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Abstract

We propose a novel measure of intraday investor attention by using messages sent on Twitter around European Central Bank announcements. We then analyze the market impact of the press conferences conditional on the level of investor attention prior to the announcements. We find that absolute price changes are higher when investor attention is high before the announcements. Twitter allows us to build more reliable measures of attention than the number of articles in the media, the volume of search queries on Google, or the number of messages sent on StockTwits. Our results are robust to the inclusion of the VIX, lagged returns, and the economic policy uncertainty index. It suggests that central bankers can use the level of attention prior to the announcements to improve their anticipation of the magnitude of the market's reaction to the announcement.

Keywords: investor attention, central bank, asset pricing, Twitter, social media.

JEL classification: G12, G14.

1. Introduction

Investor attention plays a role in the price formation process. Higher investor attention predicts positive future stock returns (Da et al., 2011), lower post-earning price drift (Ben-Rephael et al., 2017), higher sensitivity of US Treasury yields to macroeconomic announcements (Benamar et al., 2020) and higher green bonds volatility and performance (Pham and Huynh, 2020). However, the exact role of investor attention in the market equilibrium remains unclear. Investor attention can theoretically increase market efficiency if investor attention is associated with a higher demand for information and more informed traders, as in the model of Grossman and Stiglitz (1980). But investor attention can also decrease market efficiency if more attention creates extra noise and leads to market over or under-reaction (Da et al., 2011). As stated by Vozlyublennaia (2014), the problem lies, in part, in a substantial difficulty in finding the right measure of attention. In this paper, we contribute to the empirical literature on investor attention by proposing novel measures of investor attention around European Central Bank (ECB) announcements and by analyzing the relationship between investor attention and asset prices at the intraday level.

Central bank communication has emerged as an increasingly important aspect of monetary policy (see Blinder et al. (2008) for a survey of the literature). Central bank decisions and central bank communication both impact inflation expectations, future interest rates, and asset prices (Rosa and Verga, 2008; Siklos and Bohl, 2007; Gertler and Horvath, 2018; Hayo and Neuenkirch, 2010). The magnitude of the market impact depends on the surprise of the policy decision (Bohl et al., 2008) and on the tonality of words used by central bankers during press conferences (Picault and Renault, 2017). But, to the best of our knowledge, the impact of the level of attention prior to central bank announcements on the magnitude of the market reaction has never been tested.[1]

[1] In a recent working paper, Masciandaro et al. (2021) computed the similarity between tweets and central bank announcements as a proxy for monetary policy surprise before analyzing bond and stock market reactions, conditional on the level of similarity. The authors of this paper, however, do not consider the impact of investor attention in their study.

Testing this hypothesis requires : (1) a good proxy of investor attention, (2) a precise identification of the release of the decision and the timing of the press conference, and (3) a high-frequency database of price/yield changes around the announcement for a wide range of assets. First, and regarding the measurement of investor attention, a wide range of proxies has been proposed in the literature: search volume on Google (Da et al., 2011; Ding and Hou, 2015; Drake et al., 2017; Boguth et al., 2019; Choi, 2021), number of pages viewed on Wikipedia (Behrendt and Prange, 2021), Bloomberg reading activity (Ben-Rephael et al., 2017), number of clicks on news articles (Benamar et al., 2020), or the number of media articles (Peress and Fang, 2008; Drake et al., 2017).[2] In this paper, we focus on the volume of tweets related to the ECB to construct intraday investor attention, and we compare our investor attention measure with proxies constructed using Google Trends, news articles from Factiva and Bloomberg, and social media activity on StockTwits. Second, due to its unique institutional settings, the ECB is one of the only central banks that first releases its monetary policy decision (at 1:45 pm) and then, about 45 minutes later, explains its decision and answers questions during a press conference. This setting allows us to measure attention before the first announcement, but also between the announcement and the press conference to capture the attention directly related to the decision. Last, we take advantage of the EA-MPD database released by Altavilla et al. (2019) to analyze the impact of ECB announcements on a wide range of assets and to decompose the market reaction into three periods: the policy decision window (from 1:35 pm to 2 pm), the press conference window (from 2:25 pm to 3:40 pm) and the monetary event window (from 1:35 pm to 3:40 pm).

Our paper's contributions are threefold. First, we find that the level of attention prior to announcements has an impact on the magnitude of the market reaction. A higher level of attention is associated with a higher absolute market reaction on ECB announcement days. This finding is consistent with previous results in the literature (Benamar et al., 2020) and suggests that central bankers could use the level of attention prior to the announcements

[2] Other indirect proxies include the day of the week (DellaVigna and Pollet, 2009) or the co-occurrence of other events such as the World Cup or other news on the same day (Ehrmann and Jansen, 2017).

to better anticipate the magnitude of the market reaction to the announcement. Second, we find that Twitter is the most robust proxy of investor attention and provides additional information compared to indicators derived from Google Trends or the media. We thus contribute to the emerging literature on the use of social media by central banks and on its ability to communicate effectively with the public (Ehrmann and Wabitsch, 2022; Masciandaro et al., 2022) by showing that Twitter is not just noisy but reflects the perceptions of the general public and investors about the central bank's actions.[3] Last, while investor attention has predictive power for the magnitude of the price (yield) changes, we do not find any forecasting power on (non-absolute) market returns, even when we combine our investor attention proxy with a measure of investor sentiment before the news. This finding is consistent with the efficient market hypothesis in the sense of Jensen (1978): market participants cannot generate economic profits by trading on the sentiment or the level of attention prior to ECB announcements.

Our paper is organized as follows. Section 2 details the data and describes how we created our investor attention proxy from Twitter. Section 3 reports our methodology and empirical findings. Section 4 presents robustness checks. Finally, Section 5 concludes the paper.

2. Data

Investor attention is not directly observable. Thus, we construct various proxies from online data to estimate the level of attention prior to each ECB announcement[4]. Our main proxy is based on the use of Twitter as it allows us to construct intraday investor attention. We also use as a benchmark the relative number of search queries on Google, the number of press articles about the ECB from Factiva and Bloomberg, and the number of messages on

[3] Recently, Angelico et al. (2022) showed that tweets can be used to build real-time measures of inflation expectations in Italy. While not directly related to our research question, their findings confirm the added value of Twitter data for economic forecasting.

[4] We opt for these proxies because it is impossible to measure the attention of market participants/professional forecasters directly. The new survey launched in 2019 by the ECB, the ECB Survey of Monetary Analysts, does not contain any question directly related to the attention of market participants.

the social media plateform StockTwits about the ECB.

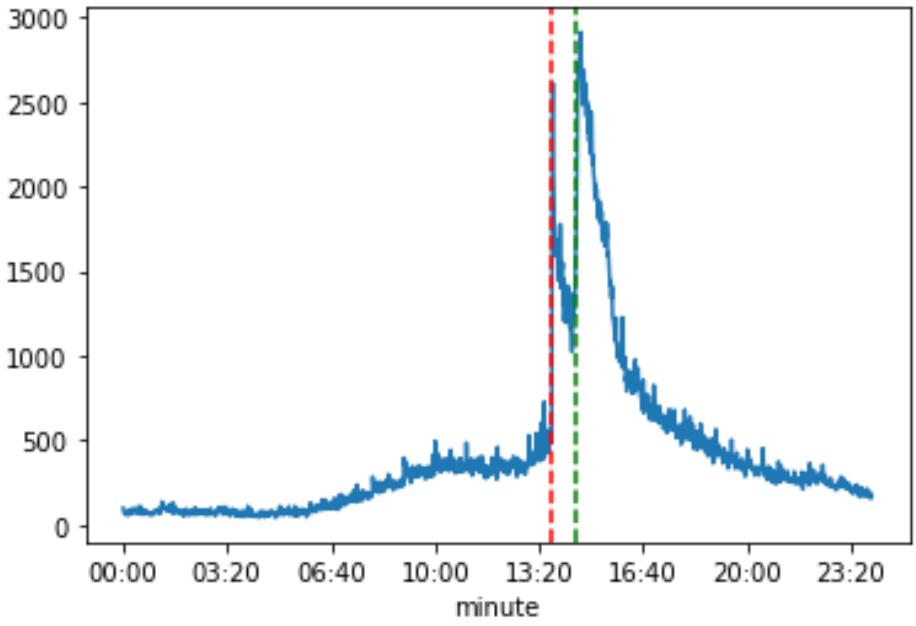
2.1. Twitter attention

We took advantage of the recent opening of the Twitter API to academic researchers in 2020 to collect all tweets sent on Twitter over a 10-year period related to the European Central Bank.[5] We use the keywords "European Central Bank", "ECB," "Draghi," and "Lagarde" to construct our sample. We also use the translation of those keywords in French, German, Spanish, and Italian to capture domestic investor attention. As in Ehrmann and Wabitsch (2022), we remove irrelevant tweets such as tweets related to the England Cricket Board whose acronym is the same as the European Central Bank. We ended up with a database of 6,164,007 tweets sent between June 1, 2011 and January 1, 2021. The day with the maximum number of tweets is January 22, 2015 (with a total of 54,671 tweets) during which the ECB announced its expanded asset purchase program (quantitative easing). On average, the number of tweets during a press conference day is 10 times higher than the number of tweets on no-announcement days. Figure 1 illustrates the relationship between ECB announcements and Twitter activity at the intraday level by showing the evolution of the number of tweets per minute around all press conferences in our sample. While we can see a surge in the volume of tweets at the exact time of the monetary policy decision (13:45) and during the press conference (14:30), we can also observe a significant activity prior to the announcements and between the monetary policy decision and the beginning of the press conference.

The availability of data with precise timestamps allows the construction of intraday attention indicators, which *a priori* gives Twitter data an advantage over media or Google data as other attention indicators are only available daily. This allows us to use the information published in the morning, before the release of the monetary policy decision (i.e. in our model between 0:00 and 13:25 on day t). We use 13:25 instead of 13:45 to match our

[5] In February 2022, following Elon Musk's takeover of Twitter, restrictions on access to Twitter's APIs for academic research were announced. We collected the data set before this announcement.

Fig. 1. Number of tweets per minute around ECB announcements



Notes: This figure presents the number of tweets around the 91 ECB announcements in our sample period. The index value is set to 100 at midnight. The red dashed line represents the release of the monetary policy decision (13:45). The green dashed line represents the beginning of the press conference (14:30).

indicator with the beginning of the "policy decision window" on the database of Altavilla et al. (2019). We also consider using the information up to 14:15 when analyzing the impact of investor attention on the "press conference window" - using the same timestamp as in Altavilla et al. (2019).

2.2. Other measures of attention

We construct four other indicators of investor attention from (1) Google queries, (2) the number of articles on Factiva, (3) the number of news items on Bloomberg, and (4) the volume of messages on StockTwits.

First, we used Google Trends to extract the evolution of the volume of requests on the subject "European Central Bank" in all countries.[6] We perform an extraction for each press conference to obtain the volume of requests on the day of the press conference and the 60 days preceding the conference. This methodology allows us to obtain daily data via Google Trends and ensures that our indicator is not biased by the search volume after the conference. Second, we use Factiva to extract the volume of articles in English on the topic "European Central Bank."[7] We identify a total of 523,391 articles over our study period. The day with the highest number of articles is 22 January 2015: the same day as the day with the highest number of tweets (ECB quantitative easing announcement). Third, we gather the number of articles and news items related to the ECB published by Bloomberg by utilizing the Bloomberg story count function. Since Bloomberg data are only available for the last ten years, our sample starts from 2012. We use this measure as a way to identify professional/institutional investor attention, as Bloomberg is not included in the Factiva database. A total of 363,544 Bloomberg news items about the ECB were identified over the last 10 years. Finally, we use StockTwits data to measure the attention of investors (mainly individual investors) on a social network dedicated to finance. StockTwits is predominantly

[6] See an example of the keywords associated with this subject at this link: https://trends.google.com/trends/explore?date=allq=%2Fm%2F02l6

[7] We use the query "fds=eurcb and la=en" on Factiva to extract the relevant articles

used by individuals located in the United States (Renault, 2017), but we still identify a total of 63,976 posts containing the keywords "ECB" or "European Central Bank" over our period.

2.3. Abnormal investor attention

To construct our proxies of investor attention, we remove the time trends and other low-frequency seasonalities as in Da et al. (2011) using the difference between the logarithm of the number of tweets/articles or search queries in a period t and the logarithm of the median number of tweets on the previous n days. Following Da et al. (2011), we define n = 56. Therefore, we define Abnormal Twitter Attention (ATA), Abnormal Media Attention (AMA), Abnormal Google Attention (AGA), Abnormal StockTwits Attention (ASA), and Abnormal Bloomberg Attention (ABA) as follows:

$$\begin{aligned}
ATA_t &= log(1 + TweetNbr_t) - log(1 + MED[TweetNbr_{t-1,t-n}]) \\
AMA_t &= log(1 + MediaArt_t) - log(1 + MED[MediaArt_{t-1,t-n}]) \\
AGA_t &= log(1 + GoogleTrend_t) - log(1 + MED[GoogleTrend_{t-1,t-n}]) \\
ASA_t &= log(1 + StockTwitsMsg_t) - log(1 + MED[StockTwitsMsg_{t-1,t-n}]) \\
ABA_t &= log(1 + BloombergArt_t) - log(1 + MED[BloombergArt_{t-1,t-n}])
\end{aligned} \tag{1}$$

To facilitate the comparison between the indexes in this subsection, we define $TweetNbr$ as the number of tweets published between 0:00 and 23:59 on each day t (but we will use the information published before the announcement on the event day in the next section). $MediaArt$ is the volume of articles published on day t. $GoogleTrend$ is the Google research queries index on the European Central Bank on day t. $StockTwitsMsg$ is the number of messages on StockTwits on day t. $BloombergArt$ is the number of articles from Bloomberg

on day t. All indicators are publicly available on our website.[8]

Figure 2 compares our five indexes of market attention. All indexes are presented in t-1 to show the level of investor attention before each ECB press conference. Table 4 in the Appendix presents the correlation between the five indexes. The correlations between ATA and the four other indexes of investor attention range from 0.54 (with ABA) to 0.75 (with ASA). This relatively high correlation between the different indicators shows that we capture a common effect as expected but that the information extracted is not the same via the different sources. This can be explained by the fact that our indicators are derived from queries or textual content generated by different types of users on different platforms: a mix between experts, journalists, and individual investors on Twitter, ordinary people on Google, individual investors on StockTwits, generic journalists on Factiva and specialized journalists on Bloomberg. Given this correlation, and to avoid problems of multicollinearity, we will analyze each indicator individually in the following section.

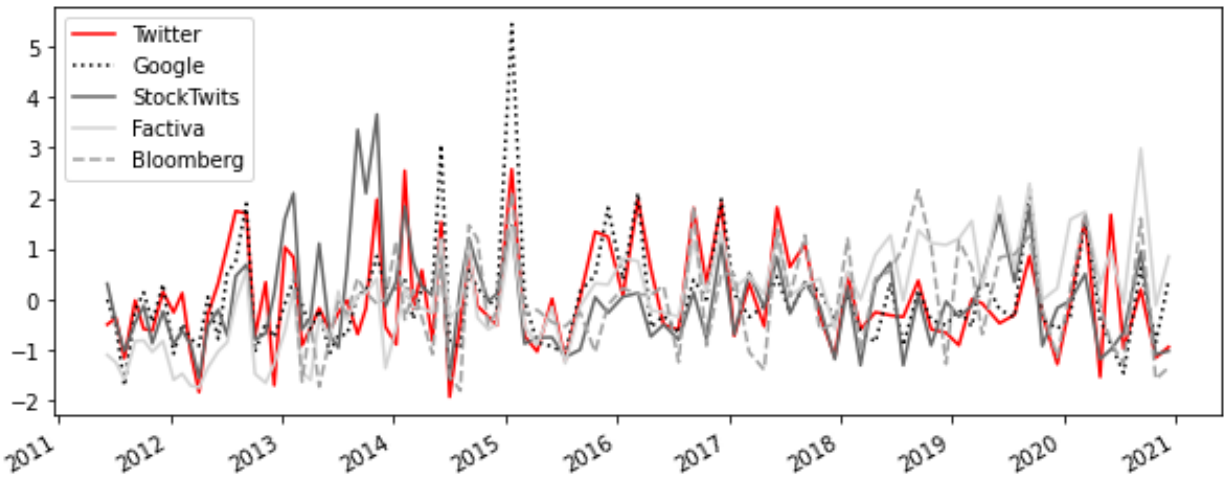
2.4. Market Data and Control Variables

We use the Euro Area Monetary Policy Event-Study Database (EA-MPD) from Altavilla et al. (2019) to obtain intraday sovereign bonds yield changes (for Germany, France, Spain, and Italy), intraday stock returns (Eurostoxx 50 and the Eurostoxx Banks labeled STOXX50 and STOXXBANKS), intraday overnight indexed swaps (OIS) change with maturity from one week to 10 years and, intraday variation of the euro (EURUSD, EURGBP, EURJPY) around ECB Governing Council announcements.[9] The authors measure asset price changes for (1) the press release window: the change in the median quote from the window 13:25-13:35 before the press release to the median quote in the window 14:00-14:10 after it, labeled *prw* (2) the press conference window: change in the median quote from the window 14:15-14:25 before the press conference to the median quote in the window 15:40-15:50 after it, labeled

[8] Data will be available after publication.

[9] We consider a total of 44 assets out of 48 from the database of Altavilla et al. (2019) after removing assets with missing observations in our sample period.

Fig. 2. ATA with alternative measures of investor attention



Notes: This Figure presents the five measures of attention regarding the ECB: the ATA using Twitter, the AMA using media coverage, the AGA using Google queries, the ABA using Bloomberg, and the ASA using StockTwits. The graph has 91 observations corresponding to the ECB press conference days.

pcw - and (3) the monetary event window: change in the median quote from the window 13:25-13:35 before the press release to the median quote in the window 15:40-15:50 after the end of the press conference, labeled *mew*. We focus our attention on the period ranging from June 1, 2011 to January 1, 2021. This period contains 91 ECB announcements.

To verify that the identified effect is related to investor attention and not to global market stress or to the level of economic uncertainty prior to the announcements, we add to all our specifications the Vstoxx (equivalent to the VIX for Europe) and the Economic Policy Uncertainty (EPU) indicator of Baker and Wurgler (2007). We also use the changes in the various assets the day before the announcement to verify that the level of attention in t-1 is not simply related to (absolute) changes in asset prices. We also add a dummy variable equal to 1 for all days with an important unconventional monetary policy announcement (see Table 5 in Appendix for a list of those events).

3. Methodology and Results

3.1. Impact on absolute returns/absolute yield changes

We use the following model to evaluate the effect of attention on future absolute returns:

$$Absolute(R_{i,w,t}) = \alpha + \beta_1 * Attention_{t-1} + \beta_2 * X_{t-1} + \epsilon_t \quad (2)$$

where $Absolute(R_{i,w,t})$ is the absolute return/yield change for an asset i during the event window w (press release window, press conference window, monetary event window) of a press conference on day t. $Attention_{t-1}$ is one of our five attention variables: ATA, AGA, ASA, AMA, and ABA. ATA_{t-1} is our measure of investor attention on Twitter prior to the press conference. AMA_{t-1} represents abnormal media attention. AGA_{t-1} represents the abnormal volume of Google searches. ABA_{t-1} is our measure of investor attention using Bloomberg articles, and ASA_{t-1} is from using StockTwits. X_{t-1} is a vector of control variables including the first lag of the dependent variable, labeled AR(1), the previous day market volatility proxied with the Eurostoxx 50 volatility, labeled $VStoxx_{t-1}$, the EPU for Europe EPU_{europe} from Baker et al. (2016), and a dummy variable $NCMP_t$ equal to 1 if an unconventional monetary policy was announced on day t. All independent variables are standardized except the lag of the dependent variable. The descriptive statistics of the independent variables are presented in Table 3 in the Appendix. The descriptive statistics of the 41 financial assets (dependent variables) are available in the online appendix.[10]

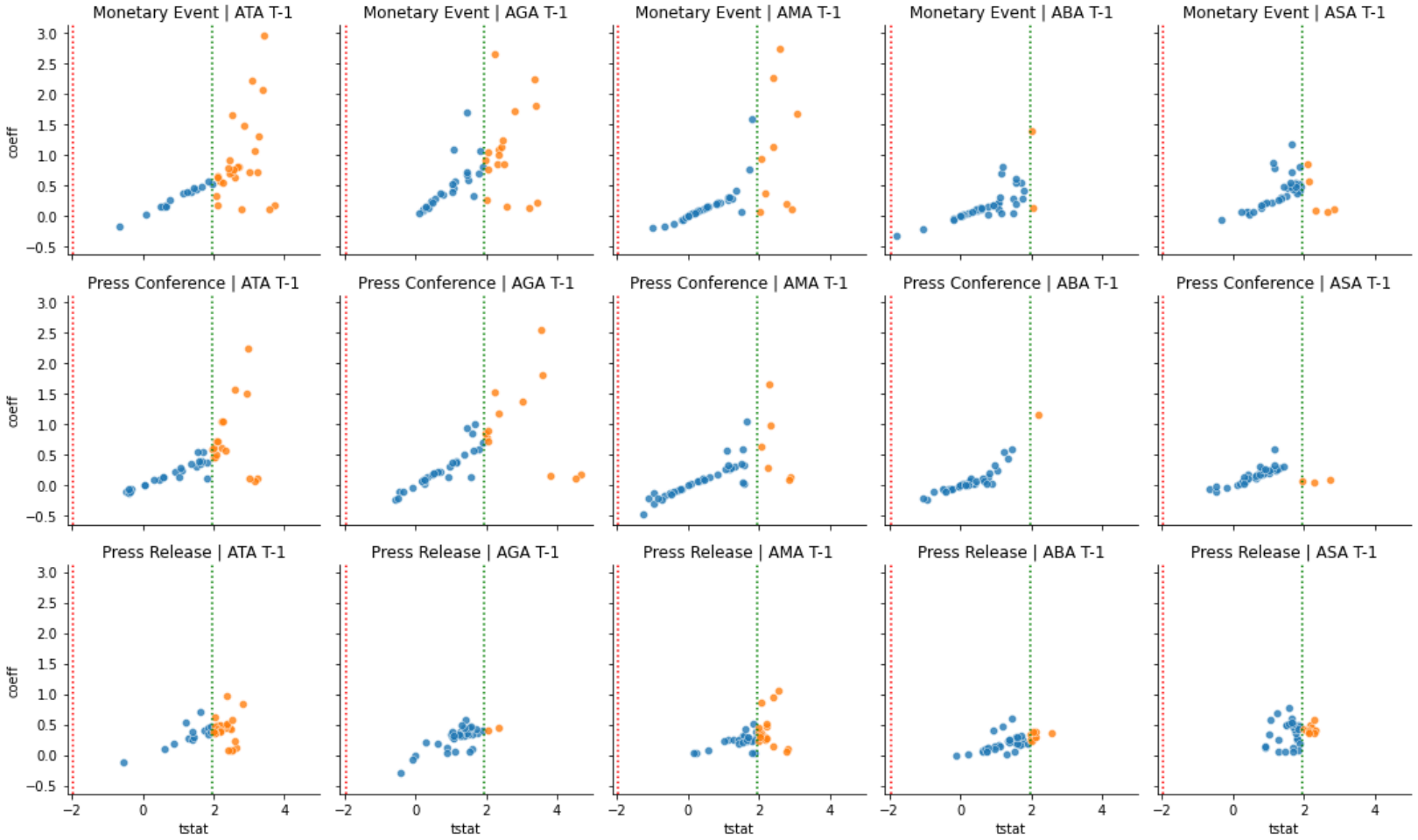
As we consider the effect on 41 assets of five attention indicators on three different windows, we run a total of 615 regressions with robust standard errors. In order to facilitate the presentation of the results of all these regressions, we graph the values of the β_1 coefficient and its t-stat in Figure 3, and we plot the distribution of the adjusted R-squared in Figure 4. Table 1 shows the percentage of regression on which each attention variable is significant at the 10%, 5%, and 1% levels for each event window. The complete results of these regressions

[10] For anonymity, the appendix is provided on a GitHub page: https://enarwen.github.io/

are available in the online Appendix.[11] We pay particular attention to three points: (1) the comparison between the attention indicators, (2) the comparison between the different windows, and (3) the comparison between the different assets.

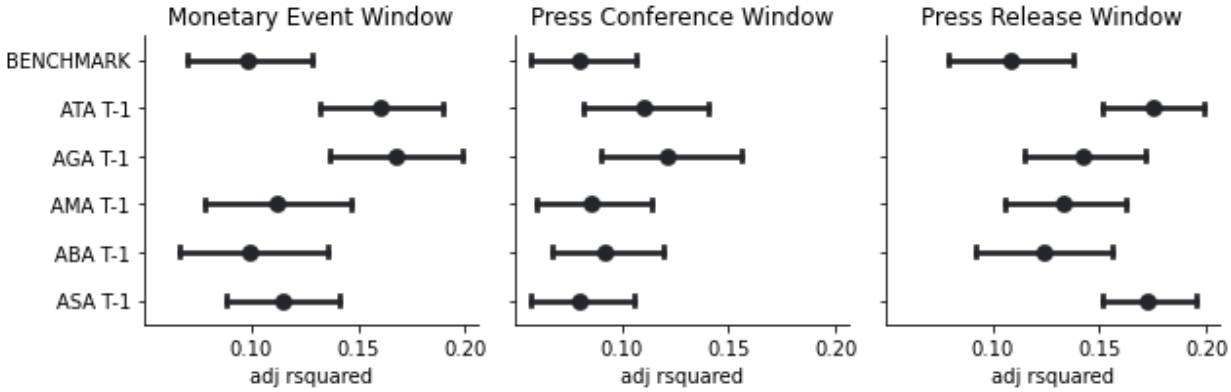
[11] https://enarwen.github.io/

Fig. 3. β_1 value and t-stats by investor attention measure and event window



Notes: This Figure presents the value of the coefficient β_1 from Equation 2 and its associated t-stats on a total of 615 regressions (41 estimates per panel) with robust standard errors. Each column provides the coefficient of a different attention measure on the day before the ECB press conference with ATA_{t-1}: Twitter, AGA_{t-1}: Google, AMA_{t-1}: Media, ABA_{t-1}: Bloomberg or ASA_{t-1}: Stocktwits (detailed in Equation 1). The dependent variables are the absolute returns/yield change of 41 assets during the monetary event window (mew, first line), the press conference window (pcw, second line) and the press release window (prw, third line). The red and green dashed lines represent, respectively, a t-stat of -1.96 and +1.96. All points in orange correspond to regressions in which the attention variable coefficient (β_1) is significant at a 5% confidence interval.

Fig. 4. Adjusted R-squared by investor attention measure and event window



Notes : This Figure represents the mean of the adjusted R-squared obtained from the linear estimation of Equation 2 with robust standard errors for each attention variable (ATA_{t-1} : Twitter, AGA_{t-1} : Google, AMA_{t-1}: Media, ABA_{t-1}: Bloomberg or ASA_{t-1} : Stocktwits; details in Equation 1). The dependent variables are the absolute returns/yield change of 41 assets during the monetary event window (mew, left), the press conference window (pcw, center) and the press release window (prw, right). The 95% confidence interval is constructed using bootstrapping methods with 10,000 [a] samples.

[a] For anonymity, the appendix is provided on a GitHub page: https://enarwen.github.io/.

Table 1: Percentage of regressions with a significant investor attention variable

Attention	Window	Nbr. of regressions	10% Significance	5% Significance	1% Significance
ABA_{t-1}	mew	41	14.63	4.88	0.00
	pcw	41	2.44	2.44	0.00
	prw	41	31.71	19.51	2.44
AGA_{t-1}	mew	41	48.78	41.46	14.63
	pcw	41	36.59	29.27	14.63
	prw	41	12.20	4.88	0.00
AMA_{t-1}	mew	41	26.83	21.95	9.76
	pcw	41	17.07	14.63	4.88
	prw	41	68.29	41.46	4.88
ASA_{t-1}	mew	41	43.90	12.20	4.88
	pcw	41	7.32	7.32	2.44
	prw	41	68.29	24.39	0.00
ATA_{t-1}	mew	41	70.73	63.41	34.15
	pcw	41	51.22	41.46	14.63
	prw	41	78.05	63.41	7.32

Notes: This table shows the percentage of linear regressions from Equation 2 with robust standard errors on which each attention variable (ATA_{t-1}: Twitter, AGA_{t-1}: Google, AMA_{t-1}: Media, ABA_{t-1}: Bloomberg or ASA_{t-1}: Stocktwits; details in Equation 1) coefficient β_1 is significant at the 10%, 5%, and 1% level. We consider the monetary event window (mew), the press conference window (pcw), and the press release window (prw) separately. The last line shows that the coefficient of the Twitter attention measure (ATA_{t-1}) is statistically significant at 10% (or less) in 78% of the 41 regressions focusing on absolute returns/yield changes during the press conference window (prw).

First, our results show that in a large number of regressions investor attention the day

before an ECB press conference predicts the magnitude of the market reaction on the day of the announcement. This is mainly true when using Google search volume and Twitter post volume as a proxy for attention, and to a lesser extent, using the number of articles published in the media. The volume of news on Bloomberg or the volume of messages on StockTwits do not seem to be good proxies for investor attention around the ECB announcements. The variable ATA_{t-1} is significant at the 5% level and for the monetary event window in more than two-thirds of the regressions, while the variable AGA_{t-1} is significant in less than half of the regressions. Although the effect varies according to the assets and the study window, which we will show later, our results show that one standard deviation of ATA_{t-1} is associated with an increase in absolute yield change of around 2 basis points. This result is consistent, albeit smaller, with Benamar et al. (2020) who found that a one-standard-deviation increase in the number of clicks on articles related to non-farm payroll in the two hours preceding non-farm payroll announcement in the US raises the sensitivity of US Treasury note yields by 4 to 6 basis points. The adjusted R-squared analysis also clearly shows that the incorporation of an attention variable (in addition to an autoregressive process, the Vstoxx, the EPU, and a dummy variable taking into account non-conventional monetary policies) greatly improves the accuracy of the model. If we consider the monetary event window, the average adjusted R-squared, on the 41 assets, of models without ATA is equal to 9.5%, while it jumps to 16% when we add ATA to the model. The results in the online Appendix show, as expected, that the variable $Vstoxx$ is highly significant in most specifications: a higher level of volatility before the announcements is associated with higher absolute market variations.

Second, we find that the contribution of the attention variables is stronger for the press release window than for the press conference window, whether we look at the size of the coefficients, the percentage of regressions where the attention variables are significant, or the difference between the adjusted R-squared of our baseline model with the control variables compared to a model with an additional attention variable. For example, the variable ATA_{t-1}

is significant at the 5% level for 32 assets out of 41 (78.05%) in the press release window and for 17 assets out of 41 (41.46%) in the press conference window. The improvement of the adjusted R-squared is also much higher in the press release window (from 6.7% to 15.4% for ATA) than in the press conference window (from 7.3% to 10.7% for ATA). The lower bound of the 95% confidence interval of the models using the ATA variable is strictly greater than the upper bound of the 95% confidence interval without the attention variable for the press release window and for the monetary event window, but not for the press conference window. This result, therefore, suggests that investor attention plays an important role mainly at the time of the press release, a window during which the ECB simply communicates its decision without any explanation or rationale. During the press conference, investor attention prior to the announcement plays a less important role, which is consistent with the fact that a lot of new information and explanations are given by the ECB during this window.

Third, concerning the effect on assets, Figure 5 provides a decomposition of the effect according to the type of assets. We focus on the variables ATA_{t-1} and AGA_{t-1} because these two proxies for investors' attention are the ones that bring the best results on average. We group the 41 assets in our database into 6 main categories: stock market (Eurostoxx and Eurostoxx banks), foreign exchange (EURUSD, EURJPY, EURGBP), short-term OIS (maturity less than 5 years), long-term OIS (maturity greater or equal than 5 years), short-term sovereign bonds (maturity less than 5 years), and long-term sovereign bonds (maturity greater or equal than 5 years). We find that attention plays a significant role mainly in the absolute changes in long-term OIS, long-term sovereign bonds, and the foreign exchange market. Focusing on the monetary event window (mew) and Twitter attention, its coefficients are significant at 5% for four of the six long-term OIS, three of the nine short-term sovereign bonds, and 14 of the 15 long-term sovereign bonds, for all stock market indexes and all exchange rates.[12] The lower coefficient for the changes in the foreign exchange market

[12] The results can be observed on the three tables included in the section "Results of the estimation of Equation 2 with OLS regressions, used to create Figures 3, 4 and 5 (p. 13, 14 and 17) and Table 1 (p. 14)" of the online appendix.

is explained by the fact that the changes are in percentages, while the changes in sovereign bonds and OIS are in basis points. The largest coefficients (between 2 and 3 basis points) are for Italian and Spanish long-term sovereign bonds. This result can be explained by the uncertainty of these two countries during our study period, which includes the eurozone crisis of 2011-2013.

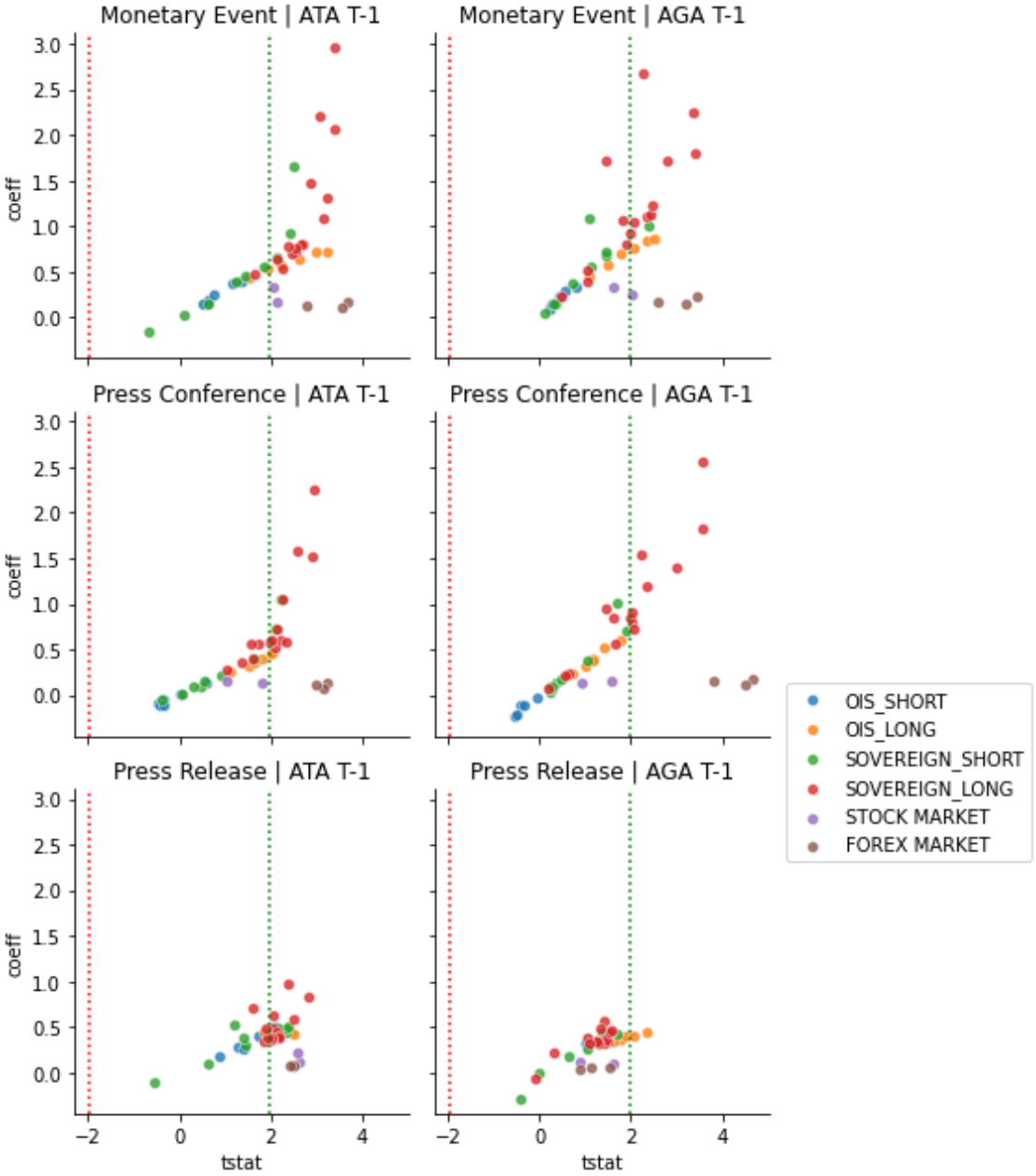
3.2. Impact on returns/yield changes

We move our attention to return and yield change - instead of absolute return and absolute yield change. We use the following model where $R_{i,w,t}$ is the return/yield change for an asset i during the event window w (press release window, press conference window, monetary event window) of a press conference on day t:

$$R_{i,w,t} = \alpha + \beta_1 * Attention_{t-1} + \beta_2 * X_{t-1} + \epsilon_t \tag{3}$$

Figure 6 summarizes our results. All tables are available on the online Appendix (615 regressions). We do not find that any of the investor attention variables have a predictive power on stock returns/yield changes. This result is consistent with the efficient market hypothesis (Fama, 1970, 1991): price changes on announcement days are unpredictable with information available prior to the announcement. Unlike Benamar et al. (2020) who analyses the effect of attention around non-farm payroll announcements in the United States, we cannot interact our attention variable with the surprise of the announcement since monetary policy surprises (defined as the difference between the announced policy rate and the consensus of market participants) are almost non-existent over the whole period (changes in the main refinancing rates are in general perfectly anticipated by the markets). Furthermore, it is not possible to construct a surprise variable for non-conventional monetary policy as there are no recurring surveys of market expectations on the non-conventional instruments. Thus, we only use pre-announcement information, which may explain the differences between our

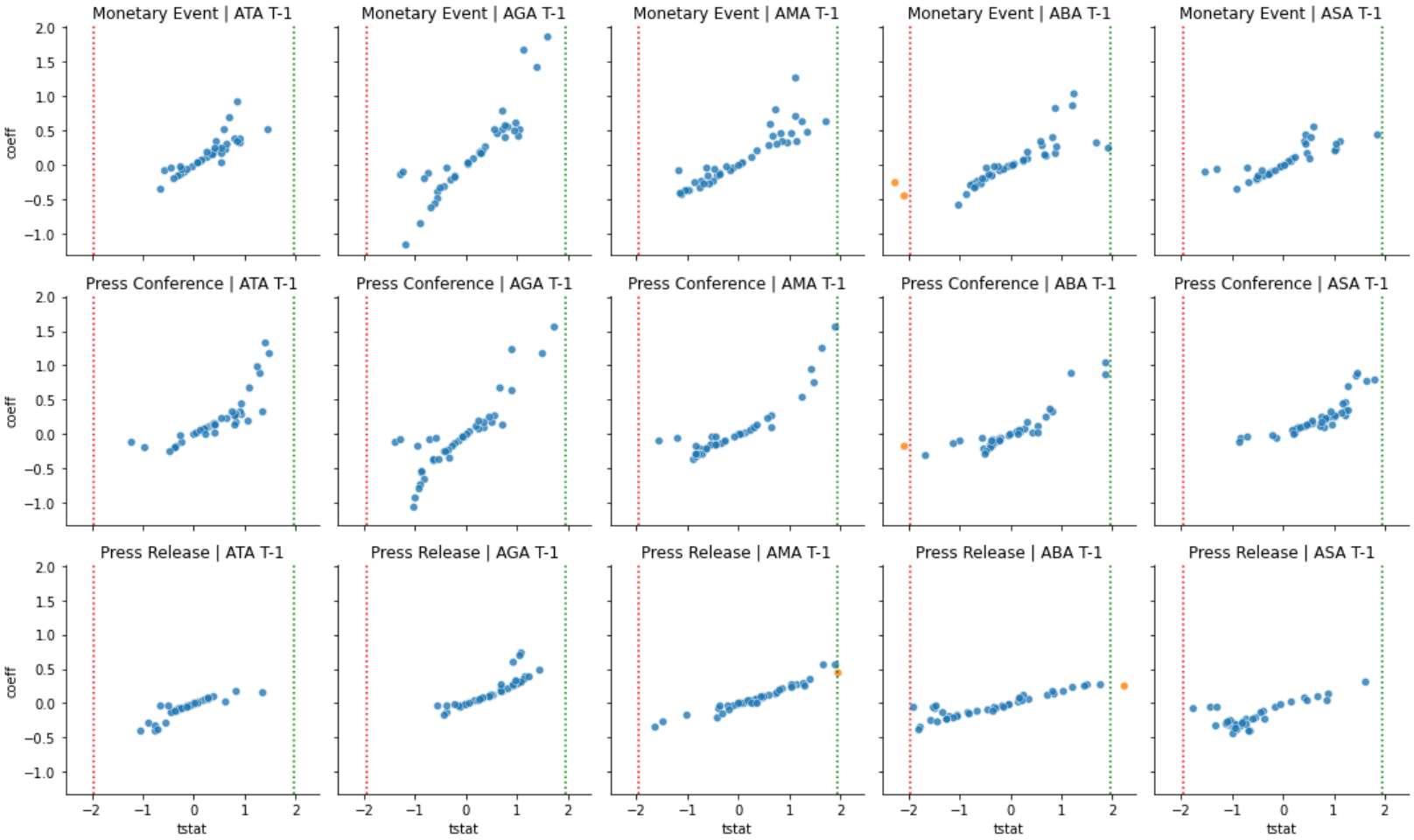
Fig. 5. β_1 value and t-stats by asset types and event window for Twitter and Google attention measures



Notes: This Figure presents the value of the coefficient β_1 from Equation 2 with robust standard errors and its associated t-stats. The dependent variables are the absolute returns/yield change of 41 assets during the monetary event window (mew, first line), the press conference window (pcw, second line), and the press release window (prw, third line). The 41 assets are split into six categories depending on their market, with a specific color for each category. The red and green dashed lines represent, respectively, a t-stat of -1.96 and +1.96 (5% confidence interval).

results and those of Benamar et al. (2020). In the next section, we will also explore the impact of investor sentiment, as measured by the content of tweets, on the market.

Fig. 6. β_1 value and t-stats by investor attention measure and event window for assets returns/yield changes



Notes: This Figure presents the value of the coefficient β_1 from Equation 2 with robust standard errors and its associated t-stats on a total of 615 regressions (41 estimates per panel). Each column provides the coefficient of a different attention measure on the day before the ECB press conference with ATA_{t-1}: Twitter, AGA_{t-1}: Google, AMA_{t-1}: Media, ABA_{t-1}: Bloomberg or ASA_{t-1}: Stocktwits (detailed in Equation 1). The dependent variables are the returns/yield change of 41 assets during the monetary event window (mew, first line), the press conference window (pcw, second line), and the press release window (prw, third line). The red and green dashed lines represent, respectively, a t-stat of -1.96 and +1.96. All points in orange correspond to regressions in which the attention variable coefficient (β_1) is significant at the 5% confidence interval.

4. Variants of the Twitter attention indicator

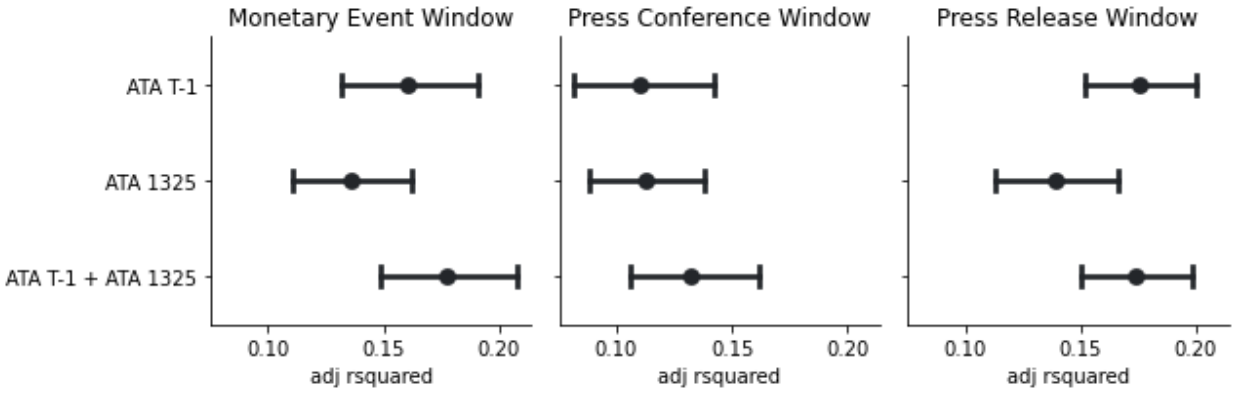
After showing in the previous section that the attention indicator constructed from Twitter data the day before an ECB announcement was relevant to explain the absolute variations of financial assets on ECB announcement days, we construct in this section variants of this indicator by (1) taking into account tweets sent on the day of the press conference t until 13:25, (2) separating from the analysis tweets in English and tweets in other languages (Spanish, French, German, and Italian), and (3) weighting each message according to its number of likes and retweets in order to take into account the relative visibility of the tweets, and (4) calculating the sentiment of the tweets in addition to the volume of messages.

4.1. Using Twitter intraday timestamp

In the previous section, we used only the messages sent on Twitter the day before an event, between 00:00 and 23:59, to construct our ATA attention indicator. However, an advantage of Twitter over the other data used in this paper is the availability of precise timestamp data (available to the second) allowing us to take into account the volume of messages on the day of the event until a few minutes before the start of the press conference. We therefore construct the new indicator $ATA_{1325,t}$ by considering the messages sent from 00:00 to 13:25 on the day of the event t. The correlation between ATA_{t-1} and $ATA_{1325,t}$ is equal to 0.66.

We consider a first model with only the variable $ATA_{1325,t}$ and a second model with the variable ATA_{t-1} and the variable $ATA_{1325,t}$. We then compare the distribution of the adjusted R-squared with those of a model based on ATA_{t-1} alone. Figure 7 presents our results. The results of the 369 regressions are available online. Surprisingly, we do not find that the addition of investor attention on the morning of the announcements improves the models. These results suggest that the number of tweets prior to the day of the announcement is a better proxy of investor attention than the number of tweets on the day of the

Fig. 7. Adjusted R-squared - ATA_{t-1} and $ATA_{1325,t}$



Notes: This Figure represents the mean of the adjusted R-squared obtained from the linear estimation of Equation 2 with robust standard errors and its 95% confidence interval for ATA_{t-1} and ATA_{1325}. The dependent variables are the absolute returns/yield change of 41 assets during the monetary event window (mew, left), the press conference window (pcw, center) and the press release window (prw, right). The 95% confidence interval is constructed using bootstrapping methods with 10,000 bootstrap samples.

announcement.

4.2. Tweeting in English or in the national language ?

Our database of more than 6 million tweets is composed of 4,716,385 tweets in English (76.5% of the database) and 1,448,090 tweets in other languages. In Equation 1, we differentiate the attention measured computed from tweets written in English ($ATA_{eng,t-1}$) and from tweets written in the relevant national language ($ATA_{lang,t-1}$). As the majority of the messages are in English, the correlation between ATA_{t-1} and $ATA_{eng,t-1}$ is large (close to 0.99). The correlation with other languages ranges from 0.60 to 0.75.

While a German (French, Italian, Spanish) ECB expert may tweet in German (French, Italian, Spanish) or English, depending on the audience he or she wishes to target (domestic or international), we believe that this method allows us to construct a proxy for domestic investor attention: the majority of users tend to send messages in their domestic languages. To explain the 10-year absolute sovereign bond yield change, we use tweets in German

(156,556 tweets containing EZB or Europische Zentralbank) for the German 10Y, in Italian (550,858 tweets containing BCE or Banca Centrale Europea) for the Italian 10Y, in French (15,2133 tweets containing BCE or Banque Centrale Europenne) for the French 10Y, and in Spanish (417,356 tweets containing BCE or Banco Central Europeo) for the Spanish 10Y. Table 2 presents our results for a small sample of relevant dependant variables during the monetary policy event window (mew). The remaining results for both the press conference (pcw) and the press release window (prw) are available in the online appendix.

Table 2: Absolute sovereign yield change and domestic investor attention

	DE10Y	ES10Y	FR10Y	IT10Y
AR1	0.045	0.305***	0.136	0.391**
	(0.122)	(0.089)	(0.121)	(0.163)
$ATA_{eng,t-1}$	0.887***	2.005***	1.530***	2.946***
	(0.317)	(0.674)	(0.484)	(0.901)
$ATA_{de,t-1}$	-0.089			
	(0.190)			
$ATA_{es,t-1}$		0.060		
		(0.451)		
$ATA_{fr,t-1}$			-0.284	
			(0.345)	
$ATA_{it,t-1}$				-0.215
				(0.491)
$VStoxx_{t-1}$	-0.058	0.956	0.565	1.944*
	(0.247)	(0.593)	(0.439)	(1.056)
EPU_{europe}	-0.506*	-1.062**	-0.509	-0.504
	(0.266)	(0.513)	(0.314)	(0.672)
$NCMP_t$	0.078	0.298	-0.275	0.196
	(0.264)	(0.480)	(0.349)	(0.705)
Constant	2.544***	2.838***	2.805***	3.622***
Observations	91	91	91	91
Adjusted R2	0.155	0.371	0.192	0.353

Notes : Estimation of Equation 2 using OLS with robust standard errors. The dependent variables are the absolute yield change of 10Y German, Spanish, French, or Italian sovereign bonds during the monetary event window (mew).

We find that domestic investor attention is not significant in our regression, while the number of tweets in English is significant at the 1% level. This result may be due to the fact that users tweeting in English are on average more informed or sophisticated than other users, so their opinions matter more than those of others. We will explore this hypothesis in the next subsection. Overall, our results suggest that the value added to analyzing tweets

in other languages is low and that focusing on English messages is sufficient to build robust indicators of investor attention around ECB announcements.

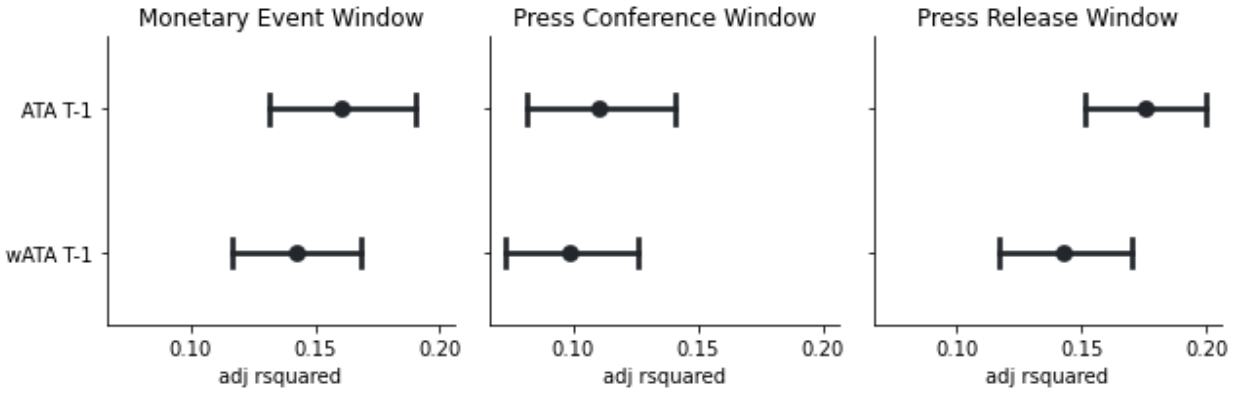
4.3. Weighting tweet by retweets and likes

In the previous sections, we simply counted the number of tweets to construct our investor attention indicators. This implies that each tweet had the same weight and that we did not differentiate between a message sent by an influential user and a message sent by a user with a small number of followers. In order to better take these differences into account, we propose in this subsection to construct a weighted attention indicator by taking into account the number of likes and retweets received by each message. We define w, the importance of a tweet, by taking into account its visibility as follows:

$$w = log(1 + likes + retweet)$$

The abnormal weighted volume of tweets in a given day $wATA_t$ is computed as in Equation 1 but using the weighted number of tweets instead of the non-weighted number of tweets. We run a total of 246 regressions (41 assets * 3 event windows * 2 attention variables) and we compare our results when we use $wATA_{t-1}$ instead of ATA_{t-1} as a proxy of investor attention. All regressions are available in the online Appendix. Figure 8 presents the average R-squared for the three event windows with a 95% confidence interval. Overall, we do not find any large differences between our weighted and our non-weighted proxies of investor attention. The coefficients and the statistical significance of ATA_t and $wATA_t$ are qualitatively similar. The adjusted R-squared values are even slightly higher when we use the non-weighted proxy of investor attention suggesting that it might be better to capture the "wisdom of the crowd" than the "wisdom of the influencers."

Fig. 8. Adjusted R-squared - ATA_{t-1} and $wATA_{t-1}$



Notes: This Figure represents the mean of the adjusted R-squared obtained from the linear estimation of Equation 2 and its 95% confidence interval for ATA_{t-1} and $wATA_{t-1}$. The dependent variables are the absolute returns/yield change of 41 assets during the monetary event window (mew, left), the press conference window (pcw, center), and the press release window (prw, right). The 95% confidence interval is constructed using bootstrapping methods with 10,000 bootstrap samples.

4.4. Looking at sentiment measures

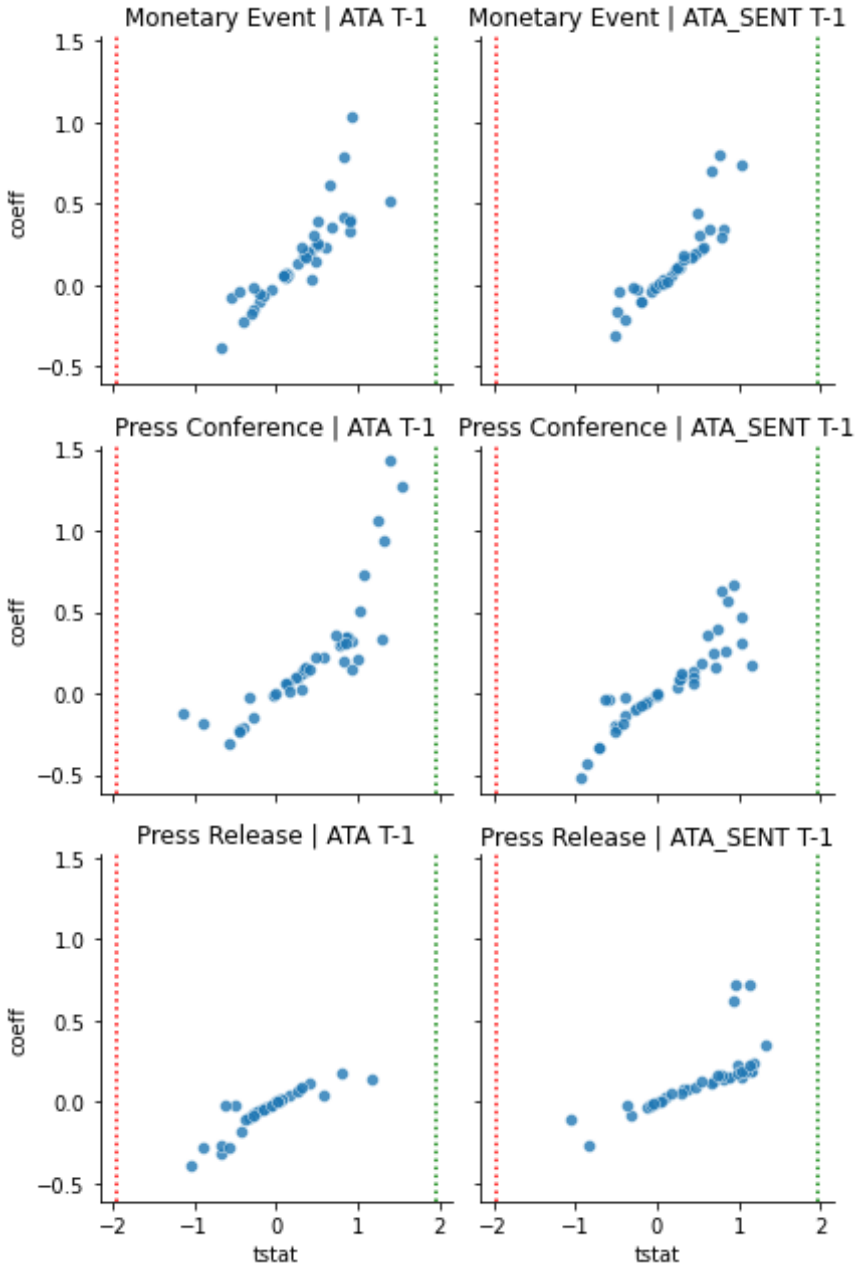
Last, we construct of proxy of investor sentiment by using the VADER sentiment analysis method proposed by Hutto and Gilbert (2014). The VADER method has the advantage of being specifically designed to analyze messages on social networks by taking into account, among other things, slang and emojis. We, therefore, calculate for each English tweet[13] a sentiment score between -1 and +1, and we compute the sentiment for each day t, $TwitterSent_t$, as the average of the sentiment of the tweets sent that day.

We then add $TwitterSent_{t-1}$ to Equation 2 to analyze if sentiment on the day before the announcement helps in predicting returns on the announcement day. Figure 9 presents a scatterplot of the coefficients and t-stats for ATA_{t-1} and $TwitterSent_{t-1}$ on return/yield of our 41 assets. The results for the absolute return/yields are provided in Figure 10 of the Appendix.

We find that both variables ATA_{t-1} and $TwitterSent_{t-1}$ are not significant in any regressions. This result differs from the findings of Azar and Lo (2016) who show that the

[13] The VADER method is not available in German or Italian.

Fig. 9. β value and t-stats for Twitter Sentiment across event windows.



Notes: This Figure presents the value of the coefficient β from Equation 2 with robust standard errors and its associated t-stats on a total of 123 regressions (41 estimates per panel). Each column provides the coefficient of a different attention measure on the day before the ECB press conference with ATA_{t-1} and the Twitter Sentiment $TwitterSent_{t-1}$. The dependent variables are the returns/yield change of 41 assets during the Monetary Event window (mew, first line), the Press conference window (pcw, second line), and the Press Release window (prw, third line). The red and green dashed lines represent, respectively, a t-stat of -1.96 and +1.96. All points in orange correspond to regressions in which the attention variable coefficient (β) is significant at the 5% confidence interval.

sentiment of tweets about the Federal Reserve can be used to predict future excess returns of the CRSP value-weighted market index. However, our analysis differs in several elements. First, while the work of Azar and Lo (2016) covers 6 years between 2009 and 2015 for the Federal Open Markets Committee (FOMC) , our analysis uses 10 years between 2011 and 2021 for the ECB. Second, we use a range of 41 assets covering a large variety of market segments: interest rate swaps, sovereign bonds, exchange rates, and stock markets. Third, we focus on intraday market reaction in a time-lapse of a maximum of 2 hours and 30 minutes (the monetary event window) while Azar and Lo (2016) study daily returns. Because of intraday data availability, we leave the topic of the differential impact of sentiment on market reactions for future research. However, the relationship between abnormal Twitter attention (ATA) and absolute market reaction remains significant in all models and specifications.

5. Conclusion

Alternative data from newspapers, social media, and search engines can be used to build new indicators to measure investor attention. However, it is difficult - ex-ante - to know which source to use to construct these indicators and the advantages and limitations of these different proxies. Each data source can capture the attention of a different audience (professional investors, individual investors, journalists, people from Main Street), and the effect of these indicators on the magnitude and direction of market reactions requires a specific empirical analysis depending on the type of assets or the analysis horizon (intraday, daily, long-term).

In this paper, we propose a novel measure of investor attention by analyzing messages sent on Twitter about the European Central Bank. We show that the level of investor attention on the day before the announcement helps explain the magnitude of the market reactions to ECB announcements and that our results are robust to the inclusion of macroeconomic variables, market volatility, economic policy uncertainty indexes, and lagged returns. We also

show that attention measures constructed from Twitter data are more informational than measures constructed from the number of media articles or the number of Google searches.

Our findings suggest that central bankers and policymakers could use those new indexes as a proxy of the expectation of the market prior to their announcements - in combination with other standard macroeconomic and financial variables already used to capture market stress. However, consistent with the efficient market hypothesis, we do not find that returns are predictable with investor attention or investor sentiment derived from Twitter. Twitter is a good proxy to forecast the magnitude of the price change, but not the direction of the market.

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Online Appendix

The online appendix is available at https://enarwen.github.io/.
It includes descriptive statistics

Appendix

Table 3: Descriptive Statistics

	count	mean	std	min	25%	50%	75%	max
Attention Variables								
ATA_{t-1}	91.0	1.09	0.07	0.95	1.05	1.07	1.13	1.28
AMA_{t-1}	91.0	1.32	0.13	1.10	1.23	1.31	1.39	1.70
AGA_{t-1}	91.0	1.09	0.11	0.91	1.03	1.07	1.13	1.69
ABA_{t-1}	71.0	1.09	0.10	0.90	1.01	1.08	1.16	1.31
ASA_{t-1}	91.0	1.61	0.47	0.87	1.26	1.54	1.81	3.31
ATA_{1325}	91.0	1.29	0.08	1.13	1.23	1.29	1.35	1.54
$ATA_{eng,t-1}$	91.0	1.10	0.08	0.96	1.05	1.08	1.14	1.32
$wATA_{t-1}$	91.0	1.10	0.09	0.88	1.04	1.08	1.15	1.34
$TwitterSent_{t-1}$	91.0	0.01	0.06	-0.27	-0.02	0.01	0.05	0.15
Control Variables								
$VStoxx_{t-1}$	91.0	21.75	7.94	12.24	16.43	19.88	24.48	53.76
EPU_{europe}	91.0	212.44	58.90	111.80	171.19	208.27	241.69	433.28
NCMP	91.0	0.11	0.31	0.00	0.00	0.00	0.00	1.00

Table 4: Pearson Correlation Matrix - Daily

	ATA_{t-1}	AMA_{t-1}	AGA_{t-1}	ABA_{t-1}	ASA_{t-1}	ATA_{1325}	$ATA_{eng,t-1}$	$wATA_{t-1}$	$TwitterSent_{t-1}$	$VStoxx_{t-1}$	EPU_{europe}
ATA_{t-1}	1.00	0.44	0.67	0.44	0.51	0.70	0.98	0.87	-0.13	0.07	-0.06
AMA_{t-1}	0.44	1.00	0.48	0.55	0.42	0.34	0.48	0.36	0.25	-0.20	0.16
AGA_{t-1}	0.67	0.48	1.00	0.47	0.50	0.51	0.68	0.65	0.17	0.05	-0.08
ABA_{t-1}	0.44	0.55	0.47	1.00	0.36	0.42	0.45	0.49	0.07	-0.03	0.07
ASA_{t-1}	0.51	0.42	0.50	0.36	1.00	0.52	0.53	0.53	0.08	-0.18	-0.18
ATA_{1325}	0.70	0.34	0.51	0.42	0.52	1.00	0.71	0.58	-0.07	-0.01	0.01
$ATA_{eng,t-1}$	0.98	0.48	0.68	0.45	0.53	0.71	1.00	0.85	-0.14	0.03	-0.04
$wATA_{t-1}$	0.87	0.36	0.65	0.49	0.53	0.58	0.85	1.00	-0.02	0.11	-0.09
$TwitterSent_{t-1}$	-0.13	0.25	0.17	0.07	0.08	-0.07	-0.14	-0.02	1.00	-0.24	0.00
$VStoxx_{t-1}$	0.07	-0.20	0.05	-0.03	-0.18	-0.01	0.03	0.11	-0.24	1.00	0.32
EPU_{europe}	-0.06	0.16	-0.08	0.07	-0.18	0.01	-0.04	-0.09	0.00	0.32	1.00

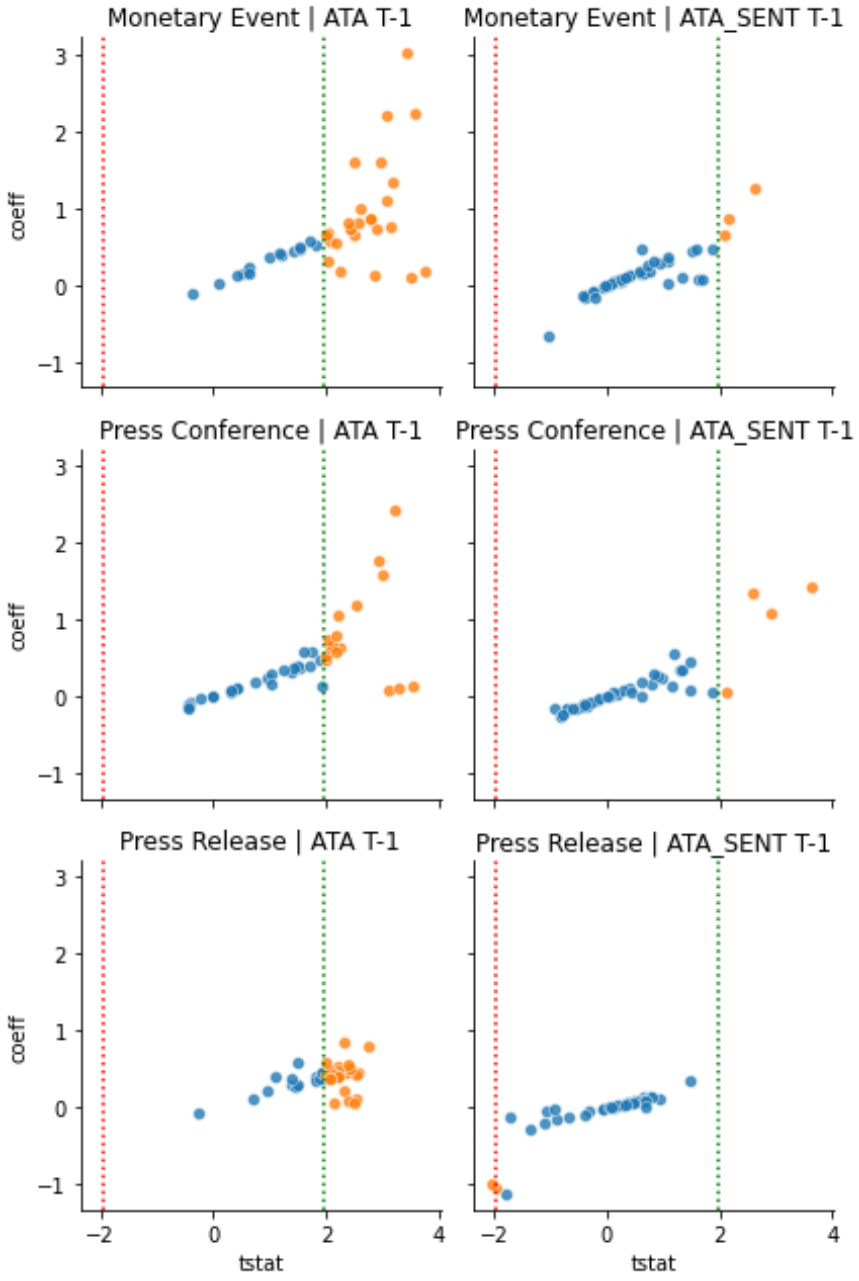
Note : The table provides the Pearson correlation matrix. Significance level are indicated by *** (1%), ** (5%) and * (10%).

Table 5: Unconventional monetary policies:

Press release date	*Unconventional monetary policy*
7 August 2011	Securities market programme, new announcement
6 October 2011	Covered bond purchase programme (second) and new LTRO
6 September 2012	Technical features of OMT
5 June 2014	Asset-backed Securities Purchase Programme and TLTRO
4 September 2014	Asset-backed securities purchase programme and Covered bond purchase programme
22 January 2015	Public Sector Purchase Programme
9 March 2015	Public Sector Purchase Programme, new announcement
10 March 2016	Public Sector Purchase Programme, new announcement (increase in size)
12 September 2019	Asset Purchase Programme, new announcement (restart)
18 March 2020	Pandemic Emergency Purchase Programme (PEPP)
4 June 2020	Pandemic Emergency Purchase Programme (PEPP), new announcement (increase in size)
10 December 2020	Pandemic Emergency Purchase Programme (PEPP), new announcement (increase in size)

Notes: Initial list from Moessner (2018), updated by the authors.

Fig. 10. β value and t-stats for Twitter Sentiment across event windows.



Notes: This Figure presents the value of the coefficient β from Equation 2 with robust standard errors and its associated t-stats on a total of 123 regressions (41 estimates per panel). Each column provides the coefficient of a Twitter attention measure, ATA_{t-1}, and the Twitter Sentiment, $TwitterSent_{t-1}$, on the day before the ECB press conference. The dependent variables are the absolute returns/yield change of 41 assets during the Monetary Event window (mew, first line), the Press conference window (pcw, second line) and the Press Release window (prw, third line). The red and green dashed lines represent, respectively, a t-stat of -1.96 and +1.96. All points in orange correspond to regressions in which the attention variable coefficient (β) is significant at the 5% confidence interval.