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Valuing Climate Change Uncertainty Reductions for Robust Energy Portfolios

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Motivation

- Better information & new data from remote sensing on climate sensitivity & other factors determining stabilization targets ⇒ adjustments to policy ⇒ uncertainty for investors in the energy sector
- Example: Hansen et al (2008) → new evidence suggests that CO_2 will need to be reduced to much lower levels! "The largest uncertainty in the target arises from possible changes of non-CO_2 forcings."
- Remote sensing monitoring GHGs & compare actual to reported emissions & computed scenarios ⇒ use numerical models to examine impact on radiative forcing ⇒ translate to appropriate policies

Methodology

- Energy sector: long-lived investments involving large sunk costs; ageing capacity will need to be replaced in the coming decades ⇒ avoid further lock-in to fossil-fuel-based energy ⇒ price on CO_2 (permit trading)
- Decision-making in the electricity sector under uncertainty about CO_2 policy ⇒ importance of Earth observations (EO)

Methodology II

- New framework of analysis integrating different methodologies: investment & operational decisions at plant level (real options model) ⇒ profit distributions informing large investor (e.g. large energy company or a region) of diversification potential (portfolio approach using the Conditional Value-at-Risk (CVaR) as a risk-measure)
- Evaluate the impact of policy uncertainty/value of better information by computing losses from being forced to have an energy portfolio robust across different scenarios (characterized by different CO_2 price depending on stabilization target)

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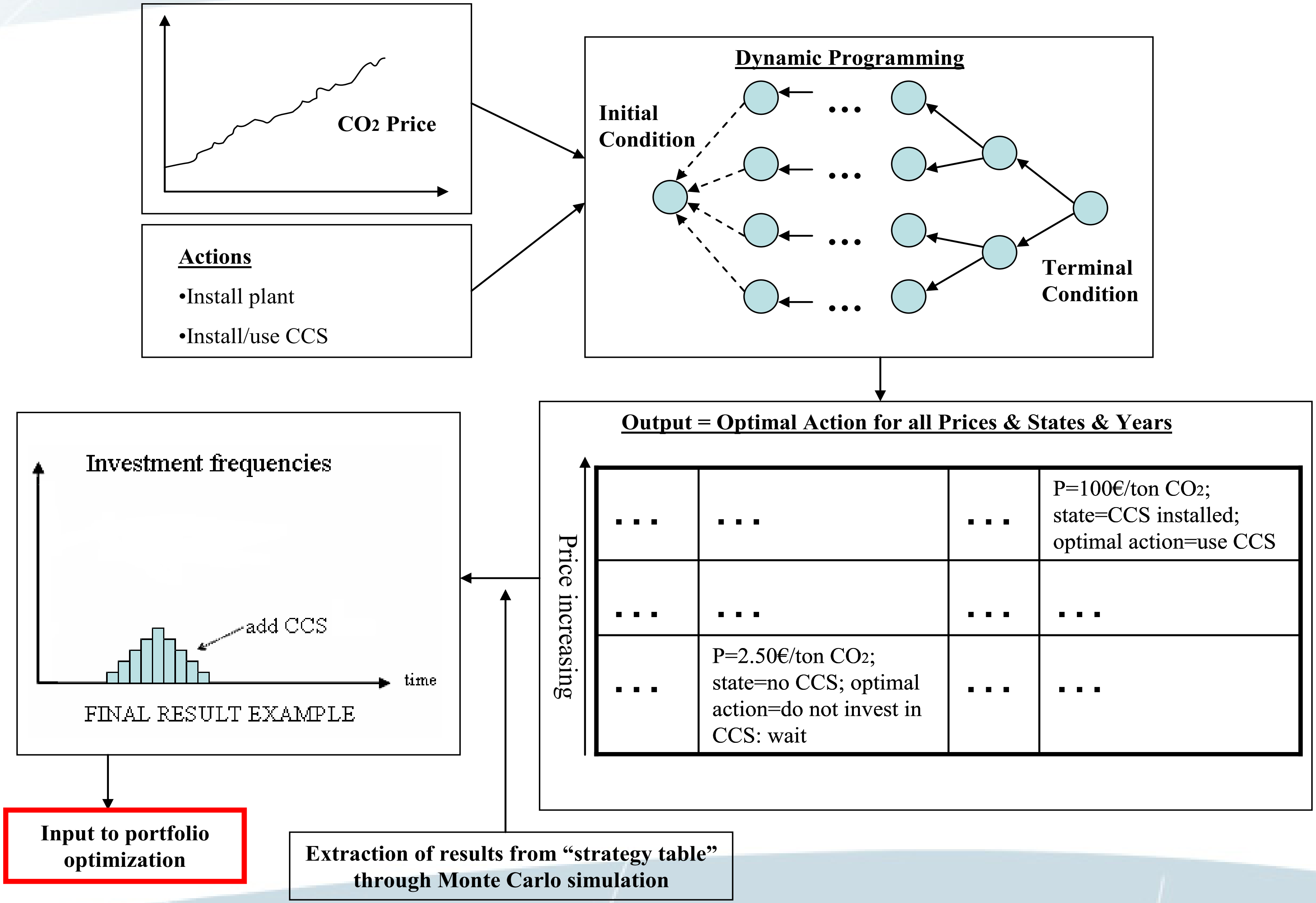
CO2 Price
Actions
•Install plant
•Install/use CCS
Dynamic Programming
Initial Condition
Terminal Condition
Output = Optimal Action for all Prices & States & Years
Price increasing
P=100€/ton CO2; state=CCS installed; optimal action=use CCS
P=2.50€/ton CO2; state=no CCS; optimal action=do not invest in CCS: wait
Investment frequencies
add CCS
time
FINAL RESULT EXAMPLE
Input to portfolio optimization
Extraction of results from “strategy table” through Monte Carlo simulation

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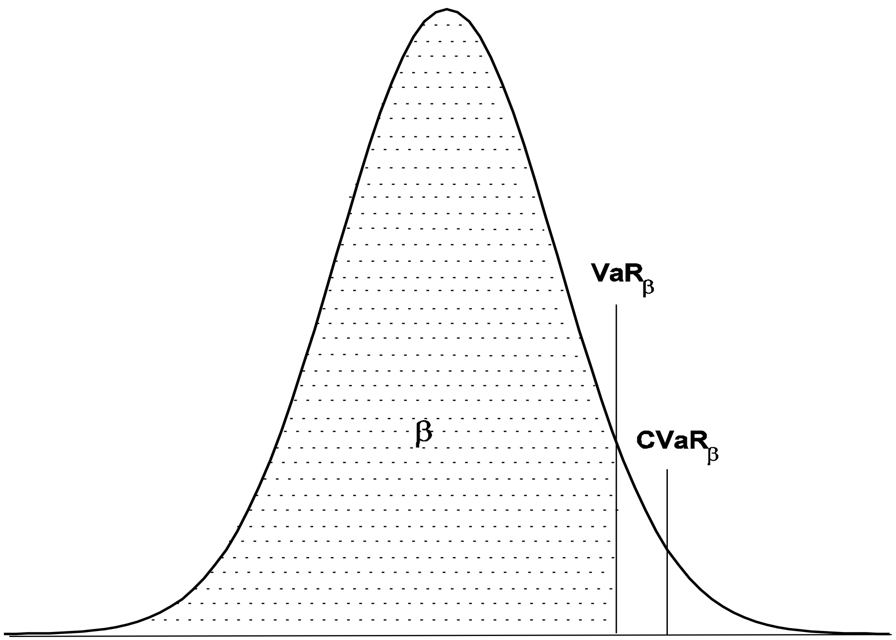
Data

Parameters	Coal	Coal+ CCS	Bio	Bio+ CCS
Output (MWh/yr)	7,446	6,475	7,446	6,475
CO_2 (t CO_2/yr)	6,047	576	0	-6,100
Fuel Cost (€/yr)	39,510	39,510	152,612	152,612
O&M (€/yr)	43,710	60,110	43,269	59,669
Installed Cap. (MW)	1	1	1	1
Capital Cost (1,000€)	1,373	1,716	1,537	1,880

Source: IEA, 2005

CVaR Risk Measure



The β-VaR corresponds to the β-percentile of the distribution, whereas the β-CVaR is the mean of the random values exceeding VaR. ⇒ Capture tail information ignored by mean-variance approach.

Source: Fuss et al, 2009

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Robust Portfolios: Minimax Criterion

$$\min_{(x,\alpha,u)} v$$

$$\text{s.t. } v \geq \alpha_s + \frac{1}{q(1-\beta)}\sum_{k=1}^{q} u_{ks},\ e^T x = 1,\ m_s^T x \geq \pi_s,$$

$$x \geq 0, u_k \geq 0, y_{ks}^T x + \alpha_s + u_{ks} \geq 0,\ u_{ks} \geq 0,$$

$$k = 1,\ldots,q,\ s = 1,\ldots,S.$$

- $u_{ks} \in \Re^n$, k=1,…,q are auxiliary variables; $e \in \Re^n$ is a vector of ones; q = sample size, m=E(y) $\in \Re^n$ expectation of profit; π = minimum portfolio profit; α = threshold of β
- $y_{ks} \in \Re^n$ are samples of NPV profits y_s for scenario s and $v \in \Re^n$ are auxiliary variables
- Solution (x*,α*,u*) yields optimal x ⇒ CVaR reaches minimum across <u>all</u> scenarios

$$\beta - \text{CVaR}(x_*) = \min_x \max_s \beta - \text{CVaR}_s(x).$$

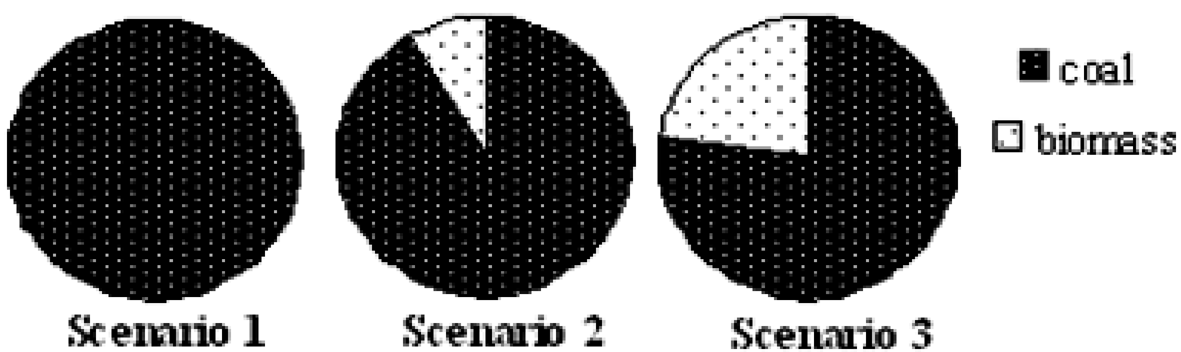
Parameters

μ^c			P_0^c (€/ton)	σ^c	r
scen.1	scen.2	scen.3			
0.00636	0.01716	0.0397	12	0.04	0.05

- P_0^c = starting CO2 price and σ^c are equal across scenarios.
- Scenarios are defined by their trend (μ^c): scenario 1 ~ 670 ppm (least strict target); scenario 2 ~ 590 ppm; scenario 3 ~ 480 ppm.
- Trends have been computed on the basis of the GHG shadow prices estimated for 2060 (GGI Scenario Database, 2009).

Scenario-specific Results

	Coal		Biomass	
Scenario	Exp. Profit (10^6 €)	-CVaR (97%)	Exp. Profit (10^6 €)	-CVaR (97%)
1	1.177	1.050	0.523	0.228
2	1.099	1.007	0.808	0.351
3	0.984	0.847	1.836	0.942

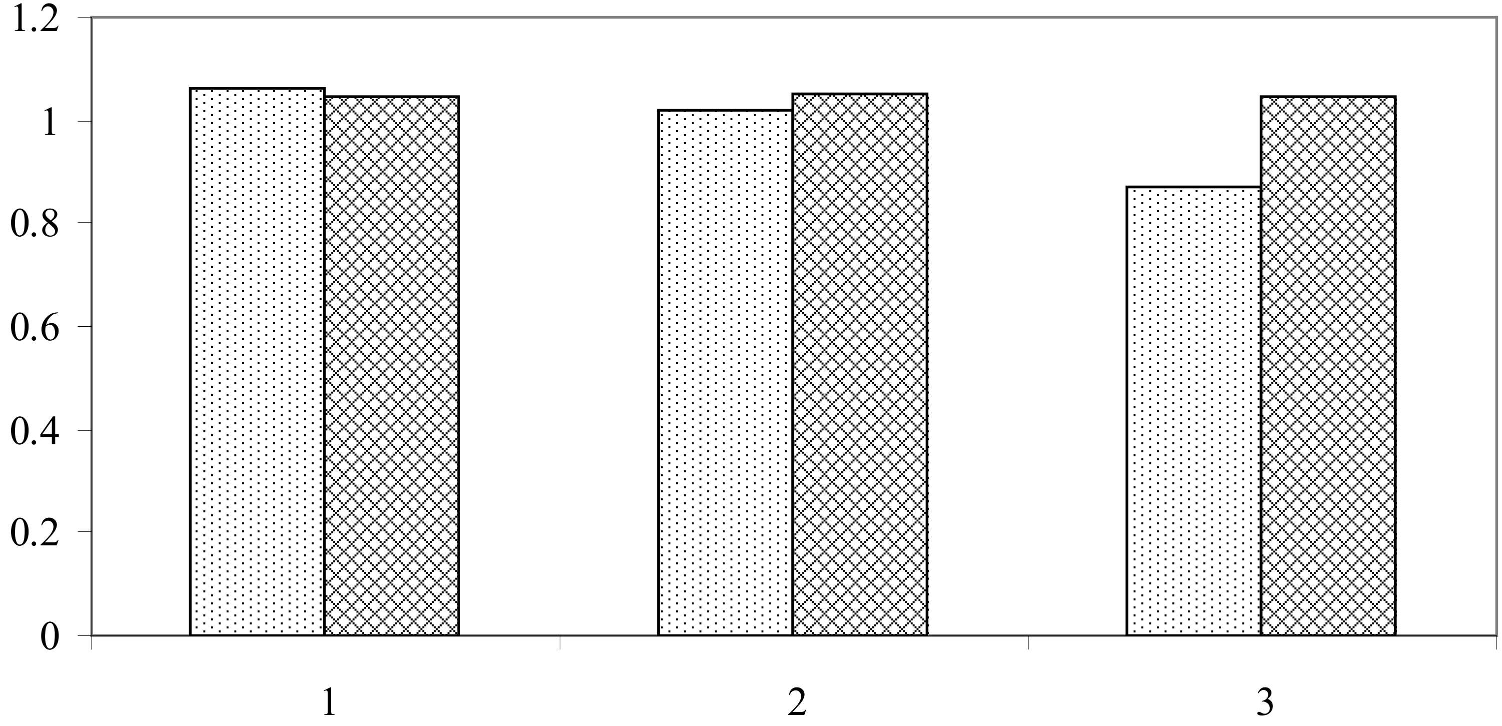


Results for Robust Portfolios

Actual scenario									
		1			2			3	
*	exp. profit	-CVaR	bio share	exp. profit	-CVaR	bio share	exp. profit	-CVaR	bio share
1	1.177	1.061	0%	1.099	1.021	0%	0.984	0.871	0%
2	1.121	1.046	8.5%	1.075	1.05	8.5%	1.056	1.049	8.5%
3	1.03	0.963	22.5%	1.034	0.979	22.5%	1.176	1.062	22.5%
123	1.122	1.047	8.4%	1.075	1.05	8.4%	1.055	1.047	8.4%

Expected profits in 10^6 € and –CVaR risk (*robust across these scenarios)

Results for Robust Portfolios II



Expected profit (in 10^6 €) across one scenario (dots) or all scenarios (diamonds)

Conclusions

- Investors having optimized for a specific scenario experience a much larger profit drop in profits than those having used the minimax-criterion.
- Security comes at the cost of lower overall profits ⇒ Missing information causing uncertainty about stabilization target leads to optimization under imperfect information ⇒ large profit losses
- Robust portfolios perform better in terms

Policy Relevance

- Robust portfolios have biomass shares below 10% ⇒ even if scenario 3 would have been possible, the chance of the other scenarios materializing drives down biomass investment.
- Precise data and information that enable the formulation of a clear and transparent stabilization target are necessary, so targets will not have to be adapted drastically.

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Thank you!

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