Risk Aversion and Institutional Information Disclosure on the European Carbon Market: a Case-Study of the 2006 Compliance Event

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The EU Emissions Trading Scheme

A Few Facts:

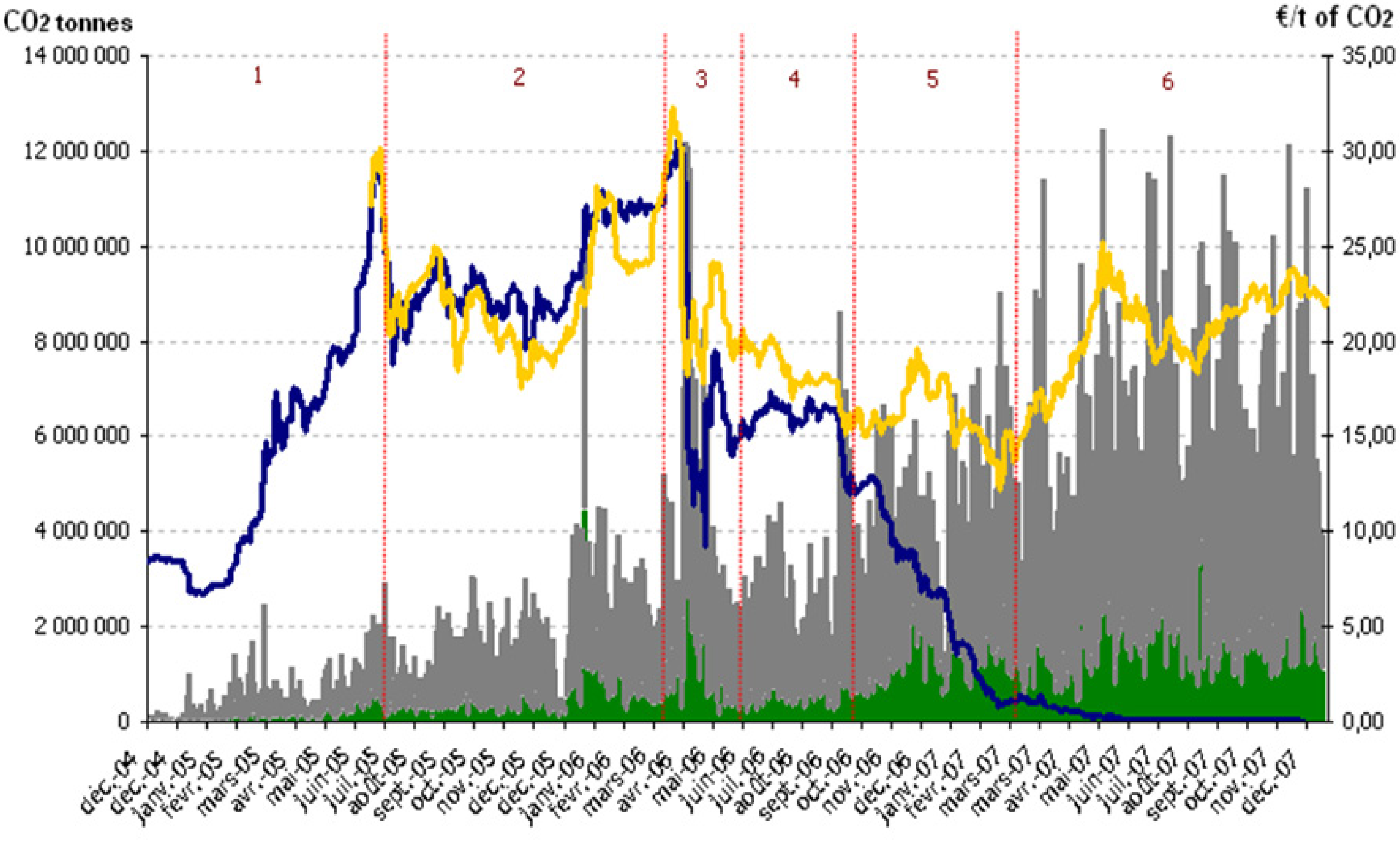
- created by the European Commission on January 1, 2005; Phase I (2005-07); Phase II (2008-12); Phase III (2013-20);
- covers up to 46% of CO_2 emissions from European energy-intensive industries;
- 2.2 billion of allowances were allocated to 10,600 installations across 27 EU Member States in 2005-07;
- one EU allowance (EUA) is equal to one ton of CO_2 emitted in the atmosphere;
- volume of transaction has been increasing steadily from 262 million tons in 2005 to 1,443 million tons in 2007;
- high spot price volatility during 2005-07; current medium-term price signal around €20 per ton;
- various European-based market places for spot, futures and derivatives prices.

The EU Emissions Trading Scheme (ctd.)

Yearly Compliance Events:

- Installations need to report by the end of March their verified emissions that occurred during the preceding year;
- the information becomes publicly available when the EC officially publishes its report by mid-May;
- 2005 compliance period: CO_2 emissions *lower* than allocated allowances;
- 2006 compliance period: CO_2 emissions *lower* than allocated allowances;
- 2007 compliance period: CO_2 emissions *lower* than allocated allowances (94% of emissions reported as of 04/04/08).

EUA Price Development

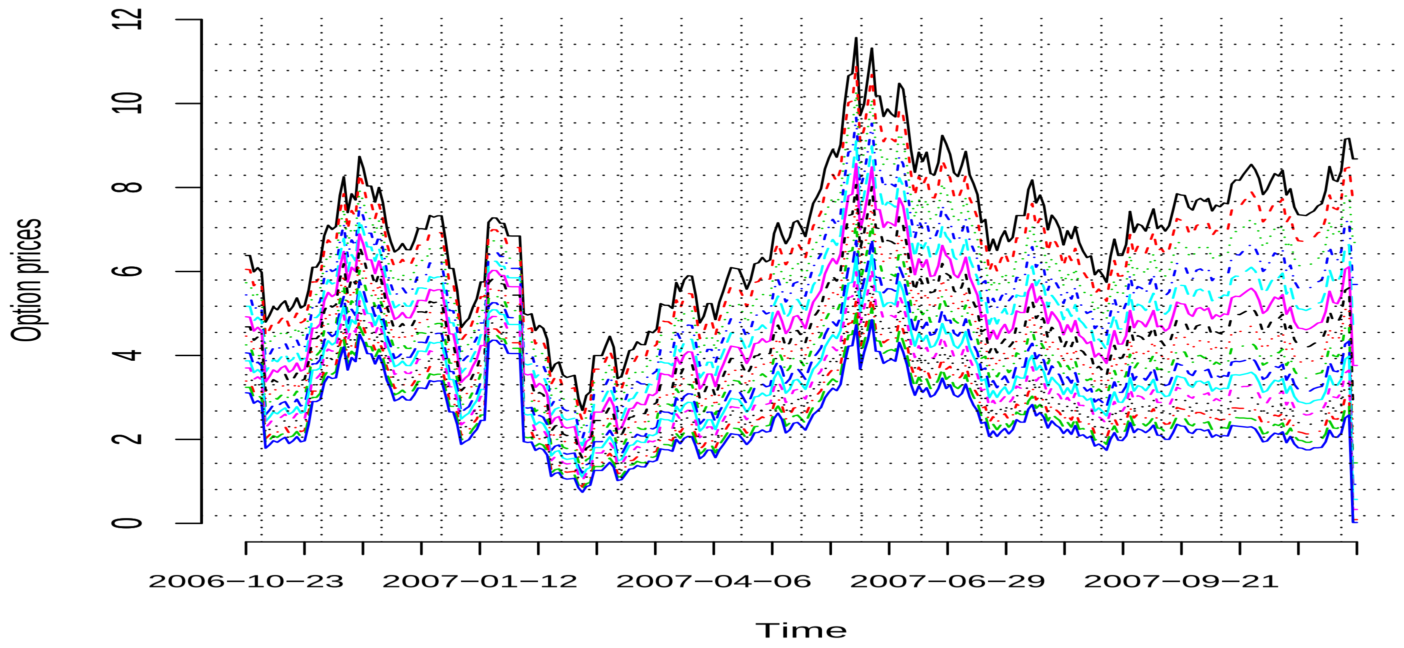


The 2006 Compliance Event

- Used as the cornerstone of another major change in investors' risk aversion;
- Lower effects on April 2007 compared to the magnitude of EUA price changes on April 2006: expectation building is becoming more efficient;
- We expect strong reversals in investors' anticipations; decrease in the level of volatility *after* the diffusion of information by the EC.

Recently Introduced Carbon Based Assets

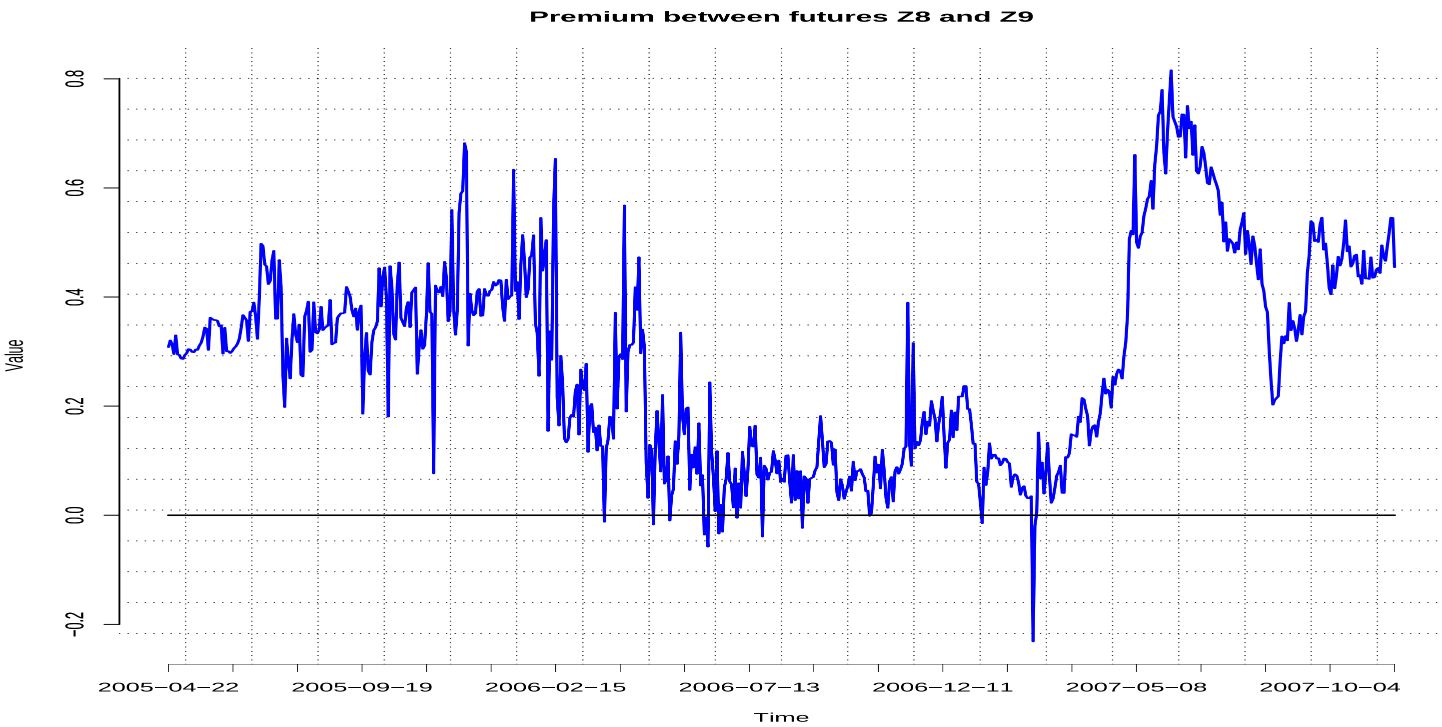
- Until recently: only spot and futures;
- Since October 2006: European options based on first and second period prices on the European Climate Exchange (ECX).



EUA Spot-Futures Parity

- ECX is a commodity market;
- *Cash and carry* rationale linking futures and spot prices does not hold:

$$S_t \neq F(t,T)e^{-r(T-t)} \quad (1)$$



Measuring Risk Aversion Using Option & Future Prices

The main relation: Leland (1980)

$$\boxed{\text{Risk Neutral Distribution} = \text{Historical Distribution} \times \text{Risk Aversion correction}} \quad (2)$$

- Relation is model free (utility based derivation);
- Extensively used in equity based literature: Jackwerth (2000), Rosenberg & Engle (2002), Ait Sahalia & Lo (2000) for the main contributions;
- Here: we are interested in the risk aversion.

We derive the RA from option and future prices: obtain the risk aversion as a by-product.

A Brief Review of the Empirical Literature

Estimation Strategies for the RN and Historical Distributions:

1. Non Parametric:

   - Ait Sahalia & Lo (1998, 2000) and Jackwerth (2000);
   - Use the link between IV and RN distribution;
   - Based on a Nadaraya Watson non parametric estimator for implied volatility for the $\mathbb{Q}$ measure;
   - Non parametric estimator for the historical distribution.

2. Semi Parametric:

   - Rosenberg & Engle (2002), Barone-Adesi, Engle & Macini (2008);
   - Use a GARCH model under the $\mathbb{P}$ measure;
   - Use a polynomial for the pricing kernel.

Data

Future Prices

- Contracts of Maturities December 2008 and December 2009;
- Traded on a daily basis from October 1, 2006 to November 23, 2007.

Option prices

- Plain vanilla option closing prices in €;
- Contracts of Maturities December 2008 and December 2009;
- Traded on a daily basis from October 1, 2006 to November 23, 2007.

	Strikes	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**
Z8	**Call**	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285
	Put	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285
	Total	570	570	570	570	570	570	570	570	570	570	570	570	570	570	570
	Strikes	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Z9	**Call**	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247
	Put	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247
	Total	494	494	494	494	494	494	494	494	494	494	494	494	494	494	494

Data (ctd.)

- Samples #1 and #2 have been split on April 30, 2007 , *i.e.* at the time where the EC issued its official report for the 2006 compliance result;

- We identify our two subsamples as being ”October 1, 2006 - April 30, 2007” and ”May 1, 2007 - November 23, 2007”;

- We work with an average time to maturity of $\tau = 1.3$ on annual basis in our dataset (same time to maturity for both sub-samples);

- Unlike RE (2002) and Jackwerth (2000), we use longer term option prices with a 16-month investor horizon;

- We only consider options of moneyness included between [0.5;1.5] to remove unreliable observations characterized by a low volume and a low sensitivity to volatility.

Our Strategy

Our Aim:

- Estimate the level of risk aversion *before* the information disclosure;
- Estimate the level of risk aversion *after* the information disclosure;
- Finally: compare both estimated levels across states.

We are interested in comparing the average risk aversion over both samples.

Estimation strategy:

- Nadaraya Watson estimator of the RN distribution (Ait Sahalia & Lo (1998)), maturity by maturity;
- A semi parametric asymmetric GARCH model for the $\mathbb{P}$ distribution (RE (2002), BAEM (2008)).

The Historical Distribution Estimation

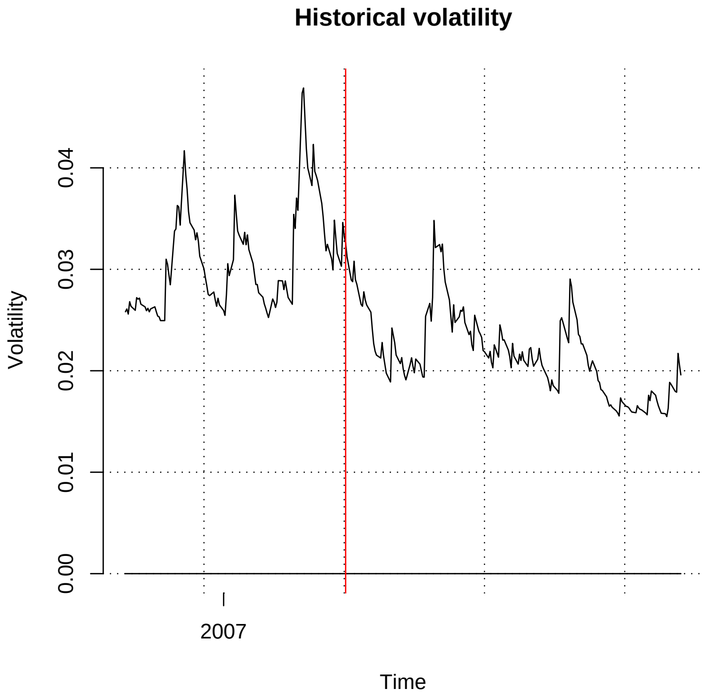
The model:

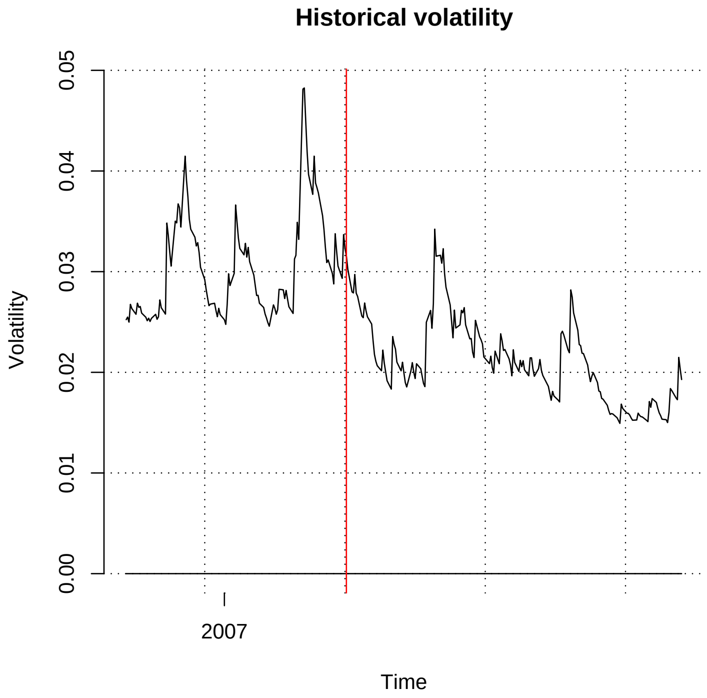
$$\begin{cases} r_t = \mu + \sigma_t \epsilon_t \\ \sigma_t^2 = \omega_0 + \omega_1 I_t + \alpha(r_{t-1} - \mu)^2 + \beta\sigma_{t-1}^2 + \delta \max(0, -(r_{t-1} - \mu))^2 \\ \epsilon_t \sim N(0, 1), \end{cases}$$

Estimation results:

		ω_0	ω_1	α	β	δ	μ	**Log-likelihood**
ARCH(1)	Estimate	0,079	-0,033	0,088	-	-	0,129	-666,097
	t-Stat.	6,074	-2,261	12,054	-	-	6,036	0,000
GARCH(1,1)	Estimate	0,010	-0,006	0,102	0,812	-	0,150	-659,105
	t-Stat.	3,552	-5,336	54,798	152,358	-	8,159	0,000
GJR-GARCH(1,1)	Estimate	0,009	-0,006	0,128	0,823	-0,061	0,181	-658,519
	t-Stat.	3,799	-5,859	39,471	164,938	-18,046	9,416	0,000

The Historical Distribution Estimation (ctd.)





The RN Distribution Estimation

Following Breeden & Litzenberger (1978), we have:

$$\frac{\partial^2 C(\tau, K)}{\partial K^2} = e^{-r(T-t)}\, q(S_T|S_T = K). \tag{3}$$

When $\sigma(K)$ is a function of the strike that is twice differentiable, using the Black-Scholes model:

$$q(S_\tau|S_\tau = K) = \left(\frac{1}{\sigma(K)K\sqrt{\tau}} + \left(\frac{2d_1}{\sigma(K)} \right) \frac{\partial \sigma}{\partial K} + \left(\frac{d_1 d_2 K \sqrt{\tau}}{\sigma} \right) \left(\frac{\partial \sigma}{\partial K} \right)^2 + K\sqrt{\tau} \frac{\partial^2 \sigma}{\partial K^2} \right) N(d_1) \tag{4}$$

The RN Distribution Estimation (ctd.)

All is required now: an estimator for implied volatilities.

Following Ait Sahalia and Lo (1998), we use a Nadaraya-Watson estimator

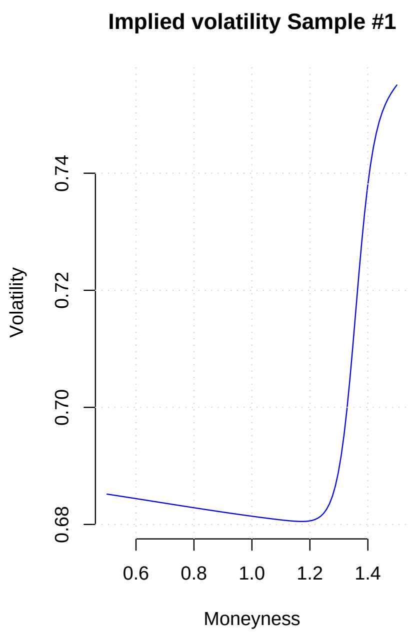
$$\sigma(k,\tau) = \frac{\sum_{i,j} K\left(\frac{\tau-\tau_i}{h_1}\right)\ K\left(\frac{k-k_j}{h_2}\right)\ \sigma(\tau_i,k_j)}{\sum_{i,j} K\left(\frac{\tau-\tau_i}{h_1}\right)\ K\left(\frac{k-k_j}{h_2}\right)} \tag{5}$$

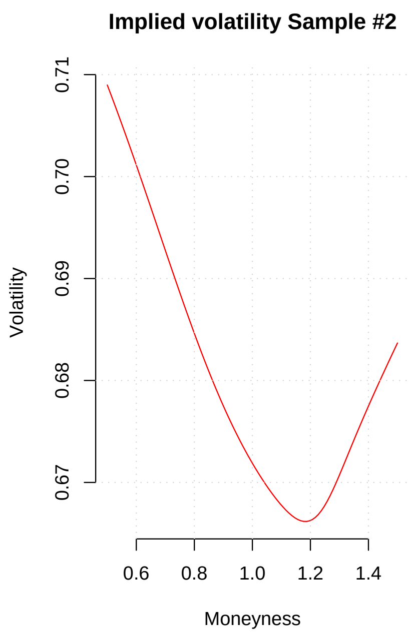
with

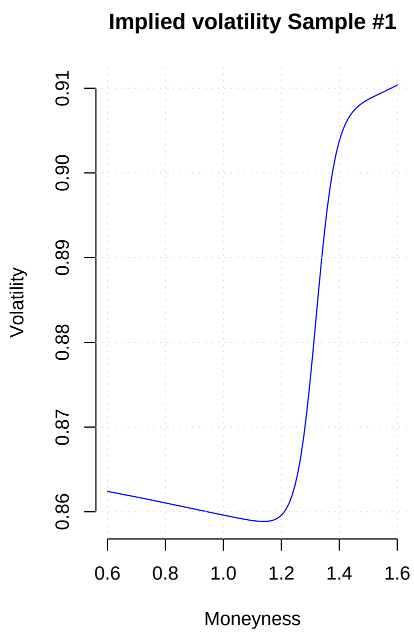
$$K(x) = \frac{1}{\sqrt{2\pi}}\, e^{-\frac{1}{2}x^2} \tag{6}$$

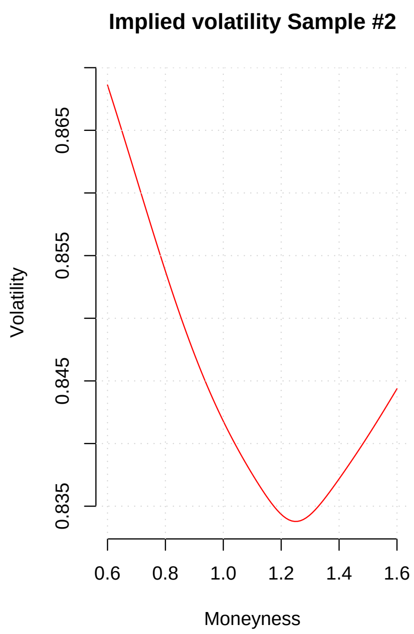
h_1 and h_2 are smoothing parameters. Selected so that we minimize the option pricing error.

The RN Distribution Estimation (ctd.)

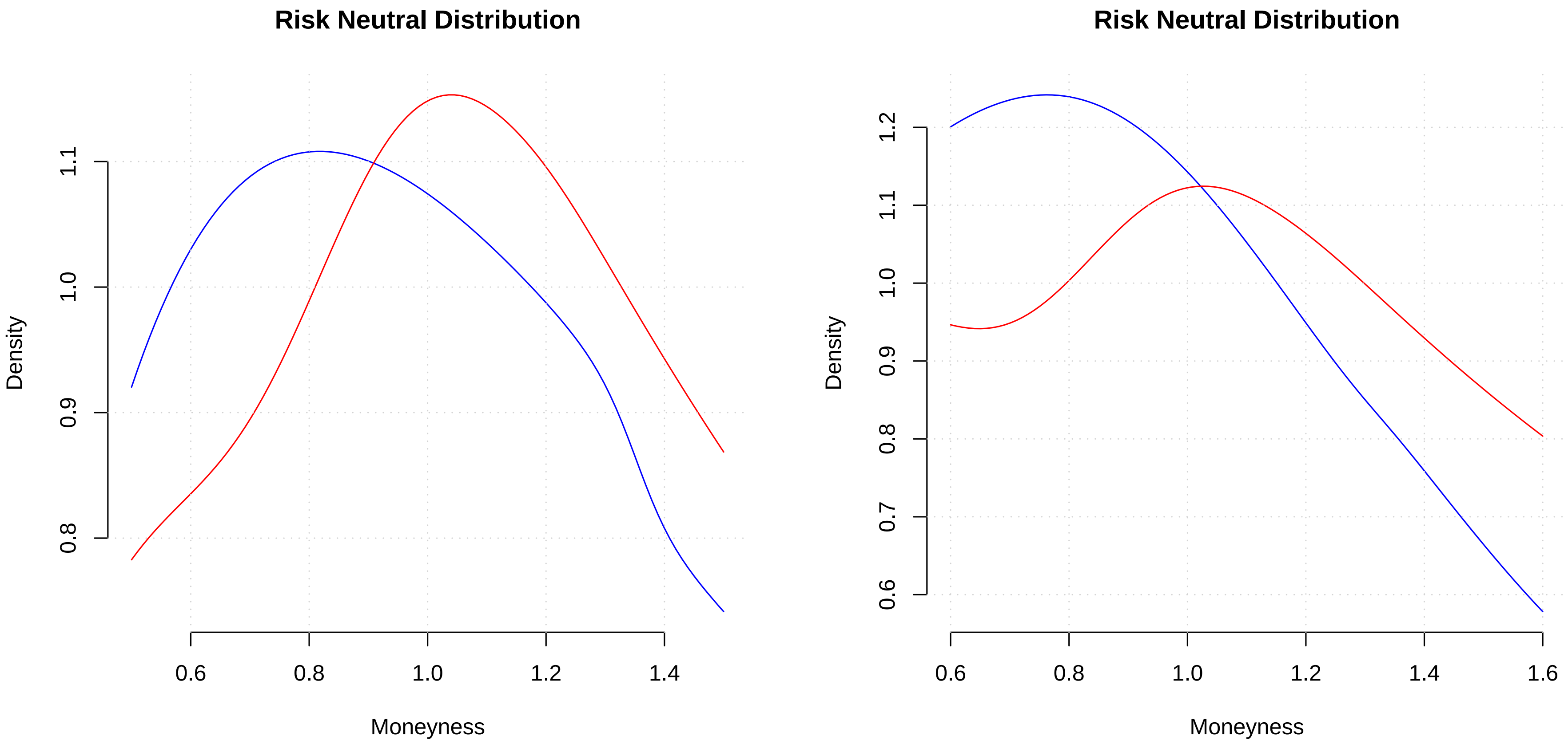








The RN Distribution Estimation (ctd.)



Empirical conclusions

<u>The information disclosure:</u>

1. Lowered the historical volatility;

2. Lowered the average implied volatility;

3. Changed the skew of implied volatilities;

4. Changed the skewness of the risk neutral distribution.

Now: what about risk aversion?

Risk Aversion Estimation

From the previous estimation, we are able to deduce the empirical pricing kernel:

$$PK(S_T|S_T = K) = \frac{d\mathbb{Q}_T}{d\mathbb{P}_T} \tag{7}$$

$$= \frac{q(S_T|S_T = K)}{p(S_T|S_T = K)} \tag{8}$$

From the EPK, the risk aversion is computed as:

$$-\partial_S \log PK(S_T|S_T = K) = RA(S_T|S_T = K) \tag{9}$$

where $RA(.)$ is the Arrow-Pratt absolute risk aversion measure.

Thus:

$$\boxed{RA(S_T|S_T = K) = \frac{p'(S_T|S_T = K)}{p(S_T|S_T = K)} - \frac{q'(S_T|S_T = K)}{q(S_T|S_T = K)}} \tag{10}$$

The pricing kernel in the Black Scholes economy

In a BS (1973) economy (linear discretization)

– Under $\mathbb{P}$, returns are $N(\mu\Delta, \sigma\sqrt{\Delta})$

– Under $\mathbb{Q}$, returns are $N(r\Delta, \sigma\sqrt{\Delta})$

$\Rightarrow$ The Radon-Nikodym – aka *Pricing Kernel* – derivative is

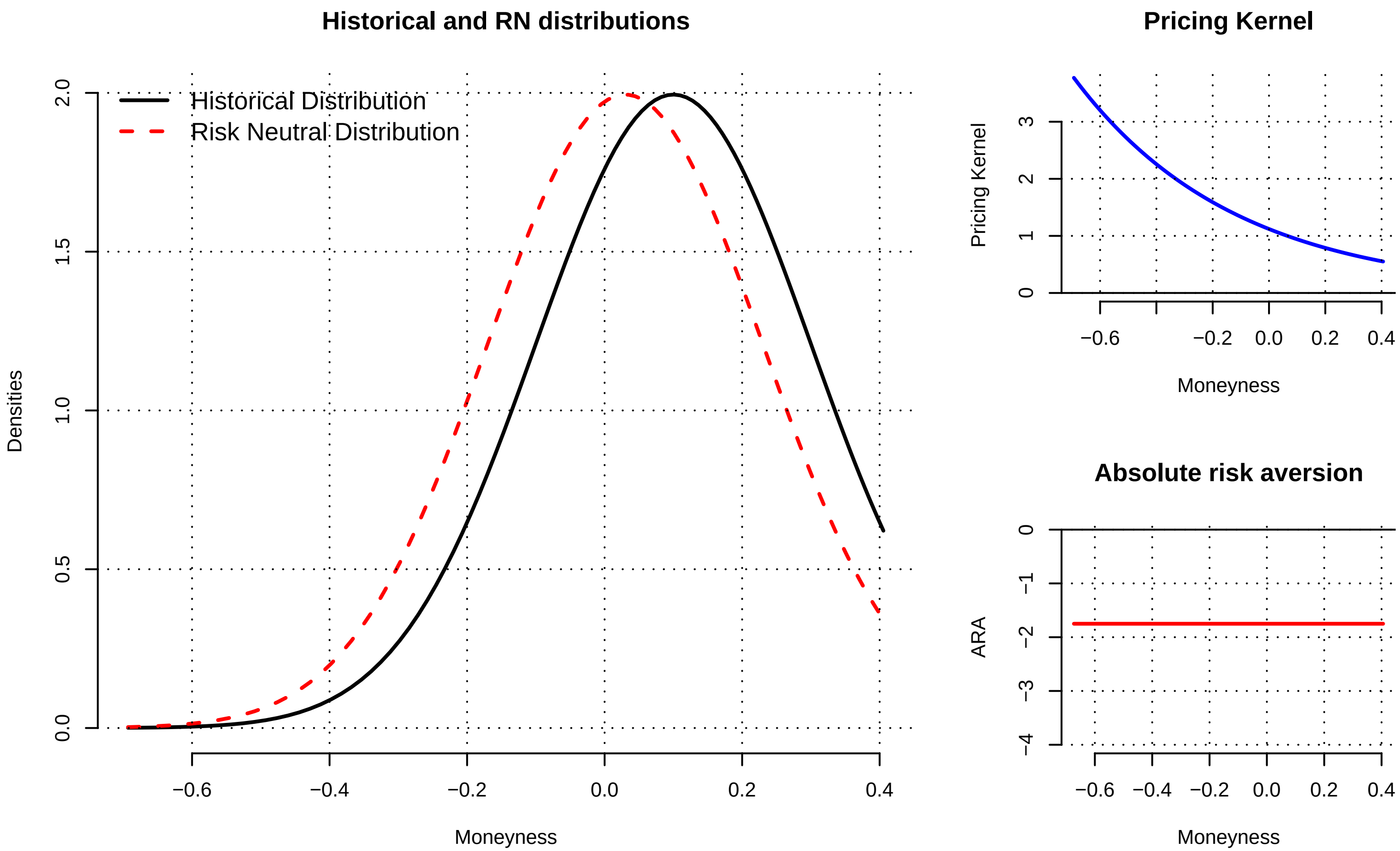
$$\frac{d\mathbb{Q}}{d\mathbb{P}} = e^{A(t,T)+B(t,T)\log\frac{S_T}{S_t}}$$

1. Exponential affine $\sim$ exponential utility function

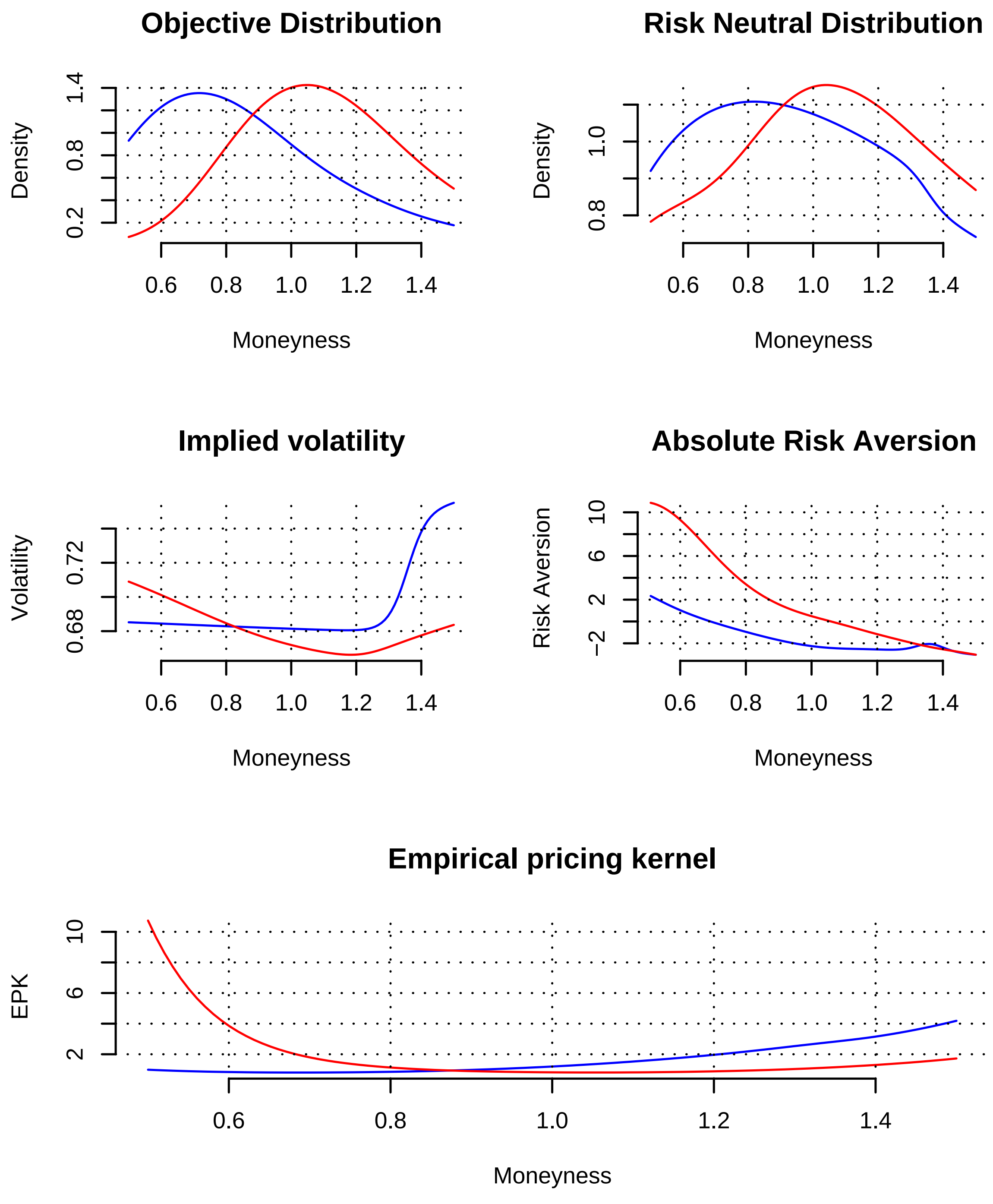
2. Implicit assumption on the slope of the risk aversion.

3. A distance measure between historical and risk neutral distribution

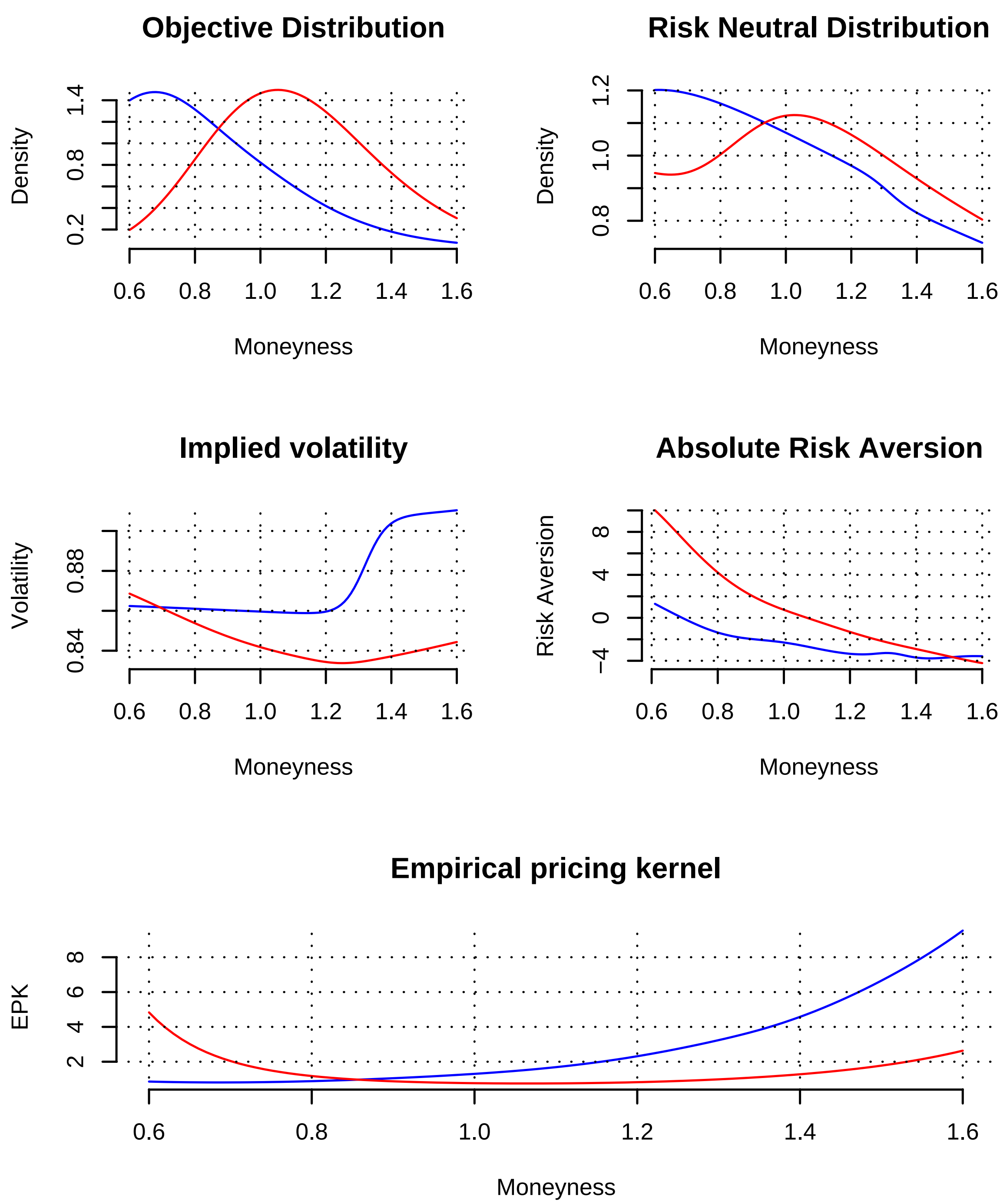
The pricing kernel in the Black Scholes economy



Risk Aversion estimation (ctd.)



Risk Aversion estimation (ctd.)



Conclusions and Future Work

Ok, we have a change in the average risk aversion in the market fostered by the information disclosure... but:

- Is it significant? (confidence interval...)
- Will this effect be stable through time? (what if the EC communicates on a quarterly basis)
- Is the compliance event the main market mover information? (other event studies)
- ...

Thanks for your attention