Energy diversification through fuel price variation within TIMES

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Motivation and goal

» Motivation
  » Some parameters like fuel prices will always be uncertain
  » Impossible to fully predict over time horizon

» Goal:
  » Single hedging strategy for the shorter term against risk aversion
  » Incorporating the uncertainty of future parameters by (almost) continuous distribution functions, taking into account covariances between the uncertainties
Handling uncertainty

Near optimal
  » Lower bound i.e. var.act
  » Post-optimality analysis (SET BENCOST YES)
  » Modeling to generate alternatives (MGA)
  » Monte Carlo/Parametric programming

Hedging outside TIMES
  » Make scenarios
  » Monte Carlo/Parametric programming

Hedging within TIMES
  » Robust Programming
  » Stochastic Programming
  » Include the cost of variation in the objective
Conditions for good investment analysis

1. Irreversibility: OK
2. Uncertainty threats: Risk Averse
3. Uncertainty opportunities/ Adaptiveness/Flexibility:
   » Not OK when perfect foresight
     » “The traditional discounted cash flow approach assumes a single decision pathway with fixed outcomes without the ability to change over time.”
   » OK, when using stochastic to get better information
     » “By having the ability to make midcourse corrections when these uncertainties become known, decision-makers have essentially hedged themselves against any downside risks.”
Diversification:
Not the single cheapest technology on average when

- **Risk aversion** (being risk neutral, you do not have diversification even with uncertain parameters in a model with a single decision path, ~ NPV calculations)

- **Adaptiveness** (even when being risk neutral)
  - Example:
    - Alternative fuel @ 4 €/GJ
    - Gas fuel @ 5 €/GJ + 3€/GJ

- **Variable demand**
  - Fixed versus variable costs
  - No cheap storage
Some history...

» 1950: **Portfolio theory**
   Markowitz

» 1960: Sharpe, Miller

» 1970: **Option pricing models**
   Fischer Black, Myron Scholes, Robert Merton

Risk averse: Fearing uncertainty

» Nobel Prize 1990

» Nobel Prize 1997

Adaptiveness = Profiting from uncertainty
## An overview

<table>
<thead>
<tr>
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<th>Risk neutral</th>
<th>Risk averse</th>
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<tbody>
<tr>
<td>Non-adaptive</td>
<td>Classical approach</td>
<td>DEVUP, ( \lambda )</td>
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<td></td>
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<td>DEVUP, Minimax</td>
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<td>Adaptive</td>
<td>Stochastic programming (Option theory, real option theory)</td>
<td>(*) A combination ? Capetown 2012</td>
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(*) Risk aversity for SOW today possible with Minimax Stochastic, Risk averse stochastic
A portfolio approach

Uncertainty (VAR, DEVUP)

Renewables

Coal

Cost (including CO₂ price)

Gas: 4,7,2,9,2,4 x4 x3 x2 x1
Coal: 5,4,5,6,5,5 x1 x1
Renewable: 7,7,7,7,7,7 x2 x2

degree of aversion: λ
Upward deviation

Mean variance

Where \( \lambda = \) the risk aversion factor

\[ \text{var}(\text{cost}) = \text{actual price variation} \]

\[
\min\{E(\text{cost}) + \lambda \text{var}(\text{cost})\}
\]

Adapted to the linear model (smaller model to validate lambda)

\[
\min\{E(\text{cost}) + \lambda \text{UpAbsDev (Cost)}\}
\]

Where \( \text{UpAbsDev (cost)} = \sum_j p_j \{\text{cost}_j - E(\text{cost})\}^+ \)
Fuel price variation

» Fuel price scenarios constructed using expected growth rates and covariance matrix

<table>
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<tr>
<th></th>
<th>Oil</th>
<th>Coal</th>
<th>Gas</th>
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</thead>
<tbody>
<tr>
<td>Oil</td>
<td>0.047666</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>0.015483</td>
<td>0.046052</td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td>0.022898</td>
<td>0.018412</td>
<td>0.046349</td>
</tr>
</tbody>
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» 150 price scenarios generated for the period 2010-2050 through Monte Carlo simulations
Fuel price variation

» Example of price volatility:

» In TIMES, DEVUP is taken for each price path and for the total of fossil fuels.
Implementation within TIMES: 
Why you don’t need 150 objective functions

OBJ = 1500 I_W + 500 I_G + 1300 I_C + 900 I_O + 5 F_G + 7 F_C + 8 F_O 
OBJ^2 = 1500 I_W + 500 I_G + 1300 I_C + 900 I_O + 3 F_G + 8 F_C + 23 F_O 
OBJ^3 = 1500 I_W + 500 I_G + 1300 I_C + 900 I_O + 14 F_G + 6 F_C + 12 F_O 
OBJ^4 = 1500 I_W + 500 I_G + 1300 I_C + 900 I_O + 7 F_G + 9 F_C + 6 F_O 
...
OBJ^{150}

OBJ^{DEVUP} = 1500 I_W + 500 I_G + 1300 I_C + 900 I_O + 5 F_G + 7 F_C + 8 F_O + \lambda/4. [ \{-2F_G + 1F_C + 15F_O\}^+ + \{9F_G - 1F_C + 4F_O\}^+ + \{2F_G + 2F_C - 2F_O\}^+] 

DEVUP is dependent on fuel choices and is not known in advance. 
It is more than just adding an extra cost to each fuel!
Fuel price variation: Results

- Total electricity production decreases

- Share of renewables increases

![Graph showing total electricity production](lambda=0)

![Graph showing share of renewables](lambda=5)
Fuel price variation: Results

- Comparison in a scenario with CO2 constraint

\( \lambda = 0 \) vs. \( \lambda = 3 \)
Results with fuel price variation

» Price variation of fossil fuels leads to
  » The introduction of renewables in the electricity mix
  » Less electricity / energy demand
  » Diversification for high values of $\lambda$ (under the assumption of limited technologies without variability)

» The effect when $\text{CO}_2$ constraint is binding
  » The effect of uncertainty is significantly reduced alternative options are reduced: all renewables already exhausted
  » More demand reduction
  » Shift towards coal as diversification policy
Conclusions and future work

1. The test case leads to diversification and other changes for a more robust energy system.

2. Advantages of the approach: it is within TIMES, covariances are included and it is fast.

1. Include CO₂ price uncertainty (possibly with shocks)
2. Include Minimax strategy (implementation is only slightly different)
3. Put risk aversion at a lower level, at least sectoral level:
   » The smaller the covered system, the larger the variability
   » But could be neutralised by hedging with options
4. Further develop to combine real options approach with portfolio approach within TIMES.