Too good to be true? How time-inconsistent renewable energy policies can deter investments

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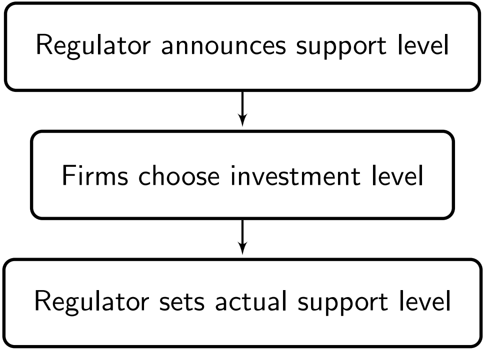
Time-Inconsistency



Many countries have cut support for renewable energy retrospectively...

- Czech Republic (2010)
- Greece (2012)
- Poland (2010-2012)
- Spain (2010-2013)
- Italy (2014)
- Romania (2017)

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Why is this an issue for renewable energy policies

- Renewable energy investments are **capital-intensive** and have low marginal costs
- Renewable energy remuneration is paid out based on **output**

Literature

- Models of time-inconsistency originated in the **monetary policy literature** (e.g. Kydland and Prescott (1977) and Barro and Gordon (1983)) and have been applied to rate-of-return regulation (Laffont and Tirole (1993), Gilbert and Newbery (1994), Salant and Woroch (1992))
- Models of time-inconsistency have since been applied in **environmental and climate policy** (e.g. Helm et al. (2003), Brunner et al. (2012), Chiappinelli and Neuhoff (2017), Golombeck et al. (2012), Montero (2011))

Research Question

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Contribution:
→ Application of a model of time inconsistency to renewable energy policies, asking whether and how repeated relationships between regulator and firm and additional policies can alleviate the issue
→ Parameterizing a model of time-inconsistency for renewable energy investments, allowing to explain cross-country variation

Renwable energy policies as regulatory game

- **Regulatory game** between firm and regulator
- Support is paid out based on output over the lifetime - a **dynamic game** where past commitments matter
- **Representative firm** in perfectly competitive environment maximizes profits Π, and the regulator maximizes welfare W

Regulatory game: The model - welfare

Regulator's period **welfare function** W_t:

$$W_t = \underbrace{\int_{s_t}^{\bar{s}} Q(z)dz}_{\text{Consumer surplus}} - \underbrace{\frac{e}{2}[Q(s_t) - X_t]^2}_{\text{Environmental damages}}$$

Direct **demand function**: $Q(s_t) = a - bs_t$
The **support levy**: $s_t = \delta s_{t-1} + p_t$
Capital **stock transition**: $X_t = \delta X_{t-1} + x_t$

- s: support levy
- X: RES capacity (output)
- x: new investments (output)
- e: pollution parameter
- c: investment costs
- a: demand w/o support
- b: slope of demand
- $\bar{s}$: maximum support
- p: support payment to firm
- δ: capital survival rate

Regulatory game: The model - profits

Firm's period **profit function** Π_t:

$$\Pi_t = \$X_t - C(x_t)$$

Total revenues in period t: $\$X_t = \$(\delta X_{t-1} + x_t) = \sum_{\tau=0}^{t} \delta^{t-\tau} p_\tau x_\tau$

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Regulatory game: Benchmark

Commitment benchmark

- Regulator can credibly commit
- Solve for optimal support level p^* and investment level $x^*(p^*)$

Regulatory game: Regulatory solutions

Commitment benchmark

- Regulator can credibly commit
- Solve for sequence of optimal support levels p^* and investment levels $x^* = x^*(p^*)$

No commitment

- Open loop strategies
- Trigger strategies

Open loop strategies

Open loop strategies

- Behavior does not take past into account
- Government announces a support level, the firm invests, and the government can deviate from announced levels
- The firm foresees this and invests less in first place

Proposition

When the government cannot commit to a support level, in each period the government sets a lower level of support ($p^{**} < p^{*}$) and the firm underinvests in renewables capacity ($x^{**} < x^{*}$) relative to the commitment benchmark.

Trigger strategies: Compliance condition

Can the commitment benchmark be sustained even without full commitment?

$$\underbrace{\sum_{t=\tau}^{\infty} \beta^t W(p_t = p^*, X_t = X^*}_{\text{pay-off under compliance}} \geq \underbrace{\sum_{t=\tau}^{\infty} \beta^t W(p_t = p^{**}, x_{i_{t=\tau}} = x_i^*, x_{i_{t\neq\tau}} = x^{**})}_{\text{pay-off under deviation}}$$

- p: support payment
- X: RES capacity (output)
- β: discount factor
- τ: deviation period
- x: new investments (output)

Regulatory game: Compliance condition

$$\underbrace{\frac{e}{2}\sum_{t=\tau}^{\infty}\beta^t\left[\left(Q(s^{**})-\delta^{t-\tau}X_\tau(p^*)\right)^2-\left(Q(s^*)-\delta^{t-\tau}X_\tau(p^*)\right)^2\right]}_{\text{lower emissions from lower demand}}$$

$$+\underbrace{e\sum_{t=\tau+1}^{\infty}\beta^t\left[X^t_{\tau+1}(p^*)-X^t_{\tau+1}(p^{**})\right]}_{\text{lower emissions from new RES}}\geq\underbrace{\sum_{t=\tau}^{\infty}\beta^t\int_{s^{**}}^{s^*}Q(z)dz}_{\text{lower costs of old + new RES}}$$

- p: support payment
- X: RES capacity (output)
- e: pollution parameter
- s: support levy
- β: discount factor
- τ: deviation period
- Q: demand
- δ: capital survival

Regulatory game: Compliance condition

Proposition

Provided the discount factor β or the capital survival rate δ are large enough, the committment benchmark solution (p^*, x^*) can be sustained as a trigger-strategy subgame-perfect Nash equilibrium.

Differences between policies

- Differences between policies reflected as reputational damage in other sectors, propotional to deviation $r(p^a - p_t)$

$$\max_{p_t} \sum_{t=0}^{\infty} \beta^t \left[\int_{s_t}^{\overline{p}} Q(z)dz - \frac{e}{2}(Q(s_t) - X_t)^2 - r(p^a - p_t) \right] \quad (2)$$

r - reputational damage

p^a - announced support payment

Proposition

When the government suffers reputational damage in other sectors of the economy ($r > 0$), the solution is superior to the no-commitment case, $p^r > p^{**}$ and $x^r > x^{**}$, and it approaches the commitment benchmark for large enough r.

Differences between policies

- Secure support levels with backing by the constitution, e.g. German feed-in tariff and sliding premium: can only be altered retrospectively with qualified majority (high r)
- Secure "reasonable profitability" like in Spain (first implicitly, now explicitly) (intermediate r)
- Security of support channel, but not of value, e.g. green certificates in Poland, Bulgaria, Sweden (low r)

But: No governmental action can rule out changes altogether and additional taxes like in Italy can usually be introduced in any case...

Targets

Example: EU 2020 renewable energy targets

$$\max_{p_t} \sum_{t=0}^{\infty} \beta^t \int_{s_t}^{\overline{p}} Q(z)dz - \frac{e}{2}(Q(s_t) - X_t)^2 - f[\overline{X_t} - X_t] \qquad (3)$$

f - fine

$\overline{X_t}$ renewable energy target in period t

Proposition

Targets for renewable energy deployment can work as a commitment devices provided the punishment from not reaching them (in terms of fines to pay) is large enough. Lower levels of δ and of β are needed to sustain the commitment benchmark (p^*, x^*) as a SPNE.

Numerical application

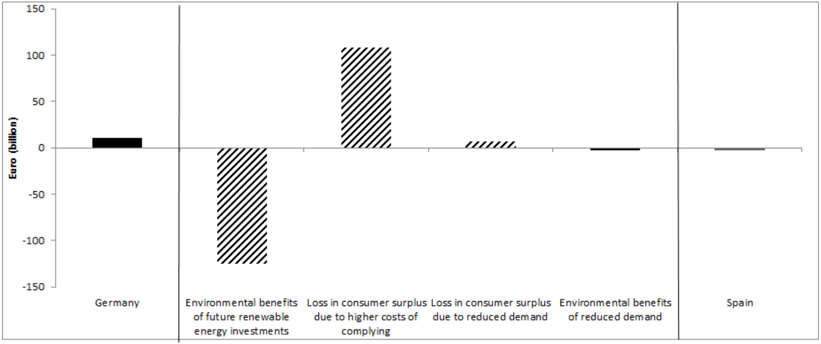
Why did Spain deviate around 2012 while Germany did not?

- Spain #4 in wind power, Germany #3
- Spain #5 in solar power, Germany #1
- Spain: costs of €34 per MWh demand, Germany: €36.9

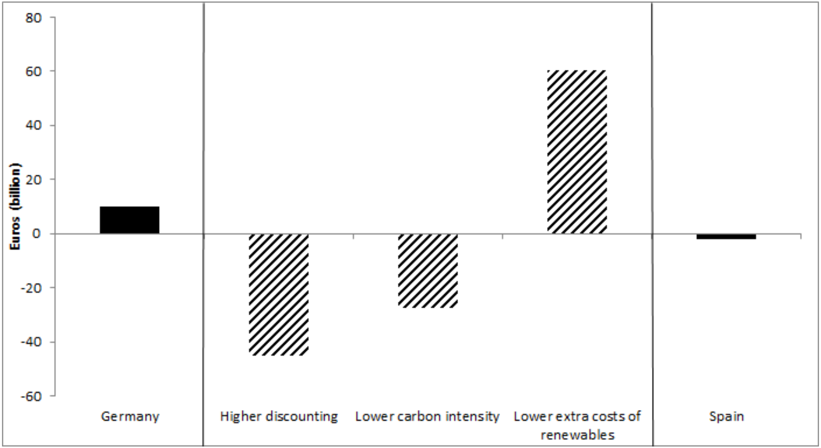
Estimating the compliance condition

- Electricity demand level and elasticity
- Renewable energy extension trajectory
- Costs of renewable energies and wholesale price level
- Renewable energy policy
- Emission intensity of thermal power plants
- Discount factor

Results: drivers of country differences



Results: Underlying parameters



Conclusion

- Time-inconsistency can arise for renewable energy investments and has occurred in several EU countries
- Repeated relations between regulator and firms partially address commitment problem
- Policies and targets can reduce the time-inconsistency issue as they render compliance more attractive
- Low discounting and a dirty thermal power plant fleet made compliance in Germany relatively more attractive than in Spain

Barro, Robert J., and David B. Gordon. 1983. "A positive theory of monetary policy in a natural rate model." *The Journal of Political Economy*, 91(4): 589–610.

Brunner, Steffen, Christian Flachsland, and Robert Marschinski. 2012. "Credible commitment in carbon policy." *Climate Policy*, 12(January 2013): 255–271, DOI: http://dx.doi.org/10.1080/14693062.2011.582327.

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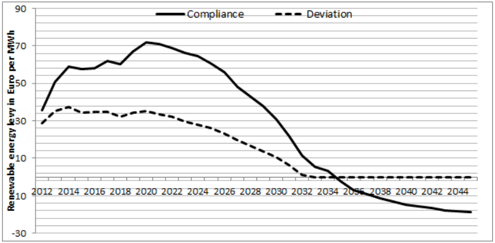
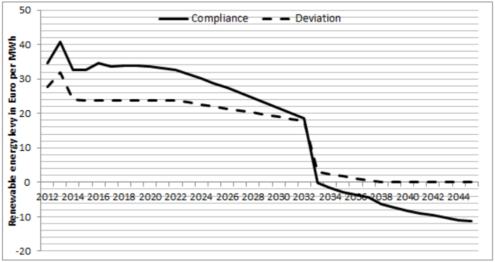
Helm, Dieter, Cameron Hepburn, and Richard Mash. 2003. "Credible carbon policy." *Oxford Review of Economic Policy*, 19(3): 438–450, DOI: http://dx.doi.org/10.1093/oxrep/19.3.438.

Kydland, Finn E., and Edward C. Prescott. 1977. "Rules Rather than Discretion: The Inconsistency of Optimal Plans." *Journal of Political Economy*, 85(3): 473–491, DOI: http://dx.doi.org/10.1086/260580.

Numerical application: Results - differences in levies





EU Targets: Germany and Spain need wind and solar power