THE RELATIONSHIP BETWEEN DAY-AHEAD AND FUTURES PRICES IN ELECTRICITY MARKET: AN EMPIRICAL ANALYSIS ON ITALY, FRANCE, GERMANY AND SWITZERLAND

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Outline

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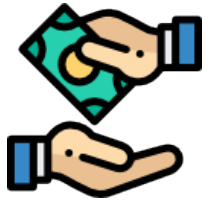
1.1 Introduction

The limited storability of electricity means that the **classic approach** used for financial **forward evaluation**, i.e. **non-arbitrage condition**, **and** the classical concepts of **convenience yield and cost of carry**, that usually explain the relationship between spot and future prices in the commodity market, **loose their meaning here**.

According to the **hedging pressure approach**, the **forward price** of a certain asset can be read as the **sum** of the **expected spot price** on that asset **and** the **risk premium** (RP). The RP is paid by the risk-averse operator in order to transfer the price risk to the counterparty. Both electricity producers and buyers may be interested in incurring an additional cost to cover themselves from price risk.

RP > 0,
Buyers are more **risk averse**

RP < 0,
Sellers are more **risk averse**



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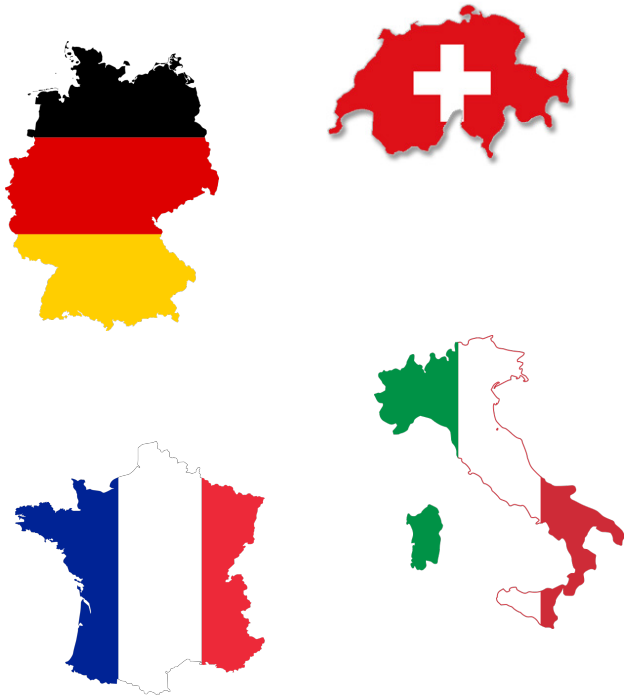
1.2 Aim of the study

Analyze the RP in four large European markets: Italy, Germany, France and Switzerland

Quantify and evaluate the **RP** for **monthly, quarterly, yearly** (**base-load** and **peak-load**) **futures contracts** exchanged in these markets in the last decade:

- **whether** and **how** the **futures prices** have **converged or not to** the **realized average spot prices**;
- **if and by how much** the **RP depended on the length of the trading period and the delivery duration**;
- **if a change in the sign of the RP is observed** when **comparing** the **beginning and the end** of the **trade period**.



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2.1 Data

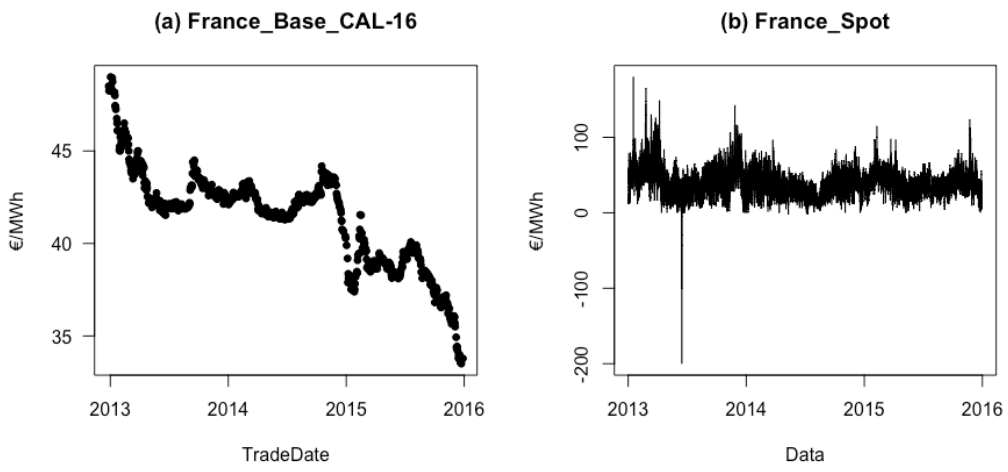
Time series considered starts **from** the beginning of **2010 to** the **end of 2019**

FUTURES CONTRACTS

We consider daily **base-load** and **peak-load** futures quotations at the daily settlement prices of futures exchanged at **EEX**.
Final dataset is composed by **166.526 observation**:
141 monthly, 45 quarterly and 10 yearly contracts for Italy;
196 monthly, 64 quarterly and 16 yearly contracts for France;
257 monthly, 89 quarterly and 21 yearly contracts for Germany;
72 monthly, 20 quarterly and 5 yearly contracts for Switzerland.

DAY-AHEAD PRICES

Day-ahead time series contains **374.783 hourly observations** for Italy, France, Germany and Switzerland.



An example of typical paths of futures prices of a given product compared to spot prices.
Different features emerged: electricity futures prices shows a lower volatility, no mean-reverting process and an absence of spikes compared to spot ones. On the contrary, the spot prices exhibit a clear mean-reverting behavior.

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2.2 Method
Risk Premium ex-post

We used ***ex post* RP approach** that has the advantage to give certain results.
Important feature: is that it is computed only at maturity when the spot price of the underlying asset is known.

One specific product

RP *Ex post* **=** **Futures prices** **-** **Arithmetic mean of spot prices verified within all the delivery period**

We computed the **risk premium for each of 936 traded futures contracts**

1. start from hourly day-ahead time series we computed both base-load and peak load daily average prices;
2. then, the average monthly, quarterly and yearly prices have been calculated to be used as the *ex-post* expected prices
3. Finally, the RP for each trading day *t* has then been calculated as:

$$RP_t^{j,f,k} = F_t^{j,f,k} - \bar{S}^{j,f,k}$$

- $RP_t^{j,f,k}$ → *the risk premium at time t, relative to country j (France, Switzerland, Italy and Germany), for a contract related to a product type k (base-load or peak-load), with a specific delivery period f;*
- $F_t^{j,f,k}$ → *is the daily settlement future price contracted at day t of the contract j ,f, k;*
- $\bar{S}^{j,f,k}$ → *is the mean of the daily spot prices verified in the delivery period of the contract j ,f, k.*

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2.3 Model
Empirical analysis

A **multivariate linear regression model** is performed with two explanatory variables:

1. trading days before the start of the delivery period (dur)
2. futures liquidity index (*liq*)

$$RP_t^{j,f,k} = \beta_0^{j,g,k} + \beta_1^{j,g,k} dur_t^f + \beta_2^{j,g,k} liq_t^{j,f,k} + \varepsilon_t^{j,f,k}$$

$RP_t^{j,f,k}$ → the risk premium as defined by the relation in the previous slide;

$\beta_0^{j,g,k}$ → the intercept that depends on country *j*, product type *k*, and periods *g*, i.e. monthly, quarterly and yearly periods;

$\beta_1^{j,g,k}$ → the coefficient monitoring the impact of the time to maturity, dur_t^f, which varies across delivery period *f*;

$\beta_2^{j,g,k}$ → measures the impact of market liquidity, $liq_t^{j,f,k}$, which is varying across country *j* (Italy, France, Germany and Switzerland), delivery period *f* and finally to the product type *k* (base-load or peak-load);

$\varepsilon_t^{j,f,k}$ → error term possibly serially correlated and/or heteroskedastic.

To summarize, all coefficients vary across country j, delivery periods g, and product type k.
This equation defines a set of linear relationships which we jointly estimate across values of j, g, and k.

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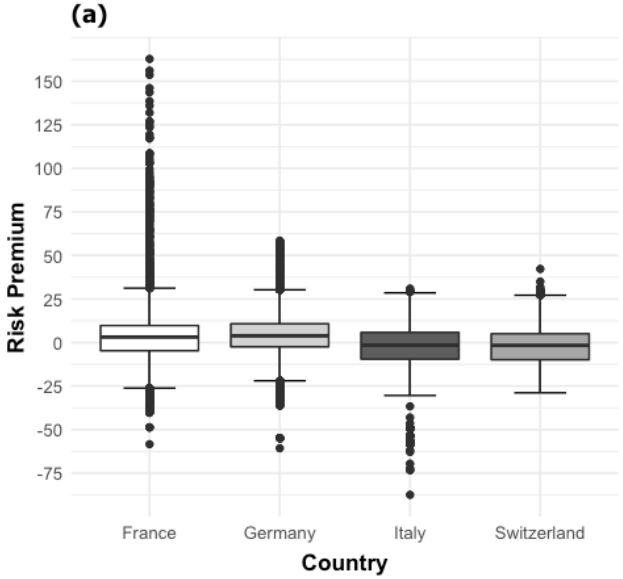
3.1 Results
RP descriptive statistics

RP is **caused** by the **hedging pressure**.
RP > 0 indicate a relatively **higher risk aversion of consumers**.
RP < 0 indicate a situation in which **producers' risk aversion is greater**.



(b)

	FR	DE	IT	CH
n	38981	83555	28833	8584
mean	2.61	4.41	-1.87	-2.13
sd	13.11	11.55	11.02	11.75
median	3.1	3.81	-1.54	-1.63
min	-58.39	-60.7	-87.46	-28.9
max	162.84	58.47	30.94	42.24
skew	0.76	0.26	-0.31	0.09
Excess kurtosis	7.44	1.2	0.96	-0.34

Plot (a) reports the boxplot representation of the RP computed for France, Germany, Italy and Switzerland. Note that there is not a clear convergence of futures prices to day-ahead ones, on average, in all countries considered. Indeed, in the figure, median values are positive or negative even if near to the zero.

Observing **table (b)** it emerges that in France and Germany RP were negative while in Italy and Switzerland the opposite is valid. The highest RP volatility has been recorded in France.

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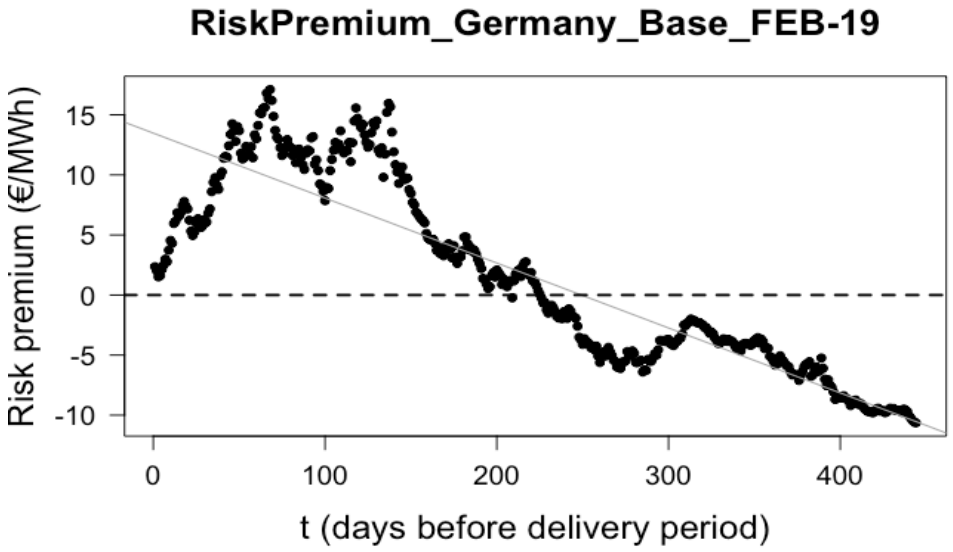
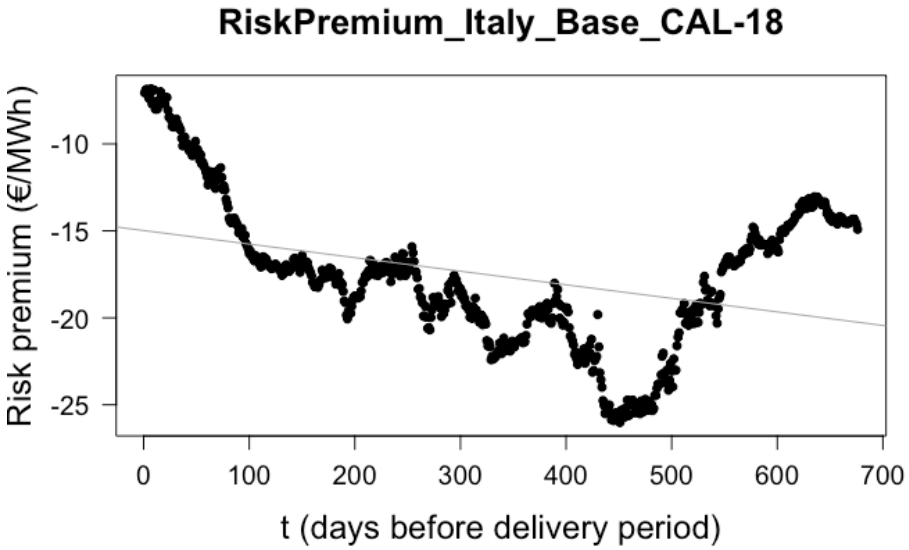
3.2 Results
Two examples of RP representation





RP on average has had a decreasing trend, i.e. a negative premium risk corresponds to more distant trading days, while as trading days approach the delivery period the premium rises, becoming positive about one year before delivery.

RP on average has been negative with a decreasing trend, i.e. lower premium risk corresponds to more distant trading days, while as trading days approach the delivery period the premium rises.

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3 Results

Regressors' table

- In the table there are the results of the estimation of the regression model presented before.
- The dependent variable is the daily RP.
- Robust standard errors are reported in parenthesis.
- Coefficients with p-values lower than 1%, 5% or 10% are highlighted with one (*), two (**) and three (***) asterisks, respectively.

		FR		DE		IT		CH	
		Base	Peak	Base	Peak	Base	Peak	Base	Peak
β_0	Monthly	2.446 ***	1.291 **	2.553 ***	2.538 ***	2.164 ***	-1.646 ***	1.116 ***	-
		(0.305)	(0.546)	(0.144)	(0.181)	(0.286)	(0.373)	(0.318)	-
	Quarterly	10.386 ***	6.330 ***	1.336 ***	0.729 ***	3.336 ***	2.492 ***	4.359 ***	-
		(0.283)	(0.432)	(0.192)	(0.237)	(0.313)	(0.474)	(0.498)	-
	Yearly	10.576 ***	10.164 ***	-1.039 ***	-7.949 ***	3.051 ***	-0.419	-11.399 ***	-
		(0.351)	(0.475)	(0.346)	(0.584)	(0.634)	(0.806)	(0.389)	-
β_1	Monthly	-0.002	0.079 ***	-0.009 ***	-0.005 **	-0.044 ***	0.026 ***	-0.064 ***	-
		(0.005)	(0.012)	(0.002)	(0.002)	(0.004)	(0.008)	(0.008)	-
	Quarterly	-0.046 ***	-0.017 ***	0.004 ***	0.014 ***	-0.034 ***	-0.031 ***	-0.049 ***	-
		(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	-
	Yearly	-0.018 ***	-0.012 ***	0.014 ***	0.026 ***	-0.029 ***	-0.031 ***	-0.022 ***	-
		(0.001)	(0.001)	(0.0004)	(0.001)	(0.002)	(0.003)	(0.001)	-
β_2	Monthly	0.0001 ***	0.003 ***	0.00000	-0.0001 ***	0.00000	0.001 ***	0.007 ***	-
		(0.00002)	(0.0003)	(0.00000)	(0.00002)	(0.00001)	(0.0001)	(0.001)	-
	Quarterly	-0.001 ***	-0.001 ***	0.00002 ***	0.0002 ***	-0.0001 ***	-0.001 **	-0.004 ***	-
		(0.00002)	(0.0003)	(0.00000)	(0.00003)	(0.00001)	(0.0003)	(0.001)	-
	Yearly	-0.002 ***	-0.011 ***	0.00000	0.002 ***	-0.0003 ***	0.004 ***	0.038 ***	-
		(0.00004)	(0.001)	(0.00001)	(0.0001)	(0.00005)	(0.001)	(0.001)	-
R2	*Monthly*	*0.006*	*0.014*	*0.003*	*0.001*	*0.022*	*0.023*	*0.097*	-
	Quarterly	*0.149*	*0.007*	*0.003*	*0.021*	*0.102*	*0.037*	*0.076*	-
	Yearly	*0.227*	*0.054*	*0.172*	*0.237*	*0.155*	*0.167*	*0.528*	-

INTERCEPT

DURATION

LIQUIDITY

DETERMINATION COEFFICIENTS

3.3.2 Results
intercept

		FR		DE		IT		CH	
		Base	Peak	Base	Peak	Base	Peak	Base	Peak
β_0	Monthly	2.446 ***	1.291 **	2.553 ***	2.538 ***	2.164 ***	-1.646 ***	1.116 ***	-
		(0.305)	(0.546)	(0.144)	(0.181)	(0.286)	(0.373)	(0.318)	-
	Quarterly	10.386 ***	6.330 ***	1.336 ***	0.729 ***	3.336 ***	2.492 ***	4.359 ***	-
		(0.283)	(0.432)	(0.192)	(0.237)	(0.313)	(0.474)	(0.498)	-
	Yearly	10.576 ***	10.164 ***	-1.039 ***	-7.949 ***	3.051 ***	-0.419	-11.399 ***	-
		(0.351)	(0.475)	(0.346)	(0.584)	(0.634)	(0.806)	(0.389)	-
β_1	Monthly	-0.002	0.079 ***	-0.009 ***	-0.005 **	-0.044 ***	0.026 ***	-0.064 ***	-
		(0.005)	(0.012)	(0.002)	(0.002)	(0.004)	(0.008)	(0.008)	-
	Quarterly	-0.046 ***	-0.017 ***	0.004 ***	0.014 ***	-0.034 ***	-0.031 ***	-0.049 ***	-
		(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	-
	Yearly	-0.018 ***	-0.012 ***	0.014 ***	0.026 ***	-0.029 ***	-0.031 ***	-0.022 ***	-
		(0.001)	(0.001)	(0.0004)	(0.001)	(0.002)	(0.003)	(0.001)	-
β_2	Monthly	0.0001 ***	0.003 ***	0.00000	-0.0001 ***	0.00000	0.001 ***	0.007 ***	-
		(0.00002)	(0.0003)	(0.00000)	(0.00002)	(0.00001)	(0.0001)	(0.001)	-
	Quarterly	-0.001 ***	-0.001 ***	0.00002 ***	0.0002 ***	-0.0001 ***	-0.001 **	-0.004 ***	-
		(0.00002)	(0.0003)	(0.00000)	(0.00003)	(0.00001)	(0.0003)	(0.001)	-
	Yearly	-0.002 ***	-0.011 ***	0.00000	0.002 ***	-0.0003 ***	0.004 ***	0.038 ***	-
		(0.00004)	(0.001)	(0.00001)	(0.0001)	(0.00005)	(0.001)	(0.001)	-
R2	*Monthly*	*0.006*	*0.014*	*0.003*	*0.001*	*0.022*	*0.023*	*0.097*	-
	Quarterly	*0.149*	*0.007*	*0.003*	*0.021*	*0.102*	*0.037*	*0.076*	-
	Yearly	*0.227*	*0.054*	*0.172*	*0.237*	*0.155*	*0.167*	*0.528*	-

- In FR the value increases as delivery period rises, both for base-load and peak-load contract.
- The opposite occurs in DE in which shorter maturity are associated with higher RP.
- For IT and CH, the highest values of RP are associated to quarterly products.
- There are negative premia for yearly DE products, yearly peak-load products and CH base-load products.

3.3.3 Results
duration

		FR		DE		IT		CH	
		Base	Peak	Base	Peak	Base	Peak	Base	Peak
β_0	Monthly	2.446 ***	1.291 **	2.553 ***	2.538 ***	2.164 ***	-1.646 ***	1.116 ***	-
		(0.305)	(0.546)	(0.144)	(0.181)	(0.286)	(0.373)	(0.318)	-
	Quarterly	10.386 ***	6.330 ***	1.336 ***	0.729 ***	3.336 ***	2.492 ***	4.359 ***	-
		(0.283)	(0.432)	(0.192)	(0.237)	(0.313)	(0.474)	(0.498)	-
	Yearly	10.576 ***	10.164 ***	-1.039 ***	-7.949 ***	3.051 ***	-0.419	-11.399 ***	-
		(0.351)	(0.475)	(0.346)	(0.584)	(0.634)	(0.806)	(0.389)	-
β_1	Monthly	-0.002	0.079 ***	-0.009 ***	-0.005 **	-0.044 ***	0.026 ***	-0.064 ***	-
		(0.005)	(0.012)	(0.002)	(0.002)	(0.004)	(0.008)	(0.008)	-
	Quarterly	-0.046 ***	-0.017 ***	0.004 ***	0.014 ***	-0.034 ***	-0.031 ***	-0.049 ***	-
		(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	-
	Yearly	-0.018 ***	-0.012 ***	0.014 ***	0.026 ***	-0.029 ***	-0.031 ***	-0.022 ***	-
		(0.001)	(0.001)	(0.0004)	(0.001)	(0.002)	(0.003)	(0.001)	-
β_2	Monthly	0.0001 ***	0.003 ***	0.00000	-0.0001 ***	0.00000	0.001 ***	0.007 ***	-
		(0.00002)	(0.0003)	(0.00000)	(0.00002)	(0.00001)	(0.0001)	(0.001)	-
	Quarterly	-0.001 ***	-0.001 ***	0.00002 ***	0.0002 ***	-0.0001 ***	-0.001 **	-0.004 ***	-
		(0.00002)	(0.0003)	(0.00000)	(0.00003)	(0.00001)	(0.0003)	(0.001)	-
	Yearly	-0.002 ***	-0.011 ***	0.00000	0.002 ***	-0.0003 ***	0.004 ***	0.038 ***	-
		(0.00004)	(0.001)	(0.00001)	(0.0001)	(0.00005)	(0.001)	(0.001)	-
R2	*Monthly*	*0.006*	*0.014*	*0.003*	*0.001*	*0.022*	*0.023*	*0.097*	-
	Quarterly	*0.149*	*0.007*	*0.003*	*0.021*	*0.102*	*0.037*	*0.076*	-
	Yearly	*0.227*	*0.054*	*0.172*	*0.237*	*0.155*	*0.167*	*0.528*	-

- Almost all base-load products we observe a negative coefficient.
- An exception is for DE quarterly and yearly contracts. This means that, as dur_t reduces, the value of the RP tends to increase.
- Similarly occurs for peak-load contracts, with the notable exceptions of monthly contracts, for which RP reduces as maturity approaches in FR and IT.
- while there is no significant difference between forward and spot prices for monthly DE ones.

3.3.4 Results
liquidity

		FR		DE		IT		CH	
		Base	Peak	Base	Peak	Base	Peak	Base	Peak
β_0	Monthly	2.446 ***	1.291 **	2.553 ***	2.538 ***	2.164 ***	-1.646 ***	1.116 ***	-
		(0.305)	(0.546)	(0.144)	(0.181)	(0.286)	(0.373)	(0.318)	-
	Quarterly	10.386 ***	6.330 ***	1.336 ***	0.729 ***	3.336 ***	2.492 ***	4.359 ***	-
		(0.283)	(0.432)	(0.192)	(0.237)	(0.313)	(0.474)	(0.498)	-
	Yearly	10.576 ***	10.164 ***	-1.039 ***	-7.949 ***	3.051 ***	-0.419	-11.399 ***	-
		(0.351)	(0.475)	(0.346)	(0.584)	(0.634)	(0.806)	(0.389)	-
β_1	Monthly	-0.002	0.079 ***	-0.009 ***	-0.005 **	-0.044 ***	0.026 ***	-0.064 ***	-
		(0.005)	(0.012)	(0.002)	(0.002)	(0.004)	(0.008)	(0.008)	-
	Quarterly	-0.046 ***	-0.017 ***	0.004 ***	0.014 ***	-0.034 ***	-0.031 ***	-0.049 ***	-
		(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	-
	Yearly	-0.018 ***	-0.012 ***	0.014 ***	0.026 ***	-0.029 ***	-0.031 ***	-0.022 ***	-
		(0.001)	(0.001)	(0.0004)	(0.001)	(0.002)	(0.003)	(0.001)	-
β_2	Monthly	0.0001 ***	0.003 ***	0.00000	-0.0001 ***	0.00000	0.001 ***	0.007 ***	-
		(0.00002)	(0.0003)	(0.00000)	(0.00002)	(0.00001)	(0.0001)	(0.001)	-
	Quarterly	-0.001 ***	-0.001 ***	0.00002 ***	0.0002 ***	-0.0001 ***	-0.001 **	-0.004 ***	-
		(0.00002)	(0.0003)	(0.00000)	(0.00003)	(0.00001)	(0.0003)	(0.001)	-
	Yearly	-0.002 ***	-0.011 ***	0.00000	0.002 ***	-0.0003 ***	0.004 ***	0.038 ***	-
		(0.00004)	(0.001)	(0.00001)	(0.0001)	(0.00005)	(0.001)	(0.001)	-
R2	*Monthly*	*0.006*	*0.014*	*0.003*	*0.001*	*0.022*	*0.023*	*0.097*	-
	Quarterly	*0.149*	*0.007*	*0.003*	*0.021*	*0.102*	*0.037*	*0.076*	-
	Yearly	*0.227*	*0.054*	*0.172*	*0.237*	*0.155*	*0.167*	*0.528*	-

- Coefficients of liq. are on average significant
- They are very small
- No clear indication arises with respect to their sign.

3.4 Results

How RP changes in relation to trading period

The first 5 trading days

		FR		DE		IT		CH
		Base	Peak	Base	Peak	Base	Peak	Base
t = 1	Monthly	0.874	5.639	1.903	3.481	-3.485	-3.604	2.359
	Quarterly	0.115	2.767	3.086	6.152	-3.583	-11.019	-2.963
	Yearly	6.138	10.088	21.602	32.146	-2.214	-6.987	-14.556
t = 2	Monthly	1.903	5.535	1.862	3.782	-2.26	0.425	2.559
	Quarterly	0.112	2.787	2.931	5.971	-3.651	-8.712	-3.27
	Yearly	5.745	9.879	20.977	32.854	-2.036	-7.425	-14.464
t = 3	Monthly	1.934	5.74	1.906	3.721	-2.324	0.561	2.357
	Quarterly	0.022	2.655	2.878	5.845	-3.76	-6.777	-3.201
	Yearly	5.498	9.478	20.105	32.194	-2.048	-7.659	-14.549
t = 4	Monthly	1.95	5.625	2.031	3.655	-2.229	0.43	2.232
	Quarterly	0.037	2.256	2.849	5.901	-3.79	-6.785	-3.481
	Yearly	4.984	9.122	20.149	32.022	-2.092	-7.601	-14.694
t = 5	Monthly	2.705	5.606	1.987	3.678	-2.111	0.526	2.053
	Quarterly	0.02	2.29	2.781	5.706	-3.712	-6.649	-3.611
	Yearly	4.986	9.201	19.951	31.531	-2.168	-7.411	-14.549

The last 5 trading days

		FR		DE		IT		CH
		Base	Peak	Base	Peak	Base	Peak	Base
t = 1	Monthly	2,103	3,143	1,103	1,021	0,11	-0,021	1,222
	Quarterly	2,415	3,794	2,029	2,385	0,477	0,833	0,88
	Yearly	3,144	5,628	3,704	4,94	0,37	0,707	1,426
t = 2	Monthly	1,927	3,018	1,307	1,132	0,168	0,032	1,155
	Quarterly	2,439	3,818	2,06	2,461	0,486	0,8	1,076
	Yearly	3,289	5,751	3,842	5,063	0,432	0,913	1,654
t = 3	Monthly	1,758	2,864	1,346	1,228	0,058	-0,087	1,012
	Quarterly	2,478	3,783	2,151	2,487	0,646	0,924	1,219
	Yearly	3,194	5,625	3,819	5,027	0,416	1,125	1,494
t = 4	Monthly	1,744	2,792	1,327	1,233	0,031	-0,036	1,136
	Quarterly	2,391	3,578	2,133	2,566	0,57	0,912	1,058
	Yearly	3,198	5,798	3,926	5,163	0,446	1,055	1,659
t = 5	Monthly	1,768	2,993	1,422	1,336	0,138	0,105	1,342
	Quarterly	2,259	3,576	2,109	2,514	0,61	0,815	1,101
	Yearly	2,951	5,633	3,597	4,879	0,092	0,729	1,439

- The **magnitude** of RP tends to **rise** as **delivery approaches** (except yearly French and German contracts).
- RP are **higher** for **products** with **longer delivery periods**.

Conclusions

OUR RESULTS SHOW THAT

- There **is no-convergence** on average **of future prices to the realized prices**.
- On average a **negative relation between RP and days before the delivery period**: the closer the trading day is to the expiration date, the bigger the RP. For all countries and products considered the RP verified at the end of the trading period is positive.
- For **Italy** and **Switzerland** there there is **an inversion of the sign of the RP**: at the begging of the trading period on average RP are negative, rising as expiration time approaches. The inversion of sign might be due to market power of the participants and in particular by the fact that power producers have a relatively weaker market power for longer maturities.
- In **France** and **Germany** the **sign of RP is on average positive**, both at the beginning and at the end of the trading period.

➡ *This results could be of interest for market participants and traders, for both speculative and hedging perspectives.*

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Thank you for your attention

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