Incorporating deep costs and an auction framework into renewable energy connection decisions

ESRI-ESB Seminar

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Overview & Aim

- Background
- Methodology
- Results
- Conclusions

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- Aim:
  - Examine different policies for selecting renewable generation for grid connection

ESRI working papers

1. How do external costs affect pay-as-bid renewable energy connection auctions?
   - Link: `http://www.esri.ie/pubs/WP517.pdf`
2. An auction framework to integrate dynamic transmission expansion planning and pay-as-bid wind connection auctions
   - Link: `http://www.esri.ie/pubs/WP523.pdf`

Background

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  - First come, first serve
- Multi-period auction framework for deciding renewable energy connections
  - Two frameworks: external costs included and not in such frameworks
  - Internal costs: capital and operating costs
  - External costs: transmission upgrade and environmental costs

Methodology: the game

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- Policymaker chooses the investors/sites that minimise total societal costs
- External costs may or may not be paid directly by the investors
- When external costs are not paid directly by investors, policymaker pays

$$\min_{a_{t=1}, a_{t,s} \in A} E[TSC] \tag{1}$$

subject to:

$$\sum_{i \in a_{t=1}} Q_i = Q_{t=1}^{\text{Target}}, \tag{2}$$

$$\sum_{i \in a_{s,t}} Q_i = Q_{t,s}^{\text{Target}}. \ \forall s, t \in T, \tag{3}$$

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$$E[TSC] = \sum_{i \in a_{t=1}} \sum_{t=1}^{\bar{T}} e^{-rt}(k_i G_i + d_{i,t,a_t}) + \sum_{\substack{s \in S, t \in T \\ i \in a_{t,s}}} \sum_{t'=t}^{t+\bar{T}-1} pc_s e^{-rt'}(k_i G_i + d_{i,t',a_{t,s}}). \tag{4}$$

$$\text{Generator Profits} = pa_i \Big[\sum_{t=1}^{\bar{T}} e^{-rt} (k_i G_i - d_{i,t,a_{t=1}}) - F_i \Big], \qquad (5)$$

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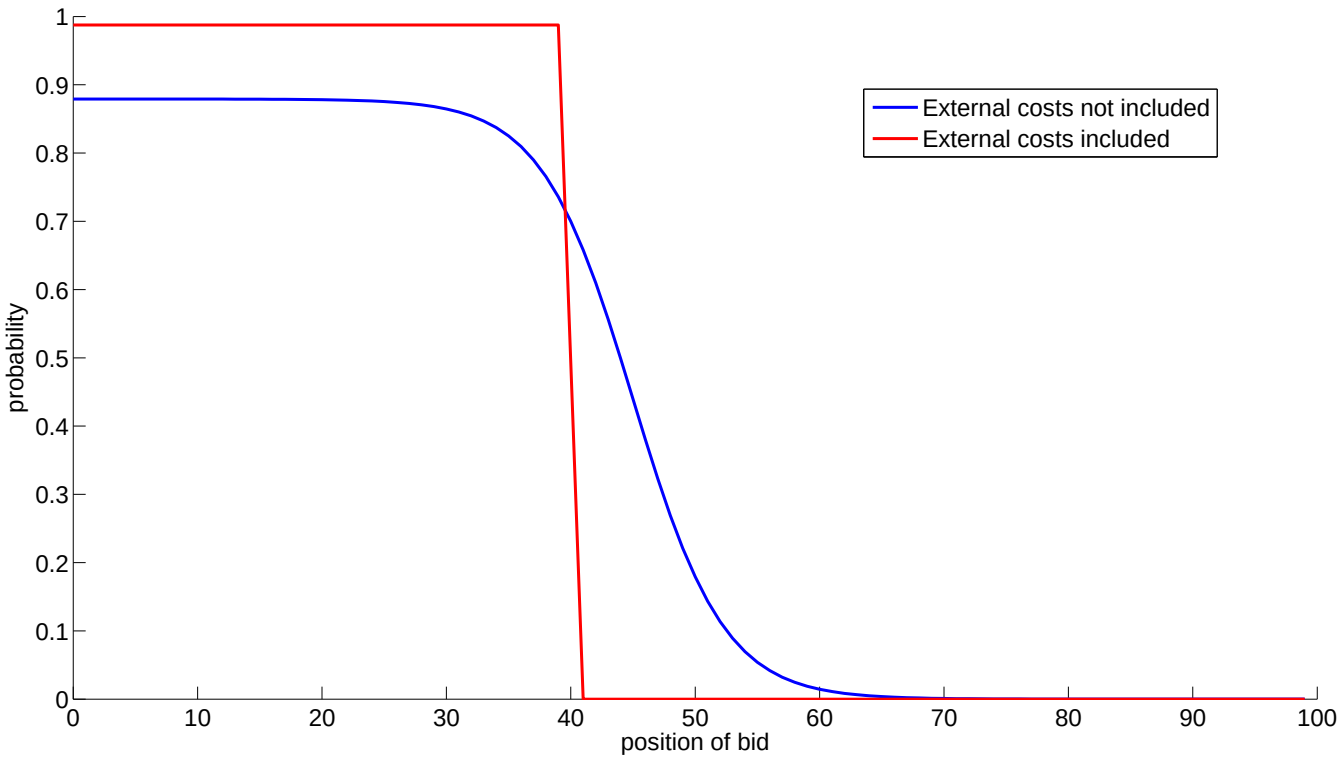

Figure: Probability of acceptance.

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4. Policymaker chooses combination of sites that minimise total societal costs.

Transmission Expansion Model (TEP)

$$\min \quad D_{a_{t=1},a_{t,s}} = \min \sum_{j,j'} \psi_{j,j'} UC_{j,j'} + \sum_{j} ls_j VOLL \tag{6}$$

subject to

$$0 \leq power^{G}_{u,j} \leq P^{\max}_{u}, \tag{7}$$

$$flow_{j,j'} = \frac{\delta_j - \delta_{j'}}{x_{j,j'}}, \tag{8}$$

$$|flow_{j,j'}| \leq P^{\max}_{\psi_{j,j'}}, \tag{9}$$

$$\sum_{j'} flow_{j,j'} + \sum_{u} power^{G}_{u,j} + power^{W}_{j} + ls_j = P^{D_0}_{j}, \tag{10}$$

$$ls_j + power^{d}_{j} = P^{D_0}_{j}, \tag{11}$$

$$power^{W}_{j} = AW_j. \tag{12}$$

Data

Parameter	Value
Reference Capital Cost (per MW)	€1.76m
Annual operating cost	2% of capital cost
Length of contract	20 years
Number of potential investors	36
Target (period one)	800MW
Targets (period two)	0, 200, 400, 800, 1300MW

Results

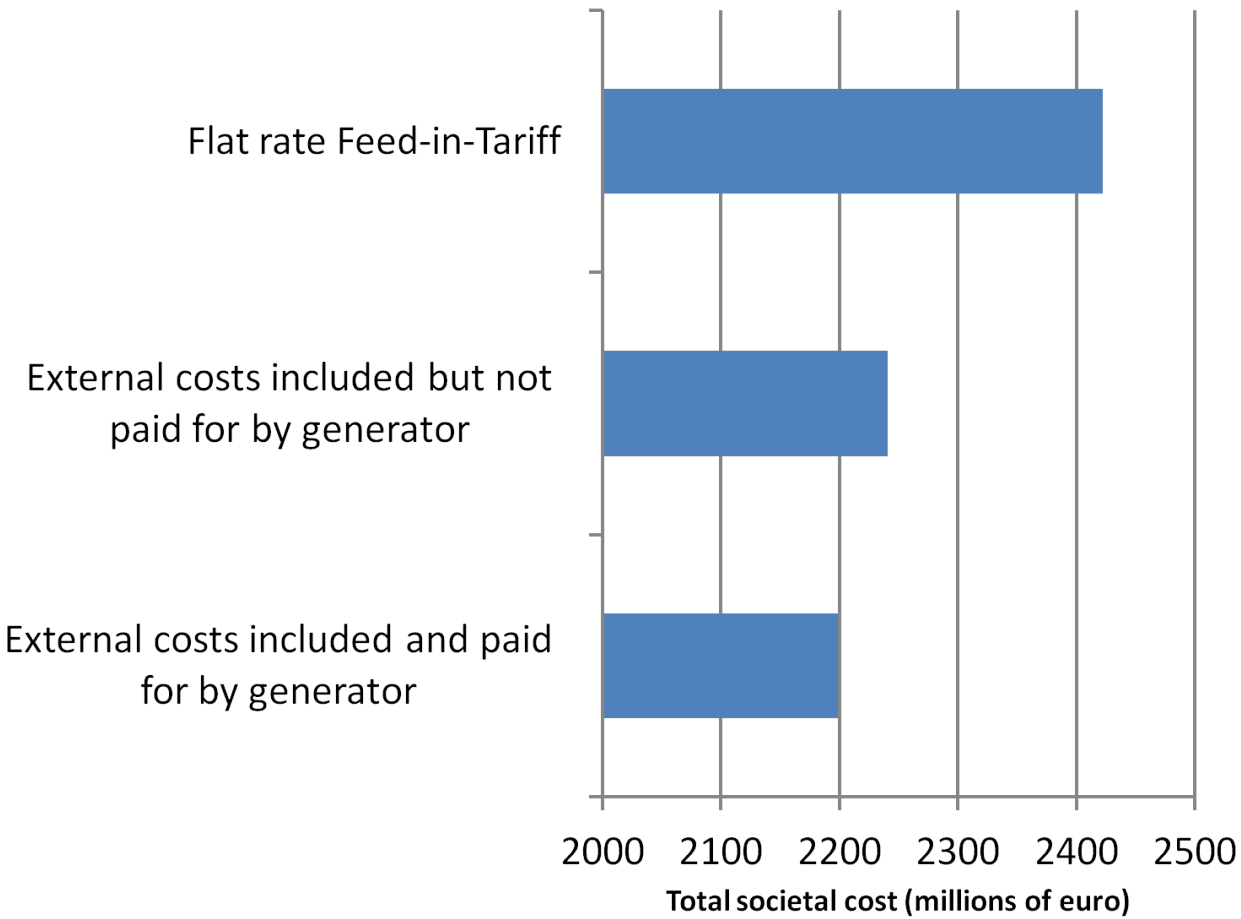

Figure: Different case studies

Results

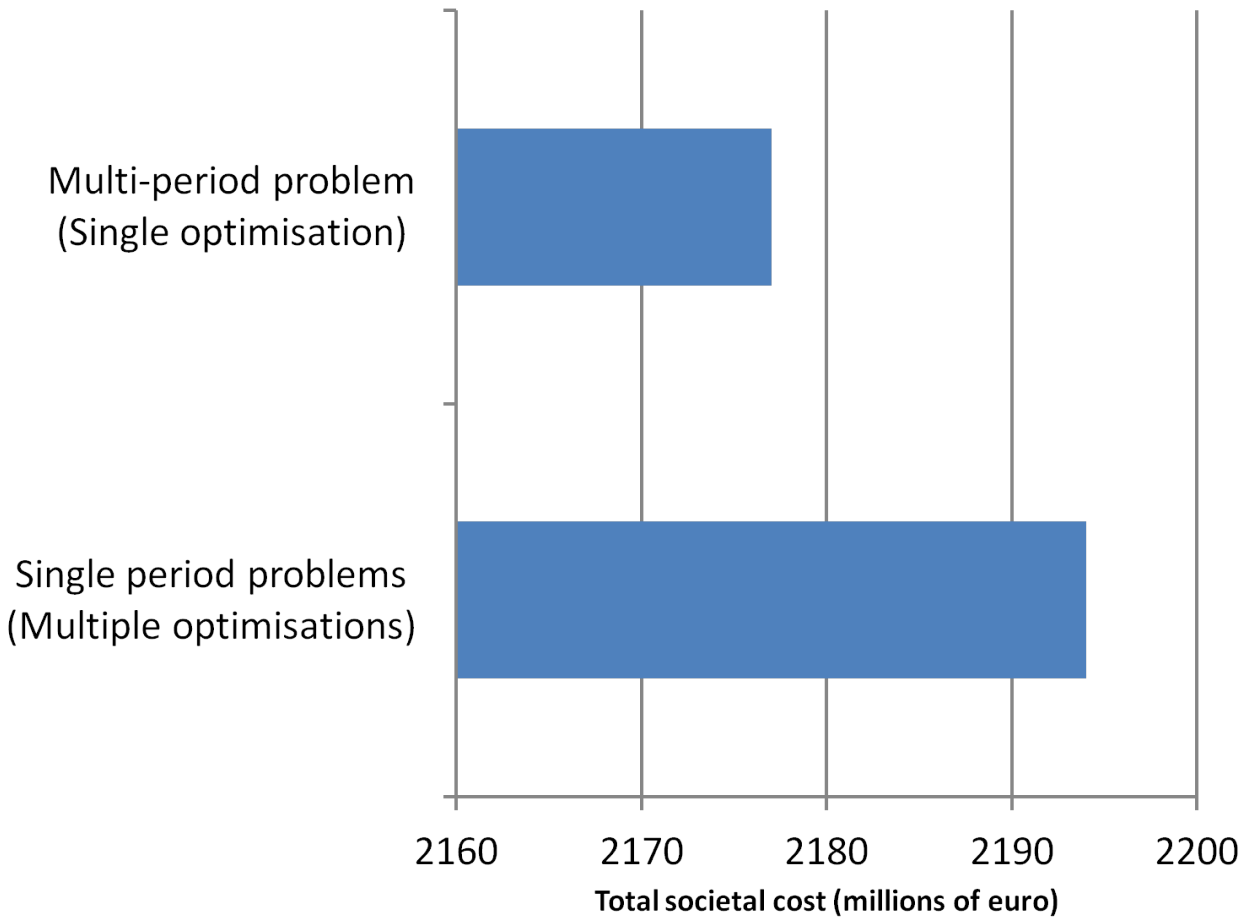

Figure: One multi-period problem vs. multiple single period problems

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- Introduced auction framework, incorporating both internal & external costs, for grid connection selection
- This framework leads to more socially efficient investment decisions.
  - Optimising over a single multi-period problem reduces total societal costs
  - Uncertainty in bid acceptance increases markup for investors
  - Efficiencies in the allocation of renewable sites was found.

Thank you!

Questions?

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