Insider trading on continuous intraday electricity markets? Some empirical evidence from Germany

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May 18, 2018

Abstract

This paper investigates how private and public information about unplanned power plant outages impact intraday electricity prices in Germany. We use data from the European Power Exchange (EPEX) day-ahead and continuous intraday markets as well as market messages concerning unscheduled power plant non-usabilities from the European Energy Exchange (EEX) transparency platform. The results of an econometric analysis suggest that private and public information about unplanned power plant outages have a significant positive effect on the intraday price. Furthermore, we show that a reduction of the lead time on the intraday market enhances the possibilities of traders reacting to unplanned non-usabilities: an increased impact of private information on the electricity price is observed. Our results contradict the main objectives of the Regulation on Wholesale Energy Market Integrity and Transparency (REMIT), whereby the possession of private information must not have an impact on electricity prices.

Keywords:

Microstructure; Intraday electricity market; Supply-side shocks; Private information; Public information; REMIT

1. Introduction

An example of asymmetric information between participants in electricity markets is knowledge of an unplanned power plant outage. Non-disclosure, or disclosure with a time lag, of this missing capacity may save the insider additional costs, since market participants cannot use this information to adapt their biddings strategically and participate in the increased buying intention. Since missing production leads to a shortage of supply, the price of the affected contracts increases, ceteris paribus. The abuse of private information in order to influence the electricity spot price is investigated for the German day-ahead market, where participants have an incentive to withhold capacities (Weigt and von Hirschhausen, 2008; Bergler et al., 2017). However, variations of the subsequent intraday price from the day-ahead price are only analyzed from a fundamental perspective (Hagemann, 2015; Pape et al., 2016).

This paper investigates how private and public information about unplanned power plant outages impact the intraday electricity price in Germany. It follows the study by Lazarczyk (2016), where messages about unexpected outages are used to proxy public information, and introduces a method to measure the impact of private information on intraday prices. For this purpose, we use data from the European Power Exchange (EPEX) day-ahead and continuous intraday markets, as well as messages concerning unscheduled power plant non-usabilities that are published online at the European Energy Exchange (EEX) transparency platform. We segregate the content of these messages into private and public information about the outages and test whether they explain the average intraday price besides market fundamentals as forecast errors of renewable energy sources (RES), load forecast errors and cross-border flows.

The results of an econometric analysis point to a significant positive impact of private and public information about unplanned power plant outages on the average intraday price during 2014 to 2016. In July 2015, to provide market participants more adjustment possibilities to actively balance their portfolios in close-to-real time, the EPEX reduced the lead time from 45 minutes to 30 minutes for trading on the continuous intraday market. We show that the policy change enhances the possibilities of traders reacting to unplanned non-usabilities: an increased impact of private information on the electricity price is observed. Our results contradict the main objectives of the Regulation on Wholesale Energy Market Integrity and Transparency (REMIT), whereby the possession of private information must not have an impact on electricity prices.

The remainder of this paper is organized as follows. The next section discusses the impact of asymmetric information about unplanned power plant outages on the intraday price. Section 3 introduces the respective spot markets and their regulatory framework. The data of this study and the empirical strategy are presented in Section 4 and Section 5, respectively. Section 6 contains the results and Section 7 concludes.

2. Asymmetric information about unplanned power plant outages

The impact of information on price building and trading on financial markets is studied within market microstructure literature (Madhavan, 2000). For instance, Kyle (1985) develops an influential model where a single trader with monopolistic information places orders over time to maximize trading profit before the information becomes common knowledge. Admati and Pfleiderer (1988) analyze the strategic timing of trades and its impact on price evolution. Informed traders or insiders exploit their informational monopoly, which only becomes public information one trading period later, thus maximizing their profits by executing the trades one period in advance. This leads to a price adjustment revealing patterns of volume and price variability in the preannouncement period.

An example of private information about electricity markets is knowledge of a power plant's non-usability. Missing production leads to a shortage of supply, but other market participants are not able to adjust their bidding strategy if this information is not published, or is published with a time lag, which provides the insider a temporal advantage. According to European Commission objectives, the various national markets should be integrated through mechanisms, such as market coupling in the day-ahead market and the intraday cross border trading, in order to facilitate the flow of electricity between the different European jurisdictions. As these arrangements rely on trustable price signals, well-functioning markets should operate with an unbiased information set that reflects the supply- and demand-side fundamentals and is not distorted by an abuse of market power.

Bergler et al. (2017) investigate how the German day-ahead market is impacted by a strategic capacity withholding on prices. The study analyzes whether market participants are withholding capacities through failures in order to influence the auction price. By using data of the EEX transparency platform, the results of an empirical analysis indicate a positive influence of prices on power plant non-usabilities. This implies that strategic capacity withholding, and thus an abuse of private information, takes place on the day-ahead market.

Hagemann (2015) analyzes price determinants in the German continuous intraday market. The study takes into account how unplanned power plant outages, forecast errors of RES, load forecast errors and cross-border physical flows impact intraday prices. The results suggest that supply-side shocks influence intraday prices differently during a day. Since missing production leads to a shortage of supply, the average price of the affected contracts increases.

Lazarczyk (2016) investigates how public information about non-usabilities impacts electricity prices for the Nordic continuous intraday market. The dataset of the study comprises messages providing information about unscheduled power plant outages that were issued between the bidding periods for the day-ahead and intraday markets. Hence, news announcing failures can only influence decisions concerning the intraday market. The results of an empirical analysis point to a significant positive effect of the number of news reports on the intraday price. However, the magnitude of this effect varies within the day and tends to be observed for news concerning changes in marginal production during peak hours, whereas the impact of news concerning changes in baseload production is observed even in off-peak hours.

Lazarczyk (2015) analyzes the behavior of prices, number of trades and traded volumes in the period of one hour prior to the publication of market messages on the Nordic intraday market. The results point to positive effects on prices through an increase in the number of news reports in the preannouncement period, indicating that private information may be used for trading before the content of these messages becomes public information.

These studies show that an unforeseen reduction in production, or even its announcement, leads to positive effects on the realized intraday price. The opportunity to trade with private information on a continuous intraday market arises if the time lag between the actual outage and its publication exceeds at least one tradable contract and provides the insider with a timely edge. The theoretical consideration in this paper is therefore twofold: Firstly, we assume that the involved power plant sold its production on the day-ahead market and is now obligated to deliver. Secondly, the power plant will not hedge its missing production against any schedule deviation penalties. Taking this into account, the trading responsible will now optimize its schedule deviations under technically feasible and economically efficient restrictions. In the very short run, these deviations may be voluntarily cross traded within a trader's own portfolio, if available, by launching highly flexible generation units. Furthermore, optional reserve contracts on a bilateral basis may be activated to substitute the missing production, which is especially the case for large-scale power generation. Finally, depending on the outage duration, the trading responsible may compensate the deviations on the continuous intraday market. Since the marginal costs of claimed or counterparty generation are higher than the realized spot prizes, trading on the intraday market could be advantageous (Hagemann and Weber, 2013). Even if the affected power plant executes a bilateral or over-the-counter (OTC) trade, the counterparty will hedge its production on the intraday market, as it seems irrational to set aside the necessary capacities.

3. The short-term electricity markets in Germany

3.1 The legal framework

The reliability of wholesale energy market places, such as energy exchanges or OTC markets, depends not least on whether market participants consider the underlying price formation as trustworthy and are willing to trade on them. To foster this rationale, the European Commission introduced a set of regulations, among which is Regulation (EU) No. 1227/2011 on Wholesale Energy Market Integrity and Transparency (REMIT), which has been in force since December 2011 in all EU member states. Its key objective is to ensure an open and fair competition in wholesale energy markets to the benefit of final consumers. In terms of integrity, the regulation should build confidence that the wholesale price formation is reflected by market fundamentals and that no profits are gained through insider trading or market manipulation. In terms of transparency, the regulation should allow all stakeholders to have a clear picture of the market situation by making all relevant market and fundamental data publicly available.

One main aim of REMIT is the prohibition of insider trading. This means that persons who possess inside information shall be prohibited from using this information to buy or sell wholesale energy products, e.g., electricity, or from "whispering" this information to any other person, recommending them to trade on this information. According to REMIT, the Agency for Cooperation of Energy Regulators (ACER) is responsible for introducing a monitoring framework to detect and prevent market abuse. Monitoring requires regular and timely access to records of transactions as well as data on capacity and use of facilities for production, storage, consumption, or transmission of electricity or natural gas. Market participants, including transmission system operators, suppliers, traders, producers, brokers, and large users who trade wholesale energy products are required to provide that information to ACER. Furthermore, ACER issues guidance to ensure that National Regulatory Authorities enforce their tasks, derived from REMIT, in national legislation. In Germany, the legislator equipped the Bundesnetzagentur, through the Energy Industry Act (EnWG), with the necessary investigation and enforcement powers. The EnWG distinguishes between various sanctions. Thus, violations can be classified as administrative or even as criminal offenses.

REMIT requires all market participants to disclose inside information. Following Article 2 (1) of REMIT, the concept of inside information includes all types of information that are likely to have a significant impact on prices of wholesale energy products. The obligation to disclose inside information lies with the market participant in accordance with Article 4(1), which is crucial for the scope of this study. According to Article 4(1) of REMIT,

> "Market participants shall publicly disclose in an effective and timely manner inside information […] relevant to the capacity and use of facilities for production […], including planned or unplanned unavailability of these facilities."

In the context of registration, the market participants must specify where they publish their inside information. As inside information should be spread as wide and publicly as possible to ensure equal and free of charge access, central platforms aggregating this information are considered effective. The EEX offers the publication of inside information via its transparency platform, which is supported by ACER in its use (EEX, 2017). The notion of timely disclosure does not refer to a specific threshold, which can be measured in time units, but in combination with Articles 4(2) and 4(4) of REMIT, it prohibits any trading on this issue before this information is published in a simultaneous, complete, and effective manner. Furthermore, it is up to market participants to decide whether information they hold constitutes inside information and should be published. Consequently, any change of planned or unplanned production has to be disclosed, if the criteria in Article 2(1) of REMIT are violated.

Following REMIT, the impact of the actual outage on the price should not deviate from the impact of outage announcement, since trading on private information contradicts the purpose of this regulation. Hence, the duration of the time lag between the event and its publication should be irrelevant, since no information gains can be accumulated. Consequently, private information about unplanned power plant outages should not have an impact on intraday prices.

3.2 Market framework

Short-term electricity trading is based on the day-ahead and the intraday market. Both markets are characterized by physical fulfilment. In the day-ahead market, the participants have the option to trade (sell or buy) electricity for delivery in an anonymous auction or OTC for the next day. The EPEX hosts the auction and intraday trading platform, where standardized contracts can be executed. In contrast, OTC is a decentralized market, where market participants also negotiate bilaterally non-standard contracts (Bönte et al., 2015).

Concerning the day-ahead auction, orders contain up to 256 price/quantity combinations for each hour of the following day must be submitted in the EPEX trading system by at least 12 pm (gate closure). The auction takes place daily after gate closure including statutory holidays. The determination of auction prices and quantities is realized by an algorithm, which sorts all sell and buy orders (offers and bids) in a price/quantity combination by increasing prices. Hence, for each hour a supply (merit-order) and demand curve is generated, and its intersection determines the market clearing price. Under this uniform pricing, the optimal strategy for auction participants is to bid at marginal costs. On the one hand, the short-term nature of the day-ahead market satisfies the trading of reliable forecasts of RES or unexpected peak demands. On the other hand, it suits the grid system characteristics, which require balanced supply and demand in advance.

After gate closure, the market participants are offered to adjust their day-ahead schedules, if necessary, on the intraday market. Moreover, the participants are obliged by the regulator to reschedule, since the original day-ahead scheduling is affected by an unforeseen event, such as an unplanned outage. Any deviation from planned production may lead to imbalance costs which are penalized accordingly to the originator. Following the current balancing costs regime in Germany, imbalance prices significantly exceed – at least on average – the intraday prices. Therefore, the expected imbalance costs incentivize all market participants to reduce imbalance volumes and can be considered as the main motivation for intraday trading (Scharff and Amelin, 2016).

On the continuous intraday market, electricity is traded for delivery on the same or on the following day on single hours. Each hour can be traded until 30 minutes before delivery begins. Starting at 3 pm on the current day, all hours of the following day can be traded. Trading is continuous 24 hours a day, 7 days a week. Unlike the day-ahead auction market, prices on the continuous intraday market are determined by the pay-as-you-bid principle, which implies trade matching at any time whenever the counterparty accepts the offer. Hence, prices vary from trade to trade and market participants may generate incremental rents by modifying their orders. Alternatively, intraday trading can also be executed in an OTC environment. However, as Zachmann (2008) and Nicolosi (2010) derive, OTC and exchange prices converge, otherwise arbitrage between these two markets would be possible.

3.3 Reduction of the lead time on the continuous intraday market

To facilitate the producer's need for rescheduling, EPEX shortened the lead time for contracts on the intraday market from 45 to 30 minutes till delivery on July 16, 2015. The lead time refers to the minimum time between the execution of a trade and the delivery of the traded electricity and its reduction is the object of an ongoing process (EPEX, 2017). This structural change was introduced to manage emerging flexibility challenges of power markets more efficiently, which is particularly necessary for unforeseen events such as power plant outages but even more so for renewable forecast errors (EPEX, 2015). Since forecasts for RES can be set up nowadays in a constant update regime, the shorter lead time trading outcome is twofold.

Firstly, the correcting trading quantities for the market participants decrease and relax, ceteris paribus, the impact on the intraday price. Secondly, which is a consequence of the first point, the reduction mitigates the imbalance costs especially associated with increased amounts of fluctuating renewable energy (Holttinen, 2005; Barth et al., 2008). Furthermore, the lead time reduction enables the market participants to arbitrage between neighboring countries, provides opportunities for cross-border trading and enhancing the reaction on load deviations (Weber, 2010; Viehmann, 2017).

Concerning private information about unplanned power plant outages, the regime change may also create constellations, which enhance or limit the timely edge to trade on the continuous intraday market. According to the example in Figure 2a, the unplanned outage starts at 15:20 and is published at 15:40. In the old regime, both the insider and the market participants can adjust their biddings until 16:15 and, therefore, at the earliest for H18, which lasts from 17:00 to 18:00. Consequently, the information gain is omitted. In the new regime, the insider may trade contract H17, which lasts from 16:00 to 17:00, until 15:30 and benefit from the non-disclosure of this information, since the market participants can only adjust their biddings for H18 until 16:30. Overall, the publication time lag creates a situation for potential insider trading, which is strictly prohibited by the REMIT legislation.

Nevertheless, the lead time regime change allows possible constellations that even limit the insider opportunity. According to the example in Figure 2b, the outage starts at 15:20 and is published at 16:20. In the old regime, the insider obtains the information gain for two tradable contracts, H17 and H18, since the market participants can only react for H19 until 17:15. In the new regime, the lead time shortage enables the market to already react for H18 until 16:30.

[Figure 1a und 1b about here]

4. Data

4.1 Dependent variable: Difference between the day-ahead and intraday price

Supply side shocks after the day-ahead gate closure cause open positions in the schedules of market participants and may induce trading activity on the continuous intraday market. Thus, the deviation of the intraday *ID* price from the day-ahead *DA* price can be explained by changes in the market fundamentals (Hagemann, 2015) or by the publication of market messages (Lazarczyk, 2016).

Table 1 sizes descriptive statistics of the EPEX day-ahead and intraday continuous prices, respectively. Our dataset begins on January 1, 2014 and ends on December 31, 2016. On average, prices on the day-ahead market coincide with prices on the intraday market (31.12 €/MWh vs. 31.32 €/MWh), and there are no significant differences in the mean prices at the hourly level. However, the standard deviation on the day-ahead market is lower than on the intraday market (12.74 €/MWh vs. 13.81 €/MWh). At the hourly level, prices are less volatile on the day-ahead market during the hours 1–6 when the demand is relatively low. They exhibit standard deviations between 8.08 and 9.16 €/MWh. Electricity is traded for the highest price on the day-ahead market with 104.96 €/MWh; this is much less than the largest price on the intraday market with 139.12 €/MWh.

Negative electricity prices on the German day-ahead market have been possible since 2008. They are the result of a high feed-in of RES in periods of low demand and/or interconnections failures (Valitov, 2018). Negative prices are also possible on the intraday market. The lowest price in our dataset was on the intraday market with –155.52 €/MWh in comparison with –130.09 €/MWh on the day-ahead market.

[Table 1 about here]

4.2 Publication of unplanned power plant outages

The EEX transparency platform publishes all unscheduled power plant non-availabilities. Every planned and unplanned non-usability of 100 MW or more and of at least one hour in duration has to be reported by the facility operator. The classification as a planned or unplanned non-usability depends on the time lag between the start of the outage and its reporting time. In case the message is issued before or simultaneously with the outage, it is classified as planned. In contrast, the message is classified as unplanned if the publication time stamp is after the beginning. Although not legally defined, news announcing failures has to be reported within 60 minutes of an outage. All messages are published online and can be updated on an on-going basis.

Our dataset is comprised of market messages regarding unplanned outages including information about the respective power plant type, the duration and magnitude of the non-usability, and its publication timestamp. From the entire dataset, we segregate messages about outages of less than 100 MW and less than one hour in duration, because facility operators are obliged to report only unplanned non-usabilities of 100 MW or more which last at least one hour. This leaves 3,481 published unexpected outages whose content could possibly influence intraday prices from 2014 to 2016.

We choose outages that arrive on time to influence decisions concerning the intraday market, but not the day-ahead market. In particular, we segregate the content of the messages into two distinct explanatory variables: Private Information and Public Information. "Private Information" is the sum of missing capacities that may influence the intraday price only in the period from the beginning of the outage until its publication on the EEX Transparency Platform. Consequently, all missing capacities that may have an impact on the intraday price from the publication timestamp until the expected end of the outage are summarized in the variable "Public Information."

4.3 Control variables: Renewable energies, load and cross border physical flows

Hagemann (2015) discusses further determinants of the German intraday price. Besides unplanned power plant outages, RES forecast errors and load forecast errors as well as cross border physical flows might influence the intraday price. Forecast errors are calculated as the difference between the actual value and the day-ahead forecasted value. Concerning the case of RES, TSOs might act as a seller of electricity on the intraday market if the actual generation exceeds the forecasted generation. Thus, an increase of the RES forecast error should lead, ceteris paribus, to a decrease of the intraday price.

In contrast, TSOs might also act as a buyer of electricity on the intraday market if the actual consumption (load) is higher than the forecasted values. Furthermore, cross border trades may influence the continuous intraday price. Electricity imports into the German intraday market are expected to decrease the prices, whereas exports to neighboring countries are expected to increase the prices.

We control for these market fundamentals and include data provided by the European Network of Transmission System operators for electricity (ENTSO-E) Transparency Platform. In our analysis, we use generation data from wind (onshore and offshore) farms as well as solar plants. Cross border physical flows are estimated by net exports from Germany to France.

5. Empirical strategy

Following Hagemann (2015) and Lazarczyk (2016), we perform OLS regressions:

$$\text{ID\_price}_t - \text{DA\_price}_t = \alpha + \beta_1 \text{Private\_information}_t + \beta_2 \text{Public\_information}_t + \gamma' C_t + \varepsilon_t, \quad (1)$$

with $t = 1, \ldots, N$ where N indicates the number of hours in the sample. The difference between the average intraday price and the day-ahead price is regressed on the missing capacities caused through unplanned power plant outages. As described above, we distinguish between private and public information about the non-usabilities. Furthermore, the regressions include a vector of control variables C as described in Section 4.3, as well as dummy variables for hours, days, and months to control for time-specific effects. Note that all explanatory variables may influence the intraday price at hour t, but have no impact on the respective day-ahead price.

The regressions are conducted with Newey-West standard errors to get autocorrelation and heteroscedasticity robust estimates. All variables are checked for the presence of a unit root by performing several Augmented Dickey-Fuller (ADF) tests. The results of the unit root tests with and without a trend suggest that all variables in the regressions are stationary (see Appendix Table A1). As a robustness check, we perform regressions with the first two lags of the dependent variable as further explanatory variables.

6. Results

Table 2 summarizes the OLS regression results of five models based on Equation 1 including data from 2014 to 2016. The first column of Table 2 presents the outcome for the total sample. The coefficient of the variable *Private information* points to a positively significant impact on the intraday price. Holding all other variables constant, the intraday price increases by 1.21 €/MWh if the privately known missing capacities increase by 1000 MW. Furthermore, publicly known missing capacities have a positively significant impact on the intraday price, which is in line with the empirical findings of Lazarczyk (2016) for the Nordic intraday market. These two results imply that the intraday price is partly affected by asymmetric information regarding unplanned power plant outages. However, from a legal perspective, there should not be any impact of private information about the actual outage on the intraday price at all. As expected by Hagemann (2015), an increase in the forecast error of RES (i.e., excess supply) has a negative impact on the intraday price. In contrast, an increase in the load forecast error (i.e., an increase in electricity consumption) leads to a higher intraday price. The coefficient of the variable *Net exports* points to a positive impact on the intraday price as theoretically predicted.

The second and third column of Table 2 present the regression coefficients of the subsamples before and after the policy change, respectively. Both subsamples contain nearly the same number of observations. In the old 45 min lead time regime, private information about missing capacities have a positive, but not statistically significant, impact on the intraday price (0.56 €/MWh). After the regime switch, however, the coefficient of the variable *Private information* points to a positively significant impact of 2.13 €/MWh. Furthermore, the impact of the *RES forecast error* increases from -1.99 €/MWh to -1.08 €/MWh, the impact of the Load forecast error increases from 0.27 €/MWh to 0.41 €/MWh, and the impact of Net exports increases from -0.14 €/MWh (not statistically significant) to 0.51 €/MWh. The increases in the coefficients might be an indicator of enhanced market adoption due to the higher flexibility of the intraday market.

In order to test the remarkable differences between both subsamples for statistical significance, we introduce a dummy variable for the lead time change which becomes one from July 16, 2015 onwards. Next, we multiply all explanatory variables with the policy change dummy and test these interaction terms for statistical significance. The results are summarized in the fourth column of Table 2. According to this test, only the increases in the coefficients *RES forecast error* and *Net exports* are statistically significant.

Since the lead time change creates situations which can enhance or limit the number of affected prices through power plant outages, we segregate the variables *Private information* and *Public information* into three further explanatory variables – *No change*, *Increase,* and *Decrease* –, respectively. *No change* means that the regime switch does not affect the number of influenced prices due to an unplanned power plant outage. Hence, the outcome of this variable is comparable with the outcome of the variable *Private information* in the 45 min subsample. *Increase* summarizes the sum of missing capacities of messages that increase the number of affected prices compared to a 45 min regime, and *Decrease* otherwise. Column 5 of Table 2 presents the results of this modified regression for the 30 min lead time subsample. Holding everything constant, the coefficient of *Private information* increases from 0.56 €/MWh in the 45 min regime to 1.62 €/MWh in the new regime (*Private information: no change*). The coefficient of *Private information: increase* is approximately 3.91 €/MWh and statistically significant. This implies that the lead time change may be responsible for the increased explanatory power of private information on the price formation in the intraday market from July 2015 onwards. Although the coefficient of the variable *Private information: decrease* is positive, it has no statistically significant impact on the intraday price.

Appendix Table A2 presents the regression results of the same five models as Table 2, with the first two lags of the dependent variable as further explanatory variables. Our major finding is robust: private information regarding missing capacities has a positive significant impact on the intraday price, especially after the switch to a 30 min lead time regime.

[Table 2 about here]

7. Conclusion

This paper investigates the impact of asymmetric information regarding unplanned power plant outages on intraday electricity prices in Germany from 2014 to 2016. In order to distinguish between private and public information, we split the content of relevant market messages into periods before and after their publication and test whether this asymmetry affects the intraday price besides further market fundamentals. The results of an econometric analysis suggest that the intraday price increases, ceteris paribus, by 1.21 €/MWh if the privately known missing capacities increase by 1000 MW. Similarly, public information regarding these missing capacities increase the intraday price by 1.05 €/MWh.

We show that a reduction of the lead time and, therefore, increased flexibility on the intraday market indicates a higher adoption of the participants: on the one hand, the impact of forecast errors of RES on electricity prices is reduced and cross-border trading becomes more relevant. On the other hand, the policy change enhances the possibilities of traders reacting to unplanned non-usabilities: an increase in the impact of private information on the electricity price is observed. This is in contrast to the main objectives of REMIT, whereby the possession of private information must not impair wholesale electricity prices.

However, we have to acknowledge that the empirical findings in this paper do not provide evidence for actual insider trading. Since prices on the EPEX intraday market are determined through anonymous bids and offers, it is not possible to assign an abnormal trade in the data to a distinct market message ("smoking gun"). Nevertheless, policy makers could increase transparency among market participants and prevent possible insider trading by introducing a real-time updated market messages framework.

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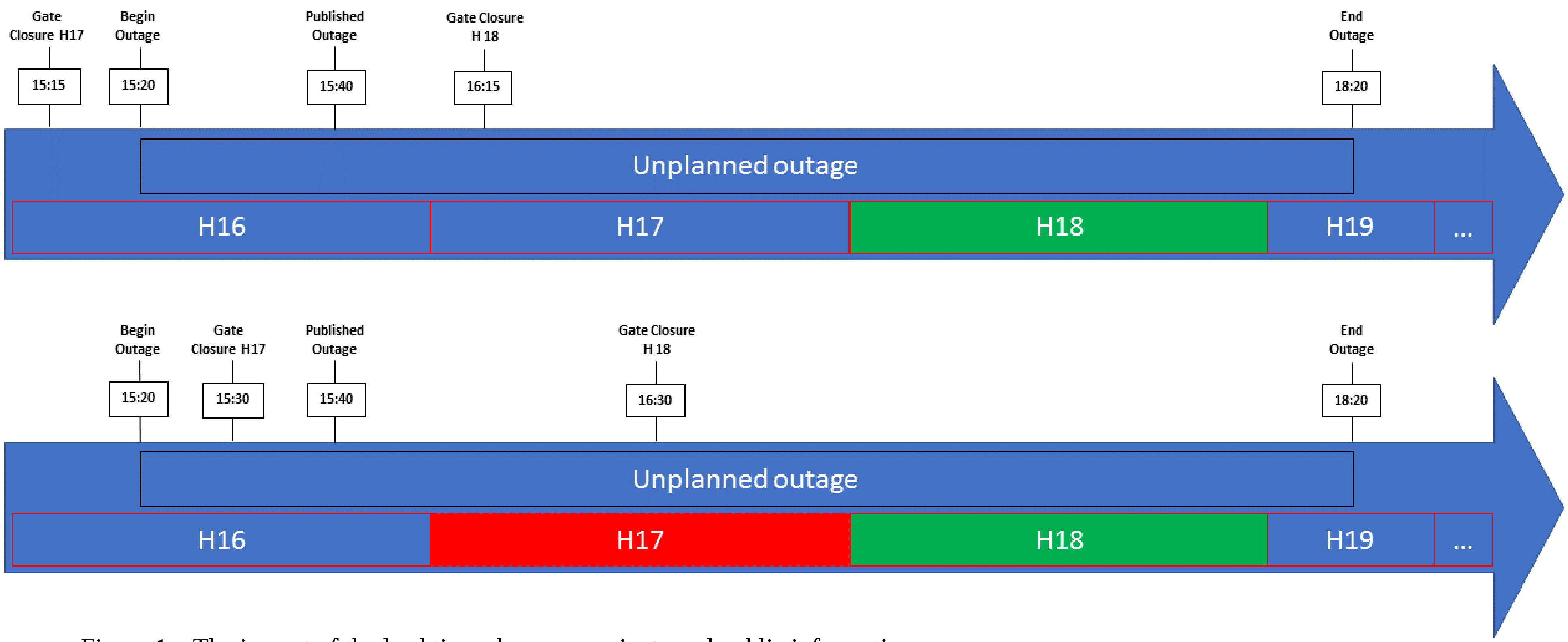

Figure 1a: The impact of the lead time change on private and public information.

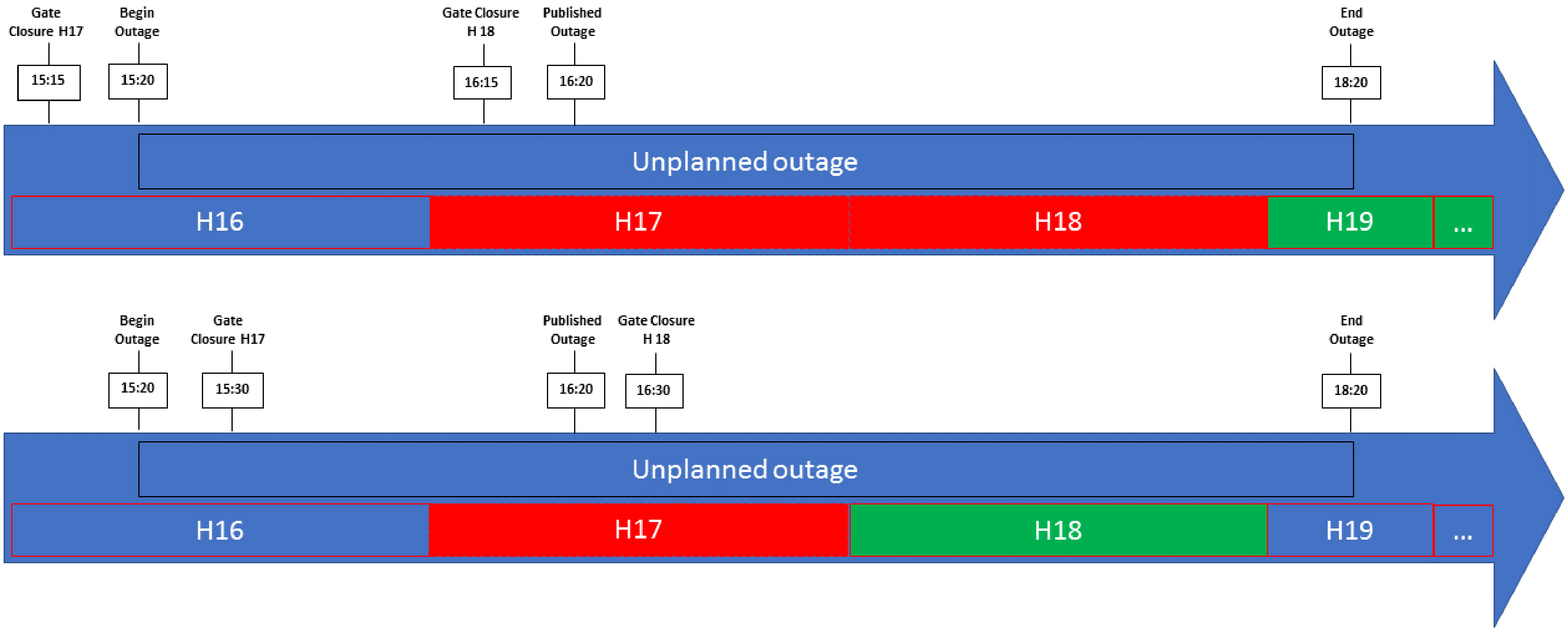

Figure 1b: The impact of the lead time change on private and public information.

Table 1
Descriptive statistics of the day-ahead and intraday prices.

DA price	Mean	S.D.	Min.	Max.	ID price	Mean	S.D.	Min.	Max.
H1	25.08	8.08	-19.98	51.68	H1	25.54	9.20	-75.82	49.03
H2	23.16	8.61	-36.1	41.58	H2	23.76	9.97	-81.04	43.29
H3	21.89	9.16	-49.98	39.02	H3	22.25	10.31	-76.62	44.92
H4	21.00	9.11	-60.26	38.56	H4	21.17	10.17	-77.52	40.61
H5	21.46	8.77	-50.65	42.93	H5	21.52	9.69	-78.25	41.88
H6	23.37	8.51	-51.49	46.66	H6	23.56	9.76	-78.32	47.17
H7	29.22	11.33	-67.07	54.11	H7	29.65	12.14	-65.47	54.11
H8	35.78	14.17	-67.09	75.06	H8	35.54	14.56	-43.16	87.23
H9	37.81	13.85	-54.20	85.05	H9	37.84	14.81	-44.27	103.43
H10	36.53	12.52	-9.11	83.54	H10	36.49	13.61	-56.70	89.69
H11	34.69	12.07	-10.31	77.17	H11	34.97	13.44	-57.76	96.41
H12	34.18	11.92	-7.09	75.94	H12	34.16	13.82	-56.67	139.12
H13	31.76	12.02	-76.09	70.8	H13	32.17	14.30	-78.53	129.71
H14	30.14	13.55	-100.06	71.48	H14	30.77	15.44	-123.46	122.63
H15	29.36	14.31	-130.09	70.82	H15	30.07	15.79	-155.52	81.82
H16	30.27	13.62	-82.06	72.99	H16	30.67	14.99	-99.46	82.48
H17	31.86	13.16	-76.00	84.92	H17	32.28	14.36	-65.39	86.49
H18	36.98	13.66	-4.20	104.96	H18	36.98	14.89	-15.10	114.70
H19	40.60	12.58	7.45	86.01	H19	40.54	13.71	-3.29	110.61
H20	41.30	11.56	2.16	98.05	H20	40.90	12.81	-2.09	98.72
H21	37.49	8.90	-1.58	67.54	H21	37.01	10.55	-34.33	121.66
H22	33.78	7.76	-3.35	59.94	H22	33.46	9.32	-49.59	76.27
H23	32.12	7.18	3.45	61.95	H23	32.47	8.94	-23.45	80.68
H24	27.11	7.40	-19.93	52.49	H24	27.84	8.84	-43.74	57.42
Total	31.12	12.74	-130.09	104.96	Total	31.32	13.81	-155.52	139.12

Table 2
OLS regression results for the years 2014-2016.

VARIABLES	(1) Total sample	(2) 45 min lead time	(3) 30 min lead time	(4) Total sample	(5) 30 min lead time
Private information	1.212*	0.563	2.127***	0.563	
	(0.734)	(1.305)	(0.510)	(1.353)	
Private information: no change					1.617***
					(0.627)
Private information: increase					3.912***
					(1.041)
Private information: decrease					1.767
					(1.792)
Public information	1.053***	1.188***	1.222***	1.188***	
	(0.256)	(0.385)	(0.313)	(0.397)	
Public information: no change					1.555***
					(0.405)
Public information: increase					0.145
					(0.542)
Public information: decrease					3.798***
					(1.387)
RES forecast error	-1.471***	-2.207***	-1.081***	-2.207***	-1.078***
	(0.218)	(0.107)	(0.259)	(0.110)	(0.259)
Load forecast error	0.264***	0.268***	0.408***	0.268***	0.407***
	(0.0530)	(0.0625)	(0.0886)	(0.0628)	(0.0887)
Net exports	0.219**	-0.141	0.510***	-0.141	0.520***
	(0.110)	(0.181)	(0.146)	(0.189)	(0.145)
Lead time change				-0.373	
				(0.864)	
Lead time change*Private information				1.564	
				(1.443)	
Lead time change*Public information				0.0342	
				(0.508)	
Lead time change*RES forecast error				1.126***	
				(0.284)	
Lead time change*Load forecast error				0.140	
				(0.110)	
Lead time change*Net exports				0.652***	
				(0.239)	
Dummies					
Hour	Yes	Yes	Yes	Yes	Yes
Day	Yes	Yes	Yes	Yes	Yes
Month	Yes	Yes	Yes	Yes	Yes
Constant	-0.0680	-0.211	-0.584	-0.211	-0.426
	(0.485)	(0.521)	(0.688)	(0.557)	(0.699)
Observations	25,697	13,097	12,600	25,697	12,600
Adjusted R-squared	0.185	0.278	0.153	0.221	0.155
Bandwidth	99	62	72	98	72

Dependent variable: ID_price – DA_price.
Newey-West standard errors in parentheses.
Optimal Bandwidth for a Bartlett kernel was determined by the Newey-West method (Newey and West, 1994).
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table A1
Augmented Dickey-Fuller tests for unit root.

Variables	ADF test statistic	ADF test statistic with trend
ID_price – DA_price	-17.695***	-17.695***
Private information	-16.863***	-16.957***
Public information	-14.668***	-14.691***
RES forecast error	-11.898***	-11.898***
Load forecast error	-10.592***	-10.907***
Net exports	-6.638***	-6.879***

Automatic lag selection: Schwarz information criterion.
Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Appendix Table A2
OLS regression results for the years 2014-2016.

VARIABLES	(1) Total sample	(2) 45 min lead time	(3) 30 min lead time	(4) Total sample	(5) 30 min lead time
$ID\_price_{t-1} - DA\_price_{t-1}$	0.865***	0.824***	0.892***	0.856***	0.892***
	(0.0241)	(0.0368)	(0.0259)	(0.0241)	(0.0260)
$ID\_price_{t-2} - DA\_price_{t-2}$	-0.0733***	-0.0750***	-0.0784***	-0.0748***	-0.0786***
	(0.0191)	(0.0285)	(0.0197)	(0.0189)	(0.0197)
Private information	0.564***	0.448	0.713***	0.444	
	(0.172)	(0.307)	(0.184)	(0.304)	
Private information: no change					0.621***
					(0.210)
Private information: increase					1.099***
					(0.410)
Private information: decrease					-1.298
					(1.176)
Public information	0.253***	0.342***	0.271***	0.306***	
	(0.0483)	(0.0775)	(0.0642)	(0.0782)	
Public information: no change					0.340***
					(0.0824)
Public information: increase					0.0524
					(0.148)
Public information: decrease					0.547
					(0.667)
RES forecast error	-0.411***	-0.685***	-0.292***	-0.620***	-0.292***
	(0.0244)	(0.0369)	(0.0278)	(0.0317)	(0.0278)
Load forecast error	0.0652***	0.0804***	0.0899***	0.0724***	0.0902***
	(0.0101)	(0.0137)	(0.0177)	(0.0138)	(0.0177)
Net exports	0.0812***	-0.0223	0.151***	-0.0172	0.153***
	(0.0191)	(0.0366)	(0.0264)	(0.0364)	(0.0265)
Lead time change				-0.0852	
				(0.323)	
Lead time change*Private information				0.326	
				(0.354)	
Lead time change*Public information				0.00406	
				(0.102)	
Lead time change*RES forecast error				0.296***	
				(0.0350)	
Lead time change*Load forecast error				0.0304	
				(0.0219)	
Lead time change*Net exports				0.183***	
				(0.0453)	
Dummies					
Hour	Yes	Yes	Yes	Yes	Yes
Day	Yes	Yes	Yes	Yes	Yes
Month	Yes	Yes	Yes	Yes	Yes
Constant	-0.245	-0.295	-0.374	-0.297	-0.342
	(0.162)	(0.225)	(0.232)	(0.228)	(0.234)
Observations	25,691	13,093	12,598	25,691	12,598
Adjusted R-squared	0.733	0.725	0.750	0.736	0.750

Dependent variable: ID_price – DA_price.
Robust standard errors in parentheses.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.