Flexibility Premium in Marketable Permits

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CO_2 abatement alternatives

In a pollution-constrained economy where polluting companies are subject to environmental regulations that cap their noxious emissions, each firm faces a basic choice from three main abatement alternatives:

1. trade marketable permits (short-term abatement option);
2. modify the production process which generates the emissions as a by-product (medium-term abatement option);
3. change the production technology (long-term abatement option).

However, typical medium and long term abatement measures are perceived as

- hardly feasible or simply not profitable compared to more flexible instruments;
- expensive and irreversible commitments lasting decades.

Purchase of allowances can be adapted to changing conditions whereas a scrubber might be under-utilized if demand falls or conversely, the cost of a scrubber might be excessive after a fall in the permit price.

Substitution principle for abatement measures

- Chao and Wilson [1993] and Zhao [2003] framed their studies of marketable permits calling into question the principle of perfect substitution between permits (short-term) and long-term abatement measures.
- Intuitively, trading permits and modifying production process are *equivalent* alternatives exclusively when both lead to equal pollution-emissions reduction for the same total costs.
- In reality, the decision to undertake a modification of the production process is typically characterized by a significant implementation lag. This implicitly has a profound impact on the profitability of the economic decision undertaken.
- In fact, depending on the evolution of the new operating profits during the implementation lag, the investment or disinvestment abatement opportunity may partially lose its attractiveness.
- For these reasons, the price of marketable permits must include a premium that recognizes the value of their flexibility.

Motivations

Disinvestment: We should account for those situations where a firm can reverse the investment decision (McDonald and Siegel [1986] and Brekke and Øksendal [1994]).

Delay: We should account for those realistic situations where a firm faces physical or technical constraints that allow the implementation of economic decisions only after a given time-interval (Bar-Ilan and Strange [1996] for investments and Øksendal [2005] for disinvestment).

Premium: The price of marketable permits should include a premium representing the value of flexibility as compared to the alternative of (non-instantaneous) investments in abatement strategies that reduce the quantity of emissions (Chao and Wilson [1993] for instantaneous irreversible investments).

Taschini (2008) in a nutshell

- In this paper I evaluate the value of flexibility implicitly embedded in the price of marketable permits in the presence of reversible pollution reduction investments.
- This model can support decision-makers in relevant companies in identifying the optimal time for undertaking a reversible abatement measure, such as a modification of the production process, in the presence of delays in the implementation processes or trading permits.
- We propose an infinite-time horizon model where a risk-neutral firm is subject to environmental regulations from time zero up to T. The firm maximizes its expected discounted pay-off flow and constantly emits α units of pollution at each instant.
- The firm can either undertake a modification of the production process at any time $(t, 0 \leq t \leq T)$ - it is reversible and can be reversed only once - or purchase the necessary emission permits at time T.
- This paper extends Chao and Wilson [1993] and Bar-Ilan and Strange [1996].

The model, the approach and results

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Aim: Derive an analytic solution of the premium for flexibility embedded in marketable permits.

Approach: The company maximizes its expected discounted pay-off flow. After production modification, the new operating profits follow a one-dimensional geometric Brownian motion. I evaluate the optimal "investment" and "disinvestment" policy for reversible abatement options under both instantaneous and Parisian criteria.

Results:

- By taking the difference between these two values at their respective optima, I derive an analytic solution of the premium for flexibility.
- This theoretical result explains the different behavior of the premium for the flexibility of emission permits under both reversible and irreversible (Chao and Wilson [1993]) investment assumptions.

Graphical interpretation of the problem

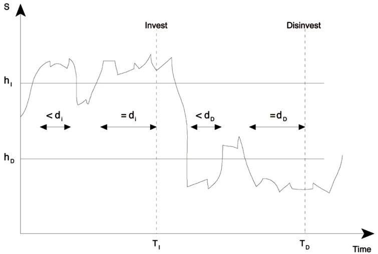
- The new operating profits S_t follows a GBM. Firm's expected sum of discounted cash flows is:

$$V_t = \mathbb{E}_t \left[\int_t^{\infty} e^{-\rho(u-t)} S_u du \right]. \quad (1)$$

- The firm maximizes the present value of the investment and disinvestment opportunity:

$$VS(V_0^S) = \max_{\tau_I < \tau_D} \mathbb{E} \left[e^{-\rho\tau_I} (V_{\tau_I} - C_I)^+ + e^{-\rho\tau_D} (C_D - V_{\tau_D})^+ \right].$$

- τ_I and τ_D are the first time that the state variable stays d_I (d_D) units of time above (below) the corresponding thresholds.



Price of emission permits

If the firm undertakes a reversible and costly modification of the production process at time τ (V_τ^S), then an equivalent (*substitute*) reduction of pollution by trading permits must corresponds to a purchase at time T of $\alpha \cdot (T-\tau)$ permits for a unit-price of P.

Lemma.(Taschini [2008]) Purchasing permits at time T is equivalent to undertaking a reversible and costly modification of the production process at time τ if, and only if, the price of the permits is

$$P = e^{\rho(T-\tau)} \cdot \frac{V_\tau^B - V_\tau^S}{\alpha(T-\tau)},$$

where V_s^B and V_τ^S are defined in equation (1), and τ is a stopping time.

Re. The strategy of undertaking a production modification at time τ corresponds to a total loss of operating profits equal to $V_s^B - V_\tau^S$.

Premium for the flexibility

I rely on the Parisian criterion introduced by Chesney et al. [1997] and use the results of Costeniuc, Schnetzer and T. [2008]. In particular, I employ the analytic solution to the optimal "starting" and "stopping" levels obtained under the Parisian criterion.

Theorem.(Taschini [2008]) Consider a company which has two pollution abatement measures at its disposal: trading permits or modifying the production process. The premium for the flexibility embedded in the price for marketable permits at time zero is:

$$\theta = e^{\rho \cdot T} \cdot \frac{VS_I^*(V_0^S) - VS_D^*(V_0^S)}{\alpha \cdot T},$$

where α is the instantaneous pollution, ρ is the discount rate and T is the end of the controlling period. $VS_I^*(V_0^S)$ is the solution of the instantaneous investment and disinvestment problem, i.e. when $d_I = d_D = 0$, whereas $VS_D^*(V_0^S)$ is the solution of the maximization problem under the Parisian criterion, i.e. when $d_D \geq 0$ and $d_I \geq 0$.

Premium for the flexibility

- When the modification of the production process can be implemented instantaneously, trading permits are equivalent to the pollution abatement measure.
- However, the presence of implementation delays, that we model by the Parisian criterion, makes production modification an attractive alternative if, and only if, a company is sufficiently compensated.
- Therefore, this premium measures the discounted expected value of the greater flexibility that emission permits provide, compared to the reversible and delayed commitments required by modifying the production process.
- The premium for the flexibility of emission permits is obtained by taking the difference between the value of the instantaneous investment and disinvestment decision problem (VS_I^*) and the Parisian investment and disinvestment decision problem (VS_D^*), at their respective optima.

Model implications

Optimal instantaneous irreversible investment value h_{II}^*, and Parisian optimal investment h_I^* and disinvestment h_D^* values.

		$d_I = d_D = 3$		$d_I = d_D = 5$	
σ	h_{II}^*	h_I^*	h_D^*	h_I^*	h_D^*
0.05	282.91	232.21	52.01	209.73	52.44
0.15	326.18	219.05	55.40	189.07	58.82
0.25	393.23	213.28	56.96	173.38	64.26
0.35	478.20	209.69	58.18	160.05	69.89
0.40	527.17	208.07	58.84	153.79	73.00

1. An increase in uncertainty delays instantaneous irreversible investments, increasing the instantaneous investment threshold.

2. In the presence of implementation delays, conventional findings on the effect of the uncertainty of the underlying process on investment and disinvestment are reversed. A higher volatility of the underlying process hastens both investment and disinvestment.

3. The work of Bar-Ilan and Strange [1996], who study the effect of delays on irreversible investment, is then nested into this model.

Model implications

When $d_D \to \infty$, the level h_I^* converges to

$$h_{OI}^* = \frac{\theta_1 C_I}{\theta_1 - 1} \frac{\phi(b\sqrt{d_I})}{\phi((b+\sigma)\sqrt{d_I})},$$

where h_{OI}^* represents the optimal investment threshold for time-window d_I while disinvestment is not possible (Gauthier and Morellec [2000]).

1. The required premium for irreversible investments (θ_{OI}) is larger than the premium for reversible investments (θ_D).

2. Policy makers should be concerned about the degree of reversibility of all abatement alternatives available to companies because the sum of the marginal cost and the premium can be correctly interpreted as a cap on the permit price. This is important when designing and implementing effective environmental regulations.

Model implications

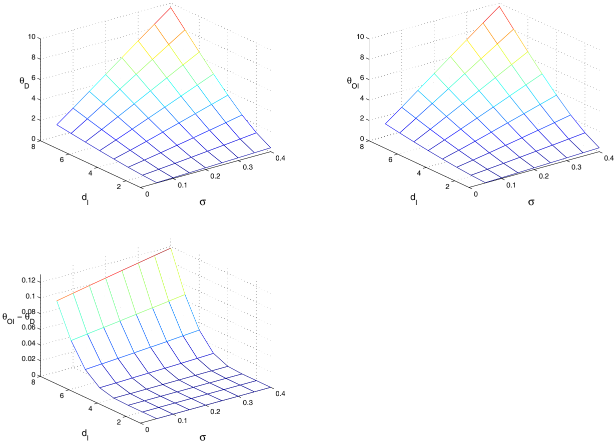


Figure: θ_D and θ_{OI} are the premia respectively for reversible (left picture) and irreversible investments (right picture). Both are functions of the investment time-window d_I and the volatility rate σ. The left picture plots the difference between the two premia.

Conclusions

- If the modification of the production process can be implemented instantaneously, trading permits are equivalent to the pollution abatement measure when both lead to equal pollution-emission reductions for the same total costs.
- On the contrary, the price of marketable permits should include a premium representing the discounted expected value of the greater flexibility that emission permits provide, compared to the reversible and delayed commitments required by modifying the production process.
- We derive an analytic solution of the premium for flexibility embedded in marketable permits extending extends Chao and Wilson [1993] and Bar-Ilan and Strange [1996].
- The existence of different levels of reversibility and implementation delay raise the important question of the development of sectorial approaches in the cap-and-trade framework.

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