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Optimal investment portfolio in renewable energy: The Spanish case

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ABSTRACT

This article presents a model for investing in renewable energies in the framework of the Spanish electricity market in a way that risk is minimised for the investor while returns are maximised. The model outlined here is based on an economic model for calculating cash flows intended to obtain the internal rate of return (IRR) of the different energies being studied: wind, photovoltaic, mini hydro and thermo electrical. The IRRs obtained are considered the returns on investments, while their standard deviations are considered associated risks. In order to minimise risk, a comprehensive portfolio of investments is created that includes all of the available energies by means of a system of linear equations. The solution of the linear system is graphically checked using the efficient frontier method for the different financing options. Several case studies within the Renewable Energies Plan (PER is its Spanish abbreviation) that is in force in Spain in the period 2005–2010 are analysed in order to illustrate the method, as are other case studies using different types of financing, helping us to reach the pertinent conclusions.

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1. Introduction

In a world that is seeing a constant rise in the demand for all kinds of energy and where the prices of raw materials, particularly oil, fluctuate wildly, it is essential to use models that help us to make decisions when investing in energy projects, and, more specifically, those involving renewable energies.

To tackle an investment project in renewable energies that is subject to risks regarding prices in an electricity market, and the investment and operating costs among others (Roques et al., 2006), it is necessary to hedge against these risks by seeking the greatest possible return. Bazilian and Roques (2008) show a detailed review of all analytical methods related to portfolio optimisation in energy.

Regarding costs, previous models have considered the estimated generation costs measured in monetary units per kWh as a relevant measure (Awerbuch, 2002; Awerbuch and Berger, 2003b). These models obtained the return as the inverse of cost (Kienzle et al., 2007) within a portfolio theory framework on energy supply planning (Huang and Wu, 2008). In the EU, cost data are available (European Commission, 2006) and Kobos et al. (2006) and Wiser and Bolinger (2007) in the USA have produced detailed cost reports related to wind power generation. On a wider scale, the International Energy Agency (2006) has provided similar cost data on renewable technologies.

A good investment portfolio must diversify its risk (Huang and Wu, 2008). Usually, investment portfolios of a financial nature use the mean-variance method (Markowitz, 1952; Luenberger, 1998; Bodie et al., 2004). Applications to energy investment where risks related to costs are considered can be seen in (Awerbuch and Berger, 2003a, b; Awerbuch et al., 2005; Awerbuch, 2006). Other models for reducing risks are shown in Biewald et al. (2003). In particular, Berger (2003) and Cleijne and Ruijgrok (2004) are exclusively applied to renewable energies. Finally, Yu (2003) presents a model to assess risks in a multi-pool setting. An excellent review of the state-of-the-art in portfolio theory applied to energy can be found in Kienzle et al. (2007).

All of the references mentioned use the mean-variance method in order to maximise the return on investment for a certain level of risk, which is defined as the standard deviation for the expected return of the investment. In our approach, the return on investment coincides with the IRR, while the risk level corresponds to the standard deviation of the IRR. The IRR measures the profitability of the investment portfolio assuming that the investor receives dividends from all technologies (equally considered) involved and that these dividends are directly derived from the profit obtained from the operation of the technologies.

If the measure of profitability or return of these assets, which are, in fact, investment projects, is achieved with the IRR, we assume that the risk comes from the IRR's standard deviation. Compared to previous approaches (Awerbuch and Berger, 2003b), where the risk is calculated from the uncertainty in the return derived from fuel price changes and availability, the IRR is

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able to consider the uncertainty in electricity prices and future subsidies.

The IRR is adjusted to its risk, allowing an investor to determine if the return received is adequate for the risk undertaken. Among several methods to measure risk-adjusted return, the Sharpe ratio (Luenberger, 1998) is a reasonable metric. It is calculated by subtracting the risk-free rate of return, assumed to be Treasury Bonds, from the expected rate of return, the IRR in our case, dividing the result by the standard deviation of the portfolio returns, which is the measure of the investment's risk. The greater the Sharpe's ratio, the better its risk-adjusted performance is, as shown in Appendix B.

Note that the risk-free assets in our model, Treasury Bonds, is the reference value that generates the optimal point in the efficient frontier made up of a renewable technologies mix. Since there can be various scenarios as a function of the risk level and profitability, there are as many optimal portfolios. The investor, according to his own risk aversion, will decide which scenario suits him better. Fig. 1 shows a scheme that depicts how an investor with different risk aversion perceptions can select the optimal portfolio. Although this work does not define an empirical risk aversion measure, it could be estimated as in (Neuhoff and de Vries, 2004; Green, 2004).

Once the return and the risk are defined, a system of linear equations is established and the efficient frontier method is used to ensure that we have created the optimal portfolio. The next step is to perform a viability study, bearing in mind the stochasticity of the parameters that define the return on investment.

The remainder of this section is devoted to explaining the peculiarities of the Spanish renewable sector, its comparison to the German sector, as well as the objectives pursued with this study.

The Spanish energy market has a high level of dependence on fossil fuels close to 80% of the total generation-making Spain very vulnerable to geopolitical developments in the countries that produce fossil fuel-based energy. See Fig. 2 depicting the future production trends of all renewable technologies in Spain. We have selected the four most representative renewable technologies in Spain: wind, photovoltaic, minihydro and thermoelectrical, since our interest is the risk-adjusted optimisation of a simple but realistic portfolio on renewables only, not the diversification of risk, as done in stock-based investment portfolios.

The instability of fossil fuel-based energy prices has increased considerably over the past few years. The need to reduce this dependence on foreign suppliers, protect the environment, and achieve sustainable development has mobilised the public administration, fomenting the use of clean sources of energy and of efficient energy use. All of this is in response to economic, social and environmental concerns and in order to meet international environmental commitments entered into in recent years.

Overall consumption of renewable energies has increased significantly in Spain, but not enough to meet these environmental targets. Furthermore, the increase in energy consumption has been even greater than expected, partly due to the growth in electrical demand and partly due to greater consumption of motor fuels used in transportation.

The sources of energy that we are going to be dealing with in this analysis are clean and renewable energies, like direct solar energy, such as photovoltaic and thermo electric, wind power on land and, finally, mini hydro, a technology that is sadly neglected in Spain.

Below we define the parameters needed for an economic and risk reduction analyses of these renewable energies. The information provided comes mainly from IDAE (2005). Information regarding investments has been taken from Royal Decree 661/2007 (2007) of the 25th of May 2007, which regulates the production of electrical energy in special regimes (Royal Decree 661/2007, 2007), and the Renewable Energies Plan (PER) 2005–2010. The PER financial data are shown in Table 1.

Germany is the European country with the highest penetration of renewable energy, wind in particular. Table 2 shows the evolution of the regulated tariff in Germany and Spain for different technologies. The current trend in Germany's tariffs reveals a progressive reduction between 2% and 8%, depending on the technology. In Spain, tariffs are increased yearly according to the consumer price index, but in cases like photovoltaic energy, tariffs have almost doubled in 2007. With the new Spanish Royal Decree 1578/2008 (2008), subsidies will go down to 32 c€/kWh and this figure will change in the coming years.

The work set out below has three main objectives: (i) to develop the economic models required to study each technology, (ii) to create an optimal investment portfolio made up of different renewable energies and (iii) to analyse these technologies individually and collectively using investment risk simulations. To achieve this, the article is structured as shown below. Section 2 deals with the economic model used to calculate the return on investment for all of the technologies considered for the portfolio. Section 3 describes the method for minimising the risk of a portfolio of renewable energies using a system of linear equations, and studies the efficient frontier method, going on to graphically demonstrate the equivalence between both methods. Section 4 presents the simulations and results obtained with the optimal portfolio of investments in renewable energies in the Spanish electricity market. Finally, the conclusions derived from the analysis of case studies are presented.

2. Economic investment model

The economic model is used mainly to establish future cash flows for every year of the investment projects. The economic, financial

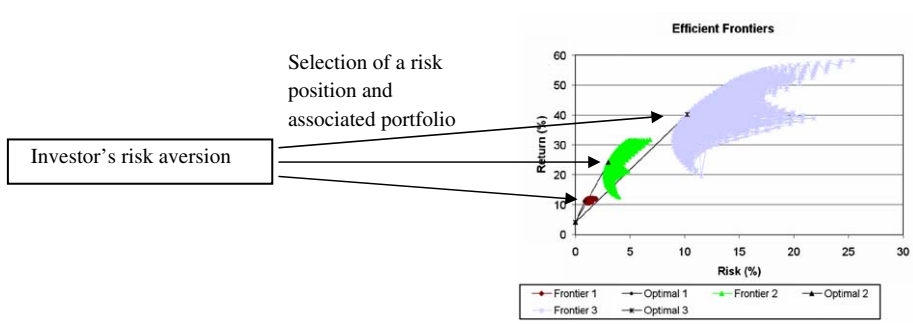

Fig. 1. Graphical check of the optimisation of the portfolio and the tangent point considering the investor's risk aversion.

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