[*A PROBABILISTIC APPROACH TO THE COMPUTATION OF THE LEVELIZED COST OF ELECTRICITY*]

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Overview

Today, most nuclear power plants under construction are located in Eurasia. This is also the region with the highest forecasted addition of nuclear capacity in the coming two decades. The estimation of a power project's economic viability by calculating the levelized cost of energy (LCOE) is a fundamental initial instrument for investment decisions. However, the methodology bears a range of drawbacks. A prominent difficulty to which the energy literature has repeatedly pointed at is that the LCOE is highly sensitive to investment costs, which, especially in the case of nuclear power, often form one of the biggest component to overall costs. Separate—though very relevant issues when weighing against alternative technology options—are so-called endogeneity issues: for instance, the failure to take into account the correlation between fuel prices and electricity prices or the volume of new investments in the market.

In this paper, the traditional approach of calculating LCOE is extended by not only implementing a probabilistic model applying Monte Carlo simulation methods to account for project risks, but also by introducing endogeneities between inputs. In addition, the role of discounting options and external costs is addressed and a rule of thumb is given to derive the minimal number of replications necessary to obtain statistically meaningful results. These issues have been neglected in previous studies.

The paper is organized as follows: chapter two summarizes the relevant literature, with a special focus on accounting for risks in project appraisal. Chapter three describes the model and the parameters' distributional assumptions. The results are analyzed in chapter four. Chapter five concludes.

Methods

The LCOE formula is embedded it into a Monte Carlo (MC) setting, where the cumulative distribution function of a stochastic variable $F(x) = P(\mathrm{X} \leq \mathrm{x})$ assumes values between 0 and 1. The inverse function G then is used for generating random samples for X via $G(y) = G[F(x)] = x$ for each probability level $y = F(x)$ by first drawig a random number r from $U(0,1)$. $G(r) = x$ subsequently produces a random sample according to the probability distribution of X. With r stemming from $U(0,1)$, the realization of X is equally likely to be generated in any percentile range, enabling us to generate a random sample for any probability distribution for which an inverse cumulative probability function G exists. MC simulation is based Latin hypercube sampling by stratifying $F(x)$ and applying random sampling without replacement to every of the resulting intervals.

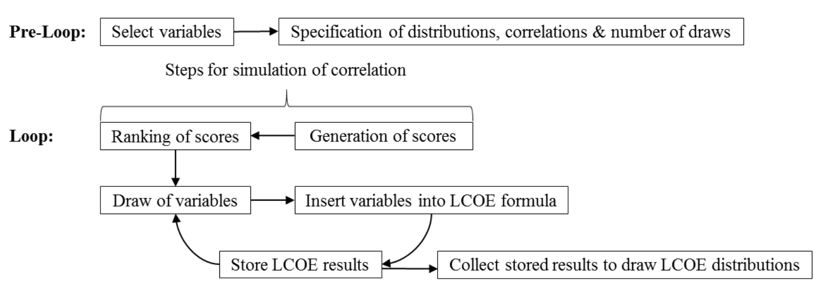

Figure 1**:** *Simulation procedure.*

The simulation procedure is depicted in Figure 1. Endogeneities account for the probability of some variables to vary in a systematic way. Predefined correlations between variables are introduced into the simulation process by using Spearman's rank-order correlation. Given that the number of iterations is known beforehand, the variable pairs to be correlated are drawn, i.e. the scores are generated, and then ranked in advance of the simulation in a fashion that yields the predefined correlation value. The necessary number of replications n is derived from $p_{1-q} = z_q \cdot s / \overline{x} \cdot n^{1/2}$, with z_q being the q percent percentile of $N(0,1)$ and $\overline{x}$ and s the to be estimated population mean and variance, respectively. For n to hold for all k varied parameters simultaneously, $p_{1-q} = [1-(1-\tilde{p}_{1-q})^k]$ is replaced by $\tilde{p}_{1-q} = [1-(1-p_{1-q})^{1/k}]$. Then n is calculated for every k and – in form of a conservative estimate – the highest result is taken as minimum number of iterations needed to receive a set of estimates that satisfies the predefined level of p_{1-q}, which e.g. could be 1 percent.

Results

Simulation results show that endogeneities between input parameters have a significant effect on the model outcome. By only controlling for a single endogeneity (construction costs and construction time), a statistically significant difference in the mean LCOE estimate and a change in the order of input leverages is observed (see Figure 2). Of course, many other potential endogeneities can be thought of, e.g. between fuel costs and inflation rates or interdependencies due to policies simultaneously affecting several variables. If investors would be forced by a regulator to internalize external costs, the economic viability of the project would be weaker.

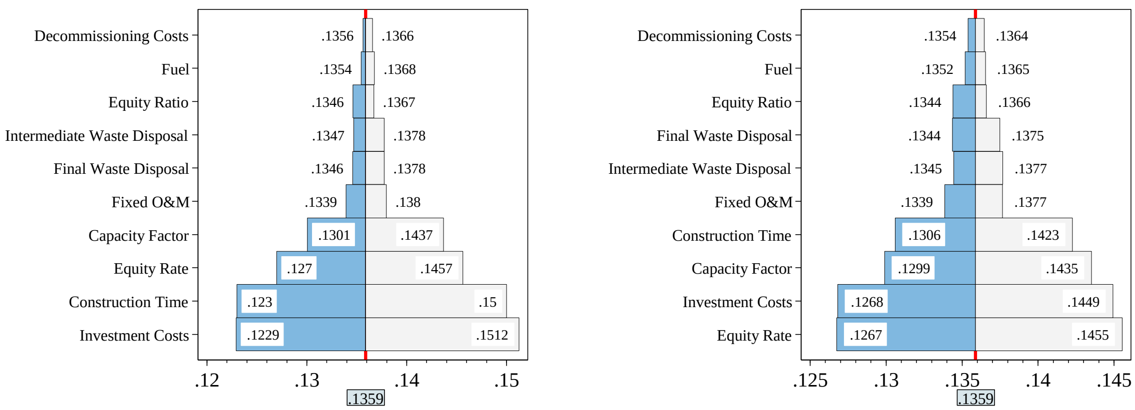

***Figure 2*:** *Input leverage on nuclear LCOE with (left) and without (right) accounting for endogeneities between input parameters.*

Conclusions

This paper sets forth a novel approach to calculate levelized costs of electricity (LCOE) using a probabilistic model that accounts for endogenous input parameters. The consideration of endogeneities between inputs is important, not only with respect to the overall LCOE estimate but also in terms of the leverage of the input factors on the LCOE estimate. Additional factors of importance for a project's economic viability are the choice of discounting options and the degree of the internalization of external costs.