Optimizing Renewable Energy Portfolios in China: Risk-Return Analysis and the Role of Geographic Diversification

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Abstract:

Renewable energy sources, such as solar and wind, are inherently weather-dependent, leading to uncertainty in electricity generation. This uncertainty presents significant challenges not only for grid management, which must maintain a real-time balance between supply and demand, but also for investors who consider renewable assets a key component of their portfolios. The risks associated with renewable energy investments stem from fluctuations in both electricity prices and the amount of electricity generated. While electricity prices can be stabilized through long-term power purchase agreements, the variability in generation can only be partially mitigated through costly energy storage projects or limited weather insurance. In this paper, we propose a novel approach to mitigating the risks associated with renewable energy generation by diversifying investments across renewable projects located in different geographical regions. Using the locations of existing renewable energy projects, along with historical and projected weather data from CMIP6, we model the risk-return curve (efficient frontier) of renewable energy portfolios in China under four scenarios: historical (2019), SSP1-2.6 (2050), SSP2-4.5 (2050), and SSP5-8.5 (2050). We also compare the efficient frontier of these diversified renewable portfolios with that of popular Chinese investment portfolios, such as the Chinese stock market index. Our results show that simple geographic diversification of renewable energy projects can significantly reduce weather-related risks, with the risk mitigation effect being most pronounced in the SSP5-8.5 scenario. When climate change exacerbates, the efficient frontier shifts upward and to the right, reflecting higher risk but also higher returns, underscoring the importance of asset management. Furthermore, the optimized renewable energy portfolio emerges as a competitive asset, especially in lower-risk regions of the risk-return curve, when compared to the Chinese stock index.