Green Investment under Subsidy Retraction Risk

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Motivation: The energy transition

In December 2022, the IMF published a piece by Daniel Yergin (Vice Chairman of S&P Global) titled ´Bumps in the energy transition', highlighting four issues:

- *The return of energy security as a prime requirement for countries*;
- *Lack of consensus on how fast the transition should and can take place, in part because of its potential economic disruptions*;
- *A sharpening divide between advanced and developing countries on priorities in the transition*;
- *Obstacles to expanding mining and building supply chains for the minerals needed for the net-zero objective*.

Motivation: Why study subsidy termination?

On the topic of the speed of the transition, he wrote: “All previous [energy] transitions were driven largely by economic and technological advantages – not by policy, which is the primary driver this time.”

However, policy makers adjust or remove subsidies over time, and investors respond to these changes; see, e.g., renewable energy and agriculture.

Research questions

1. How does the prospect of subsidy termination affect investment behavior under subsidy and after subsidy withdrawal?
2. How does the prospect of subsidy termination affect total surplus?
3. How should a social planner set its subsidy size optimally to maximize total surplus?

Papers used in this talk

Contents lists available at ScienceDirect
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Green capacity investment under subsidy withdrawal risk☆

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ABSTRACT

Subsidies initially installed to stimulate green capacity investments tend to be withdrawn after some time. This paper analyzes the effect on investment of this phenomenon in a dynamic framework with demand uncertainty. We find that increasing the probability of subsidy withdrawal incentivizes the firm to accelerate investment at the expense of a smaller investment size. A similar effect is found when subsidy size as such is increased. When subsidy withdrawal risk is zero or very limited, installing a subsidy could increase welfare. In general we get that the larger the subsidy withdrawal probability, the smaller the welfare maximizing subsidy rate is. Therefore, a policy maker aiming to maximize welfare should try to reduce subsidy withdrawal risk.

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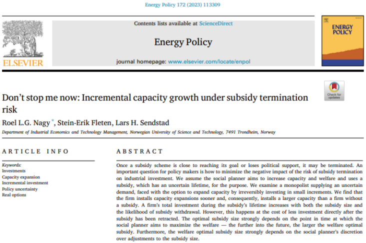
(a) Roel L.G. Nagy, Verena Hagspiel, Peter M. Kort, *Green capacity investment under subsidy withdrawal risk*, Energy Economics, Volume 98, 2021.



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Don't stop me now: Incremental capacity growth under subsidy termination risk

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ABSTRACT

Once a subsidy scheme is close to reaching its goal or loses political support, it may be terminated. An important question for policy makers is how to minimize the negative impact of the risk of subsidy termination on industrial investment. We assume the social planner aims to increase capacity and welfare and uses a subsidy, which has an uncertain lifetime, for the purpose. We examine a monopolist supplying an uncertain demand, faced with the option to expand capacity by irreversibly investing in small increments. We find that the firm installs capacity expansions sooner and, consequently, installs a larger capacity than a firm without a subsidy. A firm's total investment during the subsidy's lifetime increases with both the subsidy size and the likelihood of subsidy withdrawal. However, this happens at the cost of less investment directly after the subsidy has been retracted. The optimal subsidy size strongly depends on the point in time at which the social planner aims to maximize the welfare — the further into the future, the larger the welfare optimal subsidy. Furthermore, the welfare optimal subsidy size strongly depends on the social planner's discretion over adjustments to the subsidy size.

(b) Roel L.G. Nagy, Stein-Erik Fleten, Lars H. Sendstad, *Don't stop me now: Incremental capacity growth under subsidy termination risk*, Energy Policy, Volume 172, 2023.

Our contribution to the literature

We study investment under a lump-sum subsidy in a market with both market risk and subsidy withdrawal risk.

We find:

1. A subsidy can increase total welfare.
2. The effects of a subsidy fade away after termination (causes an investment dry spell).
3. The optimal social subsidy policy strongly depends on the social planner's flexibility and its horizon.

Model: Production capacity/investment size

Investment size is modelled differently in both papers:

1. Decision is when to install a capacity of size K.
   K is a decision variable, but constant after investment.
2. Firm has a current capacity of k, but always holds the option to increase capacity by dK.
   Decision is when to install each capacity increment.

Model: Profit flow

- Investment size influences price

$$P(X(t), K) = X(t)(1 - \eta K), \tag{1}$$
$$dX(t) = \mu X(t)dt + \sigma X(t)dW(t), \tag{2}$$

  $X(t)$ is a geometric Brownian motion (GBM): μ is the trend parameter ($r > \mu$), σ is the volatility, η is a positive constant and $dW(t)$ is the increment of a Wiener process.

- Instantaneous profit flow: $\pi(X(t), K) = P(X(t), K) \cdot K$.

Model: Investment cost and subsidy

- Investment cost of installing a capacity of size K equals $\kappa \cdot K$ without subsidy.
- The investment cost subsidy is of size θ, so investment cost equals $(1 - \theta)\kappa \cdot K$ when subsidy is available.
- At the start, the subsidy is in effect.
- Subsidy withdrawal follows a Poisson jump process of rate λ. Thus, the probability of subsidy withdrawal during time interval dt is λdt.
- The rate λ is exogenous, it is *not* a decision variable.

Objective and solution

The firm maximizes its profit, by choosing ...

- when to invest and in what capacity (if investment is one-time), or
- when to expand capacity (if investment can be done repeatedly).

Both papers provide a solution consisting of two thresholds:

- An investment threshold X_1 (one-time investment) or X_1^i (repeated investment, for increment i): invest only if $X(t)$ exceeds this threshold when the subsidy is in effect.
- An investment threshold X_0 (one-time investment) or X_0^i (repeated investment): invest only if $X(t)$ exceeds this threshold when the subsidy has been withdrawn.

Lumpy investment: Investment timing and size

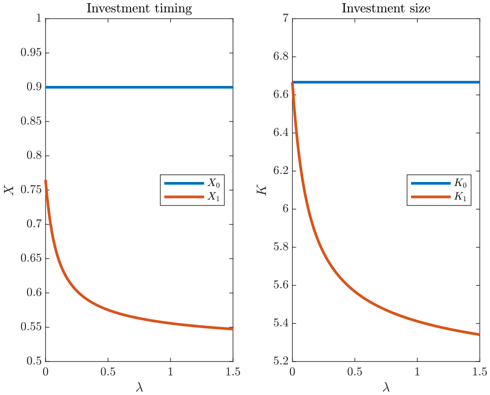


Figure: Monopolist's optimal timing and capacity choice. [Parameters: $\mu = 0.02$, $\sigma = 0.10$, $r = 0.05$, $\eta = 0.05$, $\kappa = 10$, $\theta = 0.15$]

Incremental investment threshold & subsidy withdrawal risk

The optimal investment threshold is negatively affected by the subsidy retraction risk λ.

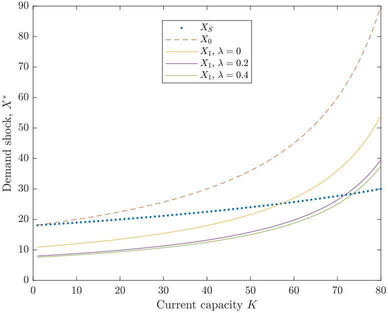


Figure: ´Incremental' investment timing as a function of the current production capacity K for different subsidy termination risk λ. [Parameters: $\mu = 0.02$, $\sigma = 0.10$, $r = 0.05$, $\eta = 0.005$, $\kappa = 300$, $dK = 1$, $\theta = 0.4$.]

Incremental investment threshold and subsidy size

The optimal investment threshold is negatively affected by the subsidy size θ.

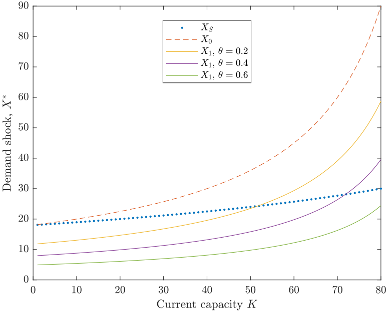
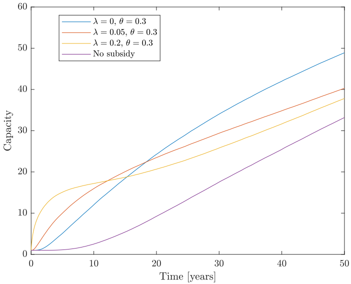


Figure: ´Incremental' investment timing as a function of the current production capacity K for different subsidy size θ. [Parameters: $\mu = 0.02$, $\sigma = 0.10$, $r = 0.05$, $\eta = 0.005$, $\kappa = 300$, $dK = 1$, $\lambda = 0.2$.]

Capacity growth over time for different withdrawal risks



(a) $\theta = 0.3$ (b) $\theta = 0.4$

Figure: Expected firm's total capacity over time for different levels of subsidy withdrawal risk λ. [General parameter values: $\mu = 0.02$, $\sigma = 0.10$, $r = 0.05$, $\eta = 0.005$, $dK = 1$, $x = 10$.]

Sensitivity results social optimal subsidy

- The socially optimal subsidy size $\theta^*(K)$ is positively affected by the industry's capacity K.
- The socially optimal subsidy size $\theta^*(K)$ is negatively affected by the subsidy retraction risk λ.

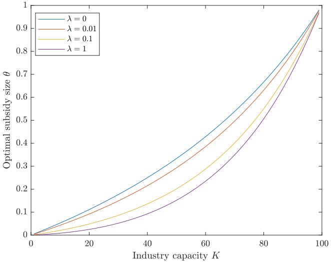
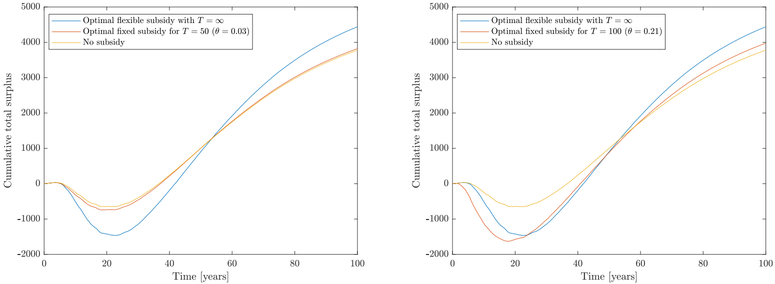


Figure: Social optimal subsidy size θ for different subsidy withdrawal risk λ. [Parameters: $\mu = 0.02$, $\sigma = 0.10$, $r = 0.05$, $\eta = 0.005$, $\kappa = 300$, $dK = 1$.]

Surplus results social optimal subsidy



(a) $T = 50$ (b) $T = 100$

Figure: Total surplus under different subsidy policy. [Parameters: $\mu = 0.02$, $\sigma = 0.10$, $r = 0.05$, $\eta = 0.005$, $\kappa = 300$, $dK = 1$, $x = 10$, $\lambda = 0$.]

Small (and incomplete) literature comparison

- Price premium (e.g., Chronopoulos et al. [2016]) or feed-in tariff (e.g. Ritzenhofen and Spinler [2016]): subsidy risk has a non-monotonic effect on timing and size.
- Lump-sum subsidy without capacity size decision (see, e.g. Dixit and Pindyck [1994], Hassett and Metcalf [1999]): subsidy risk speeds up investment.
- Green certificate pricing (see, e.g., Finjord et al. [2018]): stronger incentive to invest if the deadline of the support scheme is approaching.

Setting & results for the industry

Our setting:

- We study the effect of a lump-sum subsidy subject to withdrawal risk on the industry's incremental investment.
- The social planner aims to maximize welfare.

We find for the firm:

- It invests sooner when the likelihood of subsidy withdrawal or the subsidy size is larger.
- It invests more during the lifetime of the subsidy, but investment slows down after the subsidy has been withdrawn.

Results for the social planner

A subsidy increases expected total welfare if set optimally.

The optimal social subsidy size ...

- depends on the time horizon the social planner optimizes over;
- depends on whether the social planner can adjust the subsidy over time.

However, the optimal subsidy size generally ...

- increases with an industry's capacity;
- decreases with the subsidy withdrawal risk.

Questions and feedback

Thank you for your attention!

Any questions or feedback?
You can also send an e-mail to roel.nagy@uantwerpen.be

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