Information Assimilation in the EU Emissions Trading Scheme: A Microstructure Study

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Abstract

The European Union's Emissions Trading Scheme (ETS) is the key policy instrument of the European Commission's Climate Change Program aimed at reducing carbon emissions to eight percent below 1990 levels by 2012. The key asset traded under the scheme is the European Union Allowance (EUA).

This article examines the extent of information assimilation in the futures market of the European Unions ETS. Using ultra high frequency data, we examine intraday futures market behaviour around major scheduled macroeconomic and emissions information announcements during Phase 2 of the European Unions ETS, 2008-12. We examine December expiration contracts in 2009, 2010 and in 2011. Our study of intraday behaviour of the European Unions ETS futures market relates to price volatility and spreads as well as trading volumes.

In particular, we address questions such as [1] do order imbalance and returns respond to announcements in a way that correctly reflects the news component?; [2] is there an increase in the level of information asymmetry subsequent to an announcement?; [3] is there information leakage evident in the EU ETS futures market and [4] what is the speed of adjustment to new information? This is the first study to raise these important questions, which pertain to information assimilation, with regard to the European Unions ETS futures market.

As a result, this study sheds light on the adjustment of the EU ETS futures market to new information. The findings are compared to adjustments in well traded futures markets in the United States (Balduzzi et al., 2001; Brandt and Kavajecz, 2004; Pasquariello and Vega, 2007). Findings in the extant literature, with regard to low resolution data, indicate evidence in support of a maturing EU ETS futures market that is increasingly linked to the fundamentals of the emission of carbon (Bredin and Muckley, 2011). The corresponding emergence of an efficiently determined price of carbon emissions is a necessary condition, within a market system, to incentivate the mitigation of carbon emissions. The revelation of the price of carbon may in turn influence aggregate carbon emissions and by this mechanism climate change over time.

Keywords: Carbon trading; derivatives; market microstructure; market efficiency; informational assimilation

1 Introduction

The European Union (EU) Emissions Trading Scheme (ETS) was introduced in January 2005, as part of the EU's agreement to cut emissions of carbon dioxide (CO2) within the Kyoto Protocol, under which the EU has committed to reduce greenhouse gas (GHG) emissions by eight percent (relative to 1990 levels) by 2008-2012. The ETS issues a limited amount of emission allowances to firms on an annual basis; failure of compliance with the commitments results in a penalty of 40 (100) euros per tonne of CO2 produced without allowances for the first (second) phase. The ETS allows firms to trade the amount of emission allowances that they hold and as a result has applied a market value to this externality. In the EU ETS context the first phase of trading was 2005-2007 and the second one, which coincides with the first compliance period of the Kyoto Protocol, is 2008-2012. The third European trading phase will commence in 2013. The aim of the ETS is that this cost will encourage firms to reduce their emissions. Albeit a considerable amount of uncertainty is associated with this young market, we might expect to see it mature overtime (Paolella and Taschini, 2008; Bredin and Muckley, 2011).

In this paper, we hope to answer questions such as [1] do order imbalance and returns respond to announcements in a way that correctly reflects the news component?; [2] is there an increase in the level of information asymmetry subsequent to an announcement?; [3] is there information leakage evident in the EU ETS futures market and [4] what is the speed of adjustment to new information? With the above questions being answered, we are able to have a clear picture of the current market on how it has grown so far, and what to expect as well.

Rich literatures have addressed the responsiveness to announcements of financial instruments in different markets. Ederington and Lee (1993) studied the price volatility in the futures market, while Fleming and Remolona (1999) examined the price volatility and trading behaviour in secondary market for U.S. Treasury securities. Balduzzi et al. (2001) extended their research by incorporating a much broader set of macroeconomic announcements, a longer sample period, and a broader set of Treasury instruments. T. C. Green (2004) also studied the impact of trading on government bond prices surrounding the release of macroeconomic news, finding that the release of public information increased the level of information asymmetry in the government bond market. Faust et al. (2007) found joint movements of exchange rates and U.S. and foreign term structure over short-time windows around macro announcements, using high-frequency data. Evans and Lyons (2008) showed that the arrival of macro news could account for more than 30% of daily price variance.

Although the EU ETS market has been well examined recently, majority of the research focus on operating mechanism, pricing mechanism, and economic results of the ETS (Zhang and Wei, 2010). Only a small number of articles have studied the informational assimilation of this market. Chevallier (2009) examined the impact of macroeconomic risk factors on carbon futures on a daily basis, finding only remote connection between the two. Schmidt and Werner (2011) found inconsistent influence of verified emission announcements on daily abnormal stock returns through time. Conrad et al. (2012) studied the surprises of the European Commission's decisions on second National Allocation Plans (NAPs) as well as macroeconomic indicators on a high-frequency basis, finding significant and consistent impact immediately or within a few minutes after the release of the news using Phase I data. These articles have shed some light on the even study on EU ETS, but are far less complete and thorough.

In this paper, we follow Schmidt and Werner (2011) in using verified emissions announcements, and Conrad et al. (2012) in choosing macroeconomic announcements to construct our information set. We analyse the informational assimilation process in the similar but modified pattern to Balduzzi et al. (2001). We regress the changes in market-microstructure-level trade variables on the surprises of the macroeconomic announcements, and also examine the ratio of these variables on announcement days over non-announcement days. We study the impact of verified emission announcements on EUA futures by intuitive illustration of trade variables around the release. Novelty of our study stands from the data assessed, the information examined, the methods used, and our comparison of EUA futures market to mature market, such as U.S. Treasury-bill market.

Our results indicate that [1] information asymmetry, indicated by trade variables such as returns, volumes, bid-ask spreads, number of ticks and volatility, increases in response to announcements; [2] we find evidence of information leakages in the EUA futures market implied by abnormal trading activities prior to news release; [3] the speed of adjustment to new information varies in terms of the type of information, but generally would not exceed the 90 minutes window around release; [4] among 12 macroeconomic announcements, although we find a good portion of which leading to significant order imbalance in the EUA futures, some are in the opposite direction as we expect. Our findings have implications for the microstructure of ETS market in that we develop the understanding of how EU ETS futures market adjust to new information, pertaining to the market efficiency and improvement issues of this market.

The paper is organised as follows. Section 2 describes the EUA futures data in prices, volumes, and bid ask spreads with regard to their movement and seasonality respectively. Section 3 analyses the informational assimilation of EUA futures. In specific, various market microstructural trade variables are studied in response to macroeconomic announcements and verified emissions announcements respectively. Section 4 concludes.

2 EUA Futures Data Description

Our dataset comprises tick-by-tick trading records of three EUA[1] futures contracts, CFI2Z9 (Sep 2008 - Dec 2009), CFI2Z0 (Sep 2008 - Dec 2010), and CFI2Z1 (Sep 2008 to Dec 2011). We exclude trading records prior to the year of expiration when tradings are far less frequent. we also neglect those records with bid-ask spreads greater than 1 euro as well. For convenience, we sort the tick records into equidistant 1-minute bars. For the minutes of zero trading, we interpolate by the following rules. We set the price and bid-ask spread equal to the nearest previous trading, and volume equal to zero. Eventually, our sample include 448800[2] samples. We examine our data in the prices, number of ticks, volumes, and bid-ask spread. Table 1 gives a brief summary of the our sample.

[1]European Union Allowance futures contract, observed from Jan 2, 2009 through to December 19, 2011 with expiration in December 14, 2009, December 20, 2010, and December 19, 2009. The unit of trading is one lot of 1,000 CO2 EU Allowances. Each EU Allowance being an entitlement to emit one tonne of carbon dioxide equivalent gas.

[2]We have 148200 records of CFI2Z9 contract, 150600 of CFI2Z0, and 150000 of CFI2Z1.

Table 1: **Summary Statistics for EUA Futures**

Future symbol	CFI2Z9	CFI2Z0	CFI2Z1
Start date	2009-Jan-02	2010-Jan-04	2011-Jan-04
End date	2009-Dec-14	2010-Dec-20	2009-Dec-19
No. of trading days	243	247	246
Open Price	15.90	12.71	14.84
High Price	25.50	16.73	18.18
Low Price	8.05	12.25	6.30
Close Price	14.61	13.93	7.00
No. of Ticks	281605	261048	304862
Mean No. of Ticks per Day	1159	1057	1239
Mean Duration per Tick	64	34	31
Volume	1398540	2022053	2510464
Mean Volumne per Tick	4.9663	7.7459	8.2348
Volatility	1.6376	1.0177	2.8986
Average Bid-Ask Spread	0.0334	0.0204	0.0223

Source: European Climate Exchange.

2.1 Price of EUA futures

We first look at the the prices, as well as returns of the EUA futures contracts of interest. Figure 1 illustrates the 1-minute price movement of EUA futures for all obervations. The EUA futures witnessed a drastic fall in the beginning of the contract, from €15.85 to €8 in two months, and then hiked up to its previous level. It reached the peak €17.75 in March 2011, and then fell to its lowest level €6.30 by the end of 2011 when the contract expired.

Instead of price, the 1-minute equidistant returns of EUA futures is more informative to our analysis. Figure 2 shows that in the beginning of the future contracts, i.e., year 2009, and by the end, i.e., late 2011, the 1-minute equidistant returns are significantly more volatile than the rest of the trading period. This is consistent with what Figure 1 indicates.

Intraday seasonality and day-of-the-week effects have been pointed out in the literature, eg. Rotfuß(2011), Bredin and Muckley (2011) and Conrad et al. (2012). We illustrate the mean squared returns for every minutes from 7.00 am to 17.00 pm over all trading days to examine the intraday volatility. As shown in Figure 3, in the beginning of a trading day, the mean squared returns are much higher than the rest of the day, indicating the existence of the morning effect. The autocorrelation function of the absolute returns, shown in Figure 4, confirms this effect. The autocorrelations have long term persistance, and are significantly higher around lags 600, 1200, 1800, 2400 and 3000, indicating strong morning effect of the EUA futures. In addition to intraday volatility, we also calculate the mean absolute 1-min equidistant returns for each day of the week. Figure 5 indicate slight day-of-the-week pattern such that the returns are more volatile in the middle of the week.

Figure 1: Equidistant 1-min price of EUA futures

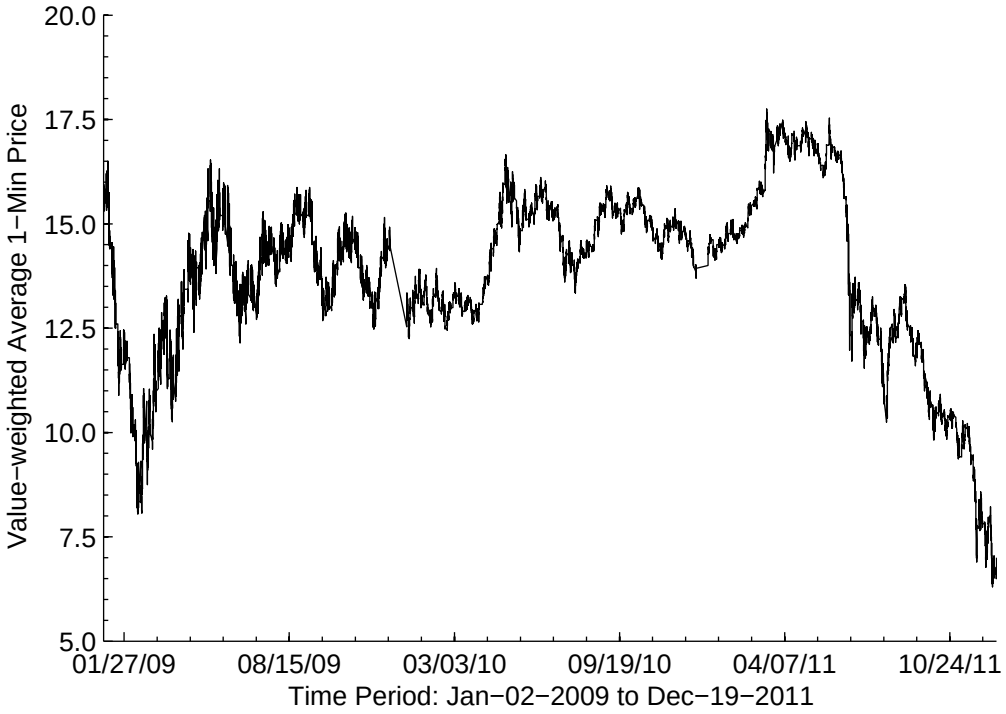

Figure 2: Equidistant 1-min return of EUA futures

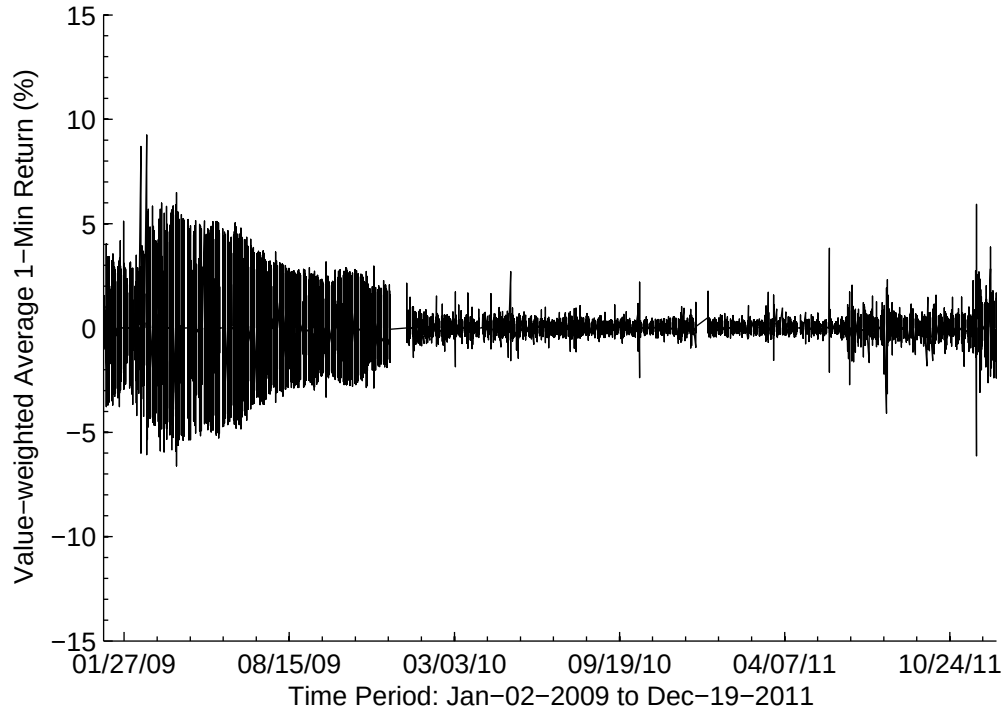

Figure 3: Intraday seasonality of EUA futures squared returns

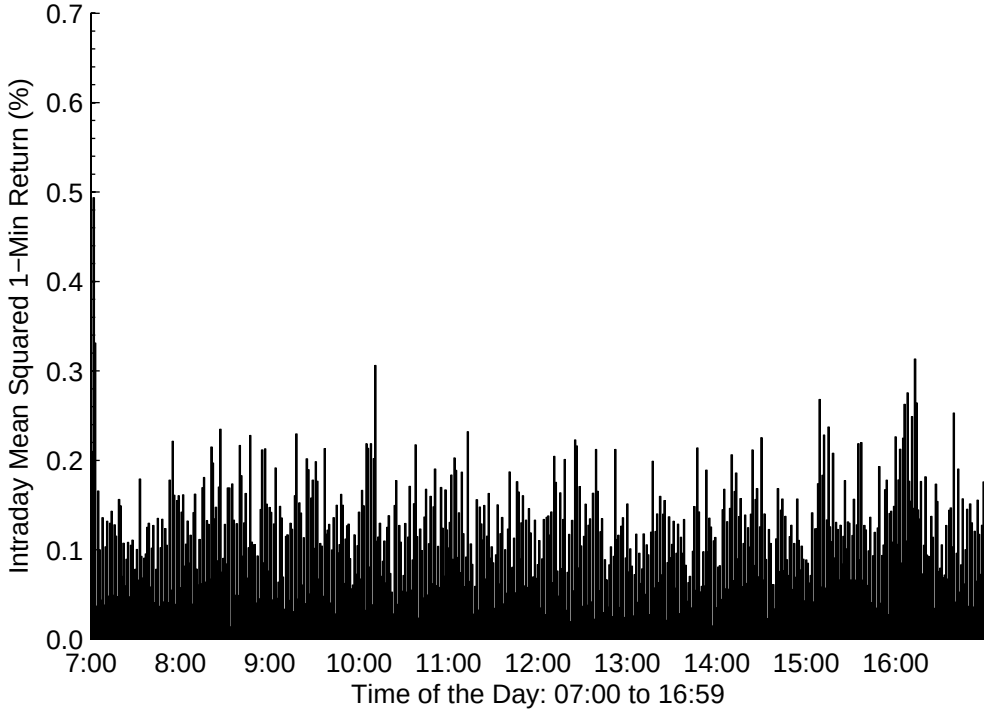

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Figure 4: Sample autocorrelation function of EUA futures absolute returns

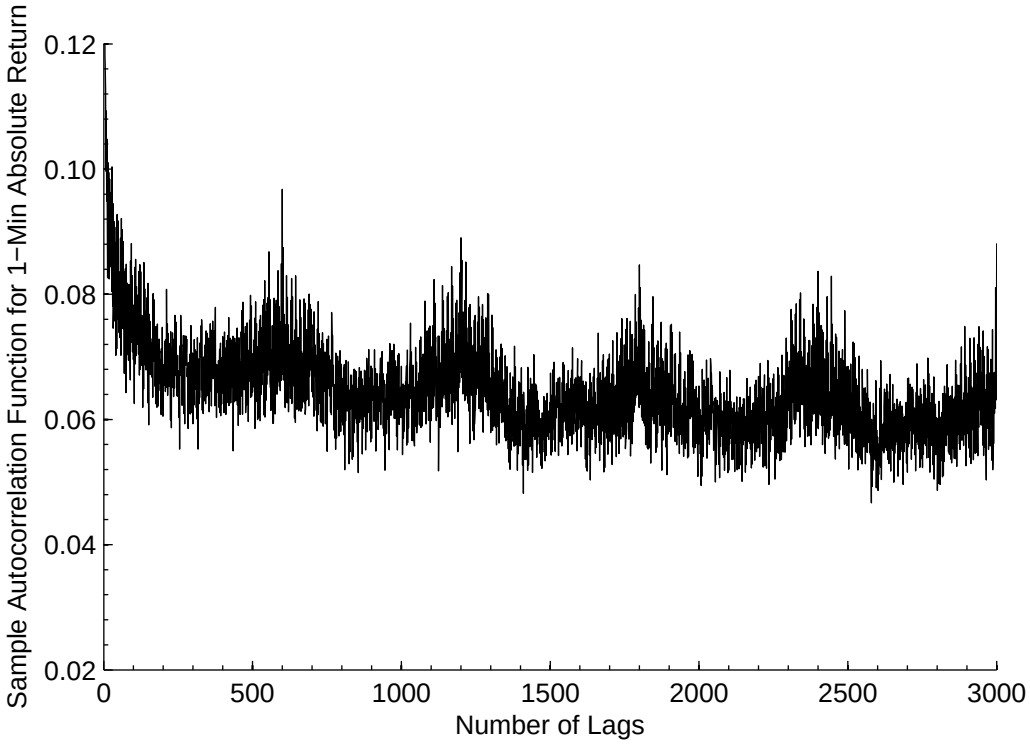
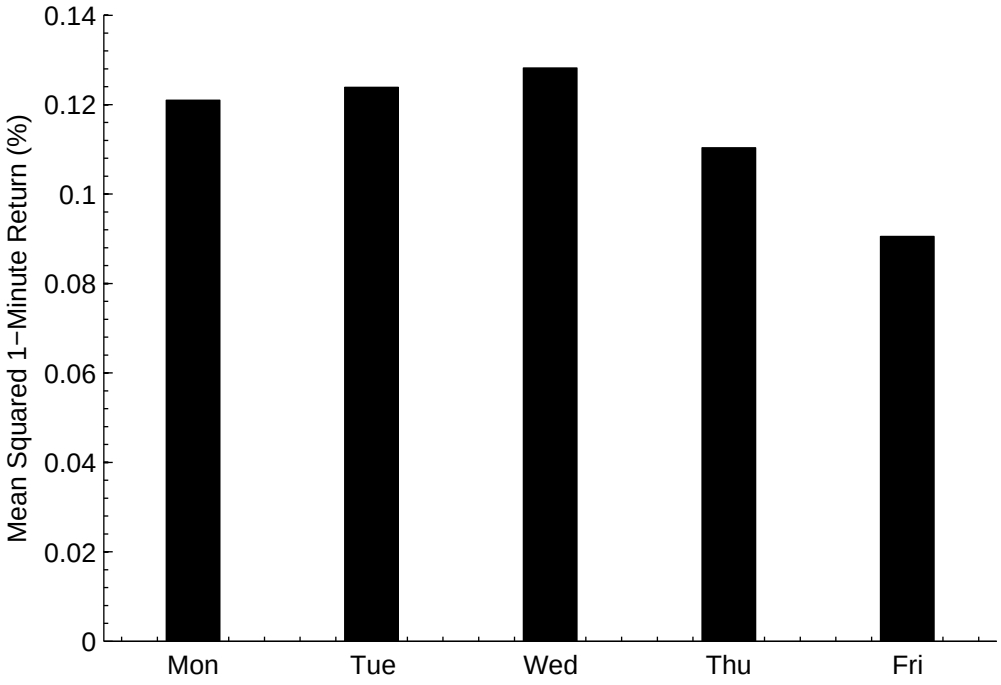


Figure 5: Day-of-the-week seasonality of EUA futures squared returns



2.2 Volume of EUA futures

Similarly, we also examine the one-minute volumes of the EUA futures. Figure 6 to Figure 8 illustrate the volumes, the daily and weekly averaged volumes, and the autocorrelation function of volumes. We find that except for a few minutes, the volumes of EUA futures increased gradually from the 2009 to 2011, indicating the market has been growing. Figure 7 shows a different intraday seasonal pattern of volumes compared to squared returns. The average 1-minute volume is significantly much higher just before the end of the trading hours. Moreover, we also find similar day-of-the-week effect in volumes to that in returns, as well as long-term persistence of autocorrelation.

2.3 Bid-ask spread of EUA futures

We also expect the Bid-ask spreads of EUA futures follow similar patterns. Figure 1 shows that the bid-ask spread is comparatively high in 2009, decreasing gruadually in 2010 and 2011, implying the improvement of EUA market. The intraday volatility of bid-ask spread is illustrated in Figure 11. Similar to EUA futures returns, it shows higher bid-ask spread in the beginning of a trading day, or the morning effect. Figure 12 reports persistent autocorrelations in large lags, as well as obvious periodic high serial autocorrelation coefficients. In addition, consistent with previous analysis, the day-of-the-week effect in bid-ask spread indicates higher liquid in the middle of the week, since the average bid-ask spread is lower.

Figure 6: Equidistant 1-min volume of EUA futures

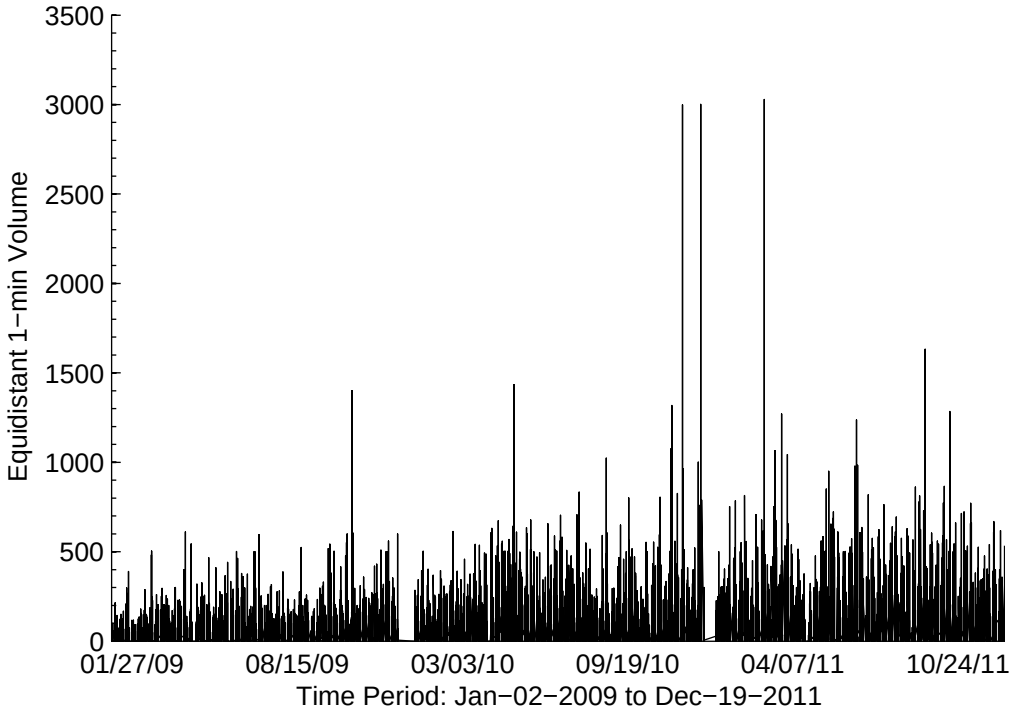


Figure 7: Intraday seasonality of EUA futures volumes

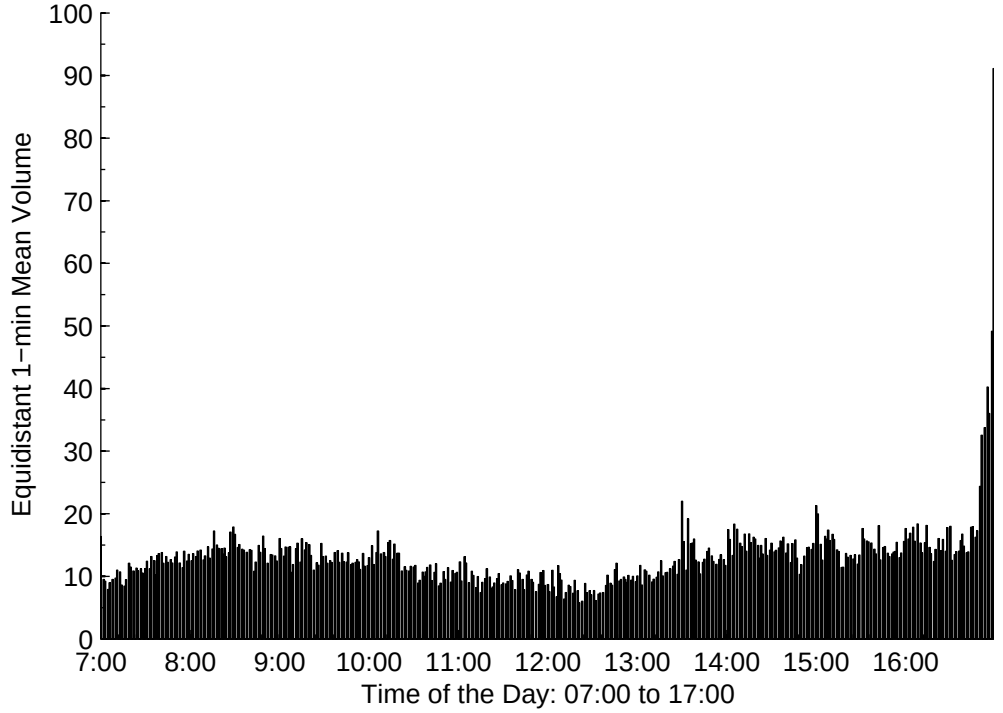


Figure 8: Sample autocorrelation function of EUA futures volumes

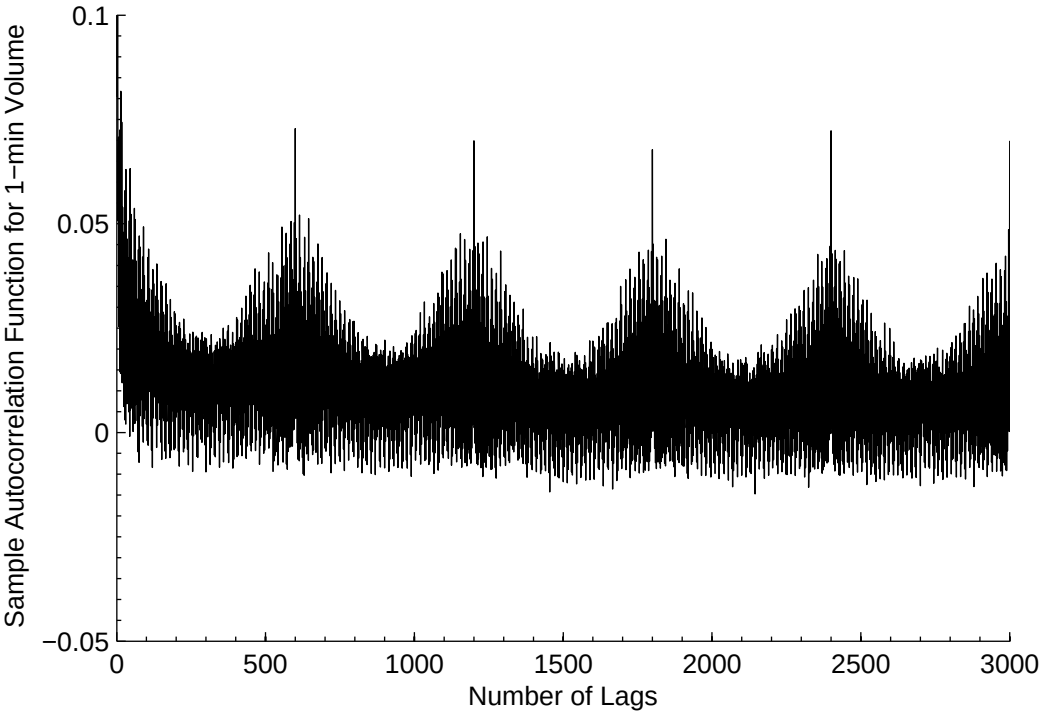


Figure 9: Day-of-the-week seasonality of EUA futures volumes

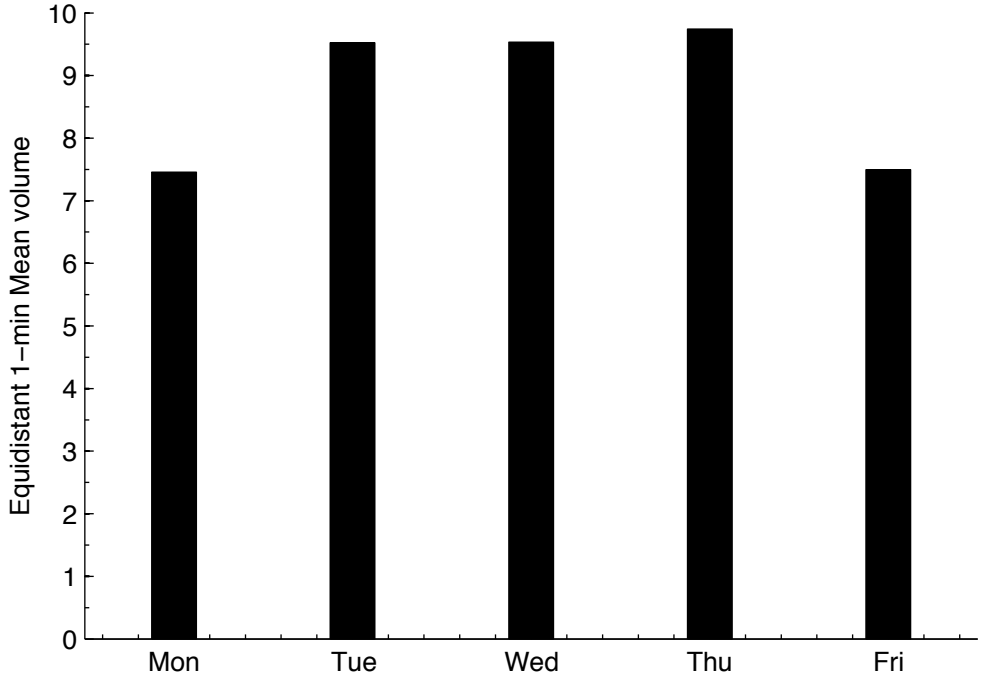


Figure 10: Equidistant 1-min bid-ask spread of EUA futures

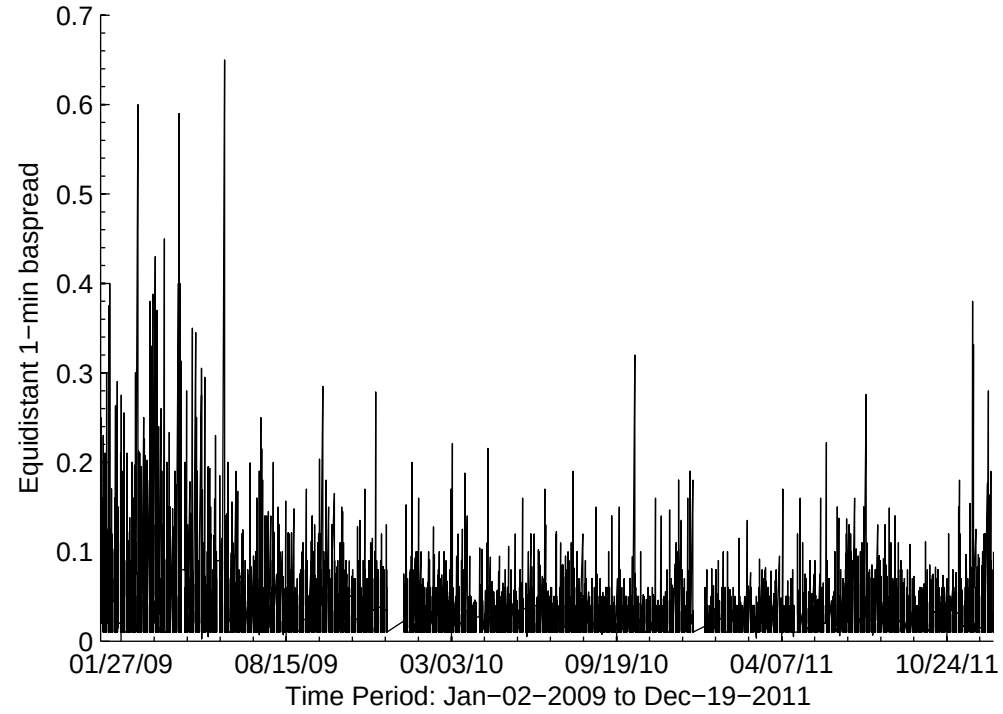


Figure 11: Intraday seasonality of EUA futures bid-ask spreads

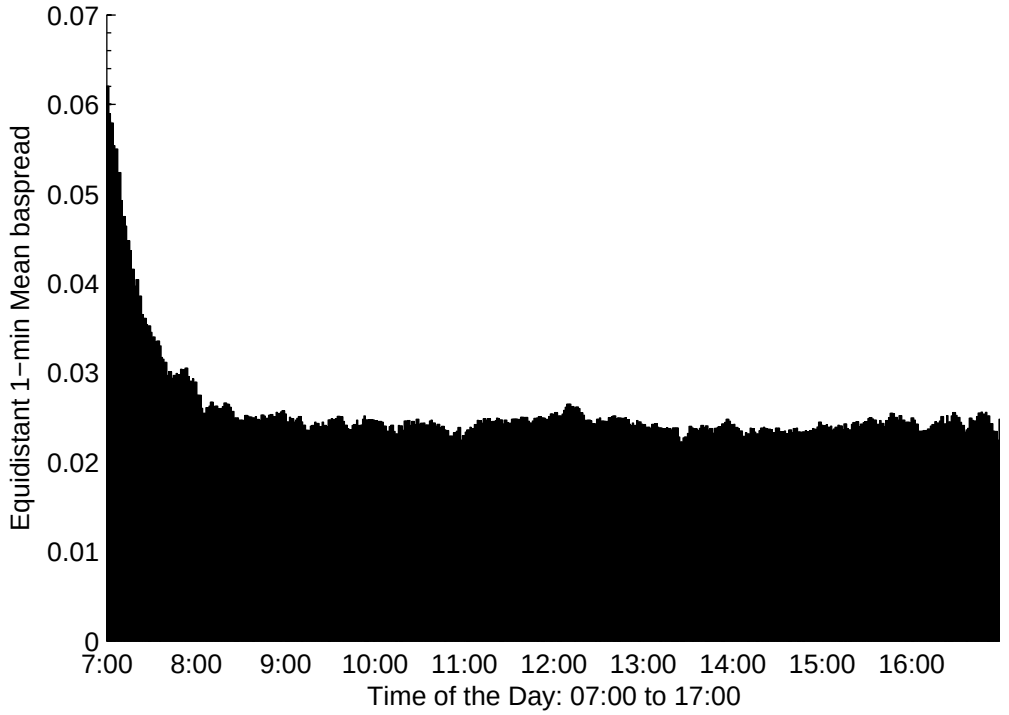


Figure 12: Sample autocorrelation function of EUA futures bid-ask spreads

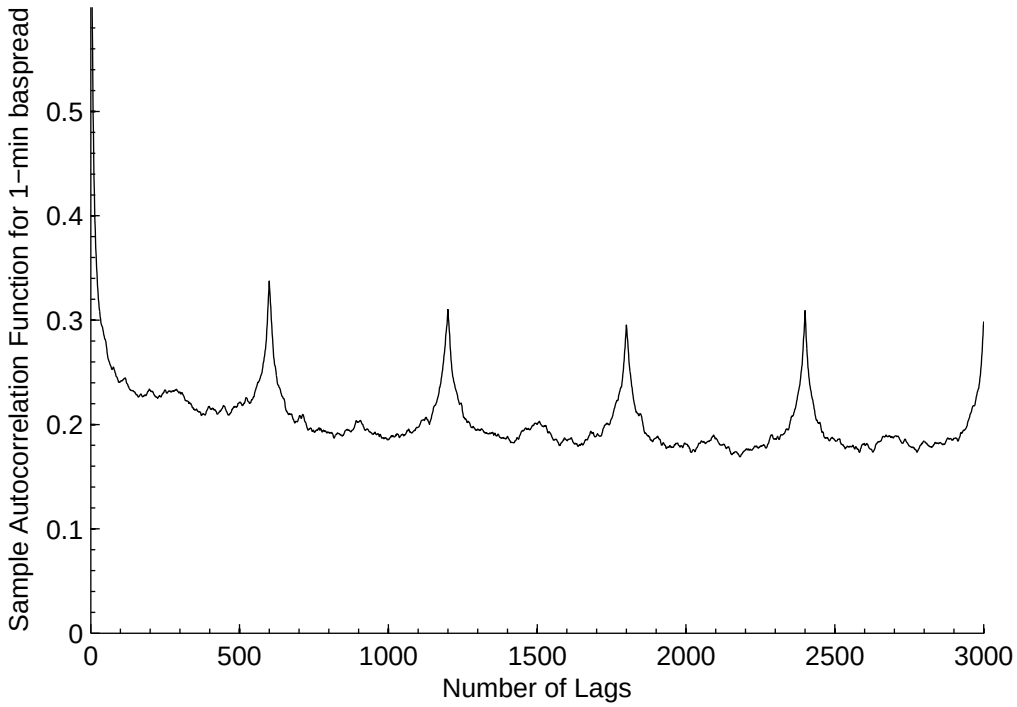
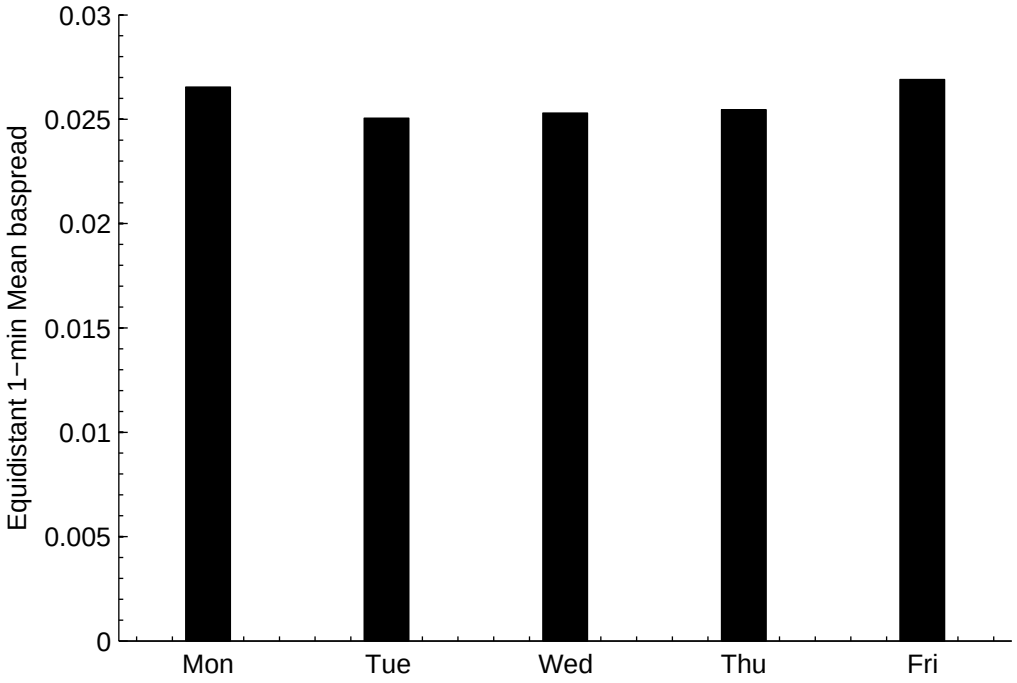


Figure 13: Day-of-the-week seasonality of EUA futures bid-ask spreads



3 Informational Assimilation of EUA Futures

In this section, we give a intuititive description and apply simple regressions on the EUA futures towards news announcements, so as to investigate, in the micro level, how information is assimilated into the EUA futures market. We mainly utilises the methods of Balduzzi et al. (2001), where he looked at the effect of macroeconomic announcements on US government bonds in market microstructure respective.

3.1 Announcements overview

We follow Rotfuß(2009) and Conrad et al. (2012) and choose 12 macroeconomic announcements of interest, summarised in Table 2. The first 6 variables measure future economic outlooks, and the rest measure current economic acticities. The macroeconomic news are all monthly announced, and very few of them are concurrent.

However, on the policy level, we follow Schmidt and Werner (2011), using the verified emission announcement instead of NAPs[3] employed by Rotfuß(2009) and Conrad et al. (2012), for the reason that NAPs for phase II were announced before 2008, whereas our sample only cover period after 2008. Information about the verified emission announcements is presented in Table 3.

As we are only interested in the news unexpected, we follow classic literatures in event study by substracting forecasted figures from announced figures, and get the surprise of each announcement. Our forecasted announcement data are collected from *Forex*.[4] In line with Balduzzi et al. (2001), we divide each surprise by the standard deviation across the whole period to get the standardised surprise. We measure the standardised surprise in announcement i at time t as

$$S_{it} = (news_{it} - forecast_{it})/\sigma_i, \tag{1}$$

where σ_i is the standard deviation of surprises across all observations.

3.2 Price changes to macroeconomic news

First of all, we look at how the prices of EUA futures respond to macroeconomic announcements. As indicated in previous work, and for convenience as well, we shrink the responding window of EUA futures to 5 minutes prior and 30 minutes after the time of announcements, since there is little influence of news on prices outside this window.

We employ the regression model of Balduzzi et al. (2001) with some modification. Let P_t^τ denote the price of EUA futures at τ minute(s) after the announcement time t, and S_{it} be the standardised surprise i at time t. We regress surprises on percentage price changes of EUA futures during certain periods, in order to see if macroeconomic news significantly changes the price of EUA futures. Balduzzi's model is

[3] NAP is short for national allocation plans.

[4] Forex (http://www.forex.com) collects forecasted macroeconomic figures from Thomas Reuters and Bloomberg.

Table 2: **Brief description of macroeconomic announcements**

Macroeconomic News Announcements

	Source	Frequency	Release Time
Future Economic Outlook			
DE Ifo index	CESinfo	Monthly	10:00 AM
DE ZEW index	ZEW	Monthly	11:00 AM
EU consumer confidence index	DG ECFIN	Monthly	4:00 PM
US U. Michigan index adv.	Reuters/U. of Michigan	Monthly	2:55 PM
EU new orders	Eurostat	Monthly	11:00 AM
US nonfarm payrolls	CES	Monthly	2:30 PM
Current Economic Activity			
DE industrial production	Eurostat	Monthly	12:00 PM
EU industrial production	Eurostat	Monthly	11:00 AM
FR industrial production	Eurostat	Monthly	8:45 AM
GB industrial production	National Statistics	Monthly	10:30 AM
US ISM manufacturing PMI	ISM	Monthly	4:00 PM
GB Manufacture PMI	Markit	Monthly	10:30 AM

Notes. Definitions of the macroeconomic announcement symbols are as follows. DE Ifo: the Ifo Business Climate for Germany; DE ZEW: ZEW Indicator of Economic Sentiment; EU CCI: EU consumer confidence indicator; US UMI: Thomson Reuters/University of Michigan Surveys of Consumers; EU NO: EU Industry new orders index; US NFP: US Employees on nonfarm payrolls; EU IP: EU industry production index; DE IP: Germany industry production index; FR IP: France industry production index; GB IP: UK industry production index; US PMI: US ISM manufacturing PMI; GB PMI: UK Manufacture PMI. CES standands for Current Employment Statistics (CES) program from the U.S. Department of Labor Bureau of Labor Statistics; ISM stands for Institute of Supply Management.

Table 3: **Brief description of verified emission announcements**

Verified Emission Announcements

	Year	Date	Time
Announcement Type			
access to installation-level 2010 verified emissions	2011	4/1/11	12:00:00
access to installation-level 2009 verified emissions	2010	4/1/10	12:00:00
access to installation-level 2008 verified emissions	2009	4/1/09	12:00:00

Notes. Among others, installation-level verified emissions are the first being publicly accessed, based on which data on the sector and national level can be calculated. Therefore we focus on this type of announcements.

$$(P_t^{30} - P_t^{\tau})/P_t^{\tau} = \beta_{0,i}^{\tau} + \beta_{1,i}^{\tau} S_{it} + \sum_{k=1}^{K} \beta_{k+1,i}^{\tau} S_{kt} + e_{it}, \tag{2}$$

where $k = 1, 2, \cdots, K$ is the kth cocurrent macroeconomic announcement. We modified this model into the following form:

$$(P_t^{\tau} - P_t^{-5})/P_t^{-5} = \beta_{0,i}^{\tau} + \beta_{1,i}^{\tau} S_{it} + e_{it}. \tag{3}$$

Table 4 reports the results of the regression. First, we find that the EU consumers confidence indicator, as well as the industrial production announcements have the most significant effects on EUA futures prices. Among industrial production announcements, Germany's have the most statistically signifcant and persistent influence, followed by EU's, and then France's, and finally UK's, which have only slight impact on EUA futures prices. Secondly, the signs of the coefficients indicate that the EUA futures prices change in accordance with EU industrial production surprises, but against EU consumers confidence indicator, as well as German, France and UK industrial production surprises. It is inconsistent with the findings of Conrad et al. (2012) who claimed it to be consistent. As expected, better macroeconomic outlooks result in larger demand for carbon emissions, and should therefore push up the price of EUA futures. Thirdly, the effects of different announcements differ in responsive windows. For EU consumers confidence indicator announcements, they begin to significantly influence the EUA futures prices immediately after the time of release, and disappear within five minutes afterwards. However, the industrial production announcements of Germany and the European Union, however, begin to influence the market at least two seconds before announcement time, and last until 30 minutes afterwards. The pre-responsiveness of industrial production implies possibility of information leakage into the market. The industry production announcements of France begin to significantly affect the EUA futures prices 3 minutes after the announcements and last for 5 minutes, whereas those of UK only have slight effect 2 minutes after the announcements and disappear immediately.

Table 4: **Price changes of EUA futures to macroeconomic announcements**

	Minutes from Announcements												
	-2	**-1**	**0**	**1**	**2**	**3**	**4**	**5**	**10**	**15**	**20**	**25**	**30**
DE Info	-3.78	5.98	-2.19	3.42	6.68	1.82	4.05	0.38	1.69	-7.74	-4.05	-11.59	-10.71
	0.5315	0.6628	0.9028	0.8124	0.5600	0.8805	0.7405	0.9794	0.9232	0.5287	0.7340	0.3075	0.4540
DE ZEW	2.87	1.55	2.96	9.09	0.67	-0.45	0.08	0.10	16.38	7.79	1.77	18.21	5.95
	0.697	0.8691	0.7169	0.413	0.9384	0.9566	0.9922	0.9909	0.2314	0.4509	0.8713	0.3569	0.6324
EU CCI	-1.92	-12.66	-8.92	-6.91**	-8.61**	-20.71*	-9.50**	-8.15	-12.24	-12.44	-9.93	-5.60	-29.29***
	0.3547	0.162	0.3247	0.0446	0.034	0.0601	0.0206	0.5294	0.1484	0.0206	0.1629	0.6603	0.0098
US UMI	7.96	13.10	9.26	10.54	18.66**	5.74	11.56	10.80	14.11	8.30	10.38	-1.18	9.45
	0.1954	0.101	0.2827	0.2229	0.0405	0.6162	0.2626	0.2998	0.2269	0.5774	0.4892	0.9342	0.4918
EU NO	3.45	4.26	4.86	3.63	3.63	4.90	5.29	4.35	-1.31	3.49	-0.37	-0.31	-0.85
	0.6908	0.5864	0.5517	0.6638	0.6762	0.5695	0.6605	0.7203	0.8931	0.7863	0.9777	0.983	0.9499
US NFP	1.59	7.09	1.15	-0.30	3.16	-0.14	-2.49	-0.11	4.37	-2.12	-4.12	16.39	-3.88
	0.5169	0.4051	0.7808	0.941	0.6208	0.9762	0.5825	0.9753	0.3017	0.677	0.6712	0.0695	0.6873
EU IP	4.11*	4.04	3.80	5.07*	6.49	22.41**	26.72**	30.85**	24.26*	22.27*	19.18*	21.92*	18.15
	0.0651	0.129	0.1389	0.0984	0.3642	0.0307	0.0131	0.0195	0.0504	0.067	0.0866	0.0662	0.1447
DE IP	-17.08*	-16.46*	-17.32*	-19.67**	-19.60**	-22.14**	-18.25*	-21.50**	-21.66**	-10.87	-18.90*	-7.51	-9.11
	0.081	0.0942	0.0732	0.0478	0.0488	0.0214	0.0503	0.0277	0.0314	0.3346	0.0563	0.3662	0.3035
FR IP	-0.57	-4.47	-4.05	-7.07	-9.32	-9.26*	-11.35*	-10.64*	-12.44**	-14.04**	-7.71	-11.07	-14.5
	0.8719	0.2524	0.2856	0.2642	0.1039	0.0947	0.0505	0.0625	0.0345	0.0485	0.2646	0.2763	0.1706
GB IP	-3.99	-4.75	1.91	-2.87	-5.34*	1.59	-3.38	-3.66	-3.02	0.74	0.17	1.00	0.97
	0.2133	0.1299	0.7341	0.6448	0.0864	0.7973	0.3527	0.222	0.5502	0.9128	0.9826	0.8885	0.8864
US PMI	5.53	8.28	6.90	6.76	7.09	3.34	4.23	4.60	16.34	2.39	16.38	5.09	9.73
	0.39	0.3524	0.339	0.3261	0.4432	0.7783	0.5774	0.6323	0.2989	0.7926	0.2001	0.6496	0.5592
GB PMI	5.45	-1.03	-1.20	-2.67	-2.94	4.03	4.35	4.35	-2.92	7.64	11.27	2.03	-0.85
	0.2474	0.5397	0.5081	0.3013	0.1873	0.5838	0.4497	0.3269	0.7528	0.2206	0.2113	0.8244	0.9151

Notes. With regard to each macroeconomic announcement, the first line reports the coefficients for corresponding τ, and the second line reports the P-values.
*, **, *** represent statistical significance that the coefficient is significantly different from zero at 90%, 95% and 99% confidence level respectively.

Table 5: **Ratio of mean sq returns of announcement to non-announcement days**

	Minutes from Announcements (τ)						
	-30 to -5	-5 to 0	0	0 to 5	5 to 15	15 to 30	30 to 60
DE Info	0.8974	0.5786	3.0192	1.7119	0.7123	0.7284	1.2247
DE ZEW	1.1731	0.6795	0.4155	0.3755	0.7061	1.0750	1.2895
EU CCI	1.7021	2.9924	2.1883	1.8192	1.5980	1.8898	1.1340
US UMI	1.0023	0.3774	0.5851	0.6279	0.6380	0.5448	0.8990
EU NO	0.7025	1.2540	0.3104	0.3101	1.1594	2.7046	0.7967
US NFP	1.6825	0.5543	1.8462	0.7436	0.7704	0.9287	0.7964
EU IP	1.8193	1.1758	0.0420	0.9095	0.8523	1.4166	0.6722
DE IP	0.9170	2.5319	0.0055	0.0878	1.0227	0.6425	0.6675
FR IP	0.2526	0.0740	0.1271	0.2220	0.3975	0.5945	1.4258
GB IP	1.0366	0.9414	0.0188	2.0521	1.2407	1.0843	1.4406
US PMI	1.3831	0.5646	0.4716	0.7896	1.8317	1.3098	1.7833
GB PMI	0.5583	0.4239	1.0927	0.4299	0.4794	0.5998	0.6533

Following Balduzzi et al. (2001), we employ the ratio of mean squared return on announcement days over that on non-announcement days. The mean squared return ratio *sqret* is calculated as

$$sqret_i^\tau = (\frac{1}{T_a}\sum_{t_a=1}^{T_a} sqret_{it_a}^\tau)/(\frac{1}{T_{na}}\sum_{t_n a=1}^{T_n a} sqret_{it_n a}^\tau), \tag{4}$$

where τ is a vector of durations with regard to announcement time. T_a and T_{na} represent the number of minutes in period τ on announcement days and non-announcement days respectively.

Table 5 lists the ratios for the 12 macroeconomic announcements and for different periods of time respectively. Announcements on EU consumers confidence indicator, US nonfarm payrolls, EU industrial production, and US ISM manufacturing PMI significantly increase the EUA futures volatility prior to the time of announcement, while DE Info index and EU new orders influence the volatility only after the release of the announcements. Among others, EU CCI and US PMI have most persistent effect on EUA futures volatility.

3.3 Trade volume changes to macroeconomic news

Trading volume is also of interest to our analysis of informational assimilation. Following Balduzzi et al. (2001), we employ the ratio of mean trade volume on announcement days over that on non-announcement days[5]. The mean trade volume ratio is calculated as

[5]Regression is not applicable in trade volumes, for we have trouble in calculating the percentage change in volumes as the series contain a lot of zeros.

Table 6: **Ratio of mean volume of announcement to non-announcement days**

	Minutes from Announcements (τ)						
	-30 to -5	-5 to 0	0	0 to 5	5 to 15	15 to 30	30 to 60
DE Info	0.9052	1.5339	1.4499	1.0649	0.9710	1.0313	1.3791
DE ZEW	1.1680	1.4441	2.2153	0.7944	1.8075	1.4893	1.3684
EU CCI	0.9452	0.9574	1.6609	1.2668	1.0818	1.0828	1.0893
US UMI	0.8470	0.4722	2.7527	0.7654	0.6537	0.7257	0.8075
EU NO	1.0107	1.3341	1.5998	1.5912	0.8633	1.2787	0.8441
US NFP	1.0630	1.0918	1.0085	0.3066	0.6970	0.8639	0.9584
EU IP	1.3520	1.3413	1.3640	1.1843	1.9330	1.0748	1.1614
DE IP	1.1902	1.0909	0.0000	0.4844	1.4981	1.1091	1.0255
FR IP	0.7644	0.7550	1.1885	0.7958	0.5827	0.7502	1.0325
GB IP	1.1464	1.2589	0.0000	1.0371	0.9127	0.7034	1.1505
US PMI	0.7042	1.5804	0.8427	1.0433	0.7438	0.5763	0.9084
GB PMI	0.5462	0.3468	0.0000	0.8909	0.4172	0.5880	1.0695

$$Volume_i^{\tau} = (\frac{1}{T_a}\sum_{t_a=1}^{T_a} Volume_{it_a}^{\tau})/(\frac{1}{T_n a}\sum_{t_n a=1}^{T_{na}} Volume_{it_n a}^{\tau}), \tag{5}$$

where τ is a vector of durations with regard to announcement time. T_a and T_{na} represent the number of minutes in period τ on announcement days and non-announcement days respectively.

Table 6 reports the mean trade volume ratio on each period τ. We find that in the 5-minute window prior to German macroeconomic future outlooks announcements, i.e., DE Info index and DE ZEW index, the average volumes are more than 50% higher than those on non-announcement days, and this increase in volumes disapears after the release of DE Info, but lasts until 60 minutes after the release of DE ZEW index. For EU future outlooks, i.e., EU consumers confidence indicator and EU new orders, they begin to affect the EUA futures volumes 5 minutes prior to the release, and disappear afterwards. This implies that European macroeconomic outlooks are likely to lead the market trade volumes, whereas US macroeconomic outlooks, i.e., US consumers survey and US nonfarm payrolls, do not have significant influence on EUA futures trade volumes.

As for current macroeconomic measures, only EU industrial production announcements have strong impact on EUA futures trade volumes, from 30 minutes prior until the announcement. US ISM manufacturing PMI increases the volumes 5 minutes before announcement and this effect soon dies out after announcement, whereas UK PMI has no significant impact on trade volumes of EUA futures contracts.

Table 7: **Bid-ask spread changes of EUA futures to macroeconomic announcements**

	Minutes from Announcements												
	-2	**-1**	**0**	**1**	**2**	**3**	**4**	**5**	**10**	**15**	**20**	**25**	**30**
DE Info	-4.10	3.44	-0.63	-0.63	4.21	11.53	11.53	3.37	23.64	-5.75	-2.00	-18.27	2.71
	0.6798	0.7599	0.9586	0.9586	0.7420	0.3782	0.3782	0.8080	0.1755	0.7813	0.9063	0.2774	0.885
DE ZEW	2.78	-8.19	-8.19	-16.71	-15.16	-15.16	-9.48	-17.03	-16.10	7.06	-15.95	-39.48**	-5.80
	0.7535	0.5620	0.5620	0.2966	0.2815	0.2815	0.5370	0.1763	0.3118	0.6629	0.3738	0.0272	0.6775
EU CCI	9.43	9.79	18.18	18.18	13.91	18.04	18.04	19.49	7.57	2.20	7.04	4.17	-10.28
	0.1504	0.1843	0.1383	0.1383	0.2256	0.1176	0.1176	0.1278	0.3425	0.8193	0.5776	0.6929	0.2562
US UMI	10.92	-1.94	-5.73	-5.73	-12.9	-18.11	-18.11	-5.73	16.41	4.80	9.55	20.43	23.25*
	0.2295	0.8628	0.5902	0.5902	0.4434	0.4032	0.4032	0.6790	0.3081	0.7648	0.5008	0.1296	0.0751
EU NO	-1.00	3.24	3.24	5.15	4.63	4.63	-8.42	-2.76	-4.45	-5.65	4.86	14.66	0.10
	0.913	0.7092	0.7092	0.6087	0.6129	0.6129	0.4040	0.7434	0.7044	0.6378	0.7164	0.2514	0.9902
US NFP	6.09	12.80	6.90	6.90	3.48	14.91	14.91	12.49	4.81	-1.26	-0.97	7.33	6.38
	0.2453	0.0174	0.2425	0.2425	0.6192	0.2076	0.2076	0.3159	0.7183	0.8964	0.9378	0.5507	0.5879
EU IP	-2.27	2.65	2.65	-2.42	1.22	1.22	-3.86	-2.20	8.42	13.93	30.61**	8.40	17.96
	0.8366	0.8336	0.8336	0.8516	0.9083	0.9083	0.7467	0.8596	0.5469	0.3073	0.0342	0.5514	0.1197
DE IP	7.29	7.29	6.66	1.15	1.15	-11.85	-9.70	-9.70	-21.57*	-10.48	2.68	-4.75	0.47
	0.3767	0.3767	0.2591	0.8338	0.8338	0.1452	0.2270	0.2270	0.0743	0.3506	0.8092	0.6663	0.9646
FR IP	151.08	61.66	-	138.63	-80.71	-	-668.86	-117.85	-12.12	-220.37	-	-	-233.87
	0.2865	0.5755	0-	0.4925	0.7740	-	0.4526	0.9102	0.7373	0.8944	-	-	0.5514
GB IP	0.96	0.96	-1.01	-4.55	-4.55	5.34	7.43	7.43	0.07	21.73**	6.61	-1.79	7.74
	0.8571	0.8571	0.8226	0.5096	0.5096	0.6261	0.3778	0.3778	0.9939	0.0423	0.4731	0.8718	0.5337
US PMI	-4.03	-15.25**	-16.93*	-16.93	-4.70	-19.78	-19.78	-31.56***	-14.08	-4.72	-13.37	-2.68	3.63
	0.6111	0.0143	0.0871	0.0871	0.6944	0.1064	0.1064	0.0083	0.2330	0.7298	0.2128	0.8534	0.7965
GB PMI	4.53	4.53	0.73	-5.81	-5.81	3.94	-2.93	-2.93	-15.68	3.33	-3.40	-3.68	-10.85
	0.5754	0.5754	0.9468	0.6169	0.6169	0.7055	0.7846	0.7846	0.3354	0.8875	0.8862	0.8807	0.4178

Notes. With regard to each macroeconomic announcement, the first line reports the coefficients or corresponding τ, and the second line reports the P-value.
*, **, *** represent statistical significance that the coefficient is significantly different from zero at 90%, 95% and 99% confidence level respectively.

Table 8: **Ratio of mean b-a spread of announcement to non-announcement days**

	Minutes from Announcements (τ)						
	-30 to -5	-5 to 0	0	0 to 5	5 to 15	15 to 30	30 to 60
DE Info	1.0411	0.9814	1.0346	1.0955	1.1212	1.0954	1.1280
DE ZEW	0.9489	0.9498	1.0569	0.9771	1.0049	0.9600	0.9669
EU CCI	1.0430	1.0164	0.9510	1.0284	0.9692	1.0599	0.9555
US UMI	0.9989	0.9833	0.9625	0.9558	0.9543	0.9903	0.9527
EU NO	1.0433	0.9526	1.0192	0.9525	0.9537	1.0420	1.0614
US NFP	1.0764	1.2033	1.0425	1.0918	1.1134	1.1412	1.0784
EU IP	1.0175	1.0031	1.1698	1.1213	1.0863	1.0323	0.9428
DE IP	1.1297	1.1341	1.1597	1.0214	0.9927	0.9023	1.0839
FR IP	1.0181	0.9697	0.9025	0.9203	0.9465	1.0169	0.9870
GB IP	1.0131	1.0549	1.1466	1.0412	0.9625	1.0157	1.1015
US PMI	0.9473	0.9120	0.8848	0.9839	1.0305	1.1060	1.0353
GB PMI	1.0598	1.1609	1.1899	1.0434	1.0764	1.0051	0.9746

3.4 Bid-ask spread changes to macroeconomic news

Similar to previous subsection, we examine the bid-ask spread changes to announcements by regressing bid-ask spread changes on surprises. Our regression model for bid-ask spread $BAspread$ is

$$(BAspread_t^{30} - B - Aspread_t^{\tau})/BAspread_t^{\tau} = \beta_{0,i}^{\tau} + \beta_{1,i}^{\tau} S_{it} + \sum_{k=1}^{K} \beta_{k+1,i}^{\tau} S_{kt} + e_{it}, \quad (6)$$

The regression results are shown in Table 8. We find little evidence of the existance of significant influence of macroeconomic news on EUA futures bid-ask spreads.

We also calculate the ratio of mean bid-ask spreads on announcement days over non-investment days in terms of certain periods τ prior, at, or after the release time. The mean bid-ask spread ratio $BAspread_i^{\tau}$ is measured as

$$BAspread_i^{\tau} = (\frac{1}{T_a} \sum_{t_a=1}^{T_a} BAspread_{it_a}^{\tau})/(\frac{1}{T_{na}} \sum_{t_n a=1}^{T_{na}} BAspread_{it_{na}}^{\tau}). \quad (7)$$

Table 8 reports the mean bid-ask spread ratio on each period τ. The results also indicate little influence of macroeconomic news on EUA futures bid-ask spreads.

3.5 EUA futures responsiveness to verified emission announcements

In this subsection, our illustration of trade variables, i.e., price, volume, number of ticks, volatility and bid-ask spread, in Figure 14 to Figure 18 aims to provide an intuitive understanding of how these variables respond to news, and how the responsiveness changes over time.

Figure 14: Price responsiveness to verified emission

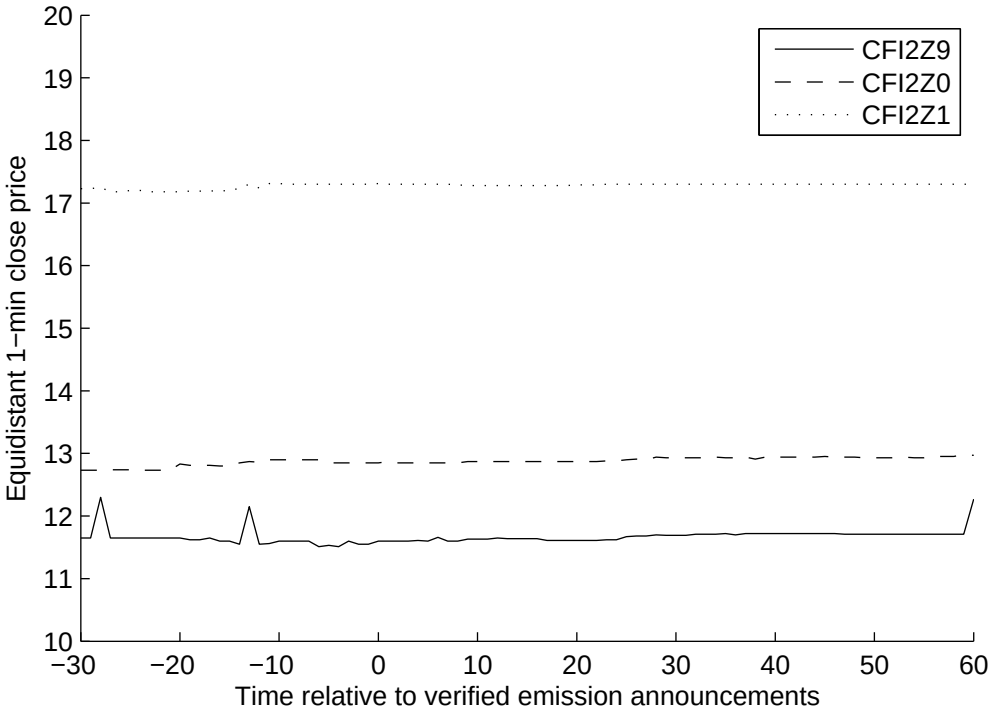


Figure 14 shows no significant changes of price in EUA futures within the 90 minutes window around announcement time. However, the volumes witness a boom before the announcement of verified emissions, which is especially obvious for contract maturing in 2010. The number of ticks indicate quite identical pattern to volumes, whereas the volatilities are significant higher before announcement. As for bid-ask spreads, the data for all three contracts are quite random, without significant changes around the time of announcement. Moreover, Figure 18 provides us an important message, which is the bid-ask spread has been decreasing over time, indicating an improved market liquidity of EUA futures.

Comparing the three EUA futures contracts, we find that CFI2Z0, one maturing by the end of 2010, is more volatile than the the other two contracts with regard to volumes and number of ticks, whereas CFI2Z9 is more volatile in volatility.

4 Conslusion

To conclude, we examined the adjustment of trade variables such as return, volume, bid-ask spread, number of ticks and volatility, in EU ETS market. We found that [1] information asymmetry increases in response to announcements; [2] we find evidence of information leakages in the EUA futures market implied by abnormal changes in trading variables prior to news releases; [3] the speed of adjustment to new information varies in terms of the type of information, but generally does not exceed the 90 minutes window around release; [4] among 12 macroeconomic announcements, although we find a good portion of which leading to significant order imbalance in the EUA futures, some are in the opposite direction as we

Figure 15: Volume responsiveness to verified emission

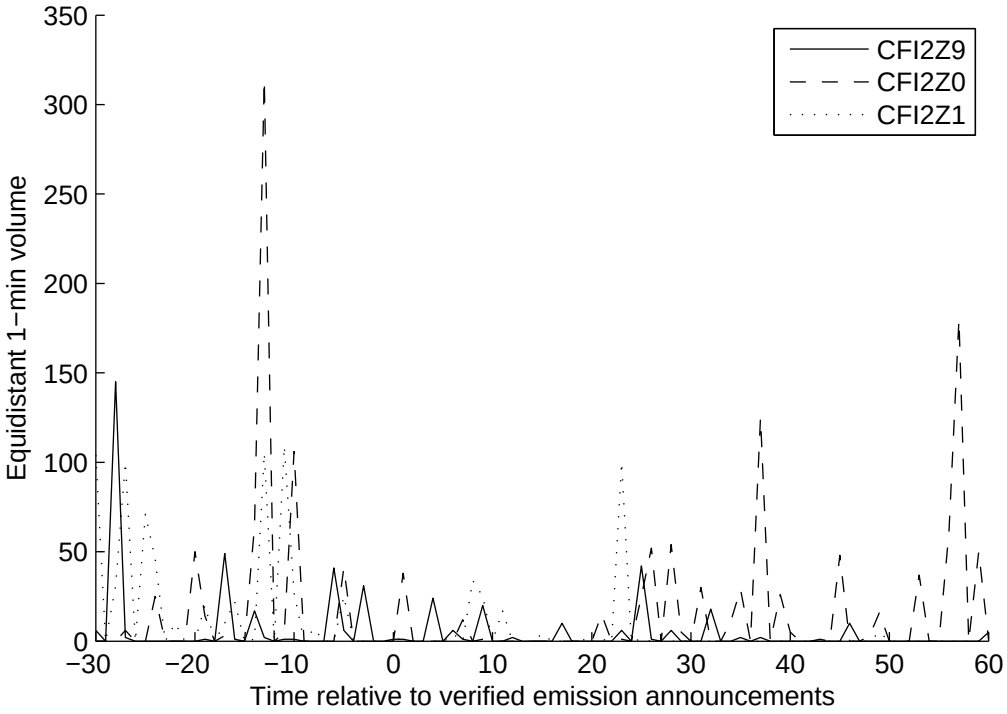


Figure 16: No. of ticks responsiveness to verified emission

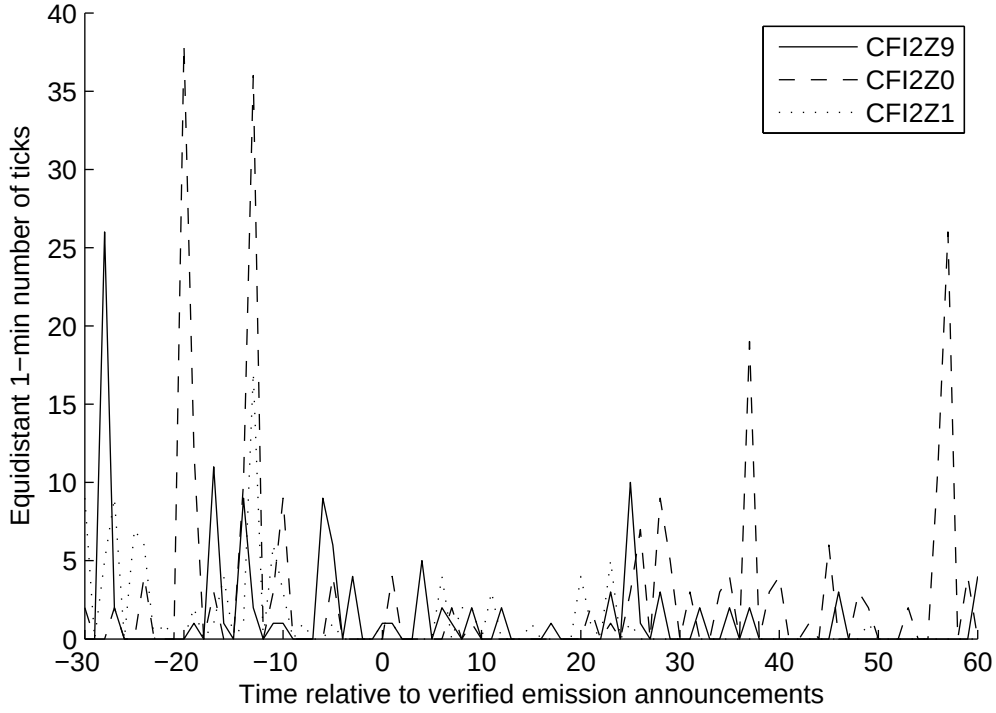


Figure 17: Volitility responsiveness to verified emission

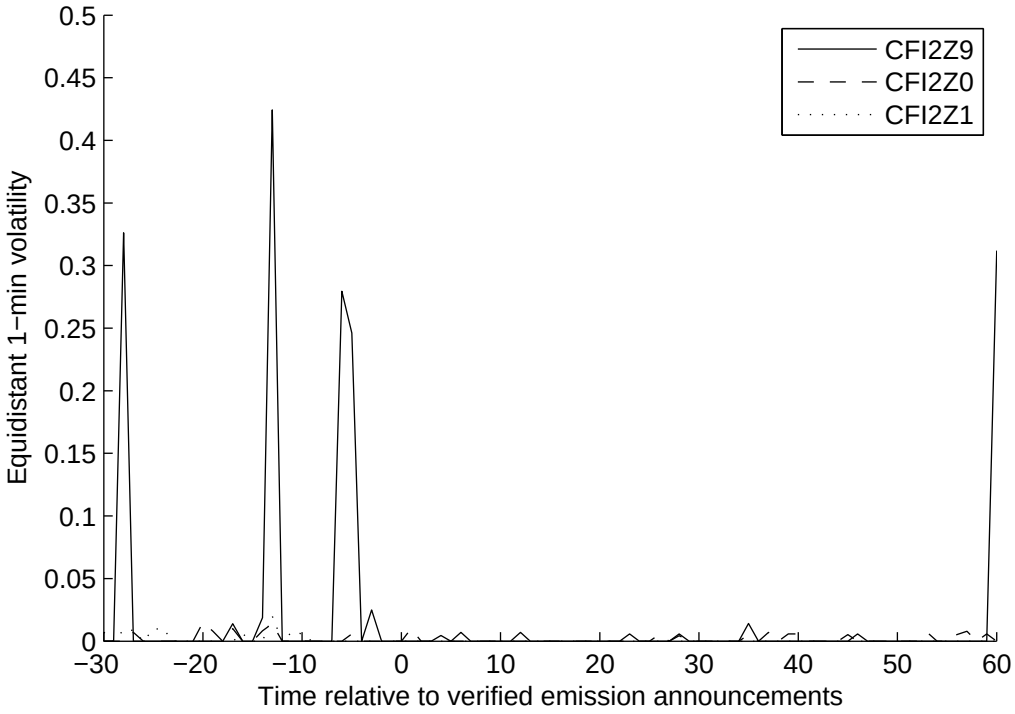
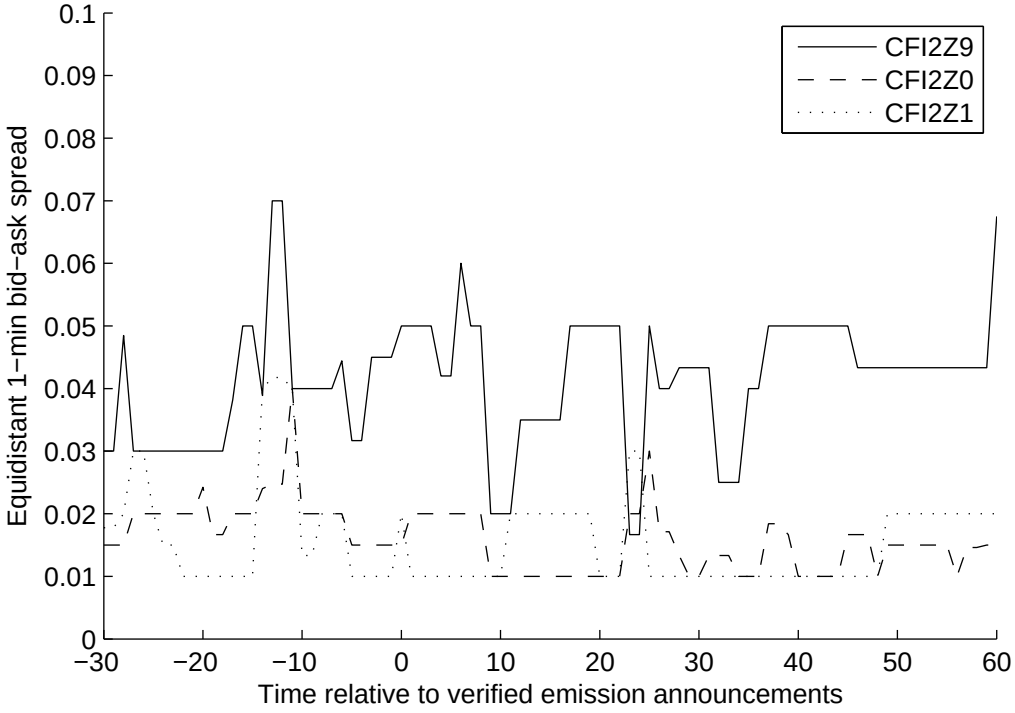


Figure 18: Bid-ask spread responsiveness to verified emission



expect.

Our findings are compared to those of Balduzzi et al. (2001) and of Conrad et al. (2012). We found similar patterns in that market microstructural trade variables in EU ETS market adjusted in response to new information releases as in well-established U.S. Treasury instrument markets studied by Balduzzi et al. (2001), however, less significantly and consistently. We also came up with different conclusions with Conrad et al. (2012) in that adjustment directions might not be all consistent, as well as that we found evidence of information leakage in EU ETS market.

This paper has implications for the microstructure of ETS market in that we developed our understanding of how EU ETS futures market adjust to new information, and it also pertains to the market efficiency and market improvement issues EU ETS markett.

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