis, and downstream for photovoltaic power plant operation. Due to supply imbalances, silicon's prices are currently plummeting, which is a major issue for all photovoltaic enterprises.

The midstream and downstream industries are benefited by the dramatic drop in the price of silicon by lowering the cost of buying silicon. It is undoubtedly a nightmare for the upstream industries when the price of silicon drops sharply. To mitigate the loss of income, these enterprises can invest in midstream and downstream industries. This method is called portfolios. The focus of this paper is on the possibility that upstream industries can reduce the impact of the drop in silicon prices by utilizing portfolio theories and the Mean-variance model. The remainder of this paper is arranged as follows. Methods, such as yield and standard deviation calculations, risk calculation for portfolios of two securities, and the Sharpe ratio, are introduced in Section 2. The portfolio calculations are completed in Section 3 by listing the data collected from three different companies, highlighting the relationship between risk and income. The conclusion is that investing portfolios from different enterprises could partially mitigate the impact of the drop in silicon's price.

2. Methodology

The Markowitz model, commonly referred to as the mean-variance model, is a portfolio optimization model that Markowitz first put forth in 1952. It assesses the usefulness of the portfolio in terms of investment risk and return and is notable for being the first to offer a quantifiable evaluation of financial risk. The theory of mean variance is based on the following three assumptions: Investors are risk averse; each asset carries risks; the ROE distribution is normal [2]. The Markowitz model clarifies the trade-off between portfolio benefits and risks.

2.1. Calculations of Yield and Standard Deviation

Calculations of average daily yield and standard deviation [3]:

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}} \tag{1}$$

$$E(R_t) = \frac{\sum_{t=1}^{n} R_t}{n} \tag{2}$$

$$\sigma(r) = \sqrt{\frac{\sum_{t=1}^{n} (r_t - \bar{r})^2}{n-1}} \tag{3}$$

R_t displays the stock's yield for the day, P_t shows the stock's closing price for the day, P_{t-1} shows the stock's opening price for today. $E(R_t)$ displays the expected return of a stock. $\sigma(r)$ represents the standard deviation of a stock's yield and n represents the times of observations in the data sampling period.

2.2. Risk Calculation for Portfolios of Two Securities

$$\sigma_{ij} = \frac{\sum_{t=1}^{n} (r_{i:t} - \bar{r_i})(r_{j:t} - \bar{r_j})}{n-1} \tag{4}$$

$r_{i:t}$ equals to the return of security i in the time period t, which refers to the return of the stock on the day, $r_{j:t}$ equals to the return of security j in the time period t, which refers to the return of the stock on the day. $\bar{r_i}$ refers to the average yield of security i, $\bar{r_j}$ refers to the average yield of security j. n refers to the number of observations of the sample.

$$\sigma_p^2 = x_1^2 \sigma_1^2 + x_2^2 \sigma_2^2 + 2 x_1 x_2 \sigma_{12} \tag{5}$$

$$STD = \sqrt{\sigma_p^2} \tag{6}$$

$$r_p = x_1 r_1 + x_2 r_2 \tag{7}$$

σ_1 and σ_2 refer to the standard deviation of the yield of Securities 1 and Securities 2. x_1 and x_2 refer to the proportion of the portfolio that invests in asset 1 or 2. σ_{12} refers to the covariance between assets 1 and 2, STD refers to portfolio's standard deviation.

2.3. Sharpe Ratio

$$sharpe\ ratio = \frac{r_p - r_f}{\sigma_p} \tag{8}$$

r_p refers to expected annualized return for the portfolio, r_f refers to annualized interest rates on risk-free assets, σ_p refers to the standard deviation of the annualized rate of return of the portfolio.

3. Data

3.1. Data Collection

Given the requirement for portfolios [4] to be both representative and distinct, this study proposes a division of criteria into two components. Firstly, the selected companies should be representative of the photovoltaic industry, necessitating their possession of large scales. Secondly, the chosen companies should also be distinct enough to form effective portfolios. Consequently, it is suggested that three companies from different categories (upstream, midstream, downstream) would be appropriate choices.

Under these criteria, three companies with large scales in photovoltaic industry are chosen from different categories:

3.1.1 Upstream Industry

Xinjiang Daqo New Energy Co., Ltd (DQ) is a company located in Shihezi, Xinjiang, with a registered capital of 2.137 billion yuan. Its main activities revolve around the development, manufacturing, and sale of high-purity polysilicon. As stated in its semi-annual report for 2023, the company has achieved a net profit exceeding 4.4 billion yuan, with a net cash flow from operating activities reaching 5.4 billion yuan.

3.1.2 Midstream Industry

Changzhou Shichuang Energy Co. (SC), Ltd has introduced a range of products in the field of photovoltaics, including wet process aids, equipment, and cells. The company is primarily engaged in the development, manufacturing, and marketing of these products. Its main focus is on addressing process-related challenges that impact the efficiency of photoelectric conversion in solar cell production, leveraging its competitive edge in technological innovation. As per the company's semi-annual report for 2023, the net profit attributable to shareholders of the listed company amounts to 1.1 billion, with a net cash flow of 1.3 billion from operating activities.

3.1.3 Downstream Industry

Sungrow Power Supply Co. (YG), Ltd is a prominent national high-tech enterprise that specializes in the research, production, promotion, and maintenance of innovative energy power systems, encompassing solar, wind, energy storage, hydrogen, and electric vehicle technologies. The company's primary offerings consist of photovoltaic inverters, wind power converters, and related products. As indicated in its semi-annual report for 2023, the company has achieved a net profit of 4.3 billion and a net cash flow from operating activities of 4.7 billion, which is attributable to its shareholders.

3.2. The Relationship between Risk and Income

Table 1. Average daily return, annualized return and standard deviation of DQ, SC and YG

Stock	Period	Average daily return (%)	Annualized return (%)	Standard deviation
DQ	3 months	0.0812	19.6989	0.2134
	12 months	-0.0862	22.158	0.1172
	5 years	-0.0247	42.9678	0.3953
	7 years	-0.0247	42.9678	0.3953
SC	3 months	-0.3877	475.0452	1.9574
	12 months	-0.3877	475.0542	1.9574
	5 years	0.3658	238.6547	1.2311
	7 years	-0.1356	211.3652	1.2212
YG	3 months	-0.1694	-39.165	0.3622
	12 months	-0.0618	24.3221	0.2371
	5 years	0.302	74.5652	0.0961
	7 years	0.188	35.4639	0.0793

This study was conducted by counting these three companies' stocks for four periods from May 27, 2023 to August 27, 2023 (3 months) and August 27, 2022 to August 27, 2023(12 months), August 27, 2018 to August 27, 2023 (5 years), August 27, 2016 to August 27, 2023 (7 years) for their average daily return, annualized return, and standard deviation. The results are displayed in Table 1.

As Table 1 shown above, it's evident that the annualized return is the income of each stock and the standard deviation is the risk of each stock. Moreover, the fluctuating trends between annualized return and standard deviation suggest that the greater the risk, the greater the income [5].

3.3. Portofolio Calculations

The purpose of this paper is to obtain efficient portfolios and simplify the process by using just two companies' stocks (DQ and YG) as samples to form portfolios. Table 2 aims to acquire more income while reducing risk by changing the weight of each stock and calculating the portfolio's annualized return, standard deviation, and Sharpe ratio. The results are displayed below.

Table 2. Annualized return, standard deviation and Sharpe ratio of different weights of DQ and YG

Portfolio	DQ	YG	Annualized return	Standard deviation	Sharpe ratio
1	100%	0	22.16%	11.72%	1.53
2	95%	5%	22.27%	11.20%	1.61
3	90%	10%	22.37%	10.81%	1.67
4	85%	15%	22.48%	10.58%	1.72
5	80%	20%	22.59%	10.51%	1.74
6	75%	25%	22.70%	10.60%	1.74
7	70%	30%	22.81%	10.86%	1.71
8	65%	35%	22.92%	11.26%	1.66
9	60%	40%	23.02%	11.81%	1.59
10	55%	45%	23.13%	12.47%	1.51
11	50%	50%	23.24%	13.22%	1.43
12	45%	55%	23.35%	14.07%	1.36
13	40%	60%	23.46%	14.98%	1.28
14	35%	65%	23.56%	15.95%	1.21
15	30%	70%	23.67%	16.97%	1.14
16	25%	75%	23.78%	18.02%	1.08
17	20%	80%	23.89%	19.11%	1.03
18	15%	85%	24.00%	20.23%	0.98
19	10%	90%	24.11%	21.37%	0.93
20	5%	95%	24.21%	22.53%	0.89
21	0%	100%	24.32%	23.71%	0.85

4. Results

As the annualized return increases in Table 2, the standard deviation and Sharpe ratio also increases until portfolio 7. To make data analysis more intuitive, I define the x-axis as standard deviation and the y-axis as annualized return. The following are the images of Figure 1 and Figure 2.

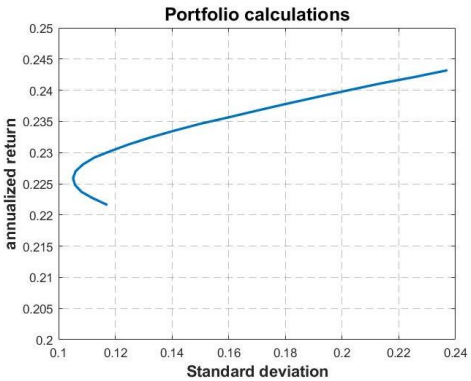


Figure 1. The relationship between annualized return and standard deviation

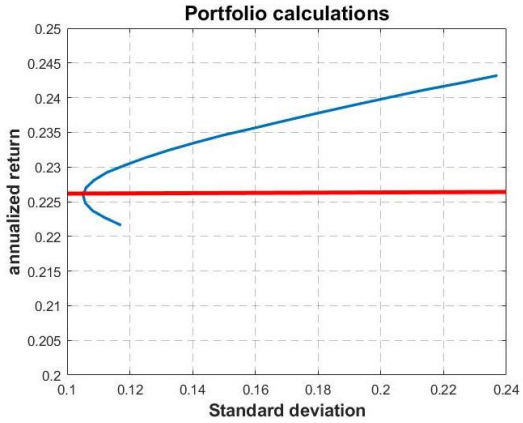


Figure 2. The relationship between annualized return and standard deviation (with efficient portfolio border)

The graphical representations in Figure 1 and Figure 2 illustrate the dynamic relationship between the annualized return and standard deviation. Notably, the red line depicted in Figure 2 serves as a demarcation point, distinguishing portfolios that are deemed inefficient from those that are considered efficient. Portfolios positioned above the red line exhibit efficiency as they demonstrate a higher level of annualized return compared to those below, while maintaining an equivalent level of standard deviation. At the inflection point, these portfolios display a relatively high annualized return and the lowest standard deviation. Additionally, they possess the highest Sharpe ratio, indicating their potential as optimal portfolios. This is supported by the understanding that a higher Sharpe ratio corresponds to a greater excess return achieved for a given level of risk [6]. The optimal portfolio occurs at the turning point with the highest Sharpe ratio, which actually combines the upstream stock and the downstream stock therefore reducing the potential risks. In other words, it represents the most meaningful investment portfolio [7].

5. Discussion

Portfolio selection is the study of how to allocate wealth in the hands of investors to different assets in a fair way to maximize wealth and effectively control investment risks. For a considerable amount of time, portfolio selection research has been a research hotspot in the field of financial engineering and risk. Since Markowitz proposed the mean-variance model [8], a series of theoretical models and methods have been proposed by many scholars who have studied the problem of portfolio selection from various angles. Despite the fact that these models and methodologies examine portfolio selections from various angles, they only consider the impact of financial market risk on these portfolios. In practical scenarios, investors are exposed to market risk arising from the volatility of financial asset prices. Additionally, they also assume certain risks that are mitigated through portfolio diversification in the financial market. These risks encompass factors such as investors' real estate holdings, health conditions, labor income, and other related variables. Collectively, these risks are referred to as background risks. [9].

The utilization of variance as a metric for assessing risk is subject to certain constraints, as it considers both the portion below and above the anticipated return of the asset portfolio as risks. However, in practical terms, the portion below the expected return is the true risk. Consequently, the Mean-semivariance Model [10] has been developed as an alternative approach. Mean-semivariance Model takes both financial risks and background risks into consideration. With the use of critical line algorithm [11], the text describes a process of calculating and analyzing a model's effective frontier in portfolio management. The portfolio is divided into two components: the portion that remains effective on the frontier in the absence of background risk, and the portion that deviates from this absence after accounting for background risk. The mean-semivariance model is proposed as a more advantageous approach for decision-making in portfolio selection compared to existing mean-variance-based models. It is evident that this research can enhance investors' ability to accurately

measure investment risks and provide a theoretical foundation for investors to formulate scientific and reasonable investment strategies.

This paper presents two models that can be utilized by upstream industries to mitigate risks in response to the decline in silicon prices. The first model, known as the traditional Mean-variance Model, examines investment portfolios consisting of two distinct industries. Analysis of Figure 1 reveals the existence of potential portfolios that offer a relatively high annualized return and a low level of standard deviation. In essence, this optimal portfolio exhibits the highest Sharpe ratio, enabling investors to allocate weights to the two industries and thereby minimize market risks. The second model, however, identifies the possibility of diversifying risks into financial market risk and background risk. While the first model solely considers financial market risk, the second model represents an improvement by employing the critical line algorithm to assess the efficient frontier. This advantage of the Mean-semivariance Model enhances its accuracy and suitability for aiding investors in making informed investment decisions.

6. Conclusion

In contemporary times, the significant decrease in the price of silicon has had a detrimental effect on the upstream entities within the photovoltaic industry. This paper proposes that these upstream companies can mitigate the adverse consequences by employing portfolio theories based on the Mean-variance model. Through the analysis of data and calculations, it is theoretically demonstrated that portfolios with a high Sharpe ratio and low risks can indeed be constructed. However, it is important to note that the Markowitz model solely accounts for financial market risks and disregards background risks. Nonetheless, investing in portfolios from diverse enterprises can partially alleviate the impact caused by the decline in silicon prices.

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