

Bankable Permits under Uncertainty and Optimal Risk Management Rules: Theory and Empirical Evidence

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On emissions permits

- Emission permits widely considered as efficient instruments for regulating firms' emissions of pollutants;
- However, emission permits may also convey a high level of **uncertainty** with respect to political decisions;
- Uncertainty depends not only on the permits price, but also on the **allocation rules** enforced by the regulator.

On the use of banking

- We examine firms' production decisions subject to the introduction of an emission permits market, and to the possibility to bank permits forward in a partial equilibrium framework;
- At the beginning of each period, firms receive an initial permits allocation;
- *Without* uncertainty, firms smooth their emissions between trading periods (Kling and Rubin (1997), Leiby and Rubin (2001));
- The introduction of uncertainty on future allocation provides further incentives for firms to bank permits, and to consider collusion as a way of insurance (Von der Fehr (1993), Etner and Jouvet (2000), Ehrhart et al. (2008)).

Central questions

- Will an **increase** in the level of **uncertainty** concerning future allocation impact *positively* or *negatively* the amount of banking by firms?
- Following a variation in the level of uncertainty, is it possible to identify an **optimal risk sharing rule** between firms?
- We focus our analysis on the banking provisions, and consider that permits trading between firms has already occurred.

Behavior of Firms

- During the 1st period, t , firms receive a permits allocation noted $\bar{P}_t$. This initial allocation may be used for production, but also banked for the next period. During the 2nd period, firms receive a permits allocation noted $\bar{P}_{t+1}$;
- During each period, each firm produces a good Y_t with a given production technology by using X_t inputs and P_t permits:

$$Y_t = F(X_t, P_t) \quad (1)$$

- The production function is strictly concave for each of its arguments and the second non-crossed derivatives are negative ($F_{ij} < 0$).

Behavior of Firms (ctd.)

- The firm maximizes its intertemporal profit as a function of its inputs, X_t and X_{t+1} , and the choice of using pollution permits P_t and P_{t+1} .
- Let $\bar{P}_t$ and $\bar{P}_{t+1}$ be the permits allocated to firms and S_t the permits bank computed as the difference between the initial permits endowment and the number of permits used by the firm:

$$S_t = \bar{P}_t - P_t \quad (2)$$

- β is the discounting factor used by the firm.

Behavior of Firms (ctd.)

- The intertemporal profit may be written as:

$$\Pi_t = \pi_t + \beta\pi_{t+1} \quad (3)$$

- with $\pi_t = F(X_t, P_t) - R_t X_t$,
- and $\pi_{t+1} = F(X_{t+1}, P_{t+1}) - R_{t+1} X_{t+1} + q_{t+1}(\bar{P}_{t+1} + S_t - P_{t+1})$,
- with R_t and R_{t+1} the inputs prices, q_t and q_{t+1} the permits prices.

Case without Uncertainty

- The optimization program of the firm is :

$$\max_{X_t, X_{t+1}, S_t \geq 0, P_t, P_{t+1}} \left\{ \begin{array}{l} F(X_t, P_t) - R_t X_t \\ + \beta \{ F(X_{t+1}, P_{t+1}) - R_{t+1} X_{t+1} + q_{t+1}(\bar{P}_{t+1} + S_t - P_{t+1}) \} \end{array} \right\}$$

- With $P_t = \bar{P}_t - S_t$, the first order conditions are:

$$F_{X_t}(X_t, P_t) = R_t \quad (4)$$

$$F_{X_{t+1}}(X_{t+1}, P_{t+1}) = R_{t+1} \quad (5)$$

$$F_{P_t}(X_t, P_t) - \beta q_{t+1} \leq 0 ; = 0 \text{ if } S_t > 0 \quad (6)$$

$$F_{P_{t+1}}(X_{t+1}, P_{t+1}) - q_{t+1} = 0 \quad (7)$$

Case without Uncertainty (ctd.)

- Combining eq.(6) and (7), we have:

$$F_{P_t}(X_t, P_t) = \beta F_{P_{t+1}}(X_{t+1}, P_{t+1}) \quad (8)$$

- From eq.(4), (5) and (8), banking is an increasing function of the first period permits allocation, $dS_t/d\bar{P}_t > 0$, and a decreasing function of the second period permits allocation, $dS_t/d\bar{P}_{t+1} < 0$.

Case with Uncertainty

- We assume a random second period permits allocation, noted $\tilde{P}_{t+1}$ with a probability distribution $G(.)$.
- At time $t + 1$, the firm knows its amount of permits $\hat{P}_{t+1}$ endowed and may decide on its inputs uses, production level and associated emissions of pollutants.
- At time t , this amount is not known with certainty.
- The firm anticipates an average amount of permits distributed during the second period equal to $\bar{P}_{t+1}$.

Case with Uncertainty (ctd.)

- The expected intertemporal profit, $E \Pi_t = \pi_t + \beta E \pi_{t+1}$ is:

$$\Pi_t = \left\{ \begin{array}{l} F(X_t, P_t) - R_t X_t \\ + \beta E \{ F(X_{t+1}, P_{t+1}) - R_{t+1} X_{t+1} + q_{t+1}(\tilde{P}_{t+1} + S_t - P_{t+1}) \} \end{array} \right\}$$

- The choice of the firm follows two steps:
 1. the firm chooses S_t and X_t by taking into account the uncertainty over the total number of permits distributed in the future,
 2. the firm chooses X_{t+1} and P_{t+1} with $P_{t+1} \leq \hat{P}_{t+1} + S_t$ given its choices during the first period.

Case with Uncertainty (ctd.)

- We obtain an expected condition similar to the case without uncertainty, *i.e.* the firm's behavior is simply based on the expected profit.
- Next, we investigate the consequences of a change in the level of risk associated with the second period permits allocation.
- We consider an increase in risk in the sense of Rothschild and Stiglitz (1971), and study the effects of this change in the probability distribution on the firm's banking choices.

Increase in risk

- For a given level of inputs, in response to an increase in risk in the sense of the mean preserving spread, the banking of pollution permits by the firm increases (decreases) if and only if the third derivative of the production function with respect to the emissions, F_{PPP} , is positive (negative).
- The intuition behind this result may be summarized as follows:

When facing a stronger (weaker) increase of their marginal productivity, firms tend to use less (more) permits, and thus are able to produce and bank more (less) permits.
- Firms with heterogeneous characteristics on their third derivative may adopt dramatically different behaviors in terms of banked permits.

Pooling Behavior

- In partial equilibrium there exists N firms and Θ states of nature.
- $\bar{P}_{t+1}^{i\theta}$ is the permits allocation that firm i receives in the state of nature θ , $\underline{\theta} \leq \theta \leq \bar{\theta}$, with a realization probability μ_θ .
- The optimization program of firm i may be written as:

$$\max_{X_t, X_{t+1}, S_t, P_{t+1}} \left\{ \begin{array}{l} F^i(X_t^i, \bar{P}_t^i - S_t^i) - R_t X_t^i \\ + \beta \sum_{\theta=0}^{\Theta} \mu_\theta \{ F^i(X_{t+1}^i, P_{t+1}^i) - R_{t+1} X_{t+1}^i + q_{t+1}(\bar{P}_{t+1}^{i\theta} + S_t^i - P_{t+1}^i) \} \end{array} \right\}$$

Pooling Behavior (ctd.)

- The pooling behavior implies the introduction of a cooperation agency between firms which is responsible to maximize the sum of firms' profits whatever their states of nature.
- This agency will thus take into account the sum of firms' permits allocations over the 2 periods:

$$\sum_i [\bar{P}_t^i + \bar{P}_{t+1}^{i\theta}] = \sum_i P_t^i + \sum_i P_{t+1}^{i\theta} \equiv \bar{P}^\theta, \quad \forall \theta \in \Theta \quad (9)$$

- The agency's program consists in maximizing the sum of profits by choosing firms' inputs levels (X_t^i and $X_{t+1}^{i\theta}$) as well as the use of permits (P_t^i and $P_{t+1}^{i\theta}$) for all states of nature:

$$\max_{\{X_t^i, X_{t+1}^{i\theta}, P_t^i, P_{t+1}^{i\theta}\}_{i,\theta}} \sum_i \left\{ F^i(X_t^i, P_t^i) - R_t X_t^i + \beta \sum_{\theta=0}^{\Theta} \mu_\theta \left\{ F^i(X_{t+1}^{i\theta}, P_{t+1}^{i\theta}) - R_{t+1} X_{t+1}^{i\theta} \right\} \right\}$$

Pooling Behavior (ctd.)

- At the optimum, the marginal rates of technical substitution of firms i and j between two states of nature, θ_1 and θ_2 , are equal:

$$\frac{F_{P_{t+1}^{i\theta_1}}^i(X_{t+1}^{i\theta_1}, P_{t+1}^{i\theta_1})}{F_{P_{t+1}^{i\theta_2}}^i(X_{t+1}^{i\theta_2}, P_{t+1}^{i\theta_2})} = \frac{F_{P_{t+1}^{j\theta_1}}^j(X_{t+1}^{j\theta_1}, P_{t+1}^{j\theta_1})}{F_{P_{t+1}^{j\theta_2}}^j(X_{t+1}^{j\theta_2}, P_{t+1}^{j\theta_2})} \quad \forall i, j, \theta_1, \theta_2 \quad (10)$$

- This condition is similar to Borch (1962) concerning agents' marginal rates of substitutions between two states of nature.
- From the set of optimality conditions, and by keeping the Borch's condition, we obtain an implicit function $\Gamma^{i\theta}$ between the number of permits allocated to each firm in a given state of nature and the total amounts of permits distributed for each of these states:

$$P_{t+1}^{i\theta} = \Gamma^{i\theta}(\bar{P}^1, \bar{P}^2, \dots, \bar{P}^\theta, \dots, \bar{P}^\Theta) \quad (11)$$

Pooling Behavior (ctd.)

- The permits distributed by the agency depend on the aggregated sum of permits available in the economy over the two periods.
- *For any given set of decisions of the regulator concerning firms' permits allocation criteria during the second period, the re-allocation of permits by the agency is Pareto-optimal for firms.*
- The expected firms' profits are similar to the case without uncertainty where the agency is in charge of redistributing the total number of permits available in the economy.
- If the agency only knows the total number of permits allocated during each period, $\bar{\bar{P}}_t = \sum_i \bar{P}_t^i$ and $\bar{\bar{P}}_{t+1} = \sum_i \bar{P}_{t+1}^i$, it will be able to redistribute the total number of permits, $\bar{\bar{P}}_t + \bar{\bar{P}}_{t+1}$, during each period for any change in permits allocation rules enforced by the regulator.

The Optimal Risk-Sharing Rule

- The uncertainty concerns the total amount of permits distributed during the second period.
- We study the variations of firms' permits allocations as a function of the variation of the second period permits bank.
- We consider the permits allocation constraint in two different states of nature θ_1 and θ_2 :

$$\sum_i [\bar{P}_t^i + \bar{P}_{t+1}^{i\theta_1}] = \sum_i P_t^i + \sum_i P_{t+1}^{i\theta_1} \quad (12)$$

$$\sum_i [\bar{P}_t^i + \bar{P}_{t+1}^{i\theta_2}] = \sum_i P_t^i + \sum_i P_{t+1}^{i\theta_2} \quad (13)$$

with $\bar{\bar{P}}_{t+1}^{\theta_1} = \sum_i \bar{P}_{t+1}^{i\theta_1}$ and $\bar{\bar{P}}_{t+1}^{\theta_2} = \sum_i \bar{P}_{t+1}^{i\theta_2}$, the total allocation for each state of nature, we have:

$$\bar{\bar{P}}_{t+1}^{\theta_1} - \bar{\bar{P}}_{t+1}^{\theta_2} = \sum_i P_{t+1}^{i\theta_1} - \sum_i P_{t+1}^{i\theta_2} \quad (14)$$

The Optimal Risk-Sharing Rule (ctd.)

- We define, for each state of nature, a relationship, $g(\cdot)$, between firms' second period permits allocations taken pairwise. For each pair of firms i and j , we have:

$$P_{t+1}^{i\theta} = g_{ij}^{\theta}(P_{t+1}^{j\theta}) \quad (15)$$

- Using equation (14) and (15), we get:

$$\frac{dP_{t+1}^{j\theta}}{d\bar{P}_{t+1}^{\theta}} = \frac{1}{\sum_i g_{ij}'^{\theta}(P_{t+1}^{j\theta})} \quad (16)$$

with

$$g_{ij}'^{\theta}(P_{t+1}^{j\theta}) = \frac{\partial F_P^j / \partial P}{\partial F_P^i / \partial P}$$

The Optimal Risk-Sharing Rule (ctd.)

- Noting σ_j^θ the elasticity of the marginal productivity of the environmental variable as a function of firm's i production with respect to the variation of the number of permits:

$$\sigma_j^\theta = P \times \frac{\partial F_P^j / \partial P}{\partial F^j / \partial P},$$

- We obtain the following proposition: *If the total permits bank during the second period is random, any optimal risk-sharing rule between firms is such that:*

$$\frac{dP_{t+1}^{j\theta}}{d\bar{P}_{t+1}^\theta} = \frac{\sigma_j^\theta / P_{t+1}^{j\theta}}{\sum_i \sigma_i^\theta / P_{t+1}^{i\theta}}$$

- When θ increases, the final second period permits allocation in this state increases proportionally to the elasticity of the marginal productivity with respect to the environmental variable.
- This sharing condition also takes into account the sensitivity of the firm's marginal productivity to the number of permits.

Policy Implications

- The regulator should strive to reduce or eliminate uncertainty in future permits allocation, by announcing and enforcing strict emissions target.
- If uncertainty arises concerning changes in allocation rules, firms may use banking in order to limit the level of risk attached to emissions trading.
- In absence of a credible commitment from the regulator in terms of allocation targets for future periods, banking therefore appears as an adequate tool for policy risk control.

Policy Implications (ctd.)

- An agency appears missing at the *sector* level: it may be useful to pool allowances between firms with different technological characteristics.
- It may be seen as an institutional "insurance" device against the variation of political decisions on emission permits markets.

Recap

- We show that when firms face an increase in the level of risk, the variation of the amount of banked permits is linked to the third derivative of their production function with respect to emissions;
- without uncertainty on the total number of permits allocated during the second period, an agency may introduce a Pareto-optimal permits re-allocation between firms;

Recap

- when uncertainty concerns the number of permits available during the second period, an optimal risk-sharing rule needs to take into account the sensitivity of firms' marginal productivity to the number of permits, as well as the elasticity of the marginal productivity with respect to the stock of pollution;
- investigating the banking behavior at the installation level, and the pooling behavior at the group level on the European carbon market.

Thanks for your attention