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An investigation into the state of the European emissions market; is the European Union's Emissions Trading Scheme effectively able to reduce emissions in the aviation sector?

Master Thesis - MSc. Finance and Investments

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Preface

Executive Summary

This research examines the effectiveness of the European Union's Emissions Trading Scheme (EU ETS) in reducing emissions within the aviation sector. The EU ETS is a market-based system where the cost of emitting is determined by supply and demand. The EU regulates the level of supply and can, therefore, indirectly determine the price. The scheme's ideology is that, as prices escalate, parties are incentivized to emit less, thereby contributing to the scheme's goal of reducing emissions.

The EU ETS has undergone significant changes over the years. As the EU continually revises its objectives regarding the level of emissions, the EU ETS evolves. These changes are announced to the public. For the EU ETS to be effective, the market needs to incorporate these changes. For instance, if the number of allowances is reduced while demand remains, there should be a corresponding increase in price. We are, therefore, determining whether the allowance market efficiently incorporates new information to assess whether the EU ETS' market-based mechanisms are effective in reducing emissions.

The first of two elements that makes this research unique is the decision to focus on the aviation sector, as it is the only sector with its own allowance. This consequently means that the (aviation) allowance market's reaction directly reflects the sector's reaction to the announcement. The second is that it includes announcements from all stages of the European legislative process.

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Research Question: To what extent do announcements of policy changes to the European Union's Emissions Trading System influence aviation emission allowance prices?

1 Introduction

In an interconnected world where aviation serves as the physical bridge that connects people across continents, plummeting prices have made air travel accessible to an increasing number of people. Yet, beneath the facade of affordability lies a hidden cost – one that is not covered by its (financial) price.

If global aviation were a country, it would rank amongst the top 10 worst greenhouse gas emitters (European Commission, n.d.-a). In 2017, commercial aviation was responsible for 2.7% of global emissions (International Energy Agency, 2023; Ritchie & Roser, 2024). It is estimated that, in 2017, 3% of the global population were frequent flyers (6+ flights per year), who in turn were responsible for 68% of aviation emissions (Rutherford, 2019). Put differently, **227 million people produced 1.8% of the worlds total greenhouse gas emissions** just by flying. In addition, the International Civil Aviation Organization expects emissions from aviation to more than triple by 2050 (2022).

Greenhouse gas emissions are a pivotal driver of climate change, exacerbating the frequency and severity of extreme weather events such as storms, heatwaves, floods, droughts, and wildfires (World Health Organization, 2023). The effects of climate change can already be perceived; children born today are up to seven times more likely to be exposed to extreme weather events than their grandparents (The Economist, 2021a). Climate change is causing a rise in sea levels; 10% of the global population resides on land that is likely to vanish. Small scale farmers, who produce a third of the world's food on farms less than 2.56 hectares, are especially susceptible to climate change, endangering the world's food supply (The Economist, 2021b). In total, the World Health Organization estimates that 3.6 billion people inhabit regions that are highly susceptible to climate change (2023). It is clear, however, that with the severity of its consequences, climate change will ultimately affect everyone.

In 2005, the European Union introduced an Emissions Trading System (EU ETS) with the goal of lowering emissions with 43% (compared to 2005 levels) by 2030 in the sectors it covers (European Commission, n.d.-a). The EU ETS regulates the total amount of emissions allowed each year through an allowance system. One allowance allows the holder to emit one metric tonne of carbon dioxide equivalent (CO_2-eq.) gasses. By decreasing the number of allowances each year, total emissions decrease. Allowances are distributed to the market through auctioning (European Commission, n.d.-b). Due to the finite supply of allowances, interested parties experience market competition trying to outbid each other for the right to emit. This consequently puts a financial price on emissions.

The EU ETS is, therefore, a market-based system where the price of emitting is determined by supply and demand. As the EU ETS determines the level of supply, it can indirectly determine the price of an allowance. The scheme's ideology is that, as prices escalate, parties are incentivized to emit less, thereby contributing to the scheme's goal of reducing emissions.

The commercial aviation sector is poised to be one of the sectors most affected by the EU ETS. The United Kingdom's Department for Energy Security calculates the level of greenhouse gas emissions associated with different modes of transport. Per passenger per kilometer, domestic, short-haul, and long-haul flights produce 246 g, 151 g, and 193 g of CO_2-eq. gas respectively. In contrast, a train, long-haul bus, or ferry produces 35 g, 27 g, and 19 g of CO_2-eq. gas respectively (2022). Consequently, any increase in price would disproportionately impact the aviation sector due to its high level of greenhouse gas emissions.

It is, therefore, expected that the market closely monitors announcements regarding the EU ETS and incorporates any new information into the price. Considering the market-based design of the EU ETS, it is essential for the market to react to policy changes for the EU ETS to be effective in reducing emissions. This research uses aviation allowance future prices to measure the market's reaction. Futures are legal contracts to purchase or sell a good in the future. Since future prices incorporate known information beforehand, they typically don't react to anticipated changes like gradual allowance reductions. Instead, they respond to unexpected events, such as the announcement of a temporary exemption on emissions. We, therefore, have to determine whether the aviation allowance market responds to the announcement of unexpected policy changes.

This research, therefore, investigates the reaction that the commercial aviation sector has had to announcements regarding policy changes to the EU ETS. Under the presumption that the EU ETS affects the aviation sector, it is to be expected that the market both monitors and incorporates the information provided by announcements. The corresponding research question, therefore, is,

To what extent do announcements of policy changes to the European Union's Emissions Trading System influence aviation emission allowance prices?

We investigate this question by conducting an event study on the announcement dates of policy changes to the EU ETS that are relevant to the commercial aviation sector. An event study determines whether the market had a significant reaction to an announcement. Furthermore, we investigate whether the market experienced a lot of volatility in anticipation of and after the announcement using a general autoregressive conditional heteroskedasticity model. This work builds upon the research conducted by Deeney et al. (2016), Mansanet-Bataller and Pardo (2009), and Conrad et al. (2012) who investigated to what extent announcements regarding the EU ETS have an effect on allowance markets.

This research contributes to the literature by specifying the effect of announcements regarding the EU ETS to the aviation sector. The aviation sector is of particular interest because it is the only sector with its own allowance (European Energy Exchange, n.d.), meaning that the reaction measured by an event study directly reflects the sector's reaction towards the announcement.

This research, furthermore, differentiates itself from previous literature by using multiple announcement dates for each policy change. The amendment process of European legislation consists of multiple stages in which different parties can propose revisions. These revisions have their own announcements. This means that, between the initial announcement of the proposed policy change and the final version, there could be months. Despite this, most event studies regarding the EU ETS only use the final announcement date – when the outcome of the vote is published. This research investigates whether the market incorporates the information provided by these earlier announcements.

Finally, most research regarding the EU ETS uses data prior to the start of Phase IV (2021). This research therefore contributes to the existing literature by determining whether previous findings can be replicated using new data.

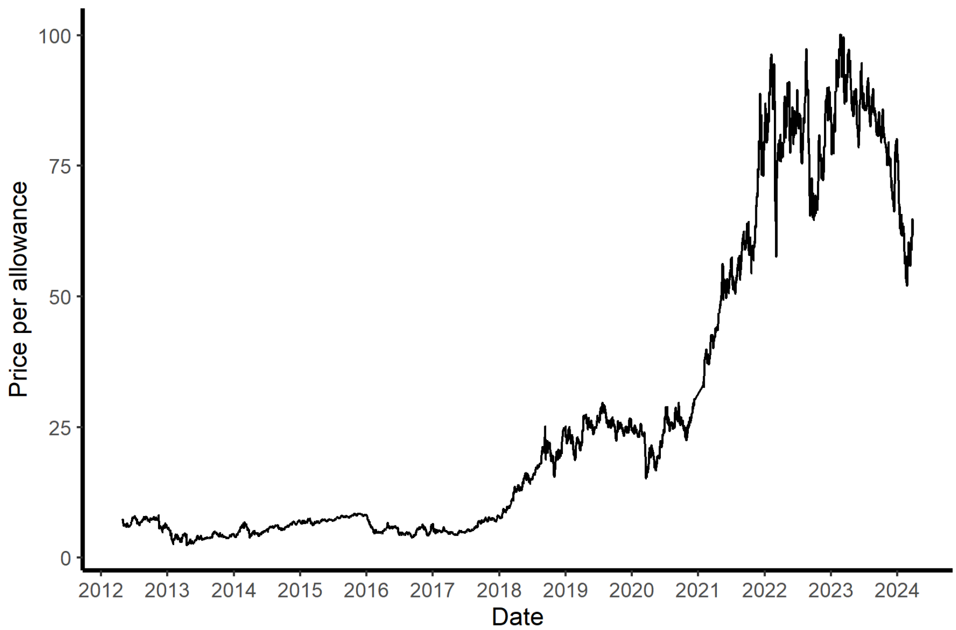
2 Literature Review

2.1 The EU ETS

The European Union's Emissions Trading System (EU ETS) is a cap and trade system designed to decrease emissions within the European Union. Within its covered sectors, only companies that own emission rights, known as European Union Allowances (EUA), are permitted to emit carbon dioxide. One EUA allows the holder to emit one metric ton of CO_2-eq. gasses. The system reduces emissions by decreasing the number of available EUAs each year. Companies in these sectors can obtain EUAs through either auctioning or trading, with the price of allowances being determined by demand. This variable price is the market-based mechanism that incentivizes companies to emit less to pay less (Peeters, 2023).

The EU ETS so-far consists of four different phases wherein each phase is more stringent than the last (Peeters, 2023). Phase I (2005-2007) was a 3-year pilot phase that only covered emissions from power generators and energy-intensive industries. Phase II (2008-2012) expanded the system to cover new sectors, amongst which the commercial aviation sector in 2012 (European Commission, n.d.-a). Phase III (2013-2020) decreased the percentage of EUAs given for free to 43%, making auctioning the standard allocation method (Peeters, 2023). Phase IV (2021-*Now*) increased the ambition of the EU ETS' goal. Rather than a 43% reduction in emissions, the aim is 62% (compared to 2005 levels of emissions). To achieve this, the speed at which the number of EUAs decrease each year was increased from 1.74% to 2.2% which will be further increased to 4.3% in 2024 and 4.4% in 2028 (European Commission, 2023).

Figure 1: EUAA Future End-of-Day Price Evolution Over Time (EUR)



Amongst the sectors covered by the EU ETS, the commercial aviation industry holds a unique status; it is the only sector with its own allowance, known as European Union Aviation Allowances (EUAA). Figure 1 shows the price evolution of EUAAs over time. EUAAs cannot be exchanged for EUAs, meaning that the commercial aviation sector – unlike all other sectors – cannot trade allowances across sectors (European Energy Exchange, n.d.). There are, therefore, no (direct) spillover effect, which makes the aviation sector more exposed to legislative changes than other sectors. Since the sector has its own allowance, any change in price or volatility on the announcement date of a policy change of the EU ETS is a perfect proxy for the sector's reaction towards this change.

2.2 Synthesis of the literature

2.2.1 The impact on price

Deeney et al. (2016) perform an event study to measure the impact that the vote result (accept or reject) of a proposed policy change to the EU ETS has on allowance prices. Their hypothesis is that legislative efforts have an effect on the EUA market. This builds on the earlier work of Daskalakis and Markellos (2009), Koch et al. (2014), and Kossoy and Guigon (2012) who found that EUA prices are affected by regulatory actions.

Event studies serve as a tool to assess market efficiency, implicitly testing the principles of the Efficient Market Hypothesis (EMH). The EMH, in its semi-strong form, states that the market incorporates all publicly available information into the price (Ţiţan, 2015). When the European Union announces a policy change to the EU ETS, an efficient market would, therefore, incorporate all the new information provided by the announcement. An event study determines whether the market has a significant reaction on the day of or in the period surrounding an announcement. **An event study therefore allows researchers to determine whether a market is efficient**.

Deeney et al. (2016) investigate the market's reaction towards 29 different pieces of legislation with an estimation window of 20 days and an event window of 11 days. They recognize that one inherent limitation is the non-constant frequency of announcements. The estimation and event window are, therefore, a compromise between obtaining an index for normal behavior, away from events, and keeping the event windows short to detect effects effectively (Kothari & Warner, 2007). At the same time, the estimation and event window need to be long enough to incorporate potential price movements before the event date due to information leakage and price movements after the event day akin to the phenomenon of post earnings announcement drift (Hirshleifer et al., 2009).

Deeney et al. (2016) use both a zero log return and a constant mean return model to calculate the expected return. They do this to stay consistent with the earlier work of Lin and Tamvakis (2010) who investigate the effect of OPEC announcements on crude oil prices. The results from both methods are, however, practically the same. They find that legislative efforts have significant (measured at both 1% and 5%) on European allowance prices on the event day and the five days following the event day.

Mansanet-Bataller and Pardo (2009) perform an event study to measure the impact that the announcement of new information has on the price of allowances. Specifically, new information regarding national allocation plans in which each member state determines the total quantity of allowances available and the allocation of said allowances amongst companies, and the announcement of the verified emissions of companies and Member States. National allocation plans were replaced with one, Union-wide allocation plan in phase III. Their hypothesis is that the announcement of new information is incorporated into the market and therefore influences allowance prices. This research expands on the work of Daskalakis and Markellos (2009) and utilizes the methodology employed by Alberola et al. (2008), who found that EUA spot prices react to energy prices forecast errors and unanticipated temperatures.

In total, they analyze 70 announcements in the period of October, 2004 to May, 2007. The authors use an estimation period of 3 days and an event window of 3 days before and after the announcement (for a total of 7 days). Like Deeney et al. (2016), they point out that the release of new information is sporadic and unscheduled.

Mansanet-Bataller and Pardo (2009) utilize two event study methods: the regression approach and the truncated mean model. With the regression approach, they use dummy variables to indicate the type of new information that is provided to the market. Using this approach, they find statistical significance (at 1%) for the announcement of verified emissions in 2005, additional information regarding national allocation plans and the approval of national allocation plans in phase I.

The authors, however, highlight that the regression approach is flawed due to the non-normality of the data. They revealed, using a Jarque-Bera normality test, that the returns are non-normally distributed. According to McKenzie et al. (2004), the use of all available data with non-normally distributed data could lead to spurious inferences. Furthermore, statistical tests revealed heteroskedasticity and autocorrelation problems within the dataset. While ordinary least squares (OLS) is equipped to handle heteroskedasticity, the OLS standard errors will be incorrect due to the error terms being serially correlated. The authors, therefore, use Newey and West's (1986) heteroskedasticity and autocorrelation consistent covariance estimator which is robust to both heteroskedasticity and autocorrelation. This approach is in line with the methodology of Alberola et al. (2008) which uses the Newey-West procedure due the presence of autocorrelation between the error terms.

The truncated mean model is a version of the constant mean return model that excludes the top and bottom results. The model is therefore suitable to calculate the mean for data that is susceptible to outliers. The authors also limit the number of announcements considered to only include announcements where there are no other announcement in the surrounding six day period to ensure that the results are not affected. This does, however, reduce the sample size from 70 to 22. The authors find statistical significance (at 1%) for additional information regarding national allocation plans and the approval of national allocation plans in both phase I and II. This is in line with the authors' hypothesis that new information is incorporated into the price of allowances.

Mansanet-Bataller and Pardo (2009) furthermore suspect that new information reaches the market before the official announcement. For instance, with the verification of actual, verified emissions in 2005 there was a small increase in price on the event day. This was, however, preceded by a huge fall, suggesting that the information had already been incorporated into the market prior to the announcement day and that the event day was a (small) correction of the previous fall. For these three reasons, the authors decide to use the truncated mean model instead.

The authors, however, continue to observe significant market reactions on the days prior to the announcement. This suggests that the arrival of new information occurs prior to the (public) announcement. Their results indicate that there is no strong evidence of a reaction on the days following the announcement. This suggests that the market incorporates the new information on the days prior to (due to data leakage) and on the event date itself. This is in contrast to other studies, such as Deeney et al. (2016) and Conrad et al. (2012), that find strong evidence for the post earnings announcement drift concept wherein the market requires significant time to process information and update its beliefs.

2.2.2 The impact on volatility

Deeney et al. (2016) use a generalized autoregressive conditional heteroskedasticity (GARCH) model to determine the effect that the vote result of a proposed policy change to the EU ETS has on the volatility of the EUA market. This is based on the work of Lin and Tamvakis (2010) and Lu and Chen (2011), who showcase that the inclusion of dummy variables in GARCH regressions models can lead to unreliable inferences. The authors use a GARCH model containing a dummy variable (d_t) that is equal to one on days within the event window:

$$\hat{\sigma}_t^2 = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 + \theta d_t, \qquad \epsilon_{t-1} \sim i.i.d.(0, \sigma^2) \tag{1}$$

where $\hat{\sigma}_t^2$ is the estimated volatility, a_0 is a measure of both unconditional variance V_L (the level to which we expect the variance will mean-revert in the long-run) and the speed at which it will revert γ, ϵ_{t-1}^2 is the residual difference between the observed and expected return which are independent and identically distributed with mean zero and conditional variance σ^2, σ_{t-1}^2 is the variance of the previous time period, and θ is a coefficient.

The variables α_1 and β_1 are estimated weights that, together with the third weight

(γ) must be equal to one. These weights are estimated within the estimation period. Deeney et al. (2016) decided to use the same estimation and event period for measuring the effect on price and volatility in order to compare the results. The utilized estimation and event period are, therefore, 20 and 11 days respectively.

The coefficient of the dummy variable (θ) shows the effect that the decision on the proposed policy change to the EU ETS has on the volatility of the EUA market. In other words, it measures whether the volatility of the EUA market is influenced by external factors.

Deeney et al. (2016) find that the decision on proposed policy changes to the EU ETS are accompanied with an increase in volatility both before and after the announcement at a significance level of 5%. They showcase this with the presence of volatility clustering before and after the event date. These findings suggest a high level of trader uncertainty around the outcome of these decisions and their potential impact on prices.

Conrad et al. (2012) measure the effect that the approval or rejection of national allocation plans has on the volatility of the EUA market. For this, they use the fractionally integrated asymmetric power GARCH (FIAPGARCH) model – an alternative version of the GARCH model. They, therefore, replicate the methodology used by Tse (1998), who investigates the conditional heteroskedasticity of the Yen-Dollar exchange rate. The FIAPGARCH model combines the long memory property of the fractionally integrated GARCH (FIGARCH) of Baillie et al. (1996) with the asymmetric power GARCH (APGARCH) model of Ding et al. (1993). The long memory property refers to how long it takes for past volatilities to dissipate from the model. With a standard GARCH model the decay is unrealistically fast whereas with an integrated GARCH model there is no decay (Leonard N Stern School of Business, n.d.-b). FIGARCH is, therefore, a more realistic model. The asymmetric power refers to δ in σ^{δ} which, by setting specific constraints for δ, allows the model to act as alternative GARCH models (Leonard N Stern School of Business, n.d.-a).

In the form of a FIAPGARCH(1,d,1):

$$(1-\beta L)\sigma_n^{\delta} = \omega + \sum_{j=1}^{J}\sum_{q=1}^{Q}\omega_{j,q}W_{n-q}^{j} + ((1-\beta L)-(1-\theta L)(1-L)^{d})(|\epsilon_n|-\gamma\epsilon_n)^{\delta} \quad (2)$$

where L denotes the lag, β and θ are the autoregressive and moving average coefficient respectively. The fractional differencing parameter $0 \leq d \leq 1$ enforces the long memory in the volatility and $\delta > 0$ showcases the optimal power transformation. Furthermore, $-1 \leq \gamma \leq 1$ ensures that both positive and negative shocks have the same asymmetric effects. The W_{n-q}^{j} are the lagged values and $\omega_{j,q}$ is the dummy variable.

One benefit of the FIAPGARCH model is that, when certain restrictions are imposed, it acts as well-established alternative GARCH models. For instance, the restriction that $\delta = 2$ transforms the model into an asymmetric FIGARCH (FIAGARCH) model. Under the additional constraint that $\gamma = 0$, it becomes a symmetric FIGARCH model. If we, instead, limit d to be equal to zero it becomes a short memory asymmetric power GARCH (APGARCH). Under the additional constraint that $\delta = 2$ it is an asymmetric GARCH (AGARCH) model. The authors consequently test the performance of each of these GARCH models.

Conrad et al. (2012) find that, out of all the models tested, the most general FIAPGARCH model delivers the best results with high frequency data. This is done by comparing the Akaike and Schwartz Information Criteria which, similar to adjusted R^2, introduce a penalty term for the number of parameters in the model to combat overfitting. This is further reinforced by the likelihood ratio tests, which comparatively ranks the fit of each model, and the Ljung–Box test, which shows that there is no remaining serial correlation in the squared standardized residuals.

The authors also find that the market reaction towards the decision to approve or reject the national allocation plan is significant at a 1% level with 10-minute frequency data and at 5% with 60-minute frequency data. The resultant change in price 10 minutes after the announcement is -3.14 and takes a value of -0.67 after 60 minutes. Considering the difference in volatility measured between a 10, 30, and 60 minute interval, the authors openly question whether end-of-day data is appropriate for event studies. They, however, find that with end-of-day data the effect of the national allocation plan decision announcement is still significant at 5%.

Tse (1998) highlights that the conditional volatility of stock prices responds asymmetrically to positive and negative shocks, with negative shocks evoking a higher response. This is also highlighted by Conrad et al. (2012) who constrains $-1 \leq \gamma \leq 1$ to ensure that both positive and negative shocks have the same asymmetric effect.

Mansanet-Bataller and Pardo (2009) perform both a Brown-Forsythe and sign test to compare the variance of the returns before and after the announcement. It is important to note that, unlike with the constant return model, the Brown-Forsythe and sign test are not susceptible to outliers. This is because these tests use the absolute deviation from the median rather than an average. The full sample of 70 announcements can, therefore, be used.

The authors find that the Brown-Forsythe test only produces an invalid result for 10%

of the announcements tested. This suggests that there is strong equality between the variances before and after the announcement. The result for the sign test are practically the same. These results are surprising considering Mansanet-Bataller and Pardo (2009) found that the market reaction to new information occurs on the days leading up to the event and on the event date – not after the event date. This implies that announcements have an effect on carbon returns but not on market volatility. The authors explain this as evidence of information leakage prior to the announcement.

2.3 Multiple announcements per policy change

This research distinguishes itself from previous literature by using multiple announcement dates per policy change. The amendment process of European legislation consists of multiple stages in which different parties can propose revisions. These revisions have their own announcements – meaning new information is provided to the market prior to the announcement of the final version which is voted upon. This research, therefore, investigates whether the market monitors these earlier announcements and incorporates any new information into the price. This aligns with the efficient market hypothesis that the market incorporates information as soon as it becomes publicly available.

These revision announcements contain crucial information for commercial aviation companies. Take, for example, Directive 2023/958 which signals a drastic change regarding the aviation emissions covered by the EU ETS. Since the inclusion of the aviation sector in 2012, emissions from flights from or towards airports outside the European Economic Area (EEA) are not covered by the EU ETS. This means that, in practice, only emissions from intra-European flights are covered by the EU ETS. This distinction stems from a number of temporary exemptions (European Commission, 2023). Directive 2023/958, however, proposed that the latest derogation would cease at the end of 2023, thereby extending coverage to all flights towards or originating from the EEA.

It is interesting to note, however, that when Directive 2023/958 was initially proposed on the 15th of July, 2021 it sought to extend the exemption on flights originating from or towards airports located outside the EEA. Only on the 8th of May, 2022, the European Parliament proposed that Directive 2023/958 should instead end the exemption, which was adopted. This highlights how a policy change can drastically change in scope throughout its development process.

This, furthermore, showcases how parties can potentially benefit from monitoring announcements and incorporating new information into their price estimates. The proposal of the European Parliament on the 8th of May, 2022 signaled significant financial repercussions for the commercial aviation sector. With all flights being covered, airlines operating routes with one airport outside the EEA would face a surge in financial costs due to the additional number of allowances required. For example, only 18.6% of the flights operated by KLM in 2022 had both airports within the EU. This means that for KLM, Directive 2023/958 could lead to a potential five fold increase in the number of allowances required[1] (KLM, 2023). It is, therefore, to be expected that airlines are closely monitoring the development of each proposal.

To determine to what extent announcements of policy changes to the EU ETS influence aviation emission allowance future prices, we have the following hypothesis,

> H_1: The market incorporates new information provided by announcements regarding policy changes to the EU ETS into the future price of aviation emission allowances.

We, furthermore, distinguish between the first, last, and revision announcement(s) to determine whether we can replicate the results of Deeney et al. (2016) and Mansanet-Bataller and Pardo (2009),

> $H_{1.1}$: The aviation emission allowance future market has an abnormal reaction within the event period surrounding the first announcement, which is the initial proposal for policy change.
>
> $H_{1.2}$: The aviation emission allowance future market has an abnormal reaction within the event period surrounding each revision announcement, wherein European institutions propose revisions to the initial proposal.
>
> $H_{1.3}$: The aviation emission allowance future market has an abnormal reaction within the event period surrounding the final announcement, which reports whether the policy change was adopted.

We, furthermore, investigate the volatility that investors experience in the event period surrounding an announcement. We hypothesize that,

> H_2: The aviation emission allowance future market has abnormal levels of volatility in the event period surrounding an announcement.

We distinguish between the first, final, and revision announcements. As such,

[1]The actual increase in the number of allowances required by KLM depends on the number of flights it operates with just one airport within the EEA. KLM's annual report does not specify what percentage of non-European flights have one or both airports outside the EEA.

$H_{2.1}$: The aviation emission allowance future market has abnormal levels of volatility in the event period surrounding the first announcement, which is the initial proposal for policy change.

$H_{2.2}$: The aviation emission allowance market has abnormal levels of volatility in the event period surrounding each revision announcement, wherein European institutions propose revisions to the initial proposal.

$H_{2.3}$: The aviation emission allowance future market has abnormal levels of volatility in the event period surrounding the final announcement, which reports whether the policy change was adopted.

3 Methodology and Data

3.1 Measuring the effect of announcements

We investigate to what extent the announcement of policy changes to the EU ETS have an effect on the future price of aviation emission allowances. We can determine whether the market had an abnormal reaction to an announcement using an event study. Furthermore, we determine whether the market experienced a lot of volatility in anticipation of and after the announcement using a GARCH model.

As a robustness check, we develop a media awareness proxy to simulate the level of investor awareness regarding changes to the EU ETS relevant to the aviation sector. This proxy is based on the number of articles or press releases made in that period. News articles and press releases are expected to be most frequent when changes to the EU ETS are announced. Therefore, assuming we have identified the correct event period, we expect it to coincide with high levels of media awareness.

3.1.1 Event study

An event study tests whether the market has an abnormal reaction in the period surrounding the event date by calculating the cumulative abnormal return (CAR). CAR is the sum of the abnormal return on each day within the event period. The event period decides the number of days before and after the event date to consider. For instance, an event period of 11 days would incorporate the abnormal return of the 5 days preceding the event, the day of the event, and the 5 days following the event.

$$CAR = \sum_{t=1}^{N} AR_t \tag{3}$$

where AR_t is the difference between the observed and expected return.

Abnormal return is the difference between the observed and expected return. The observed return is the actual return realized on that day. The expected return is an estimation of the return that can be expected on that day. To calculate the expected return, we require a return model and an estimation period prior to the event period.

There are multiple models that can be used to estimate the return. Past studies (Deeney et al., 2016; MacKinlay, 1997) have shown that the simple constant mean return model can adequately model expected returns. The constant mean return is equal to the average observed return within the estimation period:

$$\text{Constant mean return} = \frac{1}{N} \sum_{t=1}^{N} R_t \tag{4}$$

where R_t is the observed return on each day within the estimation period.

Mansanet-Bataller and Pardo (2009), however, found that observed returns within the estimation period were non-normally distributed – their sample contained many extreme values. Since the constant mean return takes the average of the observed returns, it is highly susceptible to outliers.

We, therefore, use the Jarque-Bera normality test to determine whether the observed returns within the estimation period are normally distributed. If they are, we use the constant mean return model. If they are not, we use the truncated mean model. The truncated mean model is a modified version of the constant mean return model that discards a percentage of the highest and lowest observed returns. Mansanet-Bataller and Pardo (2009), for example, remove the top and bottom 10% of observed returns. In the case of non-normality, we discard 15% of observations.

Using an event study, we therefore test whether the market has an abnormal reaction in the period surrounding the announcement of a policy change to the EU ETS. To determine whether the measured CAR implies an abnormal reaction, we use a test statistic. A test statistic determines whether a value is statistically significant in the context of the observed results.

$$\text{Test statistic} = \frac{CAR(t_1, t_2)}{\sqrt{\sigma^2(t_1, t_2)}} \tag{5}$$

where $\sigma^2(t_1, t_2) = L\sigma^2$, and σ^2 represents the variance of the AR_t computed during the estimation window. $L = t_2 - t_1 + 1$ denotes the number of days included in the CAR calculation, with t_1 fixed at -5 and t_2 varying between -5 and 5.

3.1.2 GARCH model

To determine whether the announcement of a policy change to the EU ETS has an effect on the volatility of the aviation emission allowance market, we use a GARCH(1,1) model to estimate volatility. A GARCH model determines whether the volatility of the aviation emission allowance market is (at least partially) conditionally heteroskedastic. Expressed differently, we are testing whether a portion of the volatility is caused by external factors such as an announcement.

$$\hat{\sigma}_t^2 = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2, \qquad \epsilon_{t-1} \sim i.i.d.(0, \sigma^2) \tag{6}$$

where $\hat{\sigma}_t^2$ is the estimated volatility, a_0 is a measure of both unconditional variance V_L (the level to which we expect the variance will mean-revert in the long-run) and the speed at which it will revert γ. α_1 and β_1 are estimated weights that showcase to what extent the current time volatility is determined by the residual return and volatility of the previous time period. Furthermore, the sum of the three weights must be equal to one: $\gamma+\alpha+\beta=1$. ϵ_{t-1}^2 is the residual difference between the observed and expected return which are independent and identically distributed with mean zero and conditional variance σ^2, and σ_{t-1}^2 is the variance of the previous time period.

GARCH is an evolution of the autoregressive conditional heteroskedasticity (ARCH) model. The ARCH model tests whether current volatility can be predicted using the previous time period's volatility. When multiple time periods are considered, however, the ARCH model quickly becomes unsuitable. For this reason, Bollerslev (1986) created the generalized ARCH (GARCH) model which, rather than using the volatility of each lagged time period, in its simplest GARCH(1,1) form takes the residual and volatility of the previous time period. While a generalization, GARCH(1,1) is able to adequately model real life data (as demonstrated by Engle and Ng, 1993).

Furthermore, by including a coefficient (θ) and a dummy variable (d_t) that is equal to one on days within the event period and zero on days outside the event period, we can measure whether there is a change in variance when policy changes regarding the EU ETS are announced.

$$\hat{\sigma}_t^2 = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 + \theta d_t, \qquad \epsilon_{t-1} \sim i.i.d.(0, \sigma^2) \tag{7}$$

3.1.3 Media awareness proxy

A media awareness proxy simulates the level of media awareness of the average investor based on the number of recently published articles or press releases. We can consequently use this to determine the level of attention the aviation sector received in the event and estimation period. This is important to assess whether the event and estimation period are accurately positioned.

After collecting – as later explained in section 3.3.3 – all news articles and press releases (hereafter referred to as articles) relevant to the aviation sector and the EU ETS, we count the number of articles published on each date.

We aim to simulate media awareness as a percentage ranging from 0% to 100%. To do so, we assume that 50% media awareness is equal to the average number of articles published (only considering days where at least one article was published). Consequently, 100% media awareness is equal to two times the average number of articles published.

We convert the count of the number of articles published on each day to the percentage of media awareness by dividing by two times the average. The count is restricted between 0 and two times the average number of articles published to ensure that media awareness does not exceed 100%. Consequently, if the count of articles published on a particular day does exceed two times the average, it defaults to 100%.

$$\text{Media awareness}_i = \frac{N_i}{2\mu_N} \tag{8}$$

where N_i is the number of articles published on day i and μ_N is the average number of articles published (only considering days where at least one article was published). N_i is furthermore restricted such that $0 \leq N_i \leq 2\mu_N$.

We, furthermore, assume that the media awareness generated by a published article does not immediately vanish in the following days. Instead, we propose that the effect follows an exponential decrease, where the majority of the effect is lost in the first few days after publication. To simplify this model even further, we assume that the curve is not asymptotic but instead reaches zero on day eight.

$$\text{Media awareness effect}(x) = e^{-x} \tag{9}$$

where x represents the number of days after the article was published, with zero being the publishing date. x is furthermore restricted such that $0 \leq x \leq 7$.

3.2 Estimation and event period

In line with the methodology of Deeney et al. (2016) and Mansanet-Bataller and Pardo (2009), we use the same estimation and event period for both the event study and the GARCH model to be able to compare the results.

The number of days to consider for the estimation period is a balancing act. We want the period to be long enough to be an index for normal market behavior; yet we want to keep the period short enough so that the effects from other events are excluded (Deeney et al., 2016). For the event period, we want the period to be short enough to be able to detect the abnormal reaction to an event (Kothari & Warner, 2007); yet we also want the period to be long enough to be able to detect market movements before and after the event day due to illiquid markets, time required to process information, and the the concepts of data leakage and post earnings announcement drift (Hirshleifer et al., 2009).

We, therefore, use an estimation period of 20 business days and an event period of 11 business days (5 days before and after the event date) for both models. The distinction of *business* days is because the dataset only includes allowances prices from days when the market is open. Figure 2 illustrates the estimation and event period for each announcement date.

Figure 2: *Event study of one announcement date.*

$$\underbrace{t_{\text{-}25} \longleftrightarrow t_{\text{-}6}}_{\textit{Estimation Period}} \qquad \underbrace{t_{\text{-}5} \longleftarrow t_0 \longrightarrow t_5}_{\textit{Event Period}}$$

where t_0 is the event day, $t_{\text{-}5}$ and t_5 showcase the 5-day event period on both sides of the event day, $t_{\text{-}25}$ is the start and $t_{\text{-}6}$ is the end of the 20-day estimation period.

3.3 Data

3.3.1 Announcement dates

To determine whether the market has an abnormal reaction to the announcement of changes to the EU ETS, we have compiled a list of policy changes that changed the EU ETS in a manner that is relevant for the commercial aviation industry.

This selection criteria is important to discuss. While the EU ETS has undergone many changes throughout the years, most did not affect the commercial aviation sector. Only changes to article 3, 12, 14, and 18 of Directive 2003/87/EC affect the aviation industry (European Parliament & Council of the European Union, 2023). As such, we only include policy changes to the EU ETS that included changes to the aforementioned articles or changes to annexes that are relevant to the commercial aviation industry. By only analysing policy changes that are relevant to the commercial aviation sector, we assume that the aviation allowance market will only respond to changes that directly affect them. Appendix A contains the list of policy changes that are deemed relevant to the aviation sector.

Not all of these policy changes are featured in this research, however, due to restrictions discussed hereafter. Appendix B contains the list of policy changes included in this research.

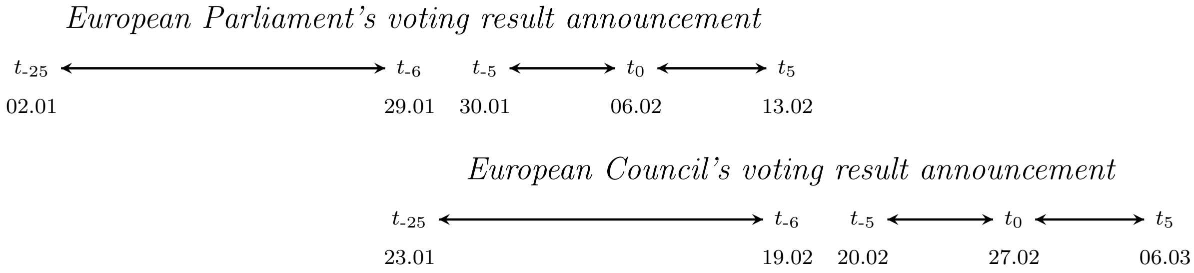
As mentioned in section 2.3, each policy change of the EU ETS goes through multiple legislative stages in which different European institutions can propose revisions. These revisions have their own announcement. For example, Directive 2023/958 was initially proposed on the 15th of July, 2021. It was ultimately voted upon and accepted on the 10th of May, 2023. Between these two dates, there were 20 announcements regarding revisions from the Council of the European Union, Economic and Social Committee, European Committee of the Regions, and the European Parliament to the initial proposal.

This research exclusively focusses on announcements originating from the European Commission, Council of the European Union (hereafter Council), and the European Parliament. The European Commission provides the initial proposal, while the (ordinary) legislative procedure requires the mutual agreement of the European Parliament and the Council for the policy changes to be adopted. The Economic and Social Committee and the European Committee of the Regions are excluded because, while they are advisory bodies that propose their own revisions, it is ultimately up to either the Council or the European Parliament to incorporate these revisions – in which case they will include the proposed revisions in their own announcement (European Parliament, n.d.). Appendix C further specifies which announcements from each institution are included. For Directive 2023/958, the number of announcements considered (besides the initial proposal) is reduced from 20 to 4.

Risk of overlap

In the event that the estimation and event period(s) of different announcements overlap, the return measured could be non-representative. Figure 3 shows two announcements regarding Directive 2018/410 that overlap. As the estimation period of the second announcement overlaps with the event period of the first announcement, it is possible that the return measured within the estimation period of the second announcement is biased as it includes the market's reaction to the first announcement. This would mean that the return measured in the estimation period is not an index for normal market behavior and consequently not suitable to judge the market's reaction to the second announcement.

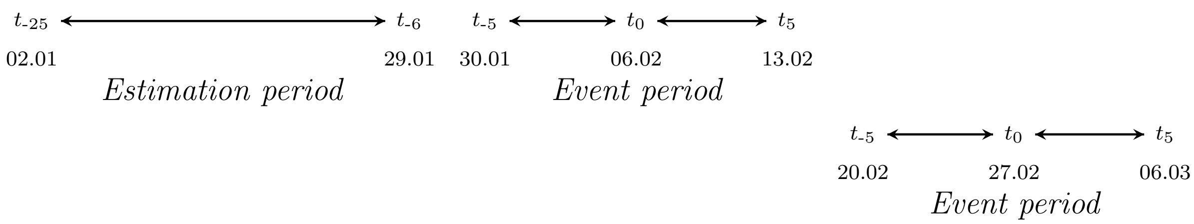
Figure 3: *Overlap between the event and estimation period of individual announcements for Directive (EU) 2018/410.*



We therefore implement a tier system that ranks announcements based on its source. For each policy change, the European Commission has just one announcement: the initial proposal. Therefore, unless the Council or the Parliament announce their own revisions in less than 23 business days, there is little risk of overlap. Announcements from the European Commission are therefore given the highest priority. As mentioned, the legislative procedure requires the mutual agreement of the European Parliament and the Council to be accepted. More specifically, the European Parliament has the first vote that decides whether to accept, revise, or outright reject the proposal. After the Parliament has adopted its position, the Council decides whether to accept the Parliament's position or propose its own revisions. If the Council accepts, the act is adopted. If the Council proposes its own revisions, it is sent back to Parliament, starting the process anew (European Parliament, n.d.). What is crucial, however, is that the Council ultimately determines whether the act is adopted. The Council is therefore given the second highest priority whereas the European Parliament has the lowest priority.

Figure 4 shows how the tier system works for the two overlapping announcements of Directive 2018/410. The estimation period for the second announcement is removed as it overlaps with the event period of the first announcement. Instead, the estimation period of the first announcement is used as a proxy of normal market behavior for the event period of both the first and second announcement. It is important to note that if the event periods were to overlap, the event period of the announcement with the lowest priority would be disregarded.

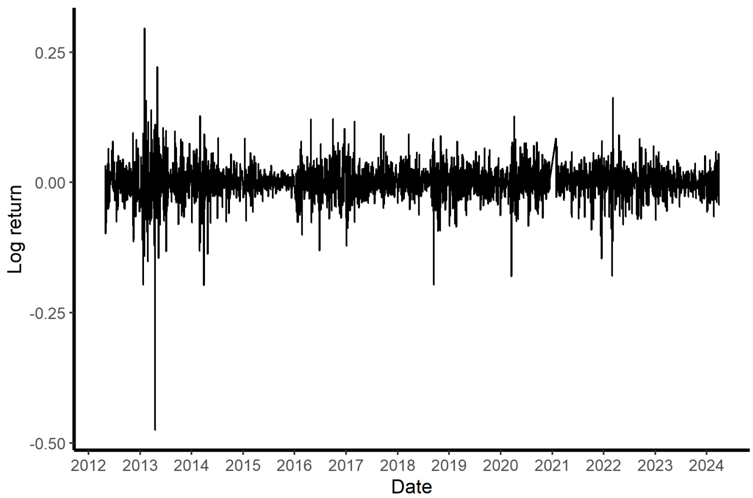
Figure 4: *Prioritising the European Council's announcement while controlling for the announcement of the European Parliament.*



3.3.2 Return and volatility

To determine whether the market has an abnormal reaction to the announcement of policy changes to the EU ETS in terms of return or volatility, we use the end-of-day price of European Union Aviation Allowances (EUAAs) futures. Specifically, one-month continuation futures which refers to the price of extending a future contract by one month. This data comes from the European Energy Exchange, accessed through Eikon Refinitiv. Figure 5 shows the descriptive statistics for the EUAA daily returns.

Figure 5: EUAA Future Log returns and descriptive statistics



Statistic	Log Return
# Obs	2989
Start date	27/04/2012
End date	28/03/2024
Mean	0.000720537
Median	0.001087549
Standard deviation	0.0340563
Skewness	-0.97281456
Excess kurtosis	18.05313899
Max	0.296168686
Min	-0.474937481
5% Percentile	-0.050932372
95% Percentile	0.050470493
Jarque-Bera (p-value)	0

The standard deviation being larger than the mean suggests that the log returns are non-normally distributed. The p-value of the Jarque-Bera test being zero confirms this. We, therefore, have to utilize a truncated mean model as explained in section 3.1.1.

3.3.3 News articles and press releases

We collect articles from Nexis Uni (n.d.). Nexis Uni is a full-text news article and press releases database. Filtering for articles related to the EU ETS and the aviation sector published between the 27th of April, 2012 and the 28th of March, 2024 leaves us with a sample of 2170 articles.

Nexis Uni, furthermore, classifies each article into categories with a confidence interval. The confidence interval represents how certain the algorithm is that a particular subject is present within the article. We use these categories and their associated confidence intervals to further filter the number of articles. We only want articles that discuss the EU ETS and the aviation sector. We, therefore, impose the restriction for each article that,

1. The confidence interval of the EU ETS being discussed must be at least 80%.
2. The confidence interval of the aviation sector being discussed must be at least 80%.

The implementation of these restrictions are detailed in Appendix D. These restrictions reduce the sample from 2170 to 380 articles.

3.4 Limitations

One limitation of using EUAAs rather than EUAs is that there is no data prior to 2012. This is because the aviation sector has only been part of the EU ETS since 2012. This means that certain policy changes, such as the initial proposal to include the aviation sector in the ETS, cannot be measured using EUAA data.

Another limitation is the use of end-of-day prices rather than intra-day prices. This is because end-of-day prices are the highest frequency data available. Conrad et al. (2012) points out that, in trying to measure the market's reaction to an announcement, it makes sense to use the highest frequency data available. They showcase that the strongest market reaction occurred in the first 10 minutes post-announcement. This reaction, however, partially reverts throughout the rest of the day. By using end-of-day prices, we are not able to measure this intra-day volatility.

Another limitation is the absence of volume data for the EUAA market. For a market to incorporate new information into the price in a timely manner, a certain level of liquidity is required. Without volume data, it is difficult to determine whether the EUAA market possesses this level of liquidity.

Finally, the list of news articles and press releases provided by Nexis Uni is not exhaustive. It does not feature every media source and its confidence interval algorithm only works for English-language articles.

4 Results and Discussions

The full list of 46 announcements from 23 unique policy changes that are used in the calculations of the event study and GARCH model are presented in Appendix B. Most policy changes have multiple announcements dates, as explained in section 2.3. At the same time, not all relevant announcements could be included due to overlapping event periods, as explained in section 3.3.1 under Risk of Overlap. A sample of 46 announcements is comparable to the number of announcements included in Deeney et al. (2016), Mansanet-Bataller and Pardo (2009), and Conrad et al. (2012) who featured 26, 75, and 13 announcements in their research respectively.

Table 1 shows the results for the event study and Table 2 shows the results for the GARCH model. The table is structured so that each column is its own category and each row is one day within the event period. The results itself are the coefficients of the test statistic for the CAR or the dummy variable. The p-value is represented using asterisks. The p-value expresses the probability that the observed data would occur if the null hypothesis were true. A low p-value, therefore, suggests that we can reject the null hypothesis.

Table 1: Event Study results

			Multiple announcements			EU ETS Phase		Institution				Type	
Day	*All*	*Single*	*First*	*Revision*	*Last*	*Phase III*	*Phase IV*	*Commission*	*Council*	*Parliament*	*Directorate*	*Directive*	*Regulation*
-5	0.16	0.12	-1.08	0.75	0.53	0.19	0.42	-0.43	0.89	-0.13	0.20	0.88	0.27
-4	-0.34	-0.39	-0.68	0.42	-1.03	-0.43	0.20	-0.53	-0.35	0.11	-0.34	1.10	0.02
-3	-0.40	-0.23	-1.24	0.53	-1.07	-0.34	0.02	-0.66	-0.13	0.07	-0.05	1.06	0.15
-2	-0.23	0.13	-1.48*	0.81	-0.86	-0.12	0.24	-0.67	0.12	0.28	0.56	0.42	0.24
-1	-0.02	0.21	-1.02	0.84	-0.49	0.13	0.36	-0.46	0.27	0.42	0.72	0.43	0.41
0	0.10	0.38	-0.73	0.66	-0.14	0.26	0.47	-0.29	0.23	0.39	1.12	0.82	0.43
1	-0.02	0.23	-0.78	0.61	-0.40	0.13	0.31	-0.42	0.11	0.27	0.91	0.30	0.33
2	-0.07	0.07	-0.74	0.42	-0.27	0.02	0.31	-0.38	0.02	0.33	1.10	0.51	0.15
3	0.11	0.33	-0.65	0.62	-0.12	0.22	0.39	-0.18	0.28	0.28	1.15	0.38	0.32
4	0.11	0.12	-0.57	0.58	0.10	0.27	0.43	-0.29	0.36	0.38	1.00	0.46	0.30
5	0.14	0.08	-0.63	0.74	0.09	0.28	0.52	-0.36	0.43	0.56	0.89	0.43	0.25
N=	46	10	10	15	11	27	17	21	19	7	6	5	22

This table shows the results from an event study determining whether the announcement of policy changes to the EU ETS that are relevant to the aviation industry have a significant effect on prices within the aviation allowance market. *Day* refers to Cumulative Abnormal Return from 5 days prior to the announcement until the nth day, where *Day 0* is the announcement date. *All* contains the aggregated results from all announcements included in this research. *Single* contains the results from announcements of policy changes without multiple announcements. As explained in section 2.3, this research uses multiple announcements per policy change of the EU ETS when applicable. *First* refers to the first announcement of each policy change if the policy change has more than one announcement in total. *Last* refers to the last announcement for each policy change if the policy change has more than one announcement in total. *Revision* refers to all announcements that are not the first or the last announcement for each policy change. *Phase III* refers to all announcements that occurred in Phase III of the EU ETS (2013-2020). *Phase IV* refers to all announcements that occurred in Phase IV of the EU ETS (2021-*Now*). *Commission* refers to the institution that made the announcement being the European Commission. *Council* refers to the institution that made the announcement being the Council of the European Union. *Parliament* refers to the institution that made the announcement being the European Parliament. *Directorate* refers to the institution that made the announcement being the Directorate-General for Climate Action. *Directive* refers to the type of policy change. *Regulation* refers to the type of policy change. N indicates the number of announcements in each category. The asterisks * , **, and *** refer to a 15%, 10%, and 5% p-value respectively.

Table 2: GARCH results

			Multiple announcements			EU ETS Phase		Institution				Type	
Day	*All*	*Single*	*First*	*Revision*	*Last*	*Phase III*	*Phase IV*	*Commission*	*Council*	*Parliament*	*Directorate*	*Directive*	*Regulation*
-5	0.05	0.10	0.00	0.29	-0.28	-0.16	0.36	0.00	-0.23	0.80	0.18	-0.60	-0.15
-4	0.02	0.07	-0.03	0.39	-0.47	-0.28	0.44	-0.03	-0.34	1.02	0.17	-0.88	-0.23
-3	0.12	0.09	0.00	0.40	-0.10	-0.16	0.49	-0.02	-0.16	1.12	0.26	-1.06	-0.32
-2	0.21	0.05	0.11	0.43	0.16	-0.08	0.55	0.03	-0.04	1.22	0.26	-1.24	-0.36
-1	0.31	0.01	0.21	0.54	0.35	-0.05	0.70	0.07	0.06	1.45*	0.29	-1.31	-0.42
0	0.35	-0.05	0.24	0.63	0.45	-0.06	0.80	0.07	0.11	1.62*	0.29	-1.43	-0.48
1	0.40	-0.09	0.26	0.67	0.59	-0.02	0.86	0.10	0.15	1.73**	0.33	-1.39	-0.51
2	0.42	-0.13	0.21	0.71	0.70	-0.01	0.88	0.07	0.21	1.76**	0.34	-1.32	-0.56
3	0.43	-0.13	0.17	0.75	0.74	0.01	0.88	0.06	0.24	1.75**	0.34	-1.29	-0.60
4	0.42	-0.13	0.10	0.78	0.73	-0.01	0.90	0.02	0.26	1.69**	0.31	-1.32	-0.65
5	0.41	-0.08	0.04	0.78	0.69	-0.03	0.90	0.01	0.25	1.64*	0.29	-1.38	-0.69
N=	46	10	10	15	11	27	17	21	19	7	6	5	22

This table shows the results from a generalized autoregressive conditional heteroskedasticity (GARCH) model determining whether the announcement of policy changes to the EU ETS that are relevant to the aviation industry have a significant effect on volatility within the aviation allowance market. *Day* refers to the average coefficient value for the dummy variable of that day within the event period. *Day 0* is the announcement date. *All* contains the aggregated results from all announcements included in this research. *Single* contains the results from announcements of policy changes without multiple announcements. As explained in section 2.3, this research uses multiple announcements per policy change of the EU ETS when applicable. *First* refers to the first announcement of each policy change if the policy change has more than one announcement in total. *Last* refers to the last announcement for each policy change if the policy change has more than one announcement in total. *Revision* refers to all announcements that are not the first or the last announcement for each policy change. *Phase III* refers to all announcements that occurred in Phase III of the EU ETS (2013-2020). *Phase IV* refers to all announcements that occurred in Phase IV of the EU ETS (2021-*Now*). *Commission* refers to the institution that made the announcement being the European Commission. *Council* refers to the institution that made the announcement being the Council of the European Union. *Parliament* refers to the institution that made the announcement being the European Parliament. *Directorate* refers to the institution that made the announcement being the Directorate-General for Climate Action. *Directive* refers to the type of policy change. *Regulation* refers to the type of policy change. *N* indicates the number of announcements in each category. The asterisks * , **, and *** refer to a 15%, 10%, and 5% p-value respectively.

Table 1 showcases the results from the event study. The event study determines whether announcements regarding changes to the EU ETS, which are relevant to the aviation sector, have a significant effect on the aviation allowance prices. The main finding is that the aviation allowance market does not react to these announcements. This implies that we can not reject the null hypothesis that the market fails to incorporate the new information provided by announcements into the (future) price of allowances.

Within our sub hypotheses, we distinguish between the reaction to the initial proposal, the final proposal, and revision announcements. In the table, this refers to the *First*, *Last*, and *Revision* columns. The finding that the market does not react to announcements is, however, consistent across all these categories. With the exception of CAR -2 for the initial proposal, all coefficients are statistically insignificant.

Table 2 shows the results from the GARCH model. The GARCH model determines whether the aviation allowance market experiences increased levels of volatility in the period surrounding announcements regarding changes to the EU ETS that are relevant to the aviation sector. The results show that the market does not experience increased levels of volatility. This implies that we can not reject the null hypothesis.

Within our sub hypothesis, we distinguish between the reaction to the initial proposal, the final proposal, and revision announcements. As can be seen in the *First*, *Last*, and *Revision* columns, the finding that the market does not experience increased levels of volatility is consistent across all these categories. We do, however, find significance for announcements from the Parliament. The positive coefficients imply that, in the 11-day event period surrounding the announcement day, the market experiences increased levels of volatility in comparison to the estimation period. We will discuss the implications of these results for our hypothesis shortly.

The finding that the market does not showcase a significant reaction in terms of price or volatility within the 11-day event period could be explained by different hypotheses:

(a) the market believes that the information provided by the announcement is not relevant for the sector;

(b) supply and demand are changing at the same speed; or

(c) the information provided by the announcement was already known.

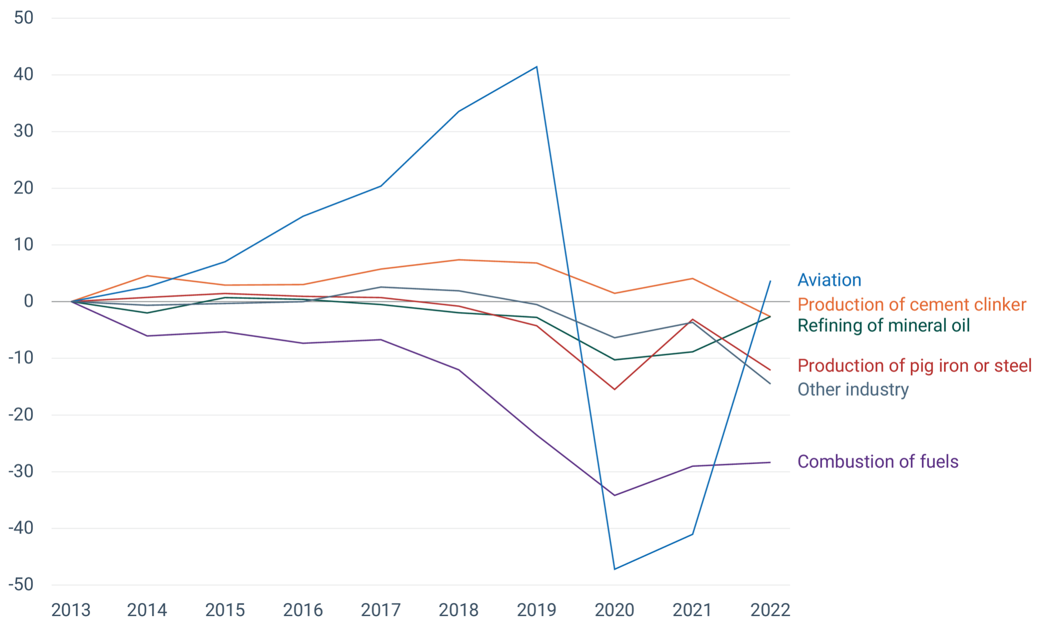
Hypothesis (a) questions the core assumption of this research. As highlighted in section 1, commercial aviation was responsible for 2.7% of the worlds total emissions in 2017. The EU ETS was created with the intention to lower the total level of emissions, which it aims to achieve by putting a price tag on emitting. It is, therefore, assumed that a sector with a large environmental footprint, such as the commercial aviation sector, closely monitors the development of the EU ETS as it threatens the viability of the sector.

To replicate the results presented in Table 1 and 2, hypothesis (a) would require all announcements featured in this research to be deemed as irrelevant to the aviation sector. As highlighted in section 2.3, the announcements of certain policy changes, like Directive 2023/958, signal significant financial ramifications for the aviation sector. It is, therefore, improbable that the market would deem these announcements as irrelevant. Hypothesis (a) can, therefore, not explain the consistency of the results.

Hypothesis (b) suggests that the lack of reaction within the market can be explained by supply and demand decreasing at the same speed. As explained, the EU ETS is a market-based tool to control the level of emissions within the Union. With the goal of reducing the level of emissions with 62% by 2030, the number of allowances available decreases each year. Theory dictates that, as supply decreases, the price – if demand remains constant – increases. If demand, however, decreases proportional to the decrease in supply, there is no effect. This could, therefore, explain the not-significant results.

Demand is, however, not decreasing. Emissions from aviation have, with the exception of 2020 and 2021, increased each year. Figure 6 shows the relative change in level of emissions compared to 2013 for each sector (European Environment Agency, 2023). The results can consequently not be explained by a decrease in demand.

Figure 6: Relative, percentage change in emissions in sectors covered by the EU ETS



An alternative hypothesis might be that the market is oversupplied. The European Union has acknowledged that the effectiveness of the EU ETS was previously hindered by an oversupply of allowances. This led to the introduction of the Market Stability Reserve (MSR) in 2019, which allows for better control of the number of allowances in the market (Directorate-General for Climate Action, n.d.). Furthermore, the evolution of the EUAA price shown in figure 1 shows the effectiveness of the MSR. Oversupply can, therefore, not explain the non-significant results after 2019.

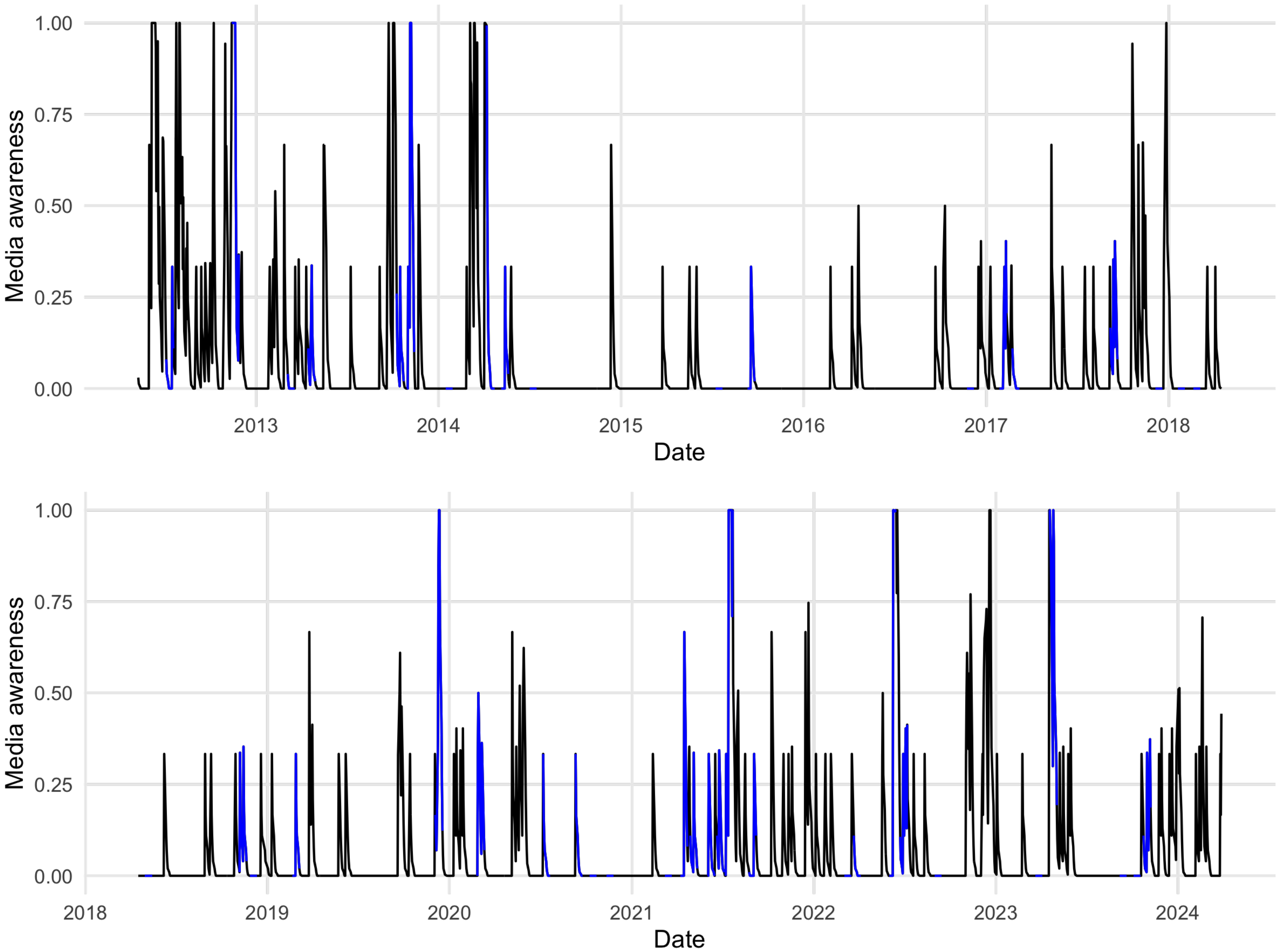
Hypothesis (c) suggests that there is no significant reaction in the 11-day event period because the information provided by the announcement was already known. This implies that the arrival of new information occurs prior to the (public) announcement. This is known as data leakage.

We can use a media awareness proxy, which simulates the expected level of media awareness of the average investor based on the number of recently published articles, to determine the level of media attention the event and estimation period receive. We, therefore, do not directly test when the news from the announcement reaches the market but we can determine whether there is media activity. We expect media awareness to be zero in the estimation period and above zero in the event period. Figure 7 shows the expected level of media awareness for the average investor over time. The line is color coded to be blue when the day is within an event period. It shows that, out of a total of 506 event period days, 241 event days occur when media awareness is above zero – around 48%. We can, therefore, assess that the event period has moderate media exposure.

We must also assess the level of media attention of the estimation period. The estimation period is used to determine whether the returns measured in the event period are significantly different. It is, therefore, important that the estimation period is a proxy of normal market behavior with no bias. We find that around 39% of all estimation period days have a media awareness above zero. This suggests that the estimation period has overlapping events which articles are being published on. The estimation is, therefore, likely biased.

The results from the media awareness proxy suggest that we are not able to control for events occurring within the estimation period. The return measured within the estimation period is, consequently, not a proxy for normal market behavior. This affects the results presented in Table 1 and 2, as both the event study and the GARCH model use the estimation period to determine the abnormality of the result measured in the event period. This is, however, not possible when the estimation period is more akin to an event period due to overlapping events – we are effectively comparing an event period with an

Figure 7: Media awareness over time



event period. Not being able to control for other events within the estimation period could, therefore, explain the the non-significance of the results.

When discussing the results from Table 2, we noted that the *Parliament* had multiple event period days with significant coefficients. We were, however, hesitant to comment on the implications of these results due to the results from the news media proxy. Despite the significance of the results, it is unlikely that the event period and/or the estimation period is not biased. To explain, we refer to diagram 3 in section 3.3.1.

Diagram 3 shows that, in the ordinary legislative procedure of the European Union, the European Parliament has the first vote to accept, revise, or reject the proposal. After the Parliament has adopted its position, the Council of the European Union decides whether to accept or revise the Parliament's position. These two votes typically take place within days of one another. We, therefore, imposed the tier system highlighted in section 3.3.1, which prioritizes the announcement from the Council. This explains the sample difference between the Council (19) and the Parliament (7). In the seven instances where we could include the announcement from the Parliament, there is often just one or two days between the event periods. Diagram 4 shows an accurate representation.

As we have established, the results are likely non-representative due to overlapping events in the estimation period. It could be, however, that rather than *other* overlapping events, the estimation period contains the reaction to the main event: the announcement. This implies that the information from the announcement reaches the market prior to the (public) announcement. Mansanet-Bataller and Pardo (2009) have previously documented data leakage in EUA returns. Consequently, it is possible that the market's reaction is towards the outcome of the Council's vote – not the Parliament's. This would explain why only the later days are significant. We can, therefore, not make any conclusions about the Parliament's results.

This, however, applies to all our results. As we are not able to control for events during the estimation period – as shown by the significant presence of media awareness – the results in Table 1 and 2 are biased. This research is, therefore, not able to answer the hypotheses whether the announcement of changes to the EU ETS relevant to the aviation sector affects the aviation allowance market in a conducive manner.

It is worth discussing the difference in results between this research and previous studies. As mentioned in the Literature Review section, both Deeney et al. (2016) and Mansanet-Bataller and Pardo (2009) use an event study with allowance prices and find that the market shows a statistically significant reaction in at least part of the event period. Deeney et al. (2016) and Conrad et al. (2012), furthermore, use a GARCH model to showcase that the market experiences increased levels of volatility during the event period. This research, in contrast, finds no significant reaction for either. This is, however, not surprising.

While this research is similar in terms of methodology, it has notable differences. First, it covers a different time period. Deeney et al. (2016) covers data spanning from October, 2007 until February, 2014 while Mansanet-Bataller and Pardo (2009) utilizes data from October, 2004 to May, 2007. Conrad et al. (2012) covers data spanning from November, 2006 until July, 2010. This research uses data from April, 2012 until March 2024, meaning that it has more than a 10-year difference in terms of data with the most recent study.

Second, the EU ETS has changed significantly since the most recent study (2014). Figure 1 shows that the price of (aviation) allowances has increased with roughly 400%. Furthermore, certain elements featured in previous studies no longer exist. For instance, Mansanet-Bataller and Pardo (2009) use the announcements of National Allocation Plans as their event day in their event study. National Allocation Plans were, however, replaced with one, Union-wide allocation plan at the start of Phase III (2013).

Third, it covers a different market. Deeney et al. (2016), Mansanet-Bataller and Pardo (2009), and Conrad et al. (2012) use European Union Allowance (EUA) prices, which are the allowance used by all other sectors of the EU ETS. This research, however, focuses on the aviation sector, which is the only sector covered by the EU ETS with its own allowance.

5 Conclusion

To what extent do announcements of policy changes to the European Union's Emissions Trading System influence aviation emission allowance prices? This research aims to answer this question by conducting an event study on the announcement dates of policy changes to the EU ETS that are relevant to the commercial aviation sector. An event study determines whether the market had a significant reaction to an announcement. It does this by comparing the return measured in the event period – the period surrounding the announcement – with the return measured in the estimation period. The estimation period occurs prior to the event period, when there are no events occurring, to ensure that it is a proxy of normal market behavior.

An event study, however, only captures changes in price. We use a generalized autoregressive conditional heteroskedasticity (GARCH) model to determine whether the market experiences increased levels of volatility in the event period. The GARCH model estimates volatility based on the previous period's volatility and residual difference – the difference between te expected and observed return. By including a dummy variable that is equal to one within the event period with a coefficient, it is able to measure the impact that an external factor (the announcement) has on the volatility. It, therefore, determines whether the market is (at least partially) conditionally heteroskedastic.

This work builds upon the research conducted by Deeney et al. (2016), Mansanet-Bataller and Pardo (2009), and Conrad et al. (2012), who investigated to what extent announcements regarding the EU ETS have an effect on the allowance market. This research contributes to the existing literature by specifying the effect to the aviation sector. The aviation sector is the only sector covered by the EU ETS with its own allowance. This means that the reaction measured by an event study or GARCH model directly reflects the sector's reaction towards an announcement.

The two main hypotheses for this research, therefore, are as follows,

H_1: The market incorporates new information provided by announcements regarding policy changes to the EU ETS into the future price of aviation emission allowances.

H_2: The aviation emission allowance future market has abnormal levels of volatility in the event period surrounding an announcement.

This research, furthermore, differentiates itself by using multiple announcement dates for each policy change. Previous studies used the final announcement – whether the policy change is accepted or not – as their event day. The amendment process of European legislation, however, consists of multiple stages in which different institutions can propose revisions. This can take months. These revisions, furthermore, have their own announcement. This means that, between the initial proposal and the final announcement, the policy change can change drastically in scope. This research, therefore, investigates whether the market incorporates the information provided by these earlier, revision announcements. For both main hypotheses, we therefore create sub-hypotheses that distinguish between the effect on the initial proposal, the revision announcements, and the final announcement.

Finally, this research uses a media awareness proxy to assess the robustness of the results. A media awareness proxy simulates the level of media awareness of the average investor based on the number of recently-published, relevant articles. We use this to determine the level of media attention within the estimation and event period. The estimation period should not be exposed to media awareness and the event period should experience a high level of media awareness.

The results of the event study and GARCH model showcase that announcements regarding changes to the EU ETS relevant to the aviation sector has no significant effect on the aviation allowance market. These results are, furthermore, consistent for all sub-hypotheses – there is no significant effect regardless of whether it is the initial proposal, revision announcement, or the final announcement. These results, therefore, indicate that we can not reject the null hypotheses.

However, using the media awareness proxy, we were able to showcase that the estimation period has significant media awareness. This implies that the estimation period has overlapping events (which resulted in articles being published) that could make the estimation period biased. The estimation period is meant to be a proxy of normal market behavior to determine whether the result measured in the period is significantly abnormal. Not being able to control for these events makes it that our results are not representative. This research is, therefore, not able to answer the hypotheses whether the announcement of changes to the EU ETS relevant to the aviation sector affects the aviation allowance market in a conducive manner.

We would, therefore, make one fundamental change to our methodology if we were to re-do this research. We would introduce the constraint that the estimation period can not have a media awareness exposure higher than a certain threshold. Using the media awareness proxy in a proactive manner rather than to assess the robustness of the results would help ensure that the estimation periods are a proxy of normal market behavior.

This research has showcased multiple avenues for further study. First, one of the limitations of this research is the absence of volume data for the EUAA market. It would, therefore, be interesting to determine whether the EUAA market showcases characteristics of a semi-strong or strong efficient market as defined by the efficient market hypothesis (Ţiţan, 2015). Second, the mismatch between the public announcement date of changes the EU ETS and the days on which articles are published could be an indicator of data leakage. Mansanet-Bataller and Pardo (2009), furthermore, also found indicators of data leakage in their return data. It would, therefore, be interesting to see whether these articles contain leaked information and whether the European Union as an institution is susceptible to data leaks.

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A List of policy changes that affect the aviation sector

The full list of 29 policy changes that are relevant to the aviation industry and consequently controlled for within this research. As mentioned in section 3.3.1 under Risk of Overlap, it is important to ensure that there is no overlap between event and estimation periods to get an index of normal market behavior.

Note that this list does not include the individual announcements for each policy change. Appendix B contains the list of announcements that are used in this research for the event study and GARCH calculations.

Table 3: List of policy changes

Policy change	Date	ELI	Reasoning
Commission Delegated Regulation (EU) 2024/873	04.04.24	Link	Announcing transitional Union-wide rules for harmonised free allocation of emission allowances: the benchmarks that will be used, the reduction factor for the number of free allowances each year.
Commission Decision (EU) 2023/2440	31.10.23	Link	The announcement of the total number of allowances available for the aviation industry for 2024. No free allowances. Directive (EU) 2023/958 made it the number of allowances industry-specific.
Commission Implementing Regulation (EU) 2023/2122	18.10.23	Link	Repeals Commission Regulation (EU) No 601/2012. Adding to Commission Implementing Regulation (EU) 2018/2067.
Regulation (EU) 2023/2405	11.10.23	Link	Sets the minimum usage of SAF in 2025 at 2%.
Directive (EU) 2023/958	25.04.23	Link	Extending the derogation that excludes flights that did not have both airports located within the EEA from the EU ETS until 31.12.26. Amended the linear reduction value from 2.2% to 4.3% for 2024 to 2027. End of free allowances.

Table 3: List of policy changes (continued)

Policy change	Date	ELI	Reasoning
Decision (EU) 2023/852	28.03.23	Link	Amending Decision (EU) 2015/1814 to make the changes introduced by Directive (EU) 2018/410 permanent.
Decision (EU) 2022/591	29.03.22	Link	Establishing the focus of the 8th Environment Action Programme, which ultimately sets the Union's environmental agenda in terms of legislation until the next EAP.
Commission Delegated Regulation (EU) 2021/1416	31.08.21	Link	Inclusion of flights originating from EEA to UK to the ETS (flights originating from the UK to EEA remain excluded).
Regulation (EU) 2021/1119	28.06.21	Link	Amends Regulation (EU) 2018/1999. Legally binding objective of reaching climate neutrality in 2050.
Commission Implementing Decision (EU) 2021/927	09.06.21	Link	Announcement of the cross-sectoral correction factor, introduced by Delegated Regulation (EU) 2019/331, for 2021 to 2025. The cross-sectoral correction factor tackles the disparity between the available number of free allowances and the actual number of free allowances given.
Decision No 156/20/COL	15.04.21	Link	EFTA Surveillance Authority Decision adopting Guidelines on certain State aid measures POST 2021 in order to prevent State aid from distorting competition in the internal market and affecting trade between Member States in a way which is contrary to the common interest.
Commission Implementing Regulation (EU) 2021/447	15.03.21	Link	Revised benchmark values for free allocation of emission allowances for the period from 2021 to 2025. Includes the aviation industry.

Table 3: List of policy changes (continued)

Policy change	Date	ELI	Reasoning
Commission Decision (EU) 2020/1722	18.11.20	Link	The announcement of the total number of allowances available for 2021 following Directive (EU) 2018/410 which increased the linear reduction rate from 1.74% to 2.2%.
Decision of the EEA Joint Committee No 112/2020	14.07.20	Link	Announcing a change in benchmark for the calculation of total emissions that arise from aviation, which affects the number of allowances of the aviation industry.
The European Green Deal	11.12.19	Link	The European Green Deal. Amongst others, setting a new target of a 90% reduction in transport emissions (which includes aviation) by 2050.
Commission Delegated Regulation (EU) 2019/331	27.02.19	Link	Announcing transitional Union-wide rules for harmonised free allocation of emission allowances: the benchmarks that will be used, the reduction factor for the number of free allowances each year.
Commission Implementing Regulation (EU) 2018/2067	31.12.18	Link	Setting out rules to check the emission reports submitted under the EU emissions trading system (EU ETS) and the accreditation of those checking operators' reports.
Regulation (EU) 2018/1999	04.12.18	Link	Repeals Regulation (EU) No 525/2013. Sets new standards for the reporting of emissions.

Table 3: List of policy changes (continued)

Policy change	Date	ELI	Reasoning
Directive (EU) 2018/410	27.02.18	Link	Amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments. Doubled the percentage rate for the number of allowances placed in reserve each year. Increased the linear reduction factor from 1.74% to 2.

B List of announcements featured within this research

List of 46 announcements from 23 policy changes (due to multiple announcements per policy change, as explained in section 2.3) that are included in the event study and GARCH calculations. The following list only includes the announcements that fit the criteria set in section 3.3.1 and **Risk of Overlap**.

Table 4: List of announcements

Policy change	Date	ELI	Reasoning
Commission Decision (EU) 2023/2440	31.10.23	Link	The announcement of the total number of allowances available for the aviation industry for 2024. No free allowances. Directive (EU) 2023/958 made it the number of allowances industry-specific.
Regulation (EU) 2023/2405	11.10.23	Link	Sets the minimum usage of SAF in 2025 at 2%.
Regulation (EU) 2023/2405	13.09.23	Link	Sets the minimum usage of SAF in 2025 at 2%.
Directive (EU) 2023/958	25.04.23	Link	Extending the derogation that excludes flights that did not have both airports located within the EEA from the EU ETS until 31.12.26. Amended the linear reduction value from 2.2% to 4.3% for 2024 to 2027. End of free allowances.

Table 4: List of announcements (continued)

Policy change	Date	ELI	Reasoning
Decision (EU) 2023/852	28.03.23	Link	Amending Decision (EU) 2015/1814 to make the changes introduced by Directive (EU) 2018/410 permanent.
Decision (EU) 2023/852	97.09.22	Link	Amending Decision (EU) 2015/1814 to make the changes introduced by Directive (EU) 2018/410 permanent.
Directive (EU) 2023/958	30.06.22	Link	Extending the derogation that excludes flights that did not have both airports located within the EEA from the EU ETS until 31.12.26. Amended the linear reduction value from 2.2% to 4.3% for 2024 to 2027. End of free allowances.
Directive (EU) 2023/958	68.06.22	Link	Extending the derogation that excludes flights that did not have both airports located within the EEA from the EU ETS until 31.12.26. Amended the linear reduction value from 2.2% to 4.3% for 2024 to 2027. End of free allowances.
Decision (EU) 2022/591	29.03.22	Link	Establishing the focus of the 8th Environment Action Programme, which ultimately sets the Union's environmental agenda in terms of legislation until the next EAP.
Decision (EU) 2022/591	10.03.22	Link	Establishing the focus of the 8th Environment Action Programme, which ultimately sets the Union's environmental agenda in terms of legislation until the next EAP.
Commission Delegated Regulation (EU) 2021/1416	31.08.21	Link	Inclusion of flights originating from EEA to UK to the ETS (flights originating from the UK to EEA remain excluded).

Table 4: List of announcements (continued)

Policy change	Date	ELI	Reasoning
Decision (EU) 2023/852	15.07.21	Link	Amending Decision (EU) 2015/1814 to make the changes introduced by Directive (EU) 2018/410 permanent.
Regulation (EU) 2021/1119	28.06.21	Link	Amends Regulation (EU) 2018/1999. Legally binding objective of reaching climate neutrality in 2050.
Commission Implementing Decision (EU) 2021/927	69.06.21	Link	Announcement of the cross-sectoral correction factor, introduced by Delegated Regulation (EU) 2019/331, for 2021 to 2025. The cross-sectoral correction factor tackles the disparity between the available number of free allowances and the actual number of free allowances given.
Regulation (EU) 2021/1119	55.05.21	Link	Amends Regulation (EU) 2018/1999. Legally binding objective of reaching climate neutrality in 2050.
Decision No 156/20/COL	15.04.21	Link	EFTA Surveillance Authority Decision adopting Guidelines on certain State aid measures POST 2021 in order to prevent State aid from distorting competition in the internal market and affecting trade between Member States in a way which is contrary to the common interest
Commission Implementing Regulation (EU) 2021/447	15.03.21	Link	Revised benchmark values for free allocation of emission allowances for the period from 2021 to 2025. Includes the aviation industry.
Commission Decision (EU) 2020/1722	18.11.20	Link	The announcement of the total number of allowances available for 2021 following Directive (EU) 2018/410 which increased the linear reduction rate from 1.74% to 2.2%.

Table 4: List of announcements (continued)

Policy change	Date	ELI	Reasoning
Decision (EU) 2022/591	15.10.20	Link	Establishing the focus of the 8th Environment Action Programme, which ultimately sets the Union's environmental agenda in terms of legislation until the next EAP.
Regulation (EU) 2021/1119	17.09.20	Link	Amends Regulation (EU) 2018/1999. Legally binding objective of reaching climate neutrality in 2050.
Decision of the EEA Joint Committee No 112/2020	14.07.20	Link	Announcing a change in benchmark for the calculation of total emissions that arise from aviation, which affects the number of allowances of the aviation industry.
Regulation (EU) 2021/1119	34.03.20	Link	Amends Regulation (EU) 2018/1999. Legally binding objective of reaching climate neutrality in 2050.
The European Green Deal	11.12.19	Link	The European Green Deal. Amongst others, setting a new target of a 90% reduction in transport emissions (which includes aviation) by 2050.
Commission Delegated Regulation (EU) 2019/331	27.02.19	Link	Announcing transitional Union-wide rules for harmonised free allocation of emission allowances: the benchmarks that will be used, the reduction factor for the number of free allowances each year.
Regulation (EU) 2018/1999	24.12.18	Link	Repeals Regulation (EU) No 525/2013. Sets new standards for the reporting of emissions.
Regulation (EU) 2018/1999	13.11.18	Link	Repeals Regulation (EU) No 525/2013. Sets new standards for the reporting of emissions.
Regulation (EU) 2018/1999	58.05.18	Link	Repeals Regulation (EU) No 525/2013. Sets new standards for the reporting of emissions.

Table 4: List of announcements (continued)

Policy change	Date	ELI	Reasoning
Regulation (EU) 2018/1999	26.02.18	Link	Repeals Regulation (EU) No 525/2013. Sets new standards for the reporting of emissions.
Regulation (EU) 2018/1999	26.01.18	Link	Repeals Regulation (EU) No 525/2013. Sets new standards for the reporting of emissions.
Regulation (EU) 2017/2392	12.12.17	Link	Extending the derogation that excludes flights that did not have both airports located within the EEA from the EU ETS until 31.12.23.
Regulation (EU) 2017/2392	13.09.17	Link	Extending the derogation that excludes flights that did not have both airports located within the EEA from the EU ETS until 31.12.23.
Directive (EU) 2018/410	31.03.17	Link	Amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments. Doubled the percentage rate for the number of allowances placed in reserve each year. Increased the linear reduction factor from 1.74% to 2,2% starting in 2021.
Regulation (EU) 2017/2392	23.02.17	Link	Extending the derogation that excludes flights that did not have both airports located within the EEA from the EU ETS until 31.12.23.
Regulation (EU) 2018/1999	30.11.16	Link	Repeals Regulation (EU) No 525/2013. Sets new standards for the reporting of emissions.
Decision (EU) 2015/1814	18.09.15	Link	Establishment of the market stability reserve in order to tackle structural supply-demand imbalances.

Table 4: List of announcements (continued)

Policy change	Date	ELI	Reasoning
Directive (EU) 2018/410	16.07.15	Link	Amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments. Doubled the percentage rate for the number of allowances placed in reserve each year. Increased the linear reduction factor from 1.74% to 2,2% starting in 2021.
Regulation (EU) No 421/2014	79.07.14	Link	Extending the derogation that excludes flights that did not have both airports located within the EEA from the EU ETS until 31.12.16.
Regulation (EU) No 662/2014	13.05.14	Link	Modifies Regulation (EU) No 525/2013. Regulation that makes allowance from the 2008-2012 period (which includes the aviation industry, which was introduced in 2012) transferable to the EUA system of 2013-2020.
Regulation (EU) No 421/2014	14.04.14	Link	Extending the derogation that excludes flights that did not have both airports located within the EEA from the EU ETS until 31.12.16.
Decision (EU) 2015/1814	22.01.14	Link	Establishment of the market stability reserve in order to tackle structural supply-demand imbalances.
Regulation (EU) No 662/2014	16.11.13	Link	Modifies Regulation (EU) No 525/2013. Regulation that makes allowance from the 2008-2012 period (which includes the aviation industry, which was introduced in 2012) transferable to the EUA system of 2013-2020.

Table 4: List of announcements (continued)

Policy change	Date	ELI	Reasoning
Regulation (EU) No 421/2014	16.10.13	Link	Extending the derogation that excludes flights that did not have both airports located within the EEA from the EU ETS until 31.12.16.
Decision No 377/2013/EU	22.04.13	Link	Initial derogation that excluded flights that did not have both airports located within the EEA. Only counts for 2012.
Regulation (EU) No 525/2013	12.03.13	Link	Targets the non-CO2 emissions from aviation.
Decision No 377/2013/EU	20.11.12	Link	Initial derogation that excluded flights that did not have both airports located within the EEA. Only counts for 2012.
Commission Regulation (EU) No 601/2012	12.07.12	Link	Establishing the system for monitoring and reporting of greenhouse gas emissions.

C Criteria for the inclusion of announcements for each policy change

European Commission	Council of the European Union	European Parliament
All	All announcements where the subject title contains 'OUTCOME OF PROCEEDINGS' or where the subject contains 'Voting result'	All except 'Signature' announcements as these are a formality (that occur after the act has been adopted)

D Filters for relevant articles

The following shows the Python code used to filter the initial sample of articles to just those that are relevant to the EU ETS and the aviation sector by requiring a confidence interval of 80% or higher for both categories.

```
import os
import glob
import pypandoc
import re
import csv

class Article:
    def __init__(self, file_name, text):
        self.file_name = file_name
        self.text = text
        self.date = self.extract_date()
        self.classifications = self.extract_classifications()

    def extract_date(self):
        match = re.search(r'^(.*?)(?=Body)', self.text, re.DOTALL)
        if match:
            matched_text = match.group(1)

            date_match =
                re.search(r'(January|February|March|April|May|June|July|August|September|Octo
                matched_text)
            if date_match:
                publication_date = date_match.group(0)
                return publication_date
        return "Unknown"

    def extract_classifications(self):
        match = re.search(r'Classification(.*?)End of Document', self.text,
            re.DOTALL)
        if match:
            subject_match = re.search(r'Subject:(.*?):', match.group(1),
                re.DOTALL)
            if subject_match:
                subject = subject_match.group(1).replace("\n", " ").strip()
                classifications = subject.split(";")[:-1]
                formatted_classifications = [
```

```
                tuple(part.strip().replace("%)", "") for part in
                    classification.split("("))
                for classification in classifications
            ]
            return formatted_classifications
    return []

def rtf_files(directory):
    rtf_files = glob.glob(os.path.join(directory, '*.rtf'))
    articles = []

    for rtf_file in rtf_files:
        try:
            file_name = os.path.basename(rtf_file)
            text = pypandoc.convert_file(rtf_file, 'plain', format='rtf')
            articles.append(Article(file_name, text))
        except Exception as e:
            print(f"Failed to process {rtf_file}: {e}")
    return articles

def filter_articles(articles):
    required_categories = ["EMISSIONS CREDITS", "EUROPEAN UNION", "AEROSPACE &
        ENVIRONMENT"]
    filtered_articles = []

    for article in articles:
        classification_dict = {category: None for category in
            required_categories}

        for classification in article.classifications:
            if len(classification) >= 2:
                category, value = classification[0], classification[1]
                if category in classification_dict:
                    classification_dict[category] = int(value)

        if all(value is not None and value >= 80 for value in
            classification_dict.values()):
            filtered_classifications = [
                (category, str(value))
                for category, value in classification_dict.items()
            ]
```

```
            article.classifications = filtered_classifications
            filtered_articles.append(article)

    return filtered_articles

def save_csv(articles, output_name):
    with open(output_name, mode='w', newline='') as csv_file:
        csv_writer = csv.writer(csv_file)

        csv_writer.writerow(['Article name', 'Date'])
        for article in articles:
            csv_writer.writerow([article.file_name, article.date])

directory = ## Path to files
articles = rtf_files(directory)

filtered_articles = filter_articles(articles)

csv_name = "EU ETS Aviation relevant articles.csv"
save_csv(filtered_articles, csv_name)
```