Revisiting the relationship between spot and futures prices in the Nord Pool electricity market

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The relationship between spot and futures prices is often analyzed by using **risk premium**:

$$rp_{t,T} = \ln(\frac{E_t(S_{t+T})}{F_{t,T}}) \approx \ln(\frac{S_{t+T}}{F_{t,T}})$$

- Many different names and definitions functioning in the literature (*forward premium, forward bias,* …)

- Discussion whether observed differences between spot and futures prices are really price of the risk or rather the result of market inefficiency (Gjolberg and Brattested, 2011)

- Theoretical model proposed by Bessembinder and Lemon (2002), underlining the effect of variance and skewness of the spot price

- Mixed empirical evidence (e.g. Longstaff and Wang, 2004 vs Haugom and Ullrich, 2012)

- Other factors play an important role, e.g. gas availability (Douglas and Popova, 2008), gas and coal prices (Bunn and Chen, 2013)

- For the Nord Pool market, variables connected to the state of the water system seem to play a role (Torro, 2009; Weron, 2008; Botterud, Kristiansen and Ilic, 2010)

Botterud, Kristiansen and Ilic (*Energy Economics 32, 2010)* analyze the behavior of the risk premium in the Nord Pool market.

They estimate the regression model for 1996-2006 weekly data and get:

$$RP_{t,T} = \alpha_0 + \alpha_1 RES_t + \alpha_2 INFD_{t,T} + \alpha_3 CONSD_{t,T} + \alpha_4 S_t + \alpha_5 VAR_t + \alpha_6 SKEW_t + \epsilon_t$$

	Intercept	Reservoir level	Inflow deviation	Cons. deviation	Spot price	Variance of spot price	Skewness of spot price
1 Week RP	0.062**	-0.53**	-0.19**	0.73**	-0.19**	-1.40*	-1.14
6 Weeks RP	0.21**	-1.79**	-0.18**	0.81**	-0.71**	0.28	-0.27

Botterud et al. claim that the negative relationship is consistent with the theory:

„For instance, the demand for futures contracts is likely to be higher when reservoir levels are low, since this increases the likelihood of price spikes in the spot market. Hence, there should be a negative relationship between risk premium and reservoir levels.”

However, the last sentence should be the opposite.

$$rp_{t,T} = \ln(\frac{E_t(S_{t+T})}{F_{t,T}})$$

How come they get significant results?

Simultaneity problem

- In the OLS regression we need the variables to be exogenous. Here, however, one of the regressors (spot price) is determined at the same time as futures price - a part of the dependent variable (risk premium)
- All estimated coefficient may be therefore inconsistent
- This may, but does not have to be a problem
- Not much we can do – it's hard to come up with an convincing instrument

Correlated measurement errors

Since we replace ex-ante risk premium with a realized one, we introduce some measurement error in dependent variable (y).

Since we use realized deviation of consumption and inflow instead of forecasts of market participants, we introduce some measurement error in regressors (z):

$$y = y^* + d,$$

$$z = z^* + e.$$

These errors are correlated!

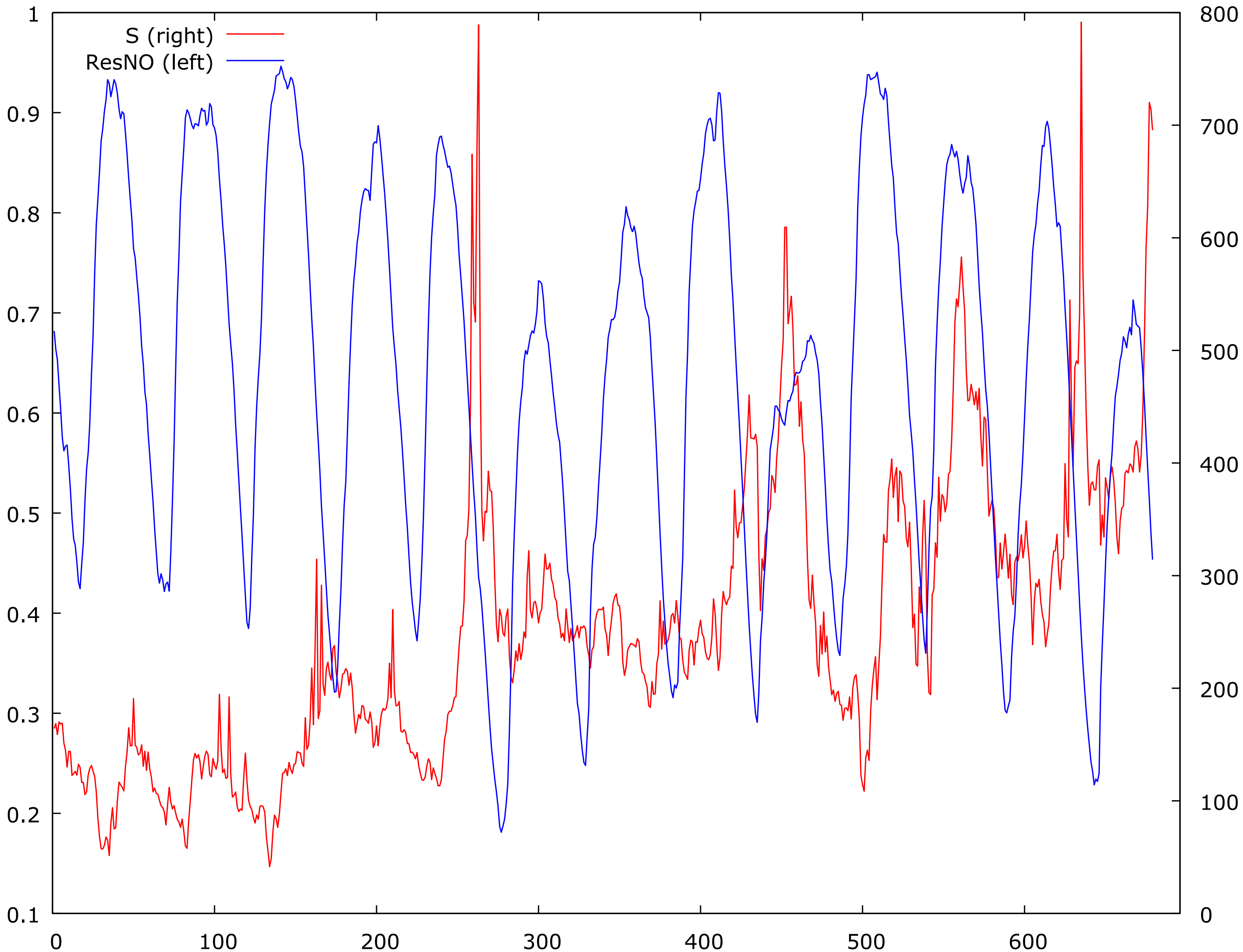
Correlated measurement errors

In such a case the OLS estimates do not converge to their true value from ex-ante risk premium model. I derive a probability limit for the coefficients:

$$\hat{\beta}_n \underset{p}{\rightarrow} \beta + \frac{Cov(\mathbf{X}, v_{W|Z})}{Var(v_{X|Z})} = \beta + \frac{Cov(\mathbf{X}, W - Z\frac{Cov(Z,W)}{Var(Z)})}{Var(v_{X|Z})} =$$

$$= \beta + \frac{-Cov(\mathbf{X}, Z) \cdot (Cov(e, d) + \theta Var(e))}{Var(Z) \cdot Var(v_{X|Z})}.$$

The sign of the bias is unknown and depends on the correlations in the data.


S (right)
ResNO (left)
1
0.9
0.8
0.7
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0.4
0.3
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800
700
600
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400
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200
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100
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400
500
600

Seasonality

Two regressors in the model have clear seasonal pattern: water level and spot price.

We may express these variables as a sum of seasonal and stochastic component (s, d).

$$X = X^S + X^D,$$
$$W = W^S + W^D,$$

The coefficient of X/W in the regression is not the same as the coefficients one would get by including stochastic and seasonal parts separately.

Seasonality

$$\hat{\beta}_n = \frac{(Var(W^S) + Var(W^D))Cov(X^D, Y)}{Var(X)Var(W)(1 - r^2_{X,W})} - \frac{[Cov(X^D, W^D) + Cov(X^S, W^S)]Cov(W^D, Y)}{Var(X)Var(W)(1 - r^2_{X,W})},$$

$$\hat{\theta}_n = \frac{(Var(X^S) + Var(X^D))Cov(W^D, Y)}{Var(X)Var(W)(1 - r^2_{X,W})} - \frac{[Cov(X^D, W^D) + Cov(X^S, W^S)]Cov(X^D, Y)}{Var(X)Var(W)(1 - r^2_{X,W})}.$$

The value of coefficients is influenced by the covariance of the seasonal components and the seasonal component of water level captures the impact of numerous different effects, e.g. the demand.

Our results

$$\mathrm{RP}_{t,T} = \beta_1 + \beta_2\mathrm{RESD}_t + \beta_3\mathrm{RESM}_t + \beta_4\mathrm{INFD}_t + \beta_5\mathrm{CONSD}_t + \beta_6\mathrm{VAR}_t + \beta_7\mathrm{SKEW}_t + \beta_8 S_t + u_t$$

T	Const.	RESD_t	RESM_t	INFD_t ($\times 10^5$)	CONSD_t ($\times 10^5$)	VAR_t ($\times 10^4$)	SKEW_t	S_t ($\times 10^4$)
				Model 1				
1W	0.077*** (0.000)	0.042 (0.288)	−0.050*** (0.000)	−0.672*** (0.005)	1.853 (0.114)	−2.833* (0.065)	0.021 (0.812)	−1.019** (0.012)
3W	0.071** (0.023)	0.044 (0.722)	−0.060 (0.134)	−1.214* (0.055)	5.596* (0.942)	1.362 (0.835)	0.205 (0.405)	−1.795 (0.132)
6W	0.076 (0.143)	0.007 (0.977)	−0.052 (0.433)	−0.829 (0.388)	12.662** 0.017)	−1.376 (0.777)	0.519 (0.140)	−2.823 (0.119)
				Model 2				
1W	0.052*** (0.000)	0.134*** (0.002)	−0.046*** (0.000)	−0.651*** 0.007)	1.128 (0.329)	−2.796* (0.062)	−0.003 (0.969)	–
3W	0.027 (0.256)	0.206 (0.119)	−0.053 (0.202)	−1.176* (0.065)	4.320 (0.197)	1.427 (0.824)	0.163 (0.500)	–
6W	0.007** (0.854)	0.262 (0.241)	−0.041 (0.551)	−0.770 (0.420)	10.654** (0.037)	−1.273 (0.789)	−0.453 (0.187)	–

However, the ARCH effect is present.

Our results – GARCH(1,1)

T	Const.	$RESD_t$	$RESM_t$	$INFD_t$ ($\times 10^5$)	$CONSD_t$ ($\times 10^5$)	VAR_t ($\times 10^4$)	$SKEW_t$	S_t ($\times 10^4$)
				Model 3				
1W	0.071*** (0.000)	0.041 (0.311)	−0.043*** (0.000)	−0.463** (0.023)	1.931 (0.115)	−0.087 (0.980)	0.056 (0.706)	−0.773*** (0.004)
2W	0.071*** (0.000)	0.109** (0.046)	−0.052** (0.025)	−0.649** (0.019)	2.215 (0.200)	−10.241*** (0.002)	0.156 (0.275)	−1.305** (0.015)
3W	0.096*** (0.021)	0.087 (0.234)	−0.127*** (0.000)	−0.341 (0.298)	4.220* (0.065)	4.712 (0.218)	−0.082 (0.622)	−1.003 (0.198)
4W	0.095*** (0.000)	0.177** (0.035)	−0.165*** (0.000)	−0.338 (0.376)	4.923** (0.029)	4.605 (0.281)	−0.319 (0.105)	−0.271 (0.737)
5W	0.155*** (0.000)	0.192* (0.096)	−0.254*** (0.000)	0.636 (0.222)	6.323** (0.018)	−5.758 (0.346)	0.337 (0.146)	−0.470 (0.704)
6W	0.126*** (0.001)	0.245 (0.104)	−0.221*** (0.000)	0.616 (0.196)	6.087** (0.031)	−1.103 (0.759)	0.252 (0.316)	−0.388 (0.729)
				Model 4				
1W	0.052*** (0.000)	0.104*** (0.004)	−0.041** (0.010)	−0.426*** 0.032)	1.676 (0.142)	0.167 (0.960)	0.057 (0.697)	–
2W	0.047*** (0.001)	0.190*** (0.000)	−0.059*** (0.008)	−0.601** 0.022)	1.739 (0.305)	−10.045 (0.004)	0.126 (0.384)	–
3W	0.078*** (0.000)	0.150** (0.033)	−0.133*** (0.000)	−0.314 0.324)	4.178 (0.078)	4.366 (0.250)	−0.108 (0.522)	–
4W	0.091*** (0.000)	0.194** (0.016)	−0.168*** (0.000)	−0.323 0.402)	4.914** (0.030)	4.566 (0.288)	−0.324* (0.093)	–
5W	0.147*** (0.000)	0.213 (0.125)	−0.258*** (0.000)	0.656 0.211)	6.270** (0.022)	−6.014 (0.352)	0.341 (0.134)	–
6W	0.118*** (0.000)	0.267 (0.109)	−0.223*** (0.000)	0.636 0.169)	5.951** (0.040)	−1.236 (0.724)	0.239 (0.334)	–

Convenience yield

T	Const	$RESD_t$	$RESM_t$	$INFD_T$ $\times 10^{-5}$	$CONSD_T$ $\times 10^{-5}$	VAR_t $\times 10^{-4}$	$SKEW_t$	S_t $\times 10^{-4}$
				Model 5				
1W	0.067*** (0.000)	0.094* (0.055)	−0.090*** (0.000)	1.376*** (0.000)	−8.804*** (0.000)	17.374*** (0.000)	0.285*** (0.002)	0.781** (0.015)
3W	0.090*** (0.000)	0.056 (0.366)	−0.162*** (0.000)	0.564*** (0.001)	−4.035*** (0.000)	18.818*** (0.000)	0.431*** (0.000)	0.920 (0.047)
6W	0.183*** (0.000)	−0.146 (0.159)	−0.420*** (0.000)	0.216 (0.136)	−4.613 (0.590)	25.208*** (0.000)	0.860*** (0.000)	2.575** (0.015)
				Model 7				
1W	0.075*** (0.000)	−0.001 (0.992)	−0.095*** (0.000)	1.036*** (0.000)	−6.163*** (0.000)	18.947*** (0.000)	0.312*** (0.005)	0.561** (0.042)
3W	0.102*** (0.000)	−0.007 (0.917)	−0.206*** (0.000)	0.346*** (0.003)	−0.9222 (0.167)	22.290*** (0.000)	0.630*** (0.000)	1.099** (0.040)
6W	0.161*** (0.000)	−0.118 (0.227)	−0.327*** (0.000)	0.243*** (0.009)	−0.258 (0.745)	31.630*** (0.000)	1.008*** (0.000)	1.319** (0.030)

The storage cost theory may be true, but is less unambigously supported by the data than claimed by Botterud et. al. (2010).

Contribution of our paper:

- The relationship of water level and risk premium is actually positive, which is to be expected but contradicts the results of Botterud et al. (2010).
- This is confirmed with newer, longer dataset and new approach (GARCH).
- OLS may be inconsistent in the context of risk premium and electricity markets. The problem of mistaking the coincidence of seasonal pattern with a real causal relationship may be of broader use.

Thank you!

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Working paper is available at Repec.org:
„*Revisiting the relationship between spot and futures prices in the Nord Pool electricity market*"; Rafał Weron, Michał Zator

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