Feed-in Tariff Contract Schemes and Regulatory Uncertainty

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IST, 29th November 2018

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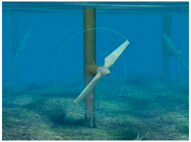
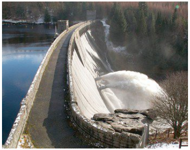
Feed in Tariff

FIT stands for Feed in Tariff

Under a feed-in tariff, eligible renewable electricity generators are paid a price for the renewable electricity they supply to the grid.

Top 10 renewable energy sources

Tidal power, wave power, solar power, wind power, hydroelectricity, radiant energy, geothermal power, biomass, compressed natural gas, and nuclear power.

O governo de Espanha vai dar início a um plano ambicioso que tem como objetivo eliminar totalmente o uso de combustíveis fósseis na produção de energia, utilizando unicamente fontes renováveis. A ideia é reduzir as emisses de gases de estufa em 90 por cento durante os próximos 30 anos, como parte de um plano para eliminar a contribuição do país para o aquecimento global. Para que a rede elétrica espanhola funcione unicamente com fontes renováveis, o governo vai financiar a instalação de uma rede de 3000 MW de produção energética com base em turbinas eólicas e painéis solares. (in TSF, 21 Novembro)

Categories of FITs

There are several types of FIT's, classified in two categories

- Market independent: contracts that pay remunerations that are not tied to the energy market price
- Market dependent: investors are paid a fixed or variable premium over the energy market price.

In 2013 the European Commission sent out a recommendation to shift from market independent FITs to market dependent, as they create more incentives to optimize production, plan design and investment according to market signals.

Need to assess the efficiency of the subsidies

Some figures

- Proportion of world electricity generated by renewables: 11% in 2016, 12.1% in 2017
- Impact: 1.8 gigatonnes of carbon dioxide emissions avoided
- Global investment in 2017: $279.8 billion
- Cumulative investment since 2010: $2.2 trillion
- Europe suffered a bigger decline in the investment, of 36% to $40.9 billion, reflecting an end of subsidies.

Risks

FITs are long-term contracts, typically within the range of 15 to 20 years.

- Along this period of time, many changes can happen (in the market conditions, technology costs, natural disasters, etc)
- This large uncertainty may lead to inefficient support schemes (leading to overcompensation, for instance)
- Taxpayers and electricity ratepayers have become more critical about these support schemes

Risks

Thus we expect changes in the regulatory schemes of the governments.

Prices and tariffs

- The market price of electricity evolves according to a stochastic process $\{P_t, t \geq 0\}$:

$$dP_t = \mu P_t dt + \sigma P_t dW_t$$

- The feed-in tariff is denoted by F, and assumed to be fixed

Payoffs and costs

- Before the investment, the firm has a zero payoff.
- The investment cost is I; we do not consider operating costs (they may be incorporated in the investment costs).
- The option to invest has an infinite lifespan.
- After investment, the firm receives a payoff π_S, that depends on the electricity price and/or the fixed tariff F.

$$\pi_S(P_t;F)=\begin{cases}\Pi_S(P_t;F) & \tau \leqslant t \leqslant \tau + T \quad \text{subsidy}\\ P_t Q & t > \tau + T \quad \text{market price}\end{cases}$$

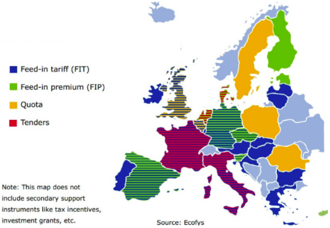
- τ: time of investment
- Π_S: profit of the firm as long as subsidy is received
- T: duration of the contract (end of subsidy regime, for that contract)
- Q: quantity of electricity produced
- F: fixed tariff

Different FIT's $\Leftrightarrow$ Different Π_S

FITs considered in the presentation

- Fixed-price scheme: $\Pi_F(P) := FQ$.
- Fixed-premium scheme: $\Pi_P(P) := (P + F)Q$.
- Minimum price guarantee: $\Pi_M(P) := \max(P, F)Q$.
- Sliding premium with cap and floor: $\Pi_C(P) := \min(\max(P, F), C)\, Q$, where $C \geqslant F$ is a price cap.

Countries and FITs



- Fixed-price scheme: Germany, France, Portugal,...
- Fixed-premium scheme: Czech Republic,...
- Minimum price guarantee: Netherlands, Ireland, Switzerland (variations...)
- Sliding premium with cap and floor: Spain (in the past)

Policy uncertainty: impact on the tariff

The subsidy affects the value of the tariff F

A change in the support scheme will decrease the fixed tariff from F to $(1\text{-}\omega)F$

Retroactivity

- If at the time of the investment (beginning of the contract) the subsidy is active, it will be active during time T (fixed, known beforehand);
- But before the beginning of the contract, the policy change may occur in a random time

$$Y \sim \text{Exp}(\lambda)$$

There is no retroactive termination/change of subsidy payments

Two models

- The subsidy policy does not change - benchmark model
- The subsidy may be removed or changed before the investment takes place - change of subsidy model.

There is a large body of literature on support schemes for renewable energy projects; in particular

Boomsma, Meade and Fleten (2012)

- Investing timing and capacity choice;
- Three stochastic processes (electricity prices, capital costs and subsidy payments)
- Changes of support scheme according to a Markov switching
- Interesting results, using mostly numerical solutions

Boomsma and Linnerud (2015)

- Investing timing and capacity choice;
- Two stochastic processes (electricity prices and subsidy payments)
- Changes of support scheme according to a Markov switching
- Retroactive and no retroactive termination of subsidy payment
- Interesting results, using mostly numerical solutions

The expected value upon investment is:

$$V_S(P) = E\left[\int_0^T \Pi_S(P_t; F)e^{-rt}dt + \int_T^\infty P_t Q e^{-rt}dt \middle| P_0 = P\right].$$

that depends on the FIT that we are considering

Fixed FITs

When we choose either fixed-price or fixed-price premium, deriving the value of the project is trivial:

- Fixed-price scheme:

$$V_F(P) = \frac{FQ}{r}(1 - e^{-rT}) + \frac{PQ}{r-\mu}e^{-(r-\mu)T}$$

- Fixed-premium scheme:

$$V_P(P) = \frac{FQ}{r}(1 - e^{-rT}) + \frac{PQ}{r-\mu}$$

Market dependent FITs

Not so easy for minimum price nor for sliding premium!

Rough idea on how to do

Example: minimum price

Derive V_M when $T = \infty$ (perpetual guarantee)

- Apply Itô's formula to V_M, and get:

$$\mu P V_M'(P) + 0.5\sigma^2 P^2 V_M''(P) - r V_M(P) + \Pi_M(P; F) = 0$$

- Solve this ODE (Euler-Cauchy equation)

$$V_M(P) = \begin{cases} \boxed{A_1 P^{\beta_1}} + A_2 P^{\beta_2} + \frac{F}{r} & P < F \\ B_1 P^{\beta_1} + \boxed{B_2 P^{\beta_2}} + \frac{P}{r-\mu} & P \geq F \end{cases}$$

Derive V_M when $T < \infty$ (finite guarantee)

- Previous result: $V_M(P;\infty)$; now we need:
- $V_M(P;T)$

$$V_M(P;\infty) - e^{-rT} E^Q[V_M(P_T;\infty)] + \frac{PQ}{r-\mu} e^{-(r-\mu)T}$$

- where $V_M(P_T;\infty)$ is given by

$$\left[A_1 P_T^{\beta_1} + \frac{F}{r}\right] 1_{\{P_T < F\}} + \left[B_2 P_T^{\beta_2} + \frac{P_T}{r-\mu}\right] 1_{\{P_T \geq F\}}$$

After some (tedious) calculations, we end up with the following:

Value of the project for the minimum price

$$V_M(P) = V_M(P;\infty) - S_M(P) + \frac{PQ}{r-\mu}e^{-(r-\mu)T}$$

- $$S_M(P) = A_1 P^{\beta_1}\Phi(-d_{\beta_1}) + \frac{FQ}{r}e^{-rT}\Phi(-d_0) + B_2 p^{\beta_2}\Phi(d_{\beta_2}) + \frac{PQ}{r-\mu}e^{-(r-\mu)T}\Phi(d_1)$$
- $$d_\beta = \frac{\ln\frac{P}{F} + \left(\mu + \sigma^2\left(\beta - \frac{1}{2}\right)\right)T}{\sqrt{T}}$$

Similar for the sliding premium with cap and floor...

Optimization problem

- Benchmark model

$$F(P) = \sup_{\tau} E\left[\int_{\tau}^{\tau+T} \Pi_S(P_s; F) e^{-rs} ds + \int_{\tau+T}^{\infty} P_s Q e^{-rs} dt - e^{-r\tau} I | P_0 = P\right]$$

- Change of subsidy model

$$F(P) = E\left[\int_{\tau}^{\tau+T} e^{-rs} \left(1_{\{Y<\tau\}} \Pi_S(P_s; \omega F) + 1_{\{Y>\tau\}} \Pi_S(P_s; F)\right) ds + \int_{T}^{\infty} P_s Q e^{-rs} ds - e^{-r\tau} I | P_0 = P\right].$$

Infinitesimal generator

- Benchmark model

$$\mathcal{L}f(P) = \mu\, P \frac{\partial f(P)}{\partial P} + 0.5\sigma^2\, P^2\, \frac{\partial^2 f(P)}{\partial P^2}$$

- Change of subsidy model

$$\mathcal{L}_{CS}f(P) = \mu\, P \frac{\partial f(P)}{\partial P} + 0.5\sigma^2\, P^2\, \frac{\partial^2 f(P)}{\partial P^2} + \\ + \lambda[f(\omega P) - f(P)]$$

HJB equations

- Benchmark model

$$\min\left(\mathcal{L}F(P) - rF(P), F(P) - V_S(P) + I\right) = 0$$

- Change of subsidy model

$$\min\left(\mathcal{L}_{CS}F(P) - rF(P), F(P) - V_S(P) + I\right) = 0$$

Quadratic equation

- Benchmark model

$$\frac{1}{2}\sigma^2\beta(\beta-1)+\beta\mu-r=0$$

- Change of subsidy model

$$0.5\sigma^2\beta(\beta-1)+\mu\beta-(r+\lambda)=0$$

Both problems are mathematically easy to solve.
Closed expressions for the value function and for the price thresholds, for all the FIT schemes considered.

Goals

- What is the impact of the regulatory uncertainty in the investment decision?
- Compare the investment behavior under different support schemes
- Advices for policymakers

Policy uncertainty

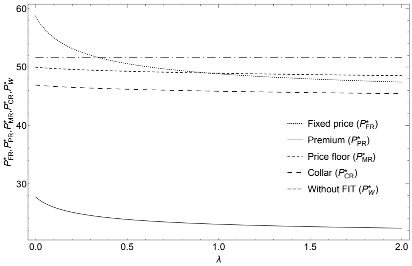
- Increasing λ: it is more likely that a change in the subsidy will occur;
- Decreasing ω: the change in the tariff is larger (therefore we expect more impact from the subsidy policy)

We assess numerically the effect of λ and ω on investment threshold, using the following base-case parameters:

Data (Ritzenhofen and Stefan Spinler, 2016)

r	risk-free rate	5%
F	tariff	25 / MWh
T	finite duration of FIT	15 years
μ	deterministic drift	0%
σ	volatility	19%
I	total investment cost	3 Millions
ω	the reduction of F is (1 - ω)	80%
ω_C	the reduction of C is (1 - ω_C)	100%
λ	mean arrival rate of a jump event	0.5

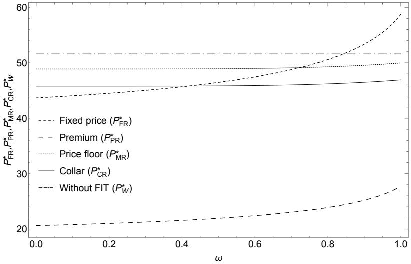
Impact of λ



Investors accelerate investment with λ

Increasing λ generates a higher reduction in the fixed price and fixed premium than in the price-floor and collar regimes

Impact of ω



Investors accelerate investment with $(1 - \omega)$

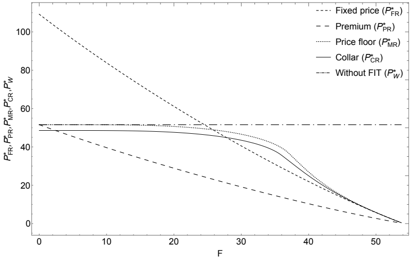
The effect is larger in the fixed-price and fixed-premium FIT scheme.

Price cap and collar reduction

λ	Collar Threshold $\omega_c = 0.8$ $\omega = 1.0$	% Reduction Threshold	Collar Threshold $\omega_c = 1.0$ $\omega = 0.8$	% Reduction Threshold	Collar Threshold $\omega_c = 0.8$ $\omega = 0.8$	% Reduction Threshold
0.10	45.32	3.42%	46.68	0.50%	45.0936	3.89%
0.20	44.39	5.40%	46.52	0.84%	44.0637	6.08%
0.50	42.88	8.62%	46.20	1.53%	42.4273	9.57%
1.00	41.71	11.11%	45.86	2.26%	41.1966	12.19%
2.00	40.67	13.32%	45.44	3.14%	40.1265	14.47%

Investment threshold has a larger reduction when the policymaker reduces the price cap than the price floor

Impact of the tariff, F



The decision to invest is accelerated when F increases

- The thresholds from the 4 FITs models are lower than the investment threshold in a free-market condition (so they accelerate the decision).

- But if the tariff F is very low, the fixed-price regime is useless to accelerate investment.
- The collar threshold is below the price-floor threshold when both regimes have the same price floor value, and thus the decision is antecipated.
- An explanation for this result is that investors want to avoid receiving the cap, and hence prefer to start the investment when the market price is lower
- From a policymaking perspective, this result suggests that the collar regime is a better policy than the price-floor regime

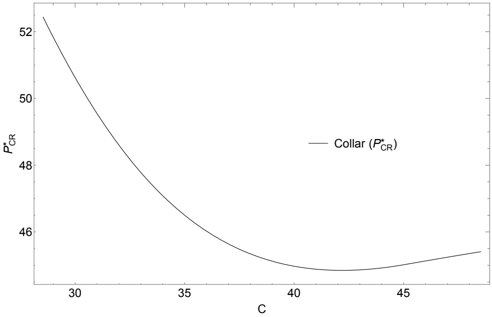
We prove analitically that

$$V_C(P) < V_M(P)$$

i.e., we prove that the value of the project with a price-floor regime is always greater than the value of the project with a collar regime but

the investment takes place earlier in the collar case!

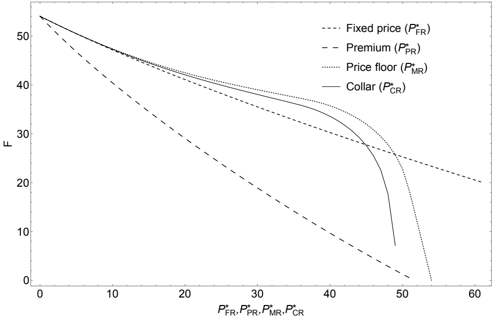
Impact of C



- The investment threshold has a minimum point
- Therefore policy makers should not offer caps above this value

F as a function of the thresholds

Which regime is the most efficient?



It seems that the fixed-premium regime is the best FIT contract because it presents the lowest tariff F that generates the same investment triggers!

- The collar regime under the risk of a regulatory uncertainty in the price cap has a higher impact on the investment threshold than the price floor.
- Policymakers should avoid offering low values of the tariff in the fixed-price regime (it does not accelerate investment)
- Collar regime is a better policy because it accelerates investment and has the property of avoiding overcompensation
- Policymakers can find the values of the tariff F that generate the same trigger for the four FIT policies

Thank you for your attention!

Acknowledgements:
FCT project PTDC/EGE-ECO/30535/2017
InvestExL project number 268093/E20 (funded by The Research Council of Norway)