8th Atlantic | Workshop on Energy and Environmental Economics

A Toxa, Galicia (Spain)
21-22 June 2018

A CAPM-Analogous Multi-Stage Model for Setting a Path towards a Decarbonized Power Generation Portfolio

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MOTIVATION

- The objective of this work is to obtain efficient generation portfolios
- An efficient generation portfolio is a portfolio that minimise either the cost or the CO_2 emission for a certain level of risk, or a portfolio that minimise the risk for a given level of cost or CO_2 emission
- The set of efficient portfolios is called the efficient frontier
- In this work we apply the MPT methodology to find both pollutant and non-pollutant efficient frontiers: by applying the methodology to a pollutant generation technologies set we are able to minimize the emission factor and the emission risk of the generation portfolio
- Then we apply the CAPM methodology to determine the CML-analogous area or CML-A

MODEL DATASET

Technology	Cost (€/MWh)	Cost Variance	Emission (kg/MWh)	Emission Cost Variance
Nuclear (N)	30.04	8.07	--	--
Wind (W)	60.69	41.69	--	--
Offshore Wind (OW)	73.81	52.04	--	--
Hydro (H)	38.62	105.79	--	--
Small Hydro (SH)	42.95	12.92	--	--
PV	212.03	110.27	--	--
Biomass (B)	96.62	162.84	1.84	0.01
Coal (C)	52.23	31.51	734.09	4.77
Coal with CCS (C CCS)	78.44	46.27	101.00	0.66
Natural Gas (NG)	38.79	12.33	356.07	2.31
Natural Gas with CCS (NG CCS)	63.60	44.45	48.67	0.32
Oil (O)	93.17	155.83	546.46	3.55

MODEL OPTIMIZATION FUNCTIONS

- Minimize cost:

$$\min \sigma_P = \min(w \times V \times w^t)^{\frac{1}{2}}, \textit{subject to:}$$
$$\begin{cases} w_i \geq 0, \forall i, i = \{1, 2, \dots, 12\} \\ \sum_{i=1}^{12} w_i = 1 \\ \textit{Technological and environmental constraints} \\ [c_P = w^t \times c = c^*] \end{cases}$$

- Minimize emission:

$$\min \sigma_P = \min(w \times V \times w^t)^{\frac{1}{2}}, \textit{subject to:}$$
$$\begin{cases} w_i \geq 0, \forall i, i = \{1, 2, \dots, 6\} \\ \sum_{i=1}^{6} w_i = 1 \\ [e_P = w^t \times e = e^*] \end{cases}$$

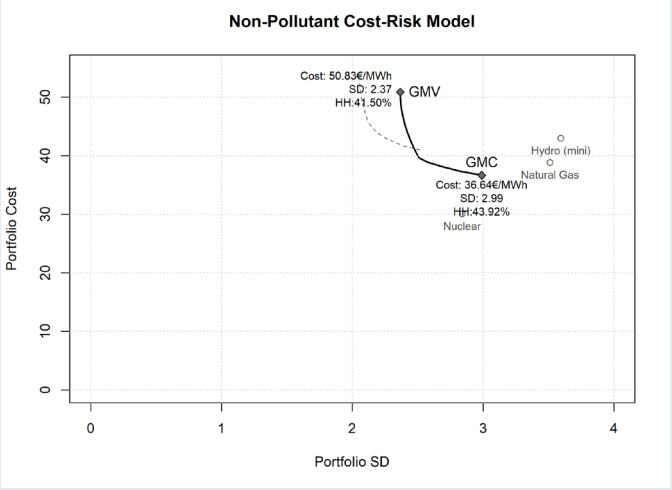
MODEL: STAGE 1

Cost-Risk Instrumental Model (Model 0)

- 12 technologies
- Minimize cost and risk
- Constraints:
  - Positiveness
  - Completeness
  - Technological and environmental constraints

Non-Pollutant Technologies Model (Model 1)

- 12 technologies
- 6 non-pollutant technologies
- Minimize cost and risk
- Constraints:
  - Positiveness
  - Completeness
  - Technological and environmental constraints



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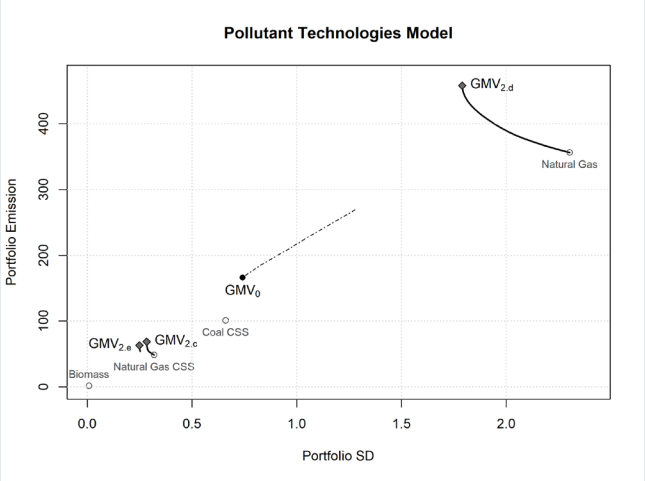
MODEL: STAGE 2

Emission-Risk Model

- Pollutant technologies
- Minimize emission and risk
- Constraints:
  - Positiveness
  - Completeness

Models

- 2.a: 6 pollutant technologies
- 2.b: without CSS
- 2.c: without Biomass
- 2.d: without both CCS and Biomass
- 2.e: 6 pollutant technologies with constraints

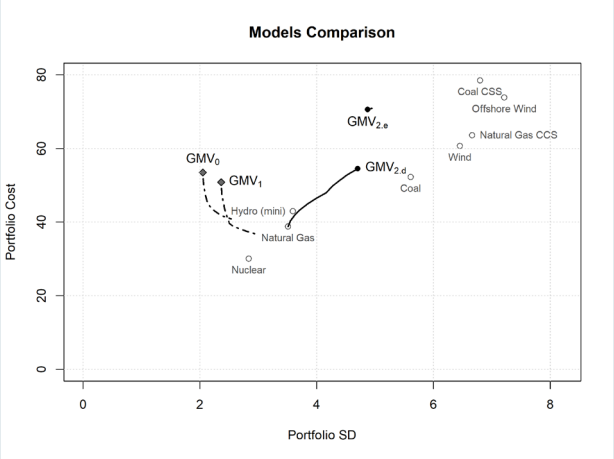


DISCUSSION

- By combining a portfolio in the pollutant generation efficient frontier with a portfolio in the non-pollutant generation efficient frontier we get a set of linear combinations –the CML-analogous area or CML-A– that allows the policy makers to reduce the CO_2 emission or risk of the generation mix
- The model gives to policy makers the possibility to focus their decision on pointing out how much emissions –or risk– do they want
  - With respect to the pollutant technologies, Biomass and CCS technologies are preferential
  - Regarding the non-pollutant technologies, Nuclear, Small Hydro and Offshore Wind are considered highly efficient in terms of cost and risk by the model
- But the elimination of pollutant technologies from power portfolio affects the Energy Security of a country or territory because it entails a less diversified generation mix

RESULTS (1)

- Non-pollutant technologies increase the generation portfolio cost but reduce its risk
- CCS and Biomass significantly reduce both the pollutant portfolio emission factor and its risk
- Optimum pollutant portfolios show higher risk than the generation portfolio. The cost is similar only in model 2.d



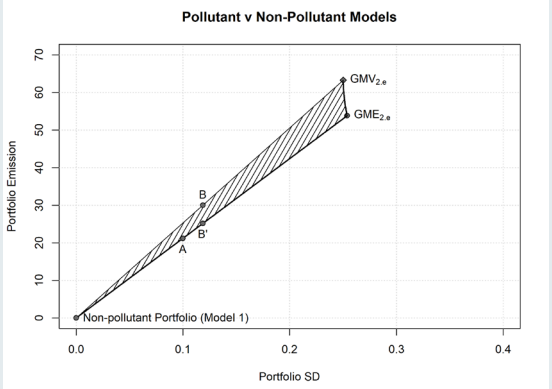
RESULTS (2)

Case 1: the policy maker wants to achieve an emission risk of 0.10kg/MWh

- The best combination in the CML-A area is A
- Given the risk of the GME portfolio (0.25kg/MWh) it is easy to determine that point A corresponds to a 39.39%-60.61% pollutant portfolio-non-pollutant portfolio

Case 2: the policy maket wants to achieve an emission of 30kg/MWh

- Point B is the best combination in the CML-A area for an emission of 30kg/MWh
- Point B' allows to reduce the emission without altering the risk



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