

# Investment Incentives in Renewable Energy

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26th Real Options Conference, July 20, 2023

## Introduction

### Goals of incentives

- Earlier investment

- Maximize social welfare

- Earlier investment vs. SW maximization

### Competition

- Earlier investment

- SW maximization

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# Option-like features of RE Investments

- ▶ Investment timing
- ▶ Capacity constraints
- ▶ Operational flexibilities
- ▶ Subsidies: floors, caps, collars
- ▶ Leverage

# Goals of incentives

- ▶ Immediate/earlier investment
- ▶ Maximize social welfare
- ▶ Induce competition

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# Option to delay

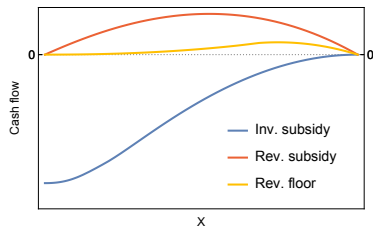
- ▶ Without competition there is a valuable option to delay
- ▶ Competition reduces its value
- ▶ If competition is for the monopolistic rights (e.g. auction), then it becomes worthless
- ▶ If not granted in a concession, there is a value destruction



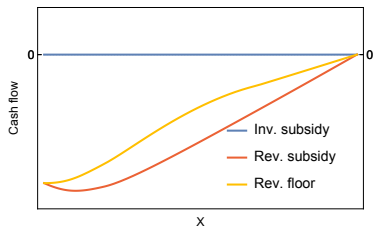
## Armada, Pereira, and Rodrigues (2012)

- ▶ Examples
  - ▶ Investment (sunk) cost subsidy
  - ▶ Revenue subsidy (e.g. premium FIT)
  - ▶ Revenue/price floors (possibly with caps (collars))
- ▶ They all cost the same: the value of the option to delay
- ▶ They differ in cash flows schedule and risk
  - ▶ Investment subsidies: upfront (certain) cost
  - ▶ In a concession revenue subsidies and floors induce higher bids: upfront gains in exchange for future (uncertain) costs

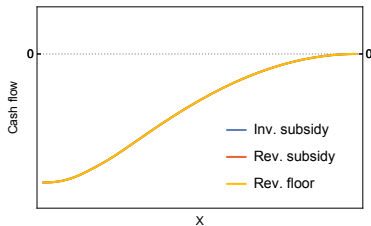
# Immediate vs future cash flows



(a) Immediate



(b) Future



(c) Total

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**Maximize social welfare**

Earlier investment vs. SW maximization

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Earlier investment

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Barbosa, Rodrigues, and Sardinha (2022)

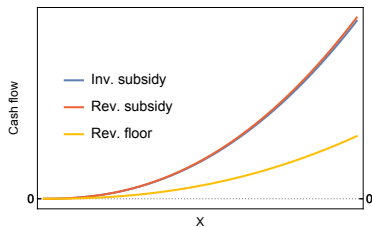
Assuming production at **full capacity**:

- ▶ All subsidies can eliminate the under-investment inefficiency
- ▶ They affect only investment timing
- ▶ They are independent of the exogenous shock
- ▶ They **do not** cost the same
- ▶ They also differ in terms of the cash flow schedule

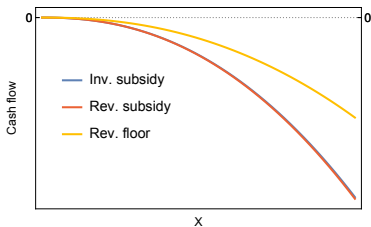
Extending for the possibility of production below full capacity

- ▶ In RE with low (almost null) production below full capacity is unlikely...
- ▶ ... unless capacity is large and demand is below capacity (at least on off-peak hours)
- ▶ In such case, incentives:
  - ▶ Affect both investment timing and SW value
  - ▶ Are not independent of the exogenous shock

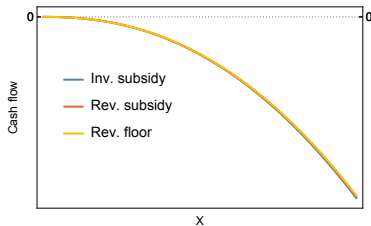
# Immediate vs future cash flows: small capacity



(a) Immediate

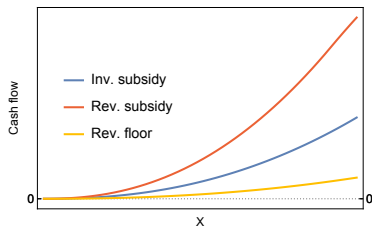


(b) Future

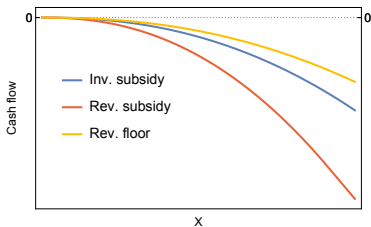


(c) Total

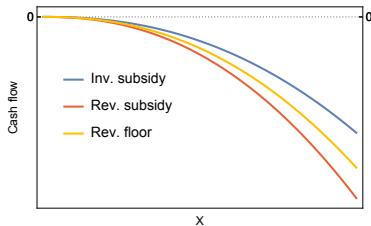
# Immediate vs future cash flows: large capacity



(a) Immediate

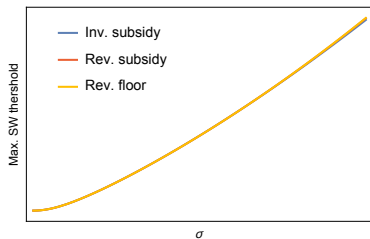


(b) Future

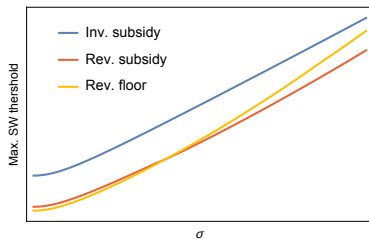


(c) Total

# Investment timing: sensitivity to uncertainty



(a) Small capacity



(b) Large capacity



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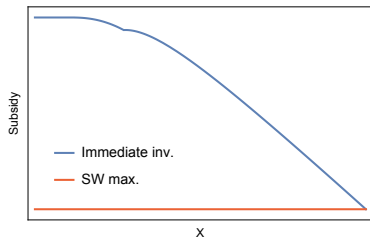
Earlier investment vs. SW maximization

### Competition

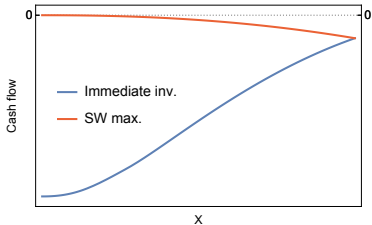
Earlier investment

SW maximization

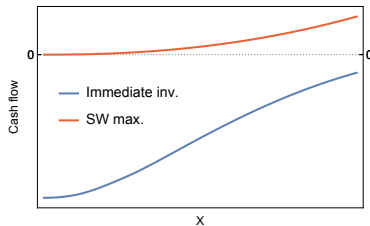
# Investment subsidy



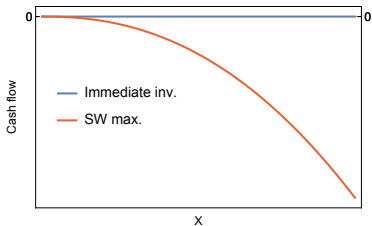
(a) Subsidy



(b) Total

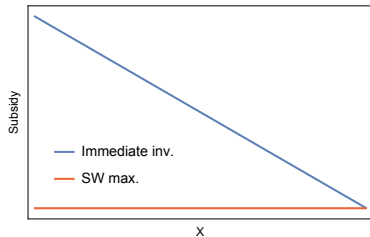


(c) Immediate

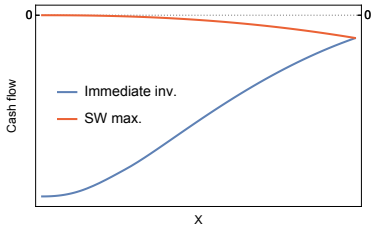


(d) Future

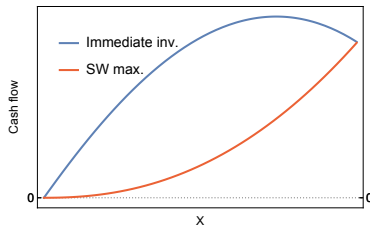
# Revenue subsidy



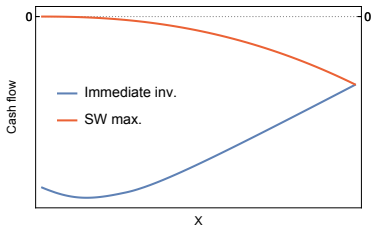
(a) Subsidy



(b) Total

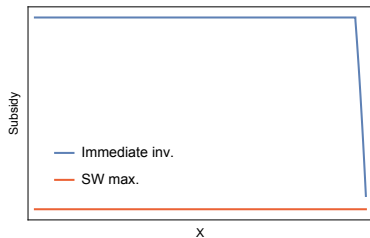


(c) Immediate

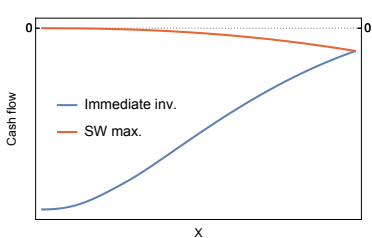


(d) Future

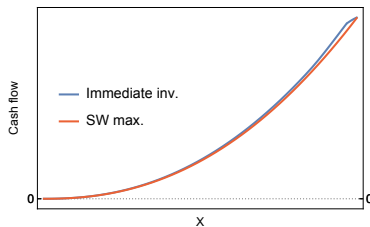
# Revenue floor



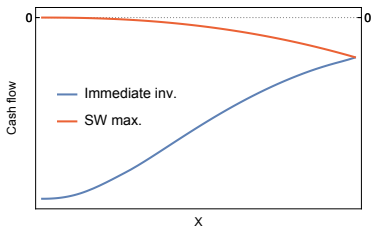
(a) Subsidy



(b) Total

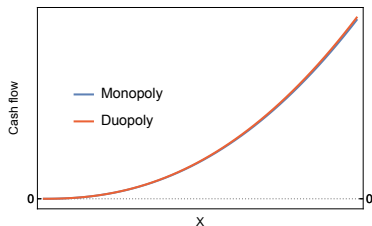


(c) Immediate

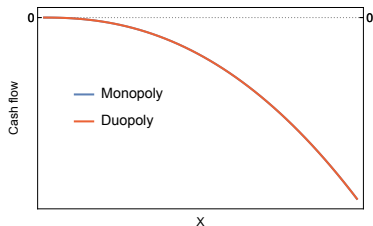


(d) Future

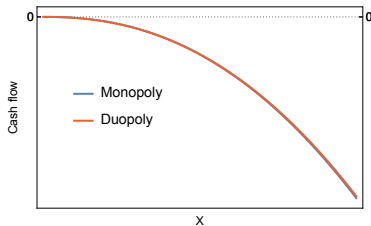
# Immediate vs future cash flows: SW



(a) Immediate



(b) Future



(c) Total

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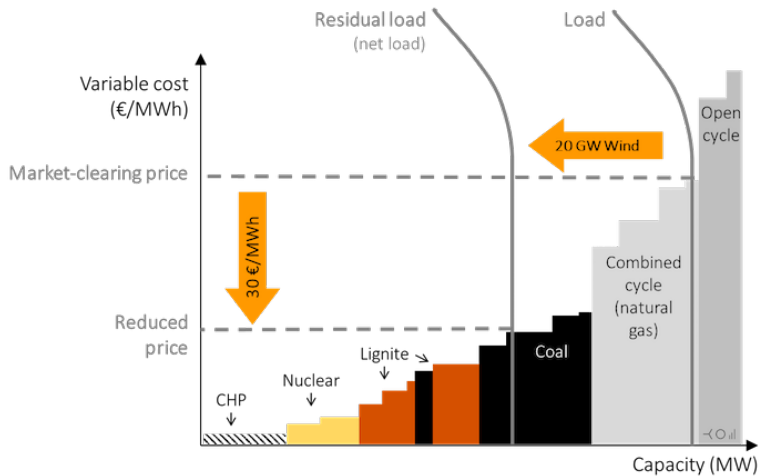
- Earlier investment vs. SW maximization

### Competition

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# The merit order in energy markets



# A simplified model

- ▶ **Barbosa, Rodrigues, and Sardinha (2023)** in this Conference:
  - ▶ Duopoly with a RE and a conventional energy producer.
  - ▶ Subsidies accelerate investment when a market has an incumbent firm and the RE firm has the option to invest.
  - ▶ The incumbent firm, anticipating the incentives offered to the RE firm, may deter investment.
- ▶ In the following slides, I use the same setting as before, and focus only on the RE investment decision (the incumbent is already active)



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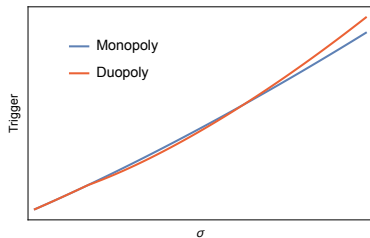
Earlier investment vs. SW maximization

### Competition

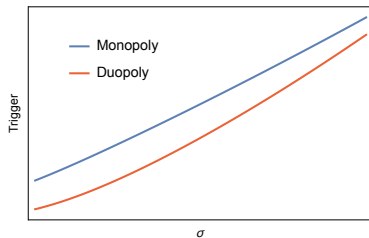
Earlier investment

SW maximization

# Investment timing: sensitivity to uncertainty

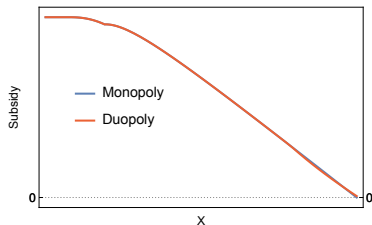


(a) Small capacity

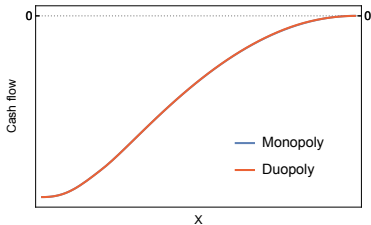


(b) Large capacity

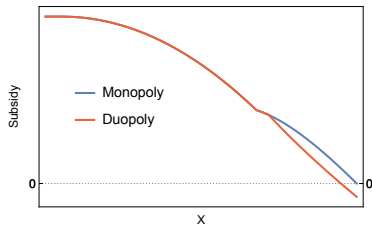
# Earlier investment: Investment subsidy



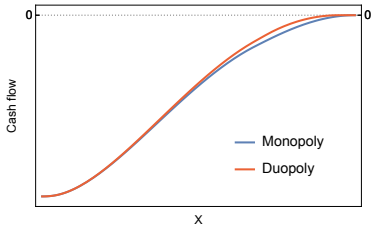
(a) Optimal subsidy: small  $Q$



(b) Total cost: small  $Q$

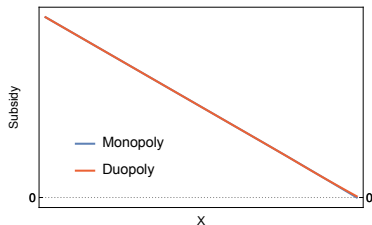


(c) Optimal subsidy: large  $Q$

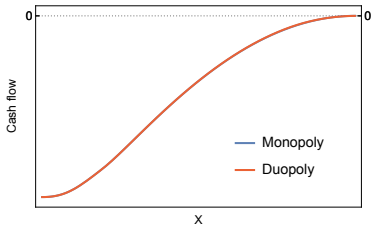


(d) Total cost: large  $Q$

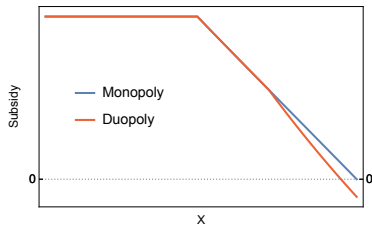
# Earlier investment: Revenue subsidy



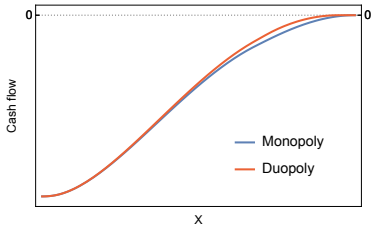
(a) Optimal subsidy: small  $Q$



(b) Total cost: small  $Q$

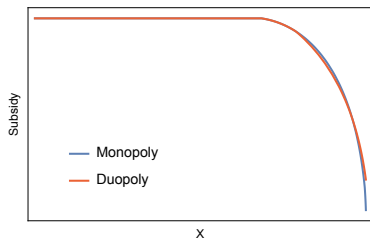


(c) Optimal subsidy: large  $Q$

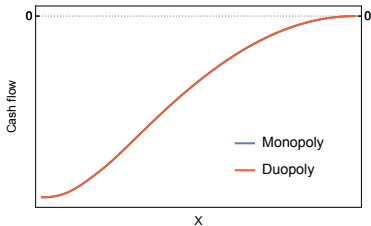


(d) Total cost: large  $Q$

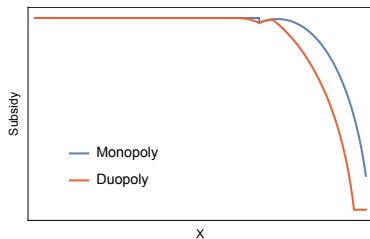
# Earlier investment: Revenue floor



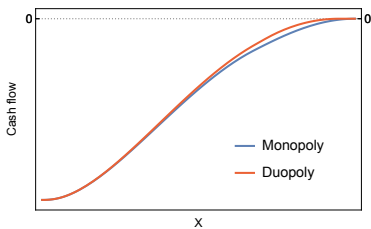
(a) Optimal subsidy: small  $Q$



(b) Total cost: small  $Q$



(c) Optimal subsidy: large  $Q$



(d) Total cost: large  $Q$

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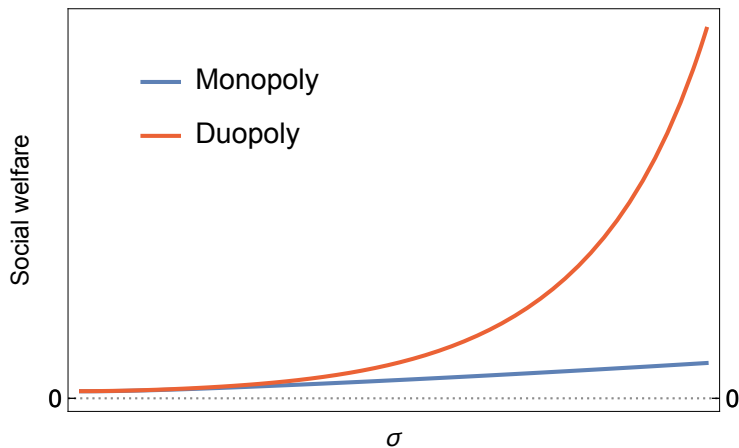
Earlier investment vs. SW maximization

### Competition

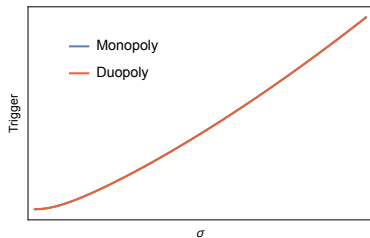
Earlier investment

**SW maximization**

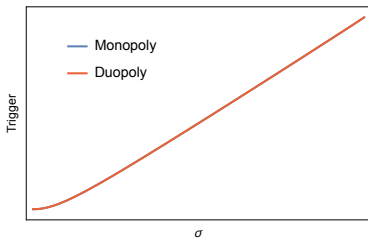
# Social welfare: sensitivity to uncertainty



# SW maximization timing: sensitivity to uncertainty



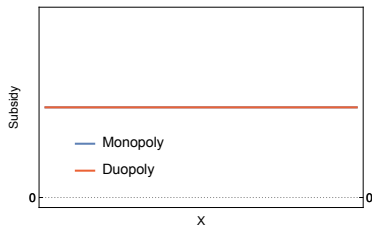
(a) Small capacity



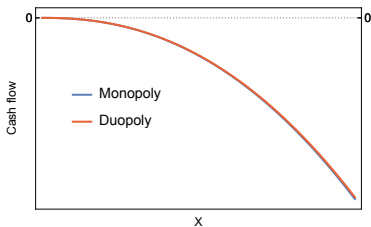
(b) Large capacity



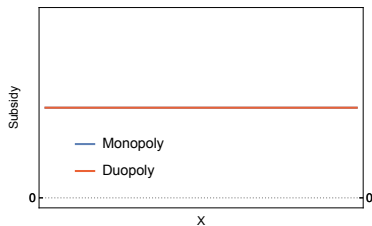
# SW maximization: Investment subsidy



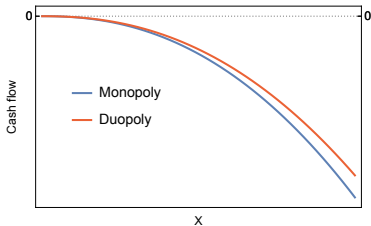
(a) Optimal subsidy: small  $Q$



(b) Total cost: small  $Q$

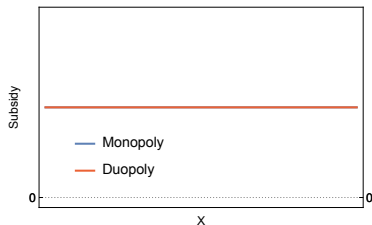


(c) Optimal subsidy: large  $Q$

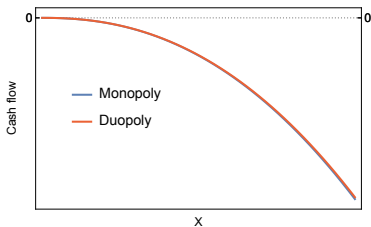


(d) Total cost: large  $Q$

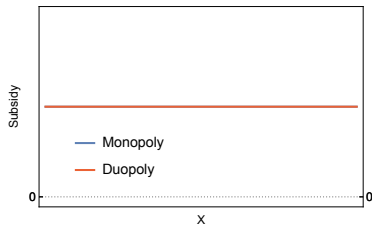
# SW maximization: Revenue subsidy



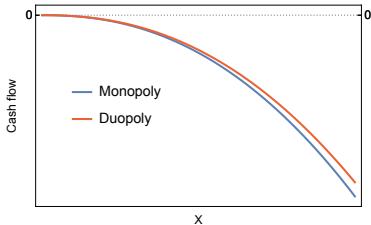
(a) Optimal subsidy: small  $Q$



(b) Total cost: small  $Q$

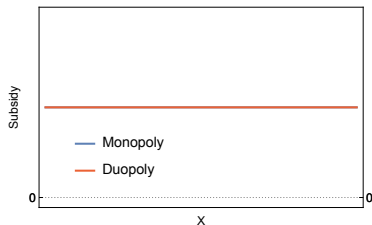


(c) Optimal subsidy: large  $Q$

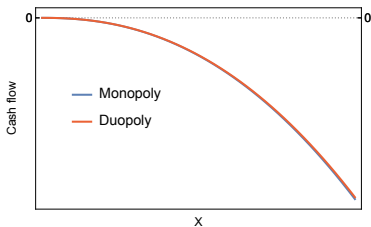


(d) Total cost: large  $Q$

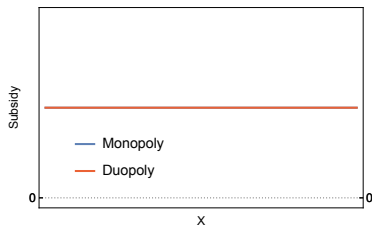
# SW maximization: Revenue floor



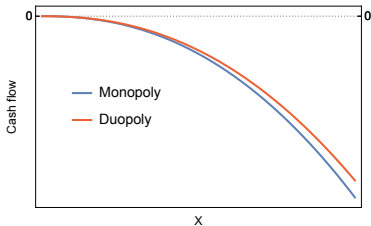
(a) Optimal subsidy: small  $Q$



(b) Total cost: small  $Q$



(c) Optimal subsidy: large  $Q$



(d) Total cost: large  $Q$

# Concluding remarks

- ▶ Incentives are not all borne equal
- ▶ As RE capacity increases, their difference becomes more significant
- ▶ But, paradoxically, they are less needed

Thank you for your attention!

- Armada, M. J. R., P. J. Pereira, and A. Rodrigues (2012). Optimal incentives to early exercise of large scale investments. *The European Journal of Finance* 18(5), 469–495.
- Barbosa, L., A. Rodrigues, and A. Sardinha (2022). Optimal price subsidies under uncertainty. *European Journal of Operational Research* 303(1), 471–479.
- Barbosa, L., A. Rodrigues, and A. Sardinha (2023). Strategic investment and subsidies within an asymmetric duopoly under uncertainty. 2023 Real Options Conference.