Long-term energy investment, uncertainty, and the role of policy commitment

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05.07.2016

Large Infrastructure Investments and Political Uncertainty

- In Europe, a large share of the existing power plants will have to be replaced in the near future
- Large power infrastructure projects have high capital cost and long planning horizons
- Future policy is highly uncertain
- This combination makes large energy infrastructure projects unattractive for investors

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High Uncertainty Surrounding Environmental Policies

- Political debate about carbon taxes for two decades now
- EU ETS price low, MSR will help?
- UK carbon floor under pressure?
- Capacity market mechanism changes?
- Nuclear phase outs? Nuclear built out?
- Feed in tariffs for new renewables will decline?

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How does Uncertainty about Future Carbon Prices affect Investment Behavior?

- How high will the carbon price be?
- When will the carbon price be implemented?
- Will there be subsidies for new renewables?
- Will there be a nuclear phase out?

Might this lead to a Suboptimal Infrastructure?

- Renewables or Nuclear being built too late and too small scale?
- Coal plants being used too long?
- Will this lead to expensive technologies like gas that can be built quickly?
- Will this have detrimental effects on CO_2 emissions?
- How will this affect the cost of the power system?

Scenarios

- Introduce a carbon tax in 2020
- Carbon tax is either 0, 5 or 10.

A Simple Model without Uncertainty

$$\min COST = \sum_t \beta^t \left(\sum_j (mc_j + co2_j \cdot \tau_t) \cdot G_{j,t} + kc_j \cdot K_{j,t} \right)$$

$$
\begin{aligned}
s.t. \quad & \sum_j G_{j,t} = d_t \quad \forall t \\
& G_{j,t} \leq K_{j,t} \quad \forall j,t \\
& K_{j,t+1} \leq \gamma_j + K_{j,t} \quad \forall j,t \\
& K_{j,t+1} \geq (1-\delta_j) \cdot K_{j,t} \quad \forall j,t \\
& given \quad K_{j,0}, d_t
\end{aligned}
$$

DATA

	K_0	mc	kc	γ	$co2$	δ
dirty	78	1	2	10	1	0.4
clean	22	1	4	10	0	0.1

TABLE: Technology characteristics

Demand	100, increasing by 2% per annum
β	0.95
τ	0, 5 or 10

TABLE: Other parameters

Generation under no Tax

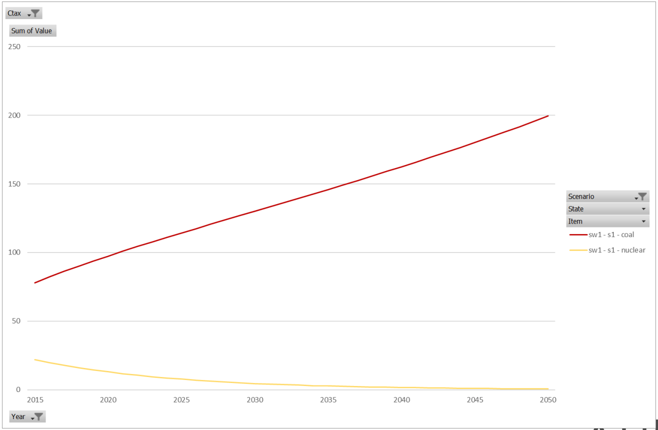

FIGURE: No tax

Generation under Tax

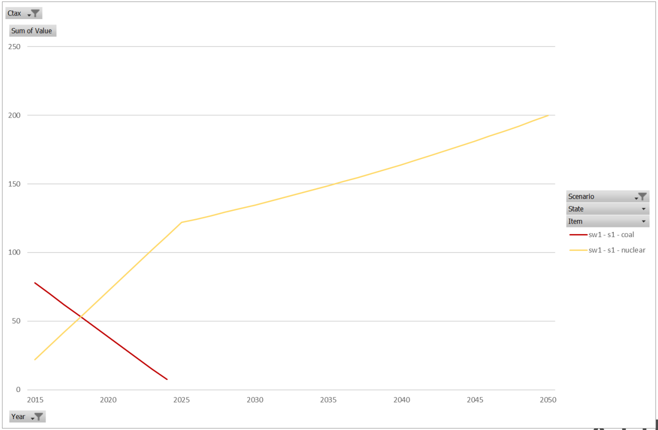

FIGURE: Tax of 5

Cost

	$\tau = 0$	$\tau = 5$	$\tau = 10$
Total	8.9	14.0 (+58%)	14.4 (+62%)
Capital	6.0	10.8 (+54%)	10.8 (+54%)
Variable	2.9	2.9 (0%)	2.9 (0%)
Tax		0.4 (+4%)	0.8 (+8%)

TABLE: Cost of a certain tax (Percentage of total cost change in parentheses)

Scenarios

- Introduce a carbon tax in 2020
- Carbon tax is either 5 or 10.
- Carbon tax is introduced with a probability of 50%

Adding Uncertainty to the Simple Model

$$\min E[COST] = \sum_s \pi_s \sum_t \beta^t \Big(\sum_j (mc_j + co2fact_j \cdot ctax_{t,s}) \cdot G_{j,t,s} + kc_j \cdot K_{j,t,s} \Big)$$

$$s.t. \quad \sum_j G_{j,t,s} = d_t \quad \forall t, s$$

$$G_{j,t,s} \leq K_{j,t,s} \quad \forall j, t, s$$

$$K_{j,t+1,s} \leq \gamma_j + K_{j,t,s} \quad \forall j, t, s$$

$$K_{j,t+1,s} \geq (1 - \delta_j) \cdot K_{j,t,s} \quad \forall j, t, s$$

$$K_{j,t,s} = K_{j,t,1}, \qquad G_{j,t,s} = G_{j,t,1} \quad t \leq 2020, s$$

$$given \quad K_{j,0,s}, d_t$$

Generation under Uncertainty

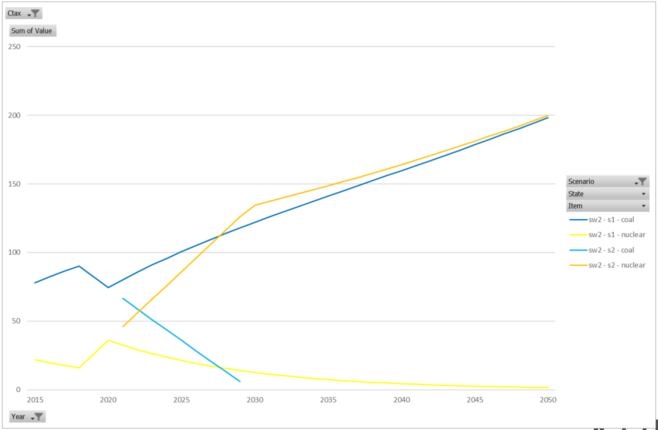

Figure: Tax of 5

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Generation under Uncertainty

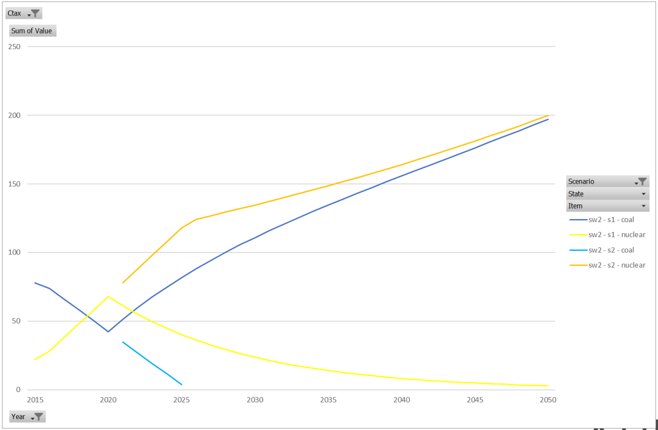

FIGURE: Tax of 10

Cost

	Certainty	$\tau = 5$	$\tau = 10$
Total	8.9	10.4 (+17%)	11.1 (+25%)
Capital	6.0	7.5 (+17%)	8.2 (+25%)
Variable	2.9	2.9 (0%)	2.9 (0%)
Tax			

TABLE: Cost without tax (Percentage of total cost change in parentheses)

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Cost

	Certainty	$\tau = 5$	Certainty	$\tau = 10$
Total	14.0	14.3 (+2%)	14.4	14.4 (+0%)
Capital	10.8	10.5 (-2%)	10.8	10.9 (+1%)
Variable	2.9	2.9 (0%)	2.9	2.9 (+0%)
Tax	0.4	1.0 (+4%)	0.8	0.6 (-1%)

TABLE: Cost with tax (Percentage of total cost change in parentheses)

Next steps

- Apply to large scale model
- Calibrate to UK data
- Load curves / dispatch with more technologies
- Capacity addition with time lag
- Different layers of uncertainty:
    - Different CO2 prices
    - Timing of CO2 price introduction
    - Other uncertainties: Technology, Demand

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Dirty Generation

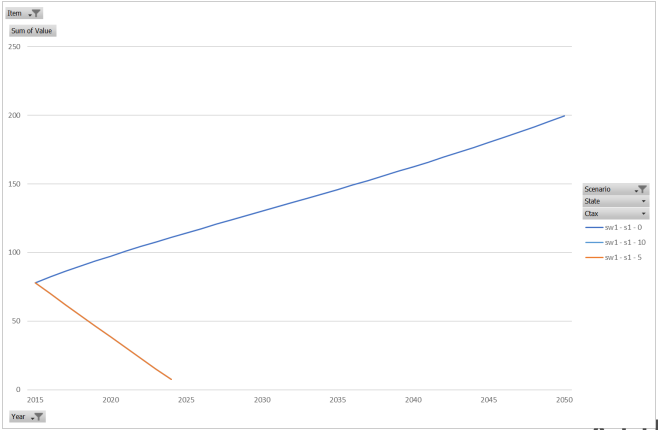

FIGURE: Dirty Generation

Clean Generation

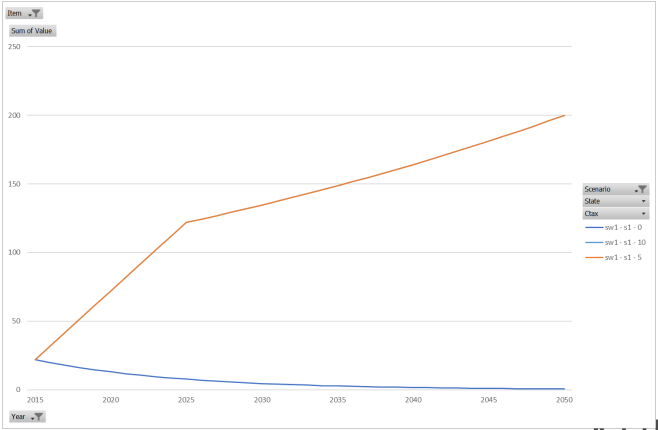

FIGURE: Clean Generation

Dirty Generation

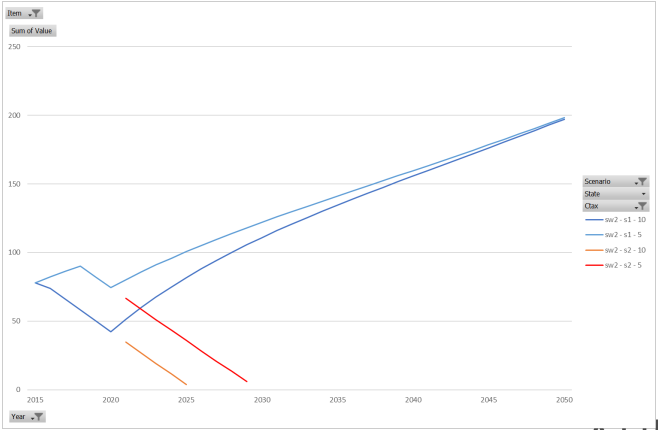

FIGURE: Dirty Generation

Clean Generation