RISK PREMIUM, VOLATILITY AND TRADING VOLUME IN OVERNIGHT ELECTRICITY FORWARD MARKETS

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Risk Premium, Volatility and Trading Volume in Overnight Electricity Forward Markets

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This paper studies the overnight risk premium and volatility of futures electricity contracts traded in the French, German/Austrian, Italian and Spanish electricity markets in 2008-2017. In the Spanish and Italian markets, the average risk premium is zero. The yearly risk premium ranges from -11% in monthly contracts to -7% in quarterly contracts, in the German/Austrian market, averaging -9%. In the French market, the risk premium in yearly contracts is -5%, but is zero in monthly and quarterly contracts. Negative risk premia suggest that forward-contract sellers are more risk-averse than buyers. Those negative risk premia vanish after 2015, suggesting that markets learn and increase their efficiency. In contrast with Fleten et al. (2015), the risk premium does not change before and after the forward contract becoming the front product. In the four markets, the volatility of the risk premium of monthly contracts increases by 28% on average when the contract becomes the front product. Trading volume explains this increase in volatility in the German/Austrian and Spanish markets, but in the French and Italian markets, trading volume has little explanatory power on the volatility.

Keywords: Electricity markets; Forward markets; Overnight risk premium; Front product; Trading volume

JEL Codes: C51; G13; L94; Q40

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1. Introduction

Electricity forward and futures markets play a crucial role in the liberalized electricity markets as facilitators of hedging and investment decisions by market participants. Contract prices from these markets are important tools for hedging price risk in volatile spot electricity markets and give signals for investments in infrastructure, contributing to an adequate matching of supply and demand. Successful futures markets are essential elements supporting the efforts to restructure electricity markets and therefore, research on their performance is of general interest, such as the evidence in Kalantzis and Milonas (2013) suggesting that electricity futures trading has reduced spot market price volatility in France and Germany.

Electricity forward trading offers benefits to electricity producers and consumers, such as price discovery, a hedge against spot price market risk, and market power mitigation. But these benefits come at a cost when the forward price has a risk premium. If the risk premium increases (decreases) the forward price in comparison with expected spot prices during the delivery period, this cost is borne by consumers (producers).

Extant literature has investigated the existence, or lack thereof, of risk premia in electricity forward markets. The importance of this topic arises for its implications about the market efficiency of power derivatives markets, which is a significant concern to financial investors, utilities, power producers, retailers, regulators, and policymakers. Economic theory (e.g. Hirshleifer, 1990, Bessembinder and Lemmon, 2002) suggests that the risk premium should compensate risk-averse market participants for bearing systematic risk, and the risk premium should be related to economic risks and the willingness of different market agents to bear these risks, but neither its sign nor its size is known before. Another source of risk premium may be the market power of producers (Ito and Reguant, 2016) which materializes even when agents are risk neutral.

The risk premium has been studied by comparing forward prices against expected spot prices. Expected spot prices cannot be observed but must be estimated. If realized (ex-post) spot prices are used, forward prices contain forecast errors that may induce bias in estimated risk premia. If estimated (ex-ante) spot prices are used, estimated risk premia become dependent on the spot price model used. There are many models of the spot price and none enjoys general acceptance[1] (see the comparisons in Benth et al., 2012 and in Weron and Zator, 2014).

As an alternative to dealing with these problems, Fleten et al. (2015) argue that risk premia got from overnight returns of electricity forward prices are more informative than risk premia based on ex-ante or ex-post returns. Considering a forward market populated by producers, retailers and financial traders, Fleten et al. (2015) posit that a financial trader commands a risk premium from producers and retailers on exposures he must carry and cannot hedge. The only exposure a trader must hold is overnight exposure because longer-term exposures can be hedged using suitable contracts. Therefore, the risk premium can be got analyzing forward prices only, avoiding the controversial estimation of expected spot prices. The risk premium may be negative (positive) when traders hold a short (long) position. Fleten et al. (2015) argue that in the first stage of the life of a contract, producers sell their products and traders take offsetting (long) positions because retailers are not sure about their commitments with final consumers. When the contract becomes the front product, retailers enter the market taking long positions and traders take the offsetting short

[1] Benth et al. (2012) document in the German market that for the same contract and time, two models (jump-diffusion and threshold) generate a negative risk premium and one model (factor) a positive risk premium.

positions. Consequently, we should see changes in the sign and size of the risk premium when the contract becomes the front product. Fleten et al. (2015) report a positive risk premium before the front date and a negative risk premium afterward, so supporting their model's predictions in the Nordic and German/Austrian markets in the period 2 January 2003 to 30 September 2012, particularly in quarterly and monthly contracts.

In this paper, we test whether Fleten et al. (2015) model's predictions hold in the German/Austrian, French, Italian and Spanish markets, in the period 2 January 2008 to 31 December 2017. This study makes several contributions to existing literature. First, while earlier studies on the risk premium concentrate in the Nordic and German/Austrian markets, in this paper besides the German/Austrian market we include the French, Italian and Spanish electricity markets, which have received limited attention in the literature so far. This paper considers a more recent period from 2008 to 2017. Second, as a novel contribution, we analyze changes in the volatility of the risk premium when the contract becomes the front product. As far as we know, this is the first study documenting the relationship between volatility and trading volume in electricity forward markets. Third and generalizing earlier literature, this paper presents models with explanatory variables both in the mean and in the volatility equation. Finally, when assessing the statistical significance of parameters in the regression equations, instead of relying of conventional significance levels (e.g. 5%) we set a reference p-value dependent on the sample size, so setting a tougher standard to lower the possibility of false discoveries, a question of concern in scientific research these days (Ioannidis, 2005).

The results on average risk premia do not support the Fleten et al. (2015) approach. No market presents a difference in average risk premium before and after the date when the contract becomes the front product. The average yearly risk premium ranges from -11% in monthly contracts to -7% in quarterly contracts, in the German/Austrian market, averaging -9%. In the French market, the risk premium in yearly contracts is -5%, but is zero in monthly and quarterly contracts. The risk premium is zero in the Spanish and Italian markets. However, we find support for Fleten at al. (2015)'s model in the four markets in the sense that, when the contract becomes the front product, the volatility of the risk premium changes. The volatility increases by 28% on average for monthly contracts when the contract becomes the front product. In the German/Austrian and Spanish markets, trading volume helps to explain the increase in volatility during the front period. But in the French and Italian markets, trading volume has little explanatory power on the volatility.

The rest of this paper is organized as follows. Section 2 reviews the literature. After describing the methodology in Section 3, we present data in Section 4. Section 5 discusses empirical results. Section 6 concludes.

2. Literature Review

Market efficiency means that forward prices converge to unbiased predictors of spot prices down the line. Therefore, investigating risk premia is akin to assess the degree of informational efficiency of the market. Several papers have investigated the existence of risk premia in electricity futures markets. The economic arguments justifying its existence stem from the different needs of the participants in power derivatives markets, namely producers, retailers, and financial traders. Producers are exposed to price uncertainty for a period determined by the remaining life of its assets, retailers decide based on the timing of their sales obligations and financial traders act based on current market conditions because they do not have commitments with final users. Therefore, the gains in terms of risk-diversification for producers, retailers, and traders will vary across time and markets and will affect forward prices and risk premia.

As far as we know, there is not conclusive evidence on the sign, size, variability, and determinants of the risk premium in forward electricity markets. Current literature has documented positive, negative and zero risk premia. The empirical evidence suggests that the risk premium may vary throughout the hour of the day, among days of the week, between months or seasons, or over the year. Results differ from one market to another market, within the same market over different periods, and whether ex-ante or ex-post measures are used. The European market receiving more attention so far is the Nordic market, analyzed in Cartea and Villaplana (2008), Weron (2008), Redl et al. (2009), Botterud et al. (2010), Lucía and Torró (2011), Huisman and Kilic (2012), Weron and Zator (2014), and Fleten et al. (2015), among many others. The second market attracting more attention is the German market, studied in Benth et al. (2008), Redl et al. (2009), Viehmann (2011), Benth et al. (2012), Fleten et al. (2015) and Valitov (2018) among others. Bunn and Chen (2013) and Cartea and Villaplana (2008) study the British market. The Dutch market is analyzed in Huisman and Kilic (2012) and the Spanish market in Capitán Herraiz and Rodriguez Monroy (2009) and in Furió and Meneu (2010). On U.S. markets, evidence on NYMEX contracts for delivery at the California–Oregon border is provided by Shawky et al. (2003); evidence on the PJM market can be found in Longstaff and Wang (2004), Douglas and Popova (2008), Cartea and Villaplana (2008), and Haugom and Ullrich (2012); Hadsell and Shawky (2006) study the NYSO market and Borenstein et al. (2008) and Woo et al. (2015) the California market. Bevin-McCrimmon, et al. (2018)

analyze the impact of liquidity on risk premia in New Zealand and conclude that liquidity impact risk premia only with long-dated futures.

Research on the relationship between volatility and trading has been the focus of many studies in the energy economics literature; see Alizadeh and Tamvakis (2016) for a recent summary. Most studies (e.g. Chevallier and Sevi, 2012) focused on oil futures and natural gas futures markets, reporting a positive relationship, but there is scarce evidence on this matter in power derivatives markets. This paper aims to shed light on this, by focusing on electricity forward markets.

Perhaps one common problem with studies focusing on the risk premium using ex-post measures, making their results hard to interpret, is that, besides the forecasting errors included in forward prices, the ex-post risk premium measures a compensation for risks that financial traders need not bear. On studies using ex-ante measures, the need of assuming a model for computing expected spot prices complicates the interpretation of results, because of lack of consensus over such a model. Additionally, when assessing the statistical significance of the estimators of parameters in the regression equations, most papers rely on "conventional" significance levels (e.g. p = 0.05) irrespective of the sample size used. This strategy increases the possibility of false discoveries and incentives "P-hacking" (Nuzzo, 2014).

3. Methodology

We generalize Fleten et al. (2015) with the following model for the electricity forward price

$$\frac{dF(t,T_1,T_2)}{F(t,T_1,T_2)} = \mu(X(t),I(t))dt + \sigma(V(t),I(t))dW(t,T_1,T_2) \ ; \ \ I(t) = \{0,1\} \quad (1)$$

Where $F(t, T_1, T_2)$ is the price at time t of a forward contract with delivery over a period $[T_1, T_2]$, $\mu(X(t), I(t))$ is the drift and $\sigma(V(t), I(t))$ is the volatility, I(t) is an indicator variable taking values equal to zero or one before and after a pre-specified event, and X(t) and V(t) are sets of explanatory variables. Both parameters may change over time depending on the values taken by the indicator variable I(t) and the explanatory variables X(t) and V(t). Under the standard assumption that entering the forward contract is costless for investors and investing in the underlying asset does not require a risk premium, $\mu(.)$ should be zero. If investors require a risk premium in forward contracts, this should hint at non-zero values for $\mu(.)$ in (1).

Consider an electricity futures market populated with producers, retailers and financial traders. When producers and retailers are equally interested in hedging their exposures in the same moment and in the same amount, there is no reason for a risk premium to exist (i.e. $\mu = 0$) and no role for financial traders. If in a period of the futures contract's life, producers want to hedge their production and retailers are not interested in hedging, financial traders would step in if they expect a compensation for holding long positions. The compensation materializes when forward prices increase during the life of the contract, therefore inducing a positive risk premium (i.e. $\mu > 0$). Conversely, a negative risk premium should arise (i.e. $\mu < 0$) when the retailers' preference to go long is not matched with the producers' interests and so financial traders take the corresponding short positions. Nevertheless, financial traders do not hold contracts over delivery periods because they have no commitments in the spot market. Therefore, at some later point during the contract's life, financial traders must take offsetting positions with either producers or retailers. Depending on whether both agree in their willingness to trade, a null risk premium, a negative risk premium or a positive risk premium may appear during this later period. Fleten et al. (2015) posit that there is a turning point in the date when the futures contract becomes the front product (the front date or TFD from now on). Before that moment, they assume that market activity is largely due to the interaction between producers and financial traders and so a positive risk premium should appear. After this moment, retailers enter the market, taking long positions. Their main counterparty is the financial traders and, assuming equal willingness to trade in both groups, the risk premium should be lower than in the preceding period. To consider this, and assuming X(t) = V(t) = 0 and constant variance in both periods (i.e. $\sigma(I(t),t) = \sigma$) equation (1) becomes

$$\frac{dF(t,T_1,T_2)}{F(t,T_1,T_2)} = (\mu + \alpha I)dt + \sigma dW(t,T_1,T_2) \quad (2)$$

Where I is a dummy variable, equal to zero before the contract becomes the front product and equal to one afterward. This is the basic model in Fleten et al. (2015). The risk premium is μ in the holding period of the traders, and $\mu+\alpha$ after the contract becomes the front product, corresponding to the holding period of the retailers. Therefore, the assumptions in Fleten et al. (2015) imply that $\mu > 0$, $\alpha \neq 0$ and $\alpha \leq \mu$.

A discrete-time equivalent of (2) based on daily data is

$$r_t = \mu + \alpha I_t + \varepsilon_t \qquad \varepsilon_t \sim iid(0,\sigma) \quad (3)$$

Where r_t is the daily log-return of the forward price. Turning to the issue of the possible time and event dependence of the variance, the discrete time approximation of (1) assuming X(t) = V(t) = 0, consists of two equations. The first one is (3) and the second is

$$\sigma_t \;\; = \beta + \delta I_t + \omega_t \qquad\qquad \omega_t \sim iid(0, \vartheta) \qquad (4)$$

When retailers enter the market the level of market activity should increase, and this may imply a step-up in volatility when the contract becomes the front product. Therefore, δ should be greater than zero. Considering i (i =1… K) contracts results in an unbalanced panel data specification for each market

$$r_{i,t} = \mu_i + \alpha_i I_t + \varepsilon_{i,t} \qquad\qquad \varepsilon_{i,t} \sim iid(0, \sigma_i) \quad (5a)$$

$$\sigma_{i,t} = \beta_i + \delta_i I_t + \omega_{i,t} \qquad\qquad \omega_{i,t} \sim iid(0, \vartheta_i) \qquad (5b)$$

We fit the system (5a) - (5b) in two steps. First, we run the regression (5a) and get estimates $\varepsilon^*_{i,t}$ of the innovation process $\varepsilon_{i,t}$. Second, we take the absolute value of $\varepsilon^*_{i,t}$ as a proxy for the volatility process $\sigma_{i,t}$ and run the regression (5b). The reason for using this proxy for the process $\sigma_{i,t}$ is based on results in Forsberg and Ghysels (2007). They show that absolute returns-based volatility measures present better population prediction properties than other measures (e.g. squared innovations) and are less sensitive to jumps. We fit the regression models in the full sample and over different periods to study changes in the value of the parameters over time.

Many authors (e.g. Cartea and Villaplana, 2014) document several explanatory variables of the risk premium. Therefore, as a discrete time approximation to equation (1), we estimate a panel multivariate linear regression model to study the impact of the control variables on the forward risk premium.

$$r_{i,t} = \mu_i + \alpha_{i,t} I_t + \sum_{j=1}^{Q} \beta_{i,j} X_{i,j,t} + \varepsilon_{i,t} \qquad \varepsilon_{i,t} \sim iid(0, \sigma_i) \quad (6a)$$

Where $X_{i,j,t}$ are j=1,…,Q explanatory variables suggested in the literature, such as fuel prices (Redl and Bunn, 2013 and Bunn and Chen, 2013), spot price variance and skewness (Bessembinder and Lemmon, 2002) carbon prices and other market-specific factors (Weron and Zator, 2014) and trading volume (Gallant et al., 1992). The explanatory variables are *dvol* (logarithmic returns of Trading Volume), *lgas* (logarithmic return of ICE UK Natural Gas Futures, Continuous Contract #1), *loil* (logarithmic return of front Futures Contract: ICE Brent Crude Oil), *lcoal* (logarithmic return of ICE Rotterdam Coal Futures, Continuous Contract #1), *lcarbon* (logarithmic return of ICE ECX EUA Futures, Continuous Contract #1), *ldax* (logarithmic return of the daily closing price of the DAX index), *varge* (spot price variance), *skewge* (spot price skewness)[2] and monthly dummy variables.

In the same vein, we include trading volume $TV_{i,t}$ as an explanatory variable in the volatility equation (Karpoff, 1987, Lamoureux and Lastrapes, 1990)

$$\sigma_{i,t} = \beta_i + \delta_i I_t + \gamma_i \log(TV_{i,t}) + \omega_{i,t} \qquad \omega_{i,t} \sim iid(0, \vartheta_i) \qquad (6b)$$

If trading in futures markets is induced by the arrival of new information, the trading volume should show information about aggregate changes in the expectations of the market participants. Therefore, the daily trading volume is a proxy for the information arrival time that, in turn, determines returns' volatility. The empirical evidence suggests there is a positive relation between trading volume and market volatility (see, among

[2] Variance and skewness are calculated using a ninety-day rolling window on the corresponding electricity spot price.

others, Chevallier and Sevi, 2012). Therefore, we expect γ_i to be positive. The estimation method of (5)-(6) is unbalanced cross-section SUR, meaning a feasible GLS specification with HAC (Newey-West) robust standard errors corrected for heteroscedasticity, autocorrelation and contemporaneous correlation.

When assessing the statistical significance of the estimators of parameters in the regression equations, we do not rely on "conventional" significance levels (e.g. 5%) because it is well known using p = 0.05 to suggest a significant effect implies to be wrong (at the very least) 30% of the time (Colquhoun, 2014). Instead, we consider the sample size in each regression by setting a reference p-value of Min [T^{-1}, 1%] where T is sample size, and work out reference t-statistics in line with this (see, for instance, Leeb and Pötscher, 2005). If the estimated t-statistic is higher than the reference t-statistic, this suggests statistical incompatibility of the data with the null hypothesis positing the parameter is equal to zero (e.g. $\mu = 0$). The reason for doing this is to guarantee that the model choice process is a consistent procedure (see also Bauer, et al. 1988) by setting a tougher standard to lower the possibility of false discoveries (Ioannidis, 2005, Goodman, 2001).

4. Data

We collect daily forward prices and trading volume of baseload and peak contracts in the period from 2 January 2008 to 31 December 2017 from the German/Austrian (GE, 334 contracts), French (FR, 247 contracts), Spanish (SP, 186 contracts, baseload only) markets, and in the period from 2 January 2014 to 31 December 2017 from the Italian (IT, 118 contracts) market[3]. The data set consists of 53 annual contracts, 213 quarterly contracts,

[3] Data was provided by OMIP and EEX. The sample size was chosen to maximize the number of contracts

and 619 monthly contracts, totaling 885 contracts and 179,072 prices and traded volumes. The total number of observations is 92,082 in the German/Austrian market, 42,177 in the French market, 23,969 in the Spanish market and 16,652 in the Italian market. Table 1 has contract definition, codes and sample period of all contracts.

[INSERT TABLE 1 HERE]

Table 2 provides information on the number and type of contracts and delivery periods for all markets.

[INSERT TABLE 2 HERE]

Descriptive statistics of the returns on forward contracts in all markets before and after (including the TFD) the front period, namely the period (the first day of the corresponding month, TFD) when the contract becomes the product with shortest time-to-maturity, are given in Table 3. M refers to monthly contracts, Q to quarterly contracts, Y to yearly contracts and M, Q, Y to all contracts put together.

[INSERT TABLE 3 HERE]

Yearly contracts in the FR market present a negative risk premium that does not change before and after the TFD. In other contracts, no clear pattern arises. In the GE market, the average premium is always negative in all contracts. The average risk premium is positive or zero in the IT market[4]. In the SP market, the average premium is negative in all contracts. In summary, the average premium is negative in FR, GE, and SP and is positive

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and prices available since 2008. We exclude contracts with zero trading volume and open interest, and with less than thirty reported prices.

[4] Except for contract Y before TFD, which is negative

(or zero) in IT. Across markets and contracts, the premium before TFD is not consistently higher or lower than the premium after TFD. In all markets and contracts,[5] the volatility after TFD is higher than before TFD.

Descriptive statistics of the trading volume of forward contracts in all markets before and after the front period are given in Table 4. M refers to monthly contracts, Q to quarterly contracts, Y to yearly contracts and M, Q, Y to all contracts put together.

[INSERT TABLE 4 HERE]

The trading volume increases in the four markets during the front period in comparison with the earlier period. However, this increase is more salient in the German/Austrian and Spanish markets where trading volume is 8.6 and 5.6 times higher, respectively. In the Italian market, the increase is 4.6 and the French market presents the smallest increment, namely 3.7.

5. Results and discussion

In this section, we present the results from regression models (5) – (6). Table 5 has the results of fitting the regression panel model (5a) to each market using the full sample. The annualized risk premium is given by [$e^{(\mu + \alpha I)252}$ – 1] for 252 trading days per year calculated with estimated parameters statistically different from zero.

[INSERT TABLE 5 HERE]

[5] Excepting contract Y in market SP.

In contrast with Fleten et al. (2015), estimated α_i parameters present t-statistics lower than reference t-statistics, suggesting statistical compatibility of the data with the null hypothesis positing that the parameter is equal to zero. Consequently, there is no evidence of changes in the risk premium during the front period in any contract or market.

In the Italian and Spanish markets, a null risk premium is a norm in all contracts before and after the front period. This suggests market efficiency and is consistent with the zero average daily risk premium documented by Longstaff and Wang (2004) in the PJM market. However, the yearly contract in the French market and all contracts in the German/Austrian market present negative risk premium with annualized values of -5.35% (Y) and of -11.62% (M), -7.37% (Q), -8.30% (Y), -9.34% (M, Q) and -9.06% (M, Q, Y) respectively. Therefore, the average return on holding a long position in the forward market is negative, as documented by Botterud et al. (2010) in the Nordic market.

The negative risk premium appears when retailers want to hedge more of their price risk than the producers do. Therefore, an excess demand for futures contracts appears. To compensate this mismatch, financial traders sell forward contracts to retailers. In doing so, their net position will be short and financial traders command a risk premium for holding price and liquidity risk. In our sample, this situation happens in the German/Austrian market (all contracts) and in the French market (yearly contracts) during the whole life of the contract and with no change when the contract becomes the front product.

As a robustness test, we fit model (5a) using four-year rolling time windows to study the extent to which parameter values change over time[6]. Table 5 shows the results for the

[6] We exclude the Italian market because the sample spans 2014-2017 and is too small for running rolling

French market (Panel A), German/Austrian market (Panel B) and the Spanish market (Panel C). The first column shows the period and the second the contract types (M, Q, Y).

[INSERT TABLE 6 HERE]

In agreement with the results using the full sample, no evidence appears of changes in the risk premium during the front period in any contract or market. In the FR market shown in Panel A, the return in the yearly contract is negative in the period 2009-2016. Monthly and quarterly contracts also present negative risk premia in 2009-2012 and 2011-2015. In the last period, 2014-2017, all contracts present zero risk premium, suggesting market learning. In the GE market, negative risk premium appears in all contracts in 2008-2015. However, in 2013-2016 only the yearly contract presents a negative risk premium. This is consistent with increases in market efficiency. The risk premium in the SP market is zero in all cases, except for yearly contracts in 2013-2016 and 2014-2017. In summary, in the three markets, the return during the front period is not different from zero in all contracts and in all periods. Therefore, the sign and size of the risk premium do not change when the contract becomes the front product. Decreasing risk premium over time suggests increases in market efficiency in France and Germany/Austria.

We turn now to analyze the extent to which the volatility of the overnight forward return is affected when the contract becomes the front product. Table 7 shows the results got from running the regression (5b).

[INSERT TABLE 7 HERE]

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regressions.

In all markets, the volatility of monthly contracts increases when the contract becomes the front product. The highest increase is in the German market (36%) and the lowest in the Italian market (23%). The average increase in all markets is 28%, suggesting that when monthly contracts approach maturity, the uncertainty about their prices increases. The volatility of quarterly and yearly contracts does not increase when considered individually, but when putting together monthly and quarterly contracts, volatility increases in all markets, possibly due to the impact of the monthly contracts. In summary, in all markets, volatility increases as contract's maturity decreases, and there is an abrupt change that takes place in the day where the contract becomes the front product.

We now turn to the study of the impact of the explanatory variables in the mean of the risk premium by the fitting of the model (6a). To save space, we present the results of the regression in the German/Austrian market[7] and report the results in Table 8.

[INSERT TABLE 8 HERE]

Adding explanatory variables does not challenge the evidence about the lack of change of the risk premium during the front period. Increases in fuel prices and stock prices are associated with increases in the risk premium as expected. In contrast with Bessembinder and Lemmon (2002), the variance and skewness of the spot price do not present explanatory power. Monthly dummies are also positive as expected. Increases in trading volume are not a salient explanatory variable of the risk premium. The results remark that the sign and size of the risk premium do not change when the contract becomes the front

[7] Results in other markets are available on request.

product.

Increases in trading volume may explain increases in volatility, Karpoff (1987), because trading in front contracts is mainly for closing or rolling over positions. We run the regression (6b) and report results in Table 9.

[INSERT TABLE 9 HERE]

Although the regression parameter (γ_i) measuring the dependence between volatility and trading volume is positive in all cases, its relevance differs between markets. In the Spanish market, trading volume explains the bulk of the increase in volatility in all contracts during the front period. Notice that the explanatory power of the dummy variable I(t) disappears when including trading volume. In the French and Italian markets, trading volume has little explanatory power for the volatility, but the significant coefficient of the dummy variable still points out to an increase in volatility during the front period, unrelated to trading volume. In the German/Austrian market, trading volume explains the volatility of monthly (and, to a lesser extent, quarterly) contracts, but the dummy variable still presents some explanatory power, unrelated to the level of trading volume. Therefore, our results are partly consistent with earlier literature documenting a positive relationship between price volatility and trading volume in financial and commodity markets.

6. Conclusions

The existing literature on the risk premium in electricity futures prices focuses on ex-ante or ex-post estimations. Since both approaches are problematic, we base the estimation of the risk premium on overnight futures returns. This risk premium measures a compensation for risks that financial traders need to bear and cannot hedge away. We analyze changes in average risk premium and volatility when the contract becomes the front product.

We base the empirical analysis on daily futures prices from monthly, quarterly and yearly delivery collected from four European markets (France, German/Austrian, Italy and Spain) in the period from 2008 to 2017. Average daily risk premia are zero in the Italian and Spanish market, suggesting market efficiency. The average yearly risk premium ranges from -11% in monthly contracts to -7% in quarterly contracts, in the German/Austrian market, averaging -9%. In the French market, the risk premium in yearly contracts is -5%, but is zero in monthly and quarterly contracts. Negative risk premia are more prominent in the period 2009-2015 vanishing afterward, suggesting market learning, increases in efficiency and perhaps the integration with other markets. Negative risk premia suggest that forward-contract sellers are more risk-averse than buyers. In contrast with Fleten et al. (2015), there is not a difference in any market in the average risk premium before and after the forward contract becoming the front product. In addition, in all markets, the volatility of the overnight return of monthly contracts increases by 28% on average when the contract becomes the front product. Although volatility increases as contract's maturity decreases, the rather abrupt change that takes place in the day where the contract becomes the front product is a result we document for all markets. We study the extent to which increases in trading volume explain increases in volatility because trading in front contracts is mainly for closing or rolling over positions. We document partial support to this hypothesis. In the German/Austrian and Spanish markets, trading volume explains the increase in volatility during the front period, but in the French and Italian markets, trading volume has little explanatory power on the volatility.

Looking forward, explanations in terms of hedging strategies justifying the differences in the size and sign of the risk premium and the impact of trading volume on volatility offer interesting avenues for further research. These differences point out to a lack of integration between European forward electricity markets, however.

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Table 1: Forward contracts code and sample period

This table contains the code and sample period of the forward contracts.

Short Code	Market	Long Code	Sample
F1BM	EEX	Phelix-DE/AT Base Month Future	2008-2017
F1BQ	EEX	Phelix-DE/AT Base Quarter Future	2008-2017
F1BY	EEX	Phelix-DE/AT Base Year Future	2008-2017
F1PM	EEX	Phelix-DE/AT Peak Month Future	2008-2017
F1PQ	EEX	Phelix-DE/AT Peak Quarter Future	2008-2017
F1PY	EEX	Phelix-DE/AT Peak Year Future	2008-2017
F2BM	EEX	French Base Month Future	2008-2011
F2BQ	EEX	French Base Quarter Future	2008-2011
F2BY	EEX	French Basel Year Future	2008-2011
F7BM	EEX	French Base Month Future	2011-2017
F7BQ	EEX	French Base Quarter Future	2011-2017
F7BY	EEX	French Base Year Future	2011-2017
F7PM	EEX	French Peak Month Future	2011-2017
F7PQ	EEX	French Peak Quarter Future	2011-2017
F7PY	EEX	French Peak Year Future	2011-2017
FDBM	EEX	Italian Base Month Future	2014-2017
FDBQ	EEX	Italian Base Quarter Future	2014-2017
FDBY	EEX	Italian Base Year Future	2014-2017
FDPM	EEX	Italian Peak Month Future	2014-2017
FDPQ	EEX	Italian Peak Quarter Future	2014-2017
FDPY	EEX	Italian Peak Year Future	2014-2017
FEBM	EEX	Spanish Base Month Future	2014-2017
FEBQ	EEX	Spanish Base Quarter Future	2014-2017
FEBY	EEX	Spanish Base Year Future	2014-2017
FTBM	OMIP	Spanish Base Month Future	2008-2015
FTBQ	OMIP	Spanish Base Quarter Future	2008-2015
FTBY	OMIP	Spanish Base Year Future	2008-2015

Table 2: Number and type of forward contracts

The table shows the number and type of contract (baseload, peak) available in the German/Austrian, French, Italian and Spanish market.

		M	Q	Y	TOTAL
FR =1	Baseload	85	32	9	126
	Peak	81	31	9	121
		166	63	18	247
GE =2	Baseload	119	39	9	167
	Peak	119	39	9	167
		238	78	18	334
IT =3	Baseload	44	14	3	61
	Peak	41	13	3	57
		85	27	6	118
SP= 4	Baseload	130	45	11	186
	Peak	0	0	0	0
		130	45	11	186
All		**619**	**213**	**53**	**885**

Table 3: Descriptive statistics for returns of forward prices

The table shows descriptive statistics for returns of forward prices in the French (FR) German/Austrian (GE), Italian (IT) and Spanish (SP) markets Before F and After F (the front period), namely the period (the first day of the corresponding month, the front date of TFD) when the contract becomes the product with the shortest time-to-maturity. M is monthly contracts, Q is quarterly contracts, Y is yearly contracts and M, Q, Y is all contracts. The sample is from 2 January 2008 to 31 December 2017 in the GE, FR and SP markets, and from 2 January 2014 to 31 December 2017 in the IT market.

RTO		**Before F**	**After F**	**Before F**	**After F**	**Before F**	**After F**	**Before F**	**After F**
		M	**M**	**Q**	**Q**	**Y**	**Y**	**M,Q,Y**	**M,Q,Y**
FR	**Obs**	7,718	3,892	12,971	3,886	9,739	3,971	30,428	11,749
	Mean	-0.06%	-0.01%	-0.03%	-0.04%	-0.02%	-0.02%	-0.04%	-0.02%
	std	2.22%	2.90%	1.43%	1.77%	1.10%	1.14%	1.59%	2.07%
	sk	0.368	0.431	0.297	-0.486	0.2143	-0.3575	0.354	0.2843
	k	19.393	22.692	10.231	22.536	7.9584	20.8194	22.424	33.9727
Sample size		42,177							
GE	**Obs**	25,810	5,589	30,996	4,877	20,246	4,564	77,052	15,030
	Mean	-0.05%	-0.10%	-0.03%	-0.06%	-0.03%	-0.02%	-0.04%	-0.06%
	std	1.29%	1.73%	1.10%	1.20%	0.89%	0.96%	1.12%	1.37%
	sk	0.629	0.343	0.362	1.149	0.6011	0.5534	0.537	0.5388
	k	12.819	10.102	8.313	18.611	11.5700	7.1770	11.925	13.8727
Sample size		92,082							
IT	**Obs**	4,285	1,964	5,885	1,671	1,449	1,398	11,619	5,033
	Mean	0.02%	0.02%	0.00%	0.03%	-0.02%	0.03%	0.00%	0.02%
	std	1.40%	1.73%	1.08%	1.16%	0.92%	0.92%	1.19%	1.36%
	sk	0.391	0.332	0.041	-0.402	-0.1191	-0.1670	0.251	0.1620
	k	15.377	10.861	7.394	7.934	8.6278	7.1717	13.730	12.8651
Sample size		16,652							
SP	**Obs**	7,084	2,898	9,997	2,747	2,974	2,461	20,055	8,106
	Mean	-0.01%	-0.13%	-0.01%	-0.01%	-0.02%	-0.01%	-0.01%	-0.05%
	std	1.26%	1.67%	0.92%	1.03%	0.72%	0.71%	1.03%	1.23%
	sk	1.072	0.089	-0.032	0.553	0.0495	0.2056	0.687	0.1150
	k	23.969	18.212	10.305	11.092	11.4786	11.5337	22.729	24.4585
Sample size		28,161							
Total Observations		179,072							

Table 4: Descriptive statistics of trading volume

The table shows descriptive statistics for trading volume in MWh of forward contracts in the French (FR) German/Austrian (GE), Italian (IT) and Spanish (SP) markets Before F and After F (the front period, namely the period starting with the first day of the corresponding month, the front date of TFD) when the contract becomes the product with the shortest time-to-maturity. M is monthly contracts, Q is quarterly contracts, Y is yearly contracts and M, Q, Y is all contracts. The sample is from 2 January 2008 to 31 December 2017 in the GE, FR and SP markets, and from 2 January 2014 to 31 December 2017 in the IT market.

		Before F	**After F**	**Before F**	**After F**	**Before F**	**After F**	**Before F**	**After F**
		M	**M**	**Q**	**Q**	**Y**	**Y**	**M,Q,Y**	**M,Q,Y**
FR	**Obs**	7,718	3,892	12,971	3,886	9,739	3,971	30,428	11,749
	Mean	4,263	21,058	9,250	22,990	11,902	55,402	8,834	33,305
	std	19,586	51,735	40,326	70,171	63,750	162,239	45,821	107,979
	sk	10.84	5.33	9.16	13.45	12.27	6.63	13.57	9.42
	k	189.63	51.16	125.08	398.61	222.39	71.98	303.12	154.22
Sample size		42,177							
GE	**Obs**	25,810	5,589	30,996	4,877	20,246	4,564	77,052	15,030
	Mean	14,727	119,889	33,289	181,462	105,477	975,201	46,039	399,592
	std	46,077	175,997	93,341	258,719	307,951	1,273,032	174,515	818,793
	sk	6.64	3.22	7.47	2.58	8.50	1.91	13.58	3.81
	k	68.07	24.38	110.32	12.94	145.33	8.79	391.11	24.02
Sample size		92,082							
IT	**Obs**	4,285	1,964	5,885	1,671	1,449	1,398	11,619	5,033
	Mean	7,996	47,850	28,965	90,114	51,098	229,538	23,992	112,349
	std	22,381	70,724	69,375	139,882	135,221	348,404	71,412	218,513
	sk	5.37	2.00	4.29	3.05	5.24	2.30	7.07	3.96
	k	45.22	7.94	28.97	20.75	41.50	10.43	87.33	26.56
Sample size		16,652							
SP	**Obs**	7,084	2,898	9,997	2,747	2,974	2,461	20,055	8,106
	Mean	3,774	19,264	5,538	28,374	4,572	33,089	4,772	26,548
	std	13,342	35,118	22,604	55,349	23,785	76,665	20,052	57,409
	sk	6.39	4.43	7.53	3.87	9.25	7.85	8.37	7.38
	k	56.13	35.25	82.18	23.80	117.60	126.73	105.14	133.64
Sample size		28,161							
Total Observations		179,072							

Table 5: Results from the panel regression model: risk premium

The table shows results from regression $r_{i,t} = \mu_i + \alpha_{i,t} I_t + \varepsilon_{i,t} \;\; \varepsilon_{i,t} \sim N(0, \sigma_i) \;\; (5a)$ run for the overnight return of forward contracts for French (FR) German/Austrian (GE), Italian (IT) and Spanish (SP) markets, where I_t is a dummy variable indicating trading in the front period (1) or not (0). M is monthly contracts, Q is quarterly contracts, Y is yearly contracts and M, Q , Y is all contracts. T is sample size. The reference p-value (R_P-value) is Min [(1/T), 1%] where T is sample size. The sample is from 2 January 2008 to 31 December 2017 in the GE, FR and SP markets, and from 2 January 2014 to 31 December 2017 in the IT market. Boldface indicates statistical significance according to the reference p-value and t Statistic.

FR	**Mu**	**t Stat**	**P-value**	**Alpha**	**t Stat**	**P-value**	**T**	**R-sq x 10^3**	**R_P-value**	**R_t Stat**	**Annual RP**
M	-0.000632	-1.76	7.92E-02	0.000581	0.793	2.14E-01	11610	0.123	8.61E-05	3.76	0.00%
Q	-0.000278	-2.13	3.31E-02	-0.000150	-0.425	3.36E-01	16857	0.017	5.93E-05	3.85	0.00%
Y	**-0.000218**	**-4.43**	9.61E-06	0.000001	0.004	4.98E-01	13710	0.000	7.29E-05	**3.80**	**-5.35%**
MQ	-0.000410	-2.61	9.18E-03	0.000171	0.440	3.30E-01	28467	0.015	3.51E-05	3.98	0.00%
MQY	-0.000349	-3.21	1.33E-03	0.000117	0.441	3.29E-01	42177	0.009	2.37E-05	4.07	0.00%
GER											
M	**-0.000490**	**-4.12**	3.80E-05	-0.000507	-1.719	4.29E-02	31397	0.197	3.19E-05	**4.00**	**-11.62%**
Q	**-0.000304**	**-4.18**	2.90E-05	-0.000310	-1.067	1.43E-01	35873	0.091	2.79E-05	**4.03**	**-7.37%**
Y	**-0.000344**	**-7.63**	2.33E-14	0.000134	0.687	2.46E-01	24810	0.033	4.03E-05	**3.94**	**-8.30%**
MQ	**-0.000389**	**-5.78**	7.33E-09	-0.000430	-2.082	1.87E-02	67270	0.156	1.49E-05	**4.18**	**-9.34%**
MQY	**-0.000377**	**-7.42**	1.20E-13	-0.000257	-1.624	5.22E-02	92080	0.066	1.09E-05	**4.25**	**-9.06%**
IT											
M	0.000155	0.65	5.15E-01	0.000002	0.004	4.98E-01	6249	0.000	1.60E-04	3.60	0.00%
Q	0.000001	0.01	9.92E-01	0.000262	0.884	1.88E-01	7556	0.097	1.32E-04	3.65	0.00%
Y	-0.000214	-1.32	1.88E-01	0.000480	2.633	4.23E-03	2847	0.680	3.51E-04	3.39	0.00%
MQ	0.000066	0.57	5.66E-01	0.000140	0.404	3.43E-01	13805	0.022	7.24E-05	3.80	0.00%
MQY	0.000031	0.30	7.65E-01	0.000192	0.730	2.33E-01	16652	0.050	6.01E-05	3.85	0.00%
SP											
M	-0.000146	-0.80	4.24E-01	-0.001105	-2.831	2.32E-03	9981	1.289	1.00E-04	3.72	0.00%
Q	-0.000110	-1.14	2.55E-01	-0.000037	-0.121	4.52E-01	12744	0.003	7.85E-05	3.78	0.00%
Y	-0.000178	-2.15	3.18E-02	0.000109	0.556	2.89E-01	5435	0.058	1.84E-04	3.56	0.00%
MQ	-0.000125	-1.32	1.85E-01	-0.000589	-2.341	9.61E-03	22725	0.477	4.40E-05	3.92	0.00%
MQY	-0.000133	-1.64	1.02E-01	-0.000385	-2.008	2.23E-02	28160	0.255	3.55E-05	3.97	0.00%

Table 6: Results from regression with rolling windows

The table shows results from regression $r_{i,t} = \mu_i + \alpha_{i,t} I_t + \varepsilon_{i,t}$ $\varepsilon_{i,t} \sim N(0, \sigma_i)$ $(5a)$ run for the overnight return of forward contracts for French (FR) German/Austrian (GE), Italian (IT) and Spanish (SP) markets, where I_t is a dummy variable indicating trading in the front period (1) or not (0). M is monthly contracts, Q is quarterly contracts, Y is yearly contracts and M,Q,Y is all contracts. T is sample size. The reference p-value (R_P-value) is Min [(1/T), 1%] where T is sample size. The sample is from 2 January 2008 to 31 December 2017 in the GE, FR and SP markets and we use rolling four-year windows. Boldface indicates statistical significance according to the reference p-value and t Statistic.

Panel A

FR		Mu	t Stat	Alpha	t Stat	T	R-sq x 10^3	R_P-value	R_t Stat
2008-2011	M	-0.001813	-3.11	0.003029	2.65	3150	2.91	3.17E-04	3.42
2008-2011	Q	-0.000672	-2.71	0.000065	0.08	5715	0.00	1.75E-04	3.58
2008-2011	Y	-0.00011	-2.11	-0.00052	-2.33	6280	0.22	1.59E-04	3.60
2008-2011	MQ	**-0.001043**	**-3.99**	0.001279	1.86	8865	0.64	1.13E-04	**3.69**
2008-2011	MQY	-0.000642	-3.73	0.00057	1.24	15145	0.16	6.60E-05	3.82
2009-2012	M	**-0.001529**	**-3.55**	0.002575	3.02	4359	2.61	2.29E-04	**3.50**
2009-2012	Q	**-0.000775**	**-3.97**	0.000425	0.93	5571	0.12	1.80E-04	**3.57**
2009-2012	Y	**-0.000488**	**-7.38**	-0.000067	-0.35	5272	0.01	1.90E-04	**3.55**
2009-2012	MQ	**-0.001089**	**-4.92**	0.001433	3.00	9930	1.05	1.01E-04	**3.72**
2009-2012	MQY	**-0.000884**	**-5.77**	0.000904	2.74	15202	0.55	6.58E-05	**3.82**
2010-2013	M	-0.000702	-2.49	0.000979	1.37	4129	0.67	2.42E-04	3.49
2010-2013	Q	-0.000226	-1.99	-0.000044	-0.11	5314	0.00	1.88E-04	3.56
2010-2013	Y	**-0.000488**	**-9.20**	0.000133	1.07	4702	0.06	2.13E-04	**3.52**
2010-2013	MQ	-0.000421	-3.09	0.000423	1.07	9443	0.17	1.06E-04	3.70
2010-2013	MQY	**-0.000443**	**-4.75**	0.000323	1.22	14145	0.13	7.07E-05	**3.81**
2011-2014	M	**-0.001294**	**-6.55**	-0.000581	-0.74	4209	0.27	2.38E-04	**3.49**
2011-2014	Q	**-0.000338**	**-4.05**	-0.000778	-2.75	5454	1.55	1.83E-04	**3.56**
2011-2014	Y	**-0.000439**	**-10.40**	0.000013	0.13	4670	0.00	2.14E-04	**3.52**
2011-2014	MQ	**-0.000727**	**-6.37**	-0.000769	-1.88	9663	0.75	1.03E-04	**3.71**
2011-2014	MQY	**-0.000635**	**-7.94**	-0.000494	-1.70	14333	0.43	6.98E-05	**3.81**
2012-2015	M	**-0.001074**	**-5.90**	0.000071	0.10	5700	0.00	1.75E-04	**3.57**
2012-2015	Q	**-0.000359**	**-5.07**	-0.000536	-2.36	7884	0.66	1.27E-04	**3.66**
2012-2015	Y	**-0.000475**	**-11.62**	0.000057	0.68	6030	0.02	1.66E-04	**3.59**
2012-2015	MQ	**-0.000632**	**-6.97**	-0.000318	-0.89	13584	0.13	7.36E-05	**3.80**
2012-2015	MQY	**-0.000585**	**-9.01**	-0.000187	-0.77	19614	0.06	5.10E-05	**3.89**
2013-2016	M	-0.000044	-0.08	-0.000663	-0.57	6123	0.15	1.63E-04	3.59
2013-2016	Q	0.000011	0.07	-0.00032	-0.68	8766	0.09	1.14E-04	3.69
2013-2016	Y	**-0.000332**	**-4.22**	0.000248	0.95	5550	0.16	1.80E-04	**3.57**
2013-2016	MQ	-0.000009	-0.04	-0.000506	-0.84	14889	0.13	6.72E-05	3.82
2013-2016	MQY	-0.000089	-0.50	-0.000284	-0.67	20439	0.05	4.89E-05	3.90
2014-2017	M	0.000115	0.19	-0.000695	-0.57	5822	0.15	1.72E-04	3.58
2014-2017	Q	0.000022	0.13	-0.000221	-0.42	7676	0.04	1.30E-04	3.65
2014-2017	Y	-0.000282	-2.63	0.000359	1.20	4428	0.28	2.26E-04	3.51
2014-2017	MQ	0.000059	0.23	-0.000455	-0.71	13498	0.10	7.41E-05	3.79
2014-2017	MQY	-0.000012	-0.06	-0.000229	-0.49	17926	0.03	5.58E-05	3.86

Panel B

GE		Mu		Alpha		N	R-sq x 10^3	R_P-value	R_t Stat
2008-2011	M	-0.000693	-3.06	-0.001192	-2.20	13269	0.81	7.54E-05	3.79
2008-2011	Q	-0.000336	-2.89	-0.000563	-0.88	16497	0.20	6.06E-05	3.84
2008-2011	Y	**-0.000186**	**-5.22**	-0.000287	-1.24	11704	0.09	8.54E-05	**3.76**
2008-2011	MQ	**-0.000489**	**-4.13**	-0.000941	-2.27	29766	0.53	3.36E-05	**3.99**
2008-2011	MQY	**-0.000403**	**-4.64**	-0.000767	-2.44	41470	0.40	2.41E-05	**4.06**
2009-2012	M	**-0.000871**	**-5.43**	-0.000818	-1.78	13317	0.50	7.51E-05	**3.79**
2009-2012	Q	**-0.000455**	**-5.13**	-0.000558	-1.30	16450	0.28	6.08E-05	**3.84**
2009-2012	Y	**-0.000443**	**-16.00**	-0.00006	-0.34	12202	0.01	8.20E-05	**3.77**
2009-2012	MQ	**-0.000635**	**-7.04**	-0.000736	-2.36	29767	0.44	3.36E-05	**3.99**
2009-2012	MQY	**-0.00058**	**-8.95**	-0.000511	-2.23	41969	0.26	2.38E-05	**4.07**
2010-2013	M	**-0.000469**	**-3.83**	-0.000903	-2.35	12893	0.79	7.76E-05	**3.78**
2010-2013	Q	**-0.00037**	**-5.63**	-0.000218	-0.62	15436	0.06	6.48E-05	**3.83**
2010-2013	Y	**-0.00057**	**-16.88**	0.000194	1.53	12164	0.10	8.22E-05	**3.77**
2010-2013	MQ	**-0.000413**	**-6.35**	-0.00059	-2.25	28329	0.38	3.53E-05	**3.97**
2010-2013	MQY	**-0.00046**	**-9.63**	-0.000342	-1.81	40493	0.16	2.47E-05	**4.06**
2011-2014	M	**-0.000762**	**-7.65**	-0.001021	-2.80	12476	1.21	8.02E-05	**3.77**
2011-2014	Q	**-0.000398**	**-6.45**	-0.00047	-1.77	14354	0.39	6.97E-05	**3.81**
2011-2014	Y	**-0.00057**	**-15.55**	0.000133	1.23	11600	0.06	8.62E-05	**3.76**
2011-2014	MQ	**-0.000563**	**-9.95**	-0.000791	-3.43	26830	0.87	3.73E-05	**3.96**
2011-2014	MQY	**-0.000565**	**-13.75**	-0.000493	-2.85	38430	0.42	2.60E-05	**4.05**
2012-2015	M	**-0.000919**	**-12.88**	-0.000128	-0.39	12483	0.02	8.01E-05	**3.77**
2012-2015	Q	**-0.000605**	**-13.76**	-0.00033	-1.82	14465	0.26	6.91E-05	**3.81**
2012-2015	Y	**-0.000736**	**-32.74**	0.000154	2.16	10552	0.12	9.48E-05	**3.73**
2012-2015	MQ	**-0.000746**	**-17.08**	-0.000248	-1.30	26948	0.11	3.71E-05	**3.96**
2012-2015	MQY	**-0.000743**	**-23.07**	-0.000118	-0.87	37500	0.03	2.67E-05	**4.04**
2013-2016	M	-0.000299	-2.00	-0.000113	-0.28	12523	0.01	7.99E-05	3.78
2013-2016	Q	-0.000229	-2.51	-0.000147	-0.46	14313	0.03	6.99E-05	3.81
2013-2016	Y	**-0.000556**	**-10.91**	0.000399	1.37	9080	0.42	1.10E-04	**3.69**
2013-2016	MQ	-0.000261	-3.11	-0.000134	-0.52	26836	0.02	3.73E-05	3.96
2013-2016	MQY	**-0.000331**	**-4.93**	0.000013	0.06	35916	0.00	2.78E-05	**4.03**
2014-2017	M	0.000021	0.13	0.000063	0.15	11940	0.00	8.38E-05	3.76
2014-2017	Q	-0.000031	-0.27	-0.000101	-0.31	12180	0.01	8.21E-05	3.77
2014-2017	Y	-0.000226	-2.54	0.000426	1.36	7100	0.45	1.41E-04	3.63
2014-2017	MQ	-0.000006	-0.06	-0.000012	-0.04	24120	0.00	4.15E-05	3.94
2014-2017	MQY	-0.00005	-0.63	0.000103	0.49	31220	0.01	3.20E-05	4.00

Panel C

SP		Mu	t Stat	Alpha	t Stat	N	R-sq x 10^3	R_P-value	R_t Stat
2008-2011	M	-0.000272	-0.83	-0.001032	-1.85	3794	1.24	2.64E-04	3.47
2008-2011	Q	-0.000053	-0.27	-0.000493	-0.73	5374	0.27	1.86E-04	3.56
2008-2011	Y	-0.000115	-0.55	-0.000006	-0.01	1738	0.00	5.75E-04	3.25
2008-2011	MQ	-0.000138	-0.80	-0.000799	-1.84	9168	0.73	1.09E-04	3.70
2008-2011	MQY	-0.000135	-0.88	-0.00057	-1.59	10906	0.44	9.17E-05	3.74
2009-2012	M	-0.000201	-0.79	-0.001084	-1.91	3851	1.59	2.60E-04	3.47
2009-2012	Q	-0.000111	-0.57	-0.000181	-0.35	5483	0.05	1.82E-04	3.56
2009-2012	Y	-0.000014	-0.07	-0.000051	-0.12	2079	0.01	4.81E-04	3.30
2009-2012	MQ	-0.000139	-0.96	-0.00065	-1.68	9334	0.59	1.07E-04	3.70
2009-2012	MQY	-0.000123	-0.96	-0.000424	-1.40	11413	0.31	8.76E-05	3.75
2010-2013	M	-0.000032	-0.14	-0.001067	-1.89	3956	1.31	2.53E-04	3.48
2010-2013	Q	0.000083	0.76	-0.000174	-0.36	5513	0.06	1.81E-04	3.57
2010-2013	Y	0.000003	0.03	0.000083	0.38	2345	0.04	4.26E-04	3.34
2010-2013	MQ	0.000038	0.34	-0.000648	-1.76	9469	0.62	1.06E-04	3.71
2010-2013	MQY	0.000033	0.34	-0.000413	-1.53	11814	0.32	8.46E-05	3.76
2011-2014	M	-0.000385	-1.83	-0.001018	-1.75	4197	0.97	2.38E-04	3.49
2011-2014	Q	-0.000088	-0.90	-0.000249	-0.70	5672	0.16	1.76E-04	3.57
2011-2014	Y	-0.000094	-0.78	-0.000026	-0.13	2611	0.01	3.83E-04	3.36
2011-2014	MQ	-0.000206	-2.00	-0.000684	-1.98	9869	0.66	1.01E-04	3.72
2011-2014	MQY	-0.000187	-2.14	-0.000468	-1.82	12480	0.40	8.01E-05	3.77
2012-2015	M	-0.000096	-0.45	-0.000913	-1.79	4671	0.79	2.14E-04	3.52
2012-2015	Q	-0.000211	-2.96	0.000179	0.59	5951	0.10	1.68E-04	3.59
2012-2015	Y	-0.000219	-2.41	0.000106	0.57	2976	0.10	3.36E-04	3.40
2012-2015	MQ	-0.000163	-1.66	-0.000364	-1.20	10622	0.20	9.41E-05	3.73
2012-2015	MQY	-0.000173	-2.11	-0.000226	-1.03	13598	0.10	7.35E-05	3.80
2013-2016	M	-0.000109	-0.39	-0.001228	-1.93	4599	1.29	2.17E-04	3.52
2013-2016	Q	-0.000287	-3.49	0.00028	0.79	5604	0.22	1.78E-04	3.57
2013-2016	Y	**-0.000313**	**-8.79**	0.000174	1.10	2922	0.25	3.42E-04	**3.40**
2013-2016	MQ	-0.000211	-1.65	-0.000474	-1.26	10203	0.30	9.80E-05	3.72
2013-2016	MQY	-0.000229	-2.20	-0.000287	-1.05	13125	0.14	7.62E-05	3.79
2014-2017	M	0.000112	0.36	-0.00118	-1.87	4172	1.31	2.40E-04	3.49
2014-2017	Q	-0.000103	-1.07	0.000342	1.08	4591	0.39	2.18E-04	3.52
2014-2017	Y	**-0.000315**	**-6.27**	0.000325	2.10	2348	1.13	4.26E-04	**3.34**
2014-2017	MQ	-0.000004	-0.03	-0.000424	-1.15	8763	0.27	1.14E-04	3.69
2014-2017	MQY	-0.000053	-0.41	-0.00024	-0.89	11111	0.11	9.00E-05	3.75

Table 7: Results from the panel regression model: volatility

The table shows results from regression $\sigma_{i,t} = \beta_i + \delta_i I_t + \omega_{i,t} \quad \omega_{i,t} \sim D(0, \vartheta_i)_{i,t}$ run for the volatility of overnight return of forward contracts for French (FR) German/Austrian (GE), Italian (IT) and Spanish (SP) markets, where I_t is a dummy variable indicating trading in the front period (1) or not (0). M is monthly contracts, Q is quarterly contracts, Y is yearly contracts and M,Q,Y is all contracts. T is sample size. The reference p-value (R_P-value) is Min [(1/T), 1%] where T is sample size. The sample is from 2 January 2008 to 31 December 2017 in the GE, FR and SP markets, and from 2 January 2014 to 31 December 2017 in the IT market. Boldface indicates statistical significance according to the reference p-value and t Statistic.

FR	**Beta**	**t Stat**	**P-value**	**Delta**	**t Stat**	**P-value**	**T**	**R-sq x 10^3**	**R_P-value**	**R_t Stat**	**% In_Vol**
M	**0.014249**	**23.29**	**0.00E+00**	**0.003624**	**4.73**	**1.14E-06**	11612	8.14	**1.72E-04**	**3.579**	**25.43%**
Q	**0.009622**	**17.79**	**0.00E+00**	0.001599	1.89	2.93E-02	16857	3.50	1.19E-04	3.676	16.62%
Y	**0.007339**	**13.43**	**0.00E+00**	-0.000086	-0.08	4.68E-01	13710	0.02	1.46E-04	3.623	-1.17%
MQ	**0.011348**	**26.47**	**0.00E+00**	**0.003201**	**5.29**	**6.26E-08**	28469	8.82	**7.03E-05**	**3.807**	**28.21%**
MQY	**0.010065**	**25.42**	**0.00E+00**	0.002018	3.67	1.22E-04	42179	4.45	4.74E-05	3.903	20.05%
GER											
M	**0.008874**	**41.89**	**0.00E+00**	**0.003234**	**9.32**	**0.00E+00**	31401	15.53	**6.37E-05**	**3.831**	**36.44%**
Q	**0.007624**	**28.09**	**0.00E+00**	0.000582	1.51	6.58E-02	35873	0.61	5.58E-05	3.864	7.63%
Y	**0.005766**	**21.89**	**0.00E+00**	0.000938	1.25	1.06E-01	24810	2.87	8.06E-05	3.773	16.27%
MQ	**0.008192**	**45.28**	**0.00E+00**	**0.002097**	**7.74**	**5.00E-15**	67274	7.11	**2.97E-05**	**4.015**	**25.60%**
MQY	**0.007555**	**38.69**	**0.00E+00**	**0.001646**	**5.42**	**3.00E-08**	92084	5.07	**2.17E-05**	**4.088**	**21.79%**
IT											
M	**0.009167**	**23.08**	**0.00E+00**	**0.002116**	**4.32**	**7.86E-06**	6249	7.89	**3.20E-04**	**3.414**	**23.08%**
Q	**0.007366**	**23.12**	**0.00E+00**	0.000656	1.03	1.52E-01	7556	1.14	2.65E-04	3.465	8.91%
Y	**0.005903**	**8.07**	**6.66E-16**	0.000385	0.37	3.55E-01	2847	0.78	7.02E-04	3.194	6.52%
MQ	**0.008125**	**32.28**	**0.00E+00**	**0.001659**	**4.11**	**1.99E-05**	13805	5.79	**1.45E-04**	**3.624**	**20.42%**
MQY	**0.007848**	**31.71**	**0.00E+00**	0.000965	2.41	8.00E-03	16652	2.30	1.20E-04	3.672	12.30%
SP											
M	**0.008216**	**26.08**	**0.00E+00**	**0.002239**	**3.99**	**3.28E-05**	9982	9.24	**2.00E-04**	**3.540**	**27.25%**
Q	**0.005890**	**16.42**	**0.00E+00**	0.001009	2.05	2.01E-02	12744	3.36	1.57E-04	3.604	17.13%
Y	**0.004459**	**7.80**	**6.22E-15**	0.000006	0.01	4.96E-01	5435	0.00	3.68E-04	3.376	0.13%
MQ	**0.006855**	**25.85**	**0.00E+00**	**0.001870**	**4.80**	**8.11E-07**	22726	8.19	**8.80E-05**	**3.751**	**27.28%**
MQY	**0.006499**	**24.77**	**0.00E+00**	0.000932	2.34	9.66E-03	28161	2.49	7.10E-05	3.805	14.34%

Table 8: Results from the panel regression model: explanatory variables

The table shows results from regression $r_{i,t} = \mu_i + \alpha_{i,t} I_t + \sum_{j=1}^{Q} \beta_{i,j} X_{i,j,t} + \varepsilon_{i,t} \quad \varepsilon_{i,t} \sim N(0,\sigma_i)$ of forward contracts for German/Austrian (GE), where I_t is a dummy variable indicating trading in the front period (1) or not (0). M is monthly contracts, Q is quarterly contracts, Y is yearly contracts and M,Q,Y is all contracts. T is sample size. The reference p-value (R_P-value) is Min [(1/T), 1%]. The sample is from 2 January 2008 to 31 December 2017. The explanatory variables are dvol, lgas, loil , lcoal, lcarbon, ldax, varge, skewge and monthly dummy variables. Boldface indicates statistical significance according to the reference p-value and t Statistic.

	M	Q	Y	MQ	MQY
Mu	**-0.001**	**-0.002**	**-0.002**	**-0.002**	**-0.002**
t Stat	**-5.04**	**-12.51**	**-25.61**	**-10.14**	**-14.68**
Alpha	-0.001	0.000	0.000	0.000	0.000
t Stat	-2.12	-1.58	0.28	-2.71	-2.33
dvol	0.0001	0.0002	0.0001	0.0002	0.0001
t Stat	1.26	3.20	1.67	2.74	3.13
lgas	**0.113**	**0.084**	**0.060**	**0.097**	**0.088**
t Stat	**15.80**	**17.60**	**10.77**	**22.01**	**22.20**
loil	**0.023**	**0.039**	**0.034**	**0.032**	**0.032**
t Stat	**6.56**	**14.67**	**13.84**	**14.11**	**18.50**
lcoal	**0.108**	**0.116**	**0.087**	**0.112**	**0.106**
t Stat	**11.87**	**18.67**	**12.49**	**21.29**	**23.26**
lcarbon	**0.098**	**0.102**	**0.080**	**0.100**	**0.094**
t Stat	**15.71**	**13.35**	**12.89**	**20.08**	**22.87**
ldax	-0.001	**0.036**	**0.030**	**0.019**	**0.022**
t Stat	-0.13	**5.72**	**7.11**	**3.17**	**4.81**
varge	-0.0001	-0.0006	-0.0008	-0.0004	-0.0005
t Stat	-0.36	-2.69	-2.47	-1.82	-2.68
skewge	-0.0001	0.0000	0.0001	0.0000	0.0000
t Stat	-0.90	0.35	2.01	-0.39	0.14
2.month	-0.001	0.001	**0.001**	0.000	0.000
t Stat	-1.48	2.12	**4.32**	-0.16	1.19
3.month	**0.002**	**0.003**	**0.003**	**0.002**	**0.002**
t Stat	**4.89**	**10.54**	**11.77**	**10.17**	**14.06**
4.month	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**
t Stat	**6.23**	**12.66**	**16.48**	**12.03**	**16.65**
5.month	**0.002**	**0.002**	**0.003**	**0.002**	**0.002**
t Stat	**4.39**	**7.90**	**9.59**	**8.11**	**11.15**
6.month	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**
t Stat	**4.79**	**7.91**	**10.21**	**8.60**	**11.38**
7.month	0.001	**0.001**	**0.001**	**0.001**	**0.001**
t Stat	1.27	**7.27**	**9.98**	**4.19**	**6.54**
8.month	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**
t Stat	**3.73**	**6.33**	**14.40**	**6.35**	**8.73**
9.month	0.001	**0.001**	**0.001**	**0.001**	**0.001**
t Stat	2.42	**5.33**	**5.11**	**4.77**	**6.68**
10.month	0.001	**0.001**	**0.001**	**0.001**	**0.001**
t Stat	3.03	**6.02**	**5.45**	**5.80**	**7.50**
11.month	0.000	**0.001**	**0.001**	**0.001**	**0.001**
t Stat	0.16	**5.17**	**8.17**	**2.49**	**4.25**
12.month	0.001	**0.002**	**0.002**	**0.001**	**0.001**
t Stat	1.96	**9.33**	**18.29**	**5.92**	**9.40**
T	27393	32575	22336	59968	82304
R-sq	16.46%	24.27%	22.62%	19.61%	19.79%
R_t Stat	**3.80**	**3.84**	**3.75**	**3.99**	**4.06**

Table 9: Results from the panel regression model: volatility and trading volume

The table shows results from regression $\sigma_{i,t} = \beta_i + \delta_i I_t + \gamma_i \log(TV_{i,t}) + \omega_{i,t} \quad \omega_{i,t} \sim D(0, \vartheta_i)$ run for the volatility of overnight return of forward contracts for French (FR) German/Austrian (GE), Italian (IT) and Spanish (SP) markets, where I_t is a dummy variable indicating trading in the front period (1) or not (0) and TV is daily trading volume. M is monthly contracts, Q is quarterly contracts, Y is yearly contracts and M, Q ,Y is all contracts. T is sample size. The reference p-value (R_P-value) is Min [(1/T), 1%] where T is sample size. The sample is from 2 January 2008 to 31 December 2017 in the GE, FR and SP markets, and from 2 January 2014 to 31 December 2017 in the IT market. Boldface indicates statistical significance according to the reference p-value and t Statistic.

FR	Beta	t Stat	Delta	t Stat	Gamma	t Stat	T	R2*10^3	R_P-value	R_t Stat
M	**0.013756**	**22.42**	**0.002733**	**3.58**	0.000315	2.67	11606	12.86	1.72E-04	3.58
Q	**0.009557**	**16.94**	0.001527	1.84	0.000041	0.51	16857	3.71	1.19E-04	3.68
Y	**0.007247**	**12.94**	-0.000267	-0.25	0.000075	1.12	13710	1.37	1.46E-04	3.62
MQ	**0.011062**	**25.69**	**0.002786**	**4.63**	0.000182	2.38	28463	11.28	7.03E-05	3.81
MQY	**0.009828**	**24.96**	0.001638	2.91	0.000162	2.53	42173	6.90	4.74E-05	3.90
GE										
M	**0.008467**	**35.60**	**0.002522**	**6.90**	**0.000117**	**4.44**	31400	18.47	6.37E-05	3.83
Q	**0.007179**	**24.78**	0.000045	0.11	0.000100	2.94	35873	4.63	5.58E-05	3.86
Y	**0.005138**	**20.71**	0.000105	0.14	0.000128	2.55	24810	13.46	8.06E-05	3.77
MQ	**0.007811**	**40.07**	**0.001559**	**5.46**	**0.000095**	**4.04**	67273	9.76	2.97E-05	4.01
MQY	**0.007207**	**34.23**	0.001158	3.82	0.000082	3.42	92083	7.42	2.17E-05	4.09
IT										
M	**0.008870**	**20.87**	**0.001745**	**3.65**	0.000101	1.65	6249	9.93	3.20E-04	3.41
Q	**0.007203**	**18.31**	0.000537	0.91	0.000039	1.11	7556	1.80	2.65E-04	3.47
Y	**0.005541**	**7.86**	0.000048	0.04	0.000099	2.08	2847	7.70	7.02E-04	3.19
MQ	**0.007952**	**27.39**	**0.001519**	**3.95**	0.000047	1.26	13805	6.55	1.45E-04	3.62
MQY	**0.007635**	**26.13**	0.000780	1.97	0.000059	1.59	16652	3.44	1.20E-04	3.67
SP										
M	**0.007793**	**25.06**	0.001212	2.34	**0.000244**	**5.56**	9982	18.10	2.00E-04	3.54
Q	**0.005636**	**15.87**	0.000265	0.56	**0.000197**	**5.02**	12744	14.85	1.57E-04	3.60
Y	**0.004336**	**7.41**	-0.000573	-1.04	**0.000170**	**5.52**	5435	15.96	3.68E-04	3.38
MQ	**0.006499**	**24.93**	0.000894	2.48	**0.000241**	**7.52**	22726	19.81	8.80E-05	3.75
MQY	**0.006150**	**23.82**	-0.000027	-0.07	**0.000257**	**8.67**	28161	17.49	7.10E-05	3.80