Does expected supply affect the price of emission permits?Evidence from Phase I in the EU ETS

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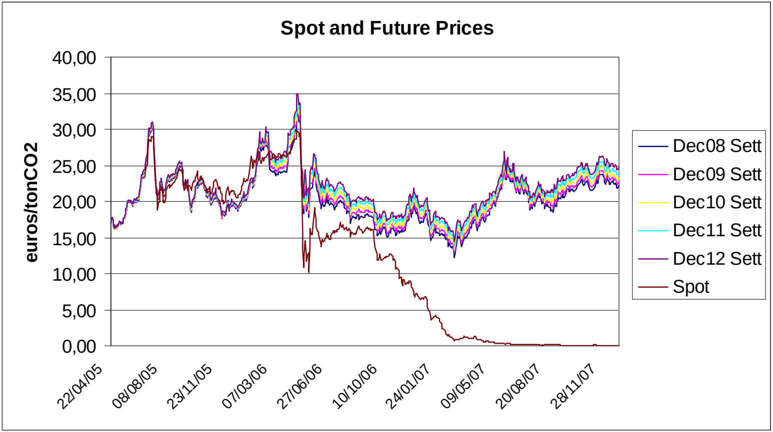
Convenience yield

The CY is the portion that has to be added in order to restore the no-arbitrage relationship between spot and future prices.
What determines the CY in the CO_2 market?



Litterature on CY in the EUA

- Borak et al. (2006) model the convenience yield as a function of the spot price and the variance of the spot price.
  - positive impact of the spot price on the convenience yield and a negative impact of variance.
- The interplay between risk-averse compliance and non-compliance agents in our model follows Maeda (2004) and Colla, Germain and van Steenberghe (2008).
  - Maeda postulates that firms' emissions to be driven by a common factor, while Colla, Germain and van Steenberghe develop a two-date model with bankable permits and no futures market.
- We innovate with respect to both papers by explicitly considering uncertainty about future environmental policy, which adds to the production risk faced by firms.

- We develop a model for the joint determination of spot and futures prices, and derive an equation to explain the difference between Phase I spot price and futures price with expiration in Phase II.
- Main ingredients of the model
    - market structure: regulated agents and speculators;
    - uncertainty on BAU emissions (economic growth), allowance endowments and financial wealth.
    - equilibrium futures and spot prices: information discovery (convenience yield issues) and expectations.

- In the testable version of our theoretical model, the convenience yield for Phase I depends on abatement costs and nonlinear variables (interaction abatement costs-spot price, abatement costs-covariance between financial wealth and production)
    - the empirical part allows identification of a coefficient measuring the future excess supply **perceived** by the market.
- Market participants were willing to believe the announcement of the EC expecting more permits to be issued in Phase II, widening the convenience yield.

The model

The analytical framework

We consider a model with two dates, $t = 1, 2$, each date representing one EU ETS Phase.

- **Allowance markets.** The spot market is open at both dates with permits prices p_1 and p_2. At date 1 market participants trade permits for date 2 delivery at the price F.
  - Banking (spot) permits across dates is not allowed.
- **Agents.** Continuum of agents price takers and risk averse.
  - Two types of market participants: compliance (λ) and non-compliance agents ($1 - \lambda$)

- At date t, firm i's BAU emissions are given by e_{it}^{B}.
  - Firm i freely receives an endowment of permits from the regulator in each phase, $\bar{e}_{it}$.
  - $\Delta e_{it} = e_{it}^{B} - \bar{e}_{it}$ is firm $i's$ permits shortage in the absence of abatements.
  - The abatement of firm i during phase t is a_{it}
  - Permits on the spot market: $\Delta e_{it} - a_{it}$.
- The abatement cost function, $C_i\left(a_{it}\right)$, is increasing and convex in a_{it}:

$$C_i\left(a_{it}\right) = \frac{1}{2} c_i a_{it}^2.$$

- Firms' payoffs reflect the cash settlement of futures transactions at price F:

$$\Pi_i = -\sum_{t=1}^{2} \frac{1}{2} c_i a_{it}^2 + \sum_{t=1}^{2} p_t \left(a_{it} - \Delta e_{it} \right) + f_i \left(p_2 - F \right), \qquad (1)$$

  where $f_i > 0$ denotes a long futures position.
- Each speculator, indexed by j, has wealth w_j originated outside of the permits market labour income.
- Speculator j can buy/sell permits forward, so that his profits are

$$\Pi_j = w_j + f_j \left(p_2 - F \right).$$

- **Economy.** At each date, the *total BAU emissions* in the economy are

$$E_t^B = \int_0^\lambda e_{it}^B \, di$$

The sum of *permits endowments* over all firms represents the environmental objective,

$$\bar{E}_t = \int_0^\lambda \bar{e}_{it} \, di.$$

The aggregate permits shortage during phase t is

$$\Delta E_t = E_t^B - \bar{E}_t.$$

The *aggregate wealth* is

$$W = \int_\lambda^1 w_j \, dj.$$

Uncertainty.

1. Aggregate production, Y_2, follows a Gaussian AR(1) process

$$Y_2 = \alpha Y_1 + \varepsilon, \tag{2}$$

with $\alpha \in (0,1)$ and $\varepsilon \sim \mathcal{N}.i.d.\left(0, \sigma_Y^2\right)$.

2. Firm i BAU emissions reflect aggregate production as well as an idiosyncratic component

$$e_{i2}^B = \beta_i Y_2 + \varepsilon_{i2}, \tag{3}$$

where $\varepsilon_{i2} \sim \mathcal{N}\left(0, \sigma_\varepsilon^2\right)$ with $cov\left(\varepsilon_{i2}, \varepsilon\right) = 0$, $\forall i$, and $cov\left(\varepsilon_{i2}, \varepsilon_{j2}\right) = 0$ for $i \neq j$.

- Note that eq. (3) yields aggregate BAU emissions as

$$E_2^B = \beta Y_2 + \int_0^\lambda \varepsilon_{i2} di, \tag{4}$$

$\beta = \int_0^\lambda \beta_i di$; $\beta < 1$: not all sectors are included in the cap-and-trade scheme.

3. Firm i allowances are distributed according to a pro-quota allocation of the environmental objective, $\bar{E}_2$, i.e.

$$\bar{e}_{i2} = \gamma_i \bar{E}_2, \tag{5}$$

where $\bar{E}_t \sim \mathcal{N}\left(\mu, \sigma^2\right)$ with $cov\left(\bar{E}_2, \varepsilon\right) = \sigma_{E,Y}$.

- Permits are allocated to regulated polluters only
  - A lax environmental policy would be characterized by $\sigma_{E,Y} > 0$ (any increase in pollution is accomodated by raising the amount of allowances).

4. Speculator j financial wealth corresponds to a fraction η_j of the aggregate wealth

$$w_j = \eta_j W \tag{6}$$

where $W \sim \mathcal{N}\left(\mu_W, \sigma_W^2\right)$ with $cov\left(W, \varepsilon\right) = \sigma_{W,Y}$ and $cov\left(W, \bar{E}_2\right) = cov\left(W, \varepsilon_{i2}\right) = 0$, $\forall i$.

- Speculators' aggregate wealth is (imperfectly) correlated with date 2 production and to date 2 total BAU emissions, E_2^B.
    - This leaves some room for speculators' to hedge their financial risk via futures transactions since w_j is correlated with the aggregate permits shortage ΔE_2, *which is the driver of spot permits*
    - $\eta = \int_0^\lambda \eta_j dj$ denotes the fraction of aggregate wealth that accrues to speculators.

- **Preferences.** All agents are risk-averse as captured by the following expected utility

$$E\left[U_k\left(\Pi_k\right)\right] = E\left(\Pi_k\right) - \left(2\tau_k\right)^{-1} V\left(\Pi_k\right) \tag{7}$$

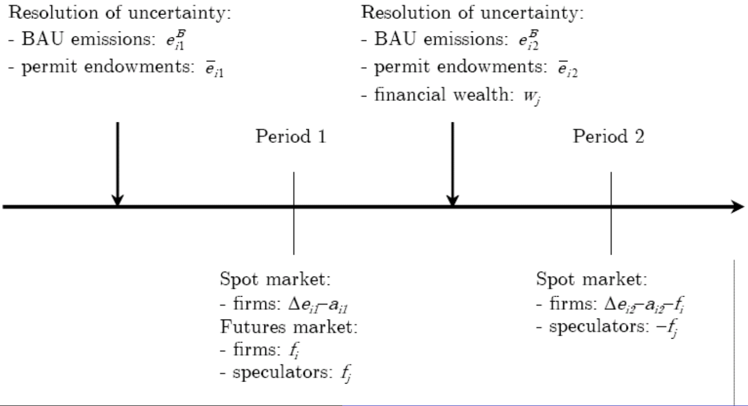
with $k = i\ , j$, and $\tau_k > 0$ is agent k risk tolerance coefficient

Sequence of decisions.

- At each date t, firms choose abatement a_{it} after observing their date t endowment, $\bar{e}_{it}$, and BAU emissions, e_{it}^{B}.
- At date 1 firms and speculators decide their futures position, f_i and f_j respectively, for delivery at the second date.
- The spot prices p_1 and p_2 as well as the futures price F are determined by market clearing.

Uncertainty

- Each speculator sets f_j before observing the realization of his labour income, w_j.
- Each firm sets abatements a_{it} under certainty but chooses f_i before knowing BAU emissions, e_{i2}^B, and its permits endowment, $\bar{e}_{i2}$.



Date 2. Firms

- Firms face no uncertainty about $\bar{e}_{i2}$ and e^B_{i2}.
- Optimality $\Leftrightarrow$ equalization between marginal abatement costs and the permits spot price

$$a^*_{i2} = \frac{p_2}{c_i}. \tag{8}$$

- Market clearing gives the equilibrium permit price, p^*_2

$$p^*_2 = \frac{\Delta E_2}{C}, \tag{9}$$

where

$$\Delta E_2 = E^B_2 - \bar{E}_2, \text{ and}$$

$$C = \int_0^\lambda c_i^{-1} di.$$

- Notice that

$$E\left(p_2^*\right) = C^{-1}\left[\beta E\left(Y_2\right) - \mu\right] \tag{10}$$

and

$$V\left(p_2^*\right) = C^{-2}\left[\beta^2\sigma_Y^2 + \lambda\sigma_\varepsilon^2 + \sigma^2 - 2\beta\sigma_{E,Y}\right]. \tag{11}$$

- The expectation of future prices increases with $E\left(Y_2\right)$, while an increase in the expected number of permits μ makes the environmental constraint more lax, and thus lower prices.
- Uncertainty about both date 2 BAU emissions as well as the overall environmental objective increase the variance of future prices.
  - Eq. (11) uncovers *tightness as a channel through with the regulator affects price volatility*.

Date 1. Firms

- The equilibrium spot price is $p_1^* = \frac{\Delta E_1}{C}$.
- Firm i futures position depends on the first two moments of date 2 spot price and the cov. between permits' shortage and p_2^*

Date 1. Speculators

- Speculators are uncertain about their future wealth and p_2^*.
- Non-compliance agents choose a long futures position whenever:
  - the spot price is expected to be above the futures price (speculative component);
  - permits provide insurance against future income fluctuations (hedging component).
- Environmental policy affects the speculators' demand for future contracts by the covariance between financial wealth and production.

Proposition

The futures market equilibrium is given by trades $\left(f_i^*, f_j^*\right)$ *and the corresponding price*

$$F^* = E\left(p_2^*\right) + \tau^{-1}\left[E\left(p_2^*\right) cov\left(\Delta E_2, p_2^*\right) - cov\left(\eta W, p_2^*\right)\right] \quad (12)$$

where τ *is the market risk tolerance:*

$$\tau = \int_0^\lambda \tau_i di + \int_\lambda^1 \tau_j dj. \quad (13)$$

Market composition (1)

- When firms only are active on the permits market, the futures equilibrium prices rewrites as

$$F^{*}\left(\lambda=1\right)=E\left(p_{2}^{*}\right)\left[1+\tau^{-1}cov\left(\Delta E_{2},p_{2}^{*}\right)\right], \tag{14}$$

- The convenience yield is determined by the comovement between firms' and aggregate permits shortage.
- The market is **always** in **Normal Contango** $F^{*}>E\left(p_{2}^{*}\right)$ since with only firms we have

$$cov\left(\Delta E_{2},p_{2}^{*}\right)=CV\left(p_{2}^{*}\right),$$

More volatile date 2 prices will require a higher risk premium.

Market composition (2)

- When speculators are the sole market participants , the futures market equilibrium is:

$$F^* (\lambda = 0) = E (p_2^*) - \tau^{-1} cov (\eta W, p_2^*) , \quad (15)$$

  - Hedging motives drive the convenience yield.
- The market is in **Normal Contango** whenever wealth and production move in opposite directions or are weakly related.
- **Normal Backwardation** $F^* < E (p_2^*)$ is likely to arise when the linear relationship between financial wealth and date 2 equilibrium permits price is sufficiently strong.

Environmental policy

- The futures equilibrium price in eq. (12) can be rewritten as

$$F^* - E\left(p_2^*\right) = \tau^{-1}\left[CE\left(p_2^*\right)V\left(p_2^*\right) - C^{-1}\beta\eta\sigma_{W,Y}\right].$$

- The latter equation highlights how a environmental policy affects the convenience yield. Suppose $\sigma_{W,Y} < 0$ so that the market is in normal contango
  - A tight environmental policy and/or uncertainty about future permits supply would make permits prices more volatile, and the convenience yield widens.

- Under some simplfying hypotheses, and by using equilibrium properties, we rewrite the CY

$$F^* - p_1^* = \frac{c}{\lambda}\left(\bar{E}_1 - \mu\right) + \frac{c^2}{\lambda^2\tau}\left(\bar{E}_1 - \mu\right) V\left(p_2^*\right) + \frac{c}{\lambda\tau} p_1^* V\left(p_2^*\right) - \frac{c}{\lambda\tau}\sigma_{W,Y}$$

- We run the following regression

$$\begin{aligned}(F_i - p)_t = \delta_0 + \delta_1 switch_t + \delta_2 switch_t^2 + \\ + \delta_3 p_t switch_t + \delta_4 switch_t Cov\left(p, r_{SM}\right)_t + \varepsilon_t\end{aligned}$$

- $\delta_1 \rightsquigarrow \frac{\left(\bar{E}_1 - \mu\right)_t}{\lambda}$, $\delta_2 \rightsquigarrow \frac{1}{\lambda^2\tau}\left(\bar{E}_1 - \mu\right) V\left(p_2^*\right)$
- $\delta_3 \rightsquigarrow \frac{V\left(p_2^*\right)}{\lambda\tau}$, $\delta_4 \rightsquigarrow -\frac{1}{\lambda\tau}$
- δ_2 measures the expectation about future allowances supply with $\delta_2 < 0$ corresponding to more permits issued during Phase II.
- switch is the theoretical switching level used as a proxy of abatement costs

Data and Method

- Futures Price: ECX data with delivery 2008 to 2012; spot price: Powernext CO2 data; from 24/06/2005 to 31/12/2007.
- Coal data: API 2 CIF ARA from Platts; Gas data: NBP from Bloomberg.
- Dow Jones StoXX 600 Return Index in log differences
- Helfand, Moore and Liu (2007) one step ahead forecast procedure to generate one-day ahead errors for each series
- OLS estimation- Standard errors are corrected using the Newey-West method.
- We allow for a break in 2006.

Regression results

- Before the break, the coefficient δ_4 is positive, but not significantly so, and δ_5 is significantly negative, as expected. δ_2 is significantly negative.
- After the break, the estimated coefficients are usually not significantly different from zero, except for that associated with the expected change in supply, which is negative for the long maturities to 2011 and 2012.

	DEC 08	DEC 09	DEC 10	DEC 11	DEC 12
δ_2	-0.0090***	-0.0092***	-0.0095***	-0.0098***	-0.0101***
	(-2.909)	(-3.035)	(-3.224)	(-3.453)	(-3.520)
δ_3	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
	(3.066)	(3.291)	(3.232)	(3.205)	(3.054)
δ_4	0.0056	0.0058	0.0056	0.0054	0.0055
	(1.116)	(1.165)	(1.151)	(1.108)	(1.076)
δ_5	-29.7205**	-30.8501**	-31.9302**	-32.3368**	-32.4492**
	(-2.240)	(-2.318)	(-2.385)	(-2.398)	(-2.326)
δ_1	-0.0387	-0.0449	-0.0417	-0.0376	-0.0328
	(-0.175)	(-0.200)	(-0.186)	(-0.166)	(-0.144)
Adj. R^2	0.102	0.105	0.109	0.111	0.111
F-stat	5.907	6.078	6.272	6.393	6.413
Prob(F-stat)	0.000	0.000	0.000	0.000	0.000
Obs	174	174	174	174	174

Conclusions

- The commitment to create a market for trading emission permits on the part of the EU was credible.
  - This was not obvious ex-ante due to lack of international coordination
- The unilateral effort on the part of a block of countries to go ahead with an allowance market could have been destroyed by mistakes in determining supply.
  - The EU was able to reaffirm its commitment, even after empirical evidence showed the existence of a large oversupply of permits in Phase
  - Investors regarded that as a sort of unavoidable cost associated with learning the position of the permits demand curve.
- Possible extension of the model: imperfect competition in the output market.