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Nr. 2020/07

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Philipps Universität Marburg

Joint Discussion Paper
Series in Economics

by the Universities of

Aachen · Gießen · Göttingen
Kassel · Marburg · Siegen

ISSN 1867-3678

No. 19-2019

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Complexity of ECB Communication and Financial Market Trading

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Completely revised version 4 December 2020

We empirically examine how complexity of ECB communications affects financial market trading based on high-frequency data from European stock index futures trading. Our sample covers ECB press conferences between January 2009 and December 2017, during which unconventional monetary policy measures (UMPM) substantially increased communication complexity. Analysing the linguistic complexity of the introductory statements and differentiating between press conferences with and without UMPM-announcements, we find more complex communication, i.e. high linguistic complexity and UMPM-announcement, is associated with a lower level of contemporaneous trading activity. Moreover, complex communication leads to a temporal shift in trading activity towards the subsequent Q&A session, which suggests that Q&A sessions facilitate market participants' information processing. Finally, we document a relatively lower similarity of unconventional monetary policy statements and argue that this might explain our findings.

JEL-Classification: *D83, E52, E58, G12, G14*

Keywords: *ECB, central bank communication, textual analysis, linguistic complexity, readability, financial markets, European stock markets*

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Declarations of interest: none (applies to all authors).

Thanks to participants at the German Economic Society Annual Conference in 2019 in Leipzig for helpful comments.

1 Introduction

Over the last decade, central bank communication has become a key component of the central bankers' toolkit (see, e.g., Dell'Ariccia, Rabanal and Sandri, 2018; Kuttner, 2018).[1] To effectively steer the expectations of the private sector with the aim of enhancing monetary policy transmission, central banks in several countries have institutionalised monetary policy communication (see, e.g., Blinder et al., 2008). Announcements about current monetary policy decisions, assessments of the economic outlook, and the expected consequences of monetary policy have become an important tool of central banks' communication strategy (see, e.g., Hansen, McMahon and Prat, 2018; Kohn and Sack, 2003).

However, the increase in complexity of monetary policy during and after the financial crisis creates significant challenges for central bank communication (e.g., Bulíř, Čihák and Jansen, 2013a; Bulíř, Čihák and Šmídková, 2013b; Hernández-Murillo and Shell, 2014). As Peter Praet, former chief economist of the ECB, put it '[i]n normal times, central banks adapted their monetary policy stance by influencing the level of one short-term interest rate. In unconventional times, communication has had to cope with the new challenge of explaining the complementarities between policy tools, as non-standard monetary policy has become multidimensional. […] In this context, it is

[1] Communication is "a process by which information is exchanged between individuals through a common system of symbols, signs, or behaviour" (Merriam Webster Dictionary, available at: https://www.merriam-webster.com/dictionary/communication (accessed: 05 Mar 2019)). Central banks can utilise communication to reduce asymmetric information and share their private information to guide expectations. Central banks' private information may stem from a myriad of sources, such as the outcome of previous policy votes (see, e.g., Meade, 2005), the discussions at the meeting (see, e.g., Hansen, McMahon and Prat, 2018), or risk balance evaluations (see, e.g., Hanson and Stein, 2015).

perhaps no coincidence that the complexity of the introductory statements delivered at the ECB's press conferences, as measured by common indices of text readability, has also increased'.[2]

While there is a large number of studies exploring central bank communication (see the surveys by Blinder et al., 2008 and de Haan and Sturm 2019), there is still little understanding as to how financial markets are influenced by the complexity of central bank communication. We address this gap in the literature by studying the European Central Bank's (ECB) press conferences following the Governing Council meeting and the impact of linguistic and content-related complexity of the introductory statement for contemporaneous trading behaviour in financial markets.

After interest rates reached the effective lower bound following the 2008 financial crisis, many central banks around the world embraced unconventional monetary policy measures (UMPM), such as quantitative easing and forward guidance (e.g., Bowdler and Radia, 2012). Arguably, the complexity – and potential ambiguity – associated with these novel monetary policy tools demands a more disciplined and coherent communication strategy, especially since the effectiveness of monetary policy potentially seems to increase in the degree of comprehension of financial market participants (see, e.g., Cœuré, 2018, Lucca and Trebbi, 2009; Praet, 2017).[3]

To date, central banks in all major economies conduct regular press conferences following the meetings of their monetary policy committees. The ECB instituted its press conferences after the Governing Council Meetings (GCM) right from its establishment.

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[2] See https://www.ecb.europa.eu/press/key/date/2017/html/ecb.sp171115.en.html (accessed Dec 2, 2020).

[3] An extensive discussion on how financial market participants themselves evaluate the success of these policies is provided in Hayo and Neuenkirch (2015a).

Each press conference begins with a prepared introductory statement and ends with a Q&A session attended by journalists. In the light of the ECB's unique communication design, we address the question of whether higher complexity of central bank communication, causes financial markets to delay trading and whether the generally less complex Q&A sessions may mitigate the effect.

We measure market trading using high-frequency data from European stock index futures trading and study ECB press conferences in the aftermath of the 2008 financial crises, during which unconventional monetary policies substantially increased communication complexity. We proceed in four steps. First, we analyse the linguistic complexity of the introductory statements. Differentiating between press conferences with and without the announcement of UMPM, we find no difference between the linguistic complexity of introductory statements. Second, examining the overall effect of linguistic complexity on trading volume, we find – in contrast to Smales and Apergis (2017a) who study the Federal Open Market Committee (FOMC) – no effect in our sample period. *Third*, differentiating between press conferences with and without the announcement of UMPM, we find higher linguistic complexity of introductory statements is associated with a lower level of contemporaneous trading activity for UMPM-announcements. Moreover, in for events we find increasing complexity to shift trading activity towards the subsequent Q&A session, which suggests that Q&A sessions facilitate market participants' information processing. *Finally*, drawing on Ehrmann and Talmi (2020), we analyse the similarity of introductory statements and infer that the observed effect of UMPM-announcements is due to their 'unconventionality', that is, their degree of novelty. Specifically, we document that UMPM communication is, on average, less similar and, therefore, more likely to transmit a higher degree of potentially complex new information.

The remainder of this paper is structured as follows: The next section develops the central research question and presents our hypotheses. Section 3 describes the dataset and provides the descriptive analysis. Section 4 illustrates our empirical design and presents the regression results. Section 5 discusses the robustness of the results and section 6 concludes.

2 Central Bank Communication and Financial Markets

Economic theory suggests that trading decisions depend on ’news’, i.e. novel information (see, e.g., Stigler, 1961), which is swiftly incorporate by efficient financial markets (Fama, 1970). Central bank communication often contains such relevant news about future economic developments, with consequences for the macroeconomy, specific industries, and individual companies (see, e.g., Bernanke and Kuttner, 2005; Funke and Matsuda, 2006). Consistent with that view and Cukierman and Meltzer’s (1986) hypothesis, Andersson (2010) and Nakamura and Steinsson (2018) find evidence that unexpected information (i.e. surprises) in central bank communication has an immediate effect on financial markets.

Most studies analysing the informational content of central bank communication focus on well-defined signals from the central bank, such as monetary policy announcements (see, e.g., Blinder et al., 2008). In an attempt to minimise omitted variable bias and endogeneity, these studies commonly take an event-study approach (see, e.g., Rosa, 2011a). The dependent variables employed typically include some short-term reactions by financial markets around monetary policy announcements (see, e.g., Boguth, Grégoire and Martineau, 2019; Brand, Buncic and Turunen, 2010; Gurkaynak, Hussain, 2011; Rosa, 2008; Rosa, 2011b; Sack and Swanson, 2005; Schmeling and Wagner, 2019). Other studies quantify the content of these announcements through text-mining techniques and investigate communication of various central banks, e.g., the ECB (Picault and Renault, 2017), the FOMC (Shapiro and Wilson, 2019), the Bundesbank (Tillmann and Walter, 2018), and the Riksbank (Apel and Grimaldi, 2014).

In general, this stream of research considers information to be a rather simple construct, easily understood and comprehended by market participants. However, several studies question this assumption and emphasise the possibility of (1) variations in the degree of understanding and interpretation of information (see, e.g., Grossman and Stiglitz, 1976; Harris and Raviv, 1993) and (2) heterogeneity in the speed of information processing. Kandel and Pearson (1995), for instance, suggest that different *ex ante* opinions may rationalise dispersion in interpretation, that is, while all market participants receive the same information, their assessment is heterogeneous. Alternatively, the (lack of) general comprehensibility of the information could be the cause for the differential interpretation of information (see, e.g., Loughran and McDonald, 2016; Smith and Taffler, 1992; You and Zhang, 2009). That is, all market participants receive the same information but decode it differently and/or at a different speed due to the contents' complexity. Hong and Stein (1999) argue that private information may be required to transform public news into an opinion and heterogeneity in private information may result in gradually updated opinions and, thus, an underreaction of the market to public news.

Regarding central bank communication, Ehrmann and Talmi (2020) report substantial similarity in press releases announcing monetary policy decisions. They find that similarity of press releases of the Bank of Canada is negatively associated with market volatility. Examining FOMC statements, Hernández-Murillo and Shell (2014) document that these statements have become more complex since the beginning of UMPM. Smales and Apergis (2017a, 2017b) investigate in two studies the effect of linguistic complexity of FOMC statements and find that complexity positively affects daily trading volume. The authors rationalise their finding with heterogeneity in beliefs and opinions because of the complexity of information in light of Harris and Raviv (1993) and Kandel and Pearson (1995).

In this paper, we extend the analysis of Smales and Apergis (2017a, 2017b) along two dimensions. *First*, we are interested in the *dynamics* of information processing and trading behaviour in financial markets. In light of Hong and Stein (1999), we argue that at a given level of cognitive ability and private information, the time to process news is positively correlated with the complexity of the text containing that news. Hence, we expect that the market underreacts to more complex central bank communication and that contemporaneous trading volume is negatively correlated with complexity:

H1: *Complexity of central bank communication has a negative impact on contemporaneous trading behaviour.*

Second, we argue that it is not only the linguistic complexity of the transcripts that matters, but also the complexity of the context and content that matters. Following Peter Praet, former chief economist of the ECB, who argues '*[a] multi-instrument policy toolkit [UMPM] is more complex because it adds a further dimension to the* *central bank reaction function'*[4], we posit that announcements of UMPM are more complex in context and content. Hence, in the case of UMPM-events, we expect the underreaction of the market to be even more pronounced.

H2: *Complexity of central bank communication has a more negative impact on contemporaneous trading behaviour, when communication refers to unconventional monetary policy measures.*

Finally, we shed some light on the question of whether the unique communication design of the ECB, where each press conference begins with a prepared introductory statement and ends with a Q&A session attended by journalists, may mitigate the underreaction of the market. Arguing that communication in Q&A sessions is less formal and thus less complex, we hypothesise that Q&A sessions may be helpful for reducing heterogeneity in information processing and opinions and thus attenuate the underreaction of the market to complex news.

H3: *There is a positive relationship between ECB communication complexity and a temporal shift of trading activity to the Q&A session.*

3 Sample and Descriptive Analysis

To test the three hypotheses, we analyse the effect of complexity in introductory statements of the ECB press conferences using high-frequency trading volume data

[4] See https://www.ecb.europa.eu/press/key/date/2017/html/ecb.sp171115.en.html (accessed Dec 2, 2020).

from European stock index futures. Our core sample contains all press conferences from January 2009 to December 2017.[5] It covers the aftermath of the 2008 financial crises, when the ECB started conducting UMPM on a recurring basis. Specifically, it covers the announcement of ECB's first covered bond purchase programme on 07 May 2009 (see, e.g., Henseler and Rapp, 2018).

3.1 Introductory Statements to ECB Press Conferences

The main decision-making body of the ECB is the Governing Council, which assesses economic and monetary developments and conducts monetary policy decisions on a regular basis at the ECB's premises in Frankfurt am Main, Germany.[6] After GCMs, the ECB issues a press statement at 13:45 CET on its interest rate decision, followed by a press conference, where the monetary policy decisions are explained in detail by the ECB's president, sometimes supported by other members of the Executive Board.

A typical GCM press conference proceeds as follows. After the official start at 14:30 CET, the ECB's president reads a prepared introductory statement, which covers the GCM's decisions, the underlying rationale, and a monetary policy outlook. This introductory statement takes between 10 and 20 minutes, with mean and median at 15 minutes (for our sample). Subsequently, a 40- to 60-minute Q&A session is held, starting at around 14:50 CET. During this, local participants (usually press represent-

[5] In the robustness checks, we extend the sample to cover the January 2003 to December 2017 period. Our results remain unaffected (see Section 5.1).

[6] A detailed and comprehensive description of the Governing Council's responsibilities can be found at: https://www.ecb.europa.eu/ecb/orga/decisions/govc/html/index.en.html (accessed: 17 Feb 2019).

atives) ask questions, which are answered by the president. The Q&A session is explicitly intended to make the correspondence of the ECB as clear as possible (see, e.g., Cœuré, 2018). The press conference concludes between 15:30 to 15:50 CET.

Searching the ECB webpage, we identify all GCM press conferences during our sample period. For each press conference, we download transcripts of the introductory statement and save it in a separate text file.[7] We opt for analysing the GCM press conference introductory statements, since they represent an important and standardised part of ECB communication (e.g., Hayo, Henseler, and Rapp, 2019): important, as it embodies the communication as intended by the ECB, and standardised, as the statements exhibit a common structure and duration. Still the statements differ in content and, hence, provide an appropriate basis for comparative text analysis. Overall, our sample covers 95 introductory statements.

3.2 Unconventional Monetary Policy Measures

In a detailed content analysis, we assess the introductory statements with regard to the disclosure of Asset Purchase Programmes, Swap Agreements, Allotment Policy, and/or Forward Guidance. If at least one of these topics is discussed substantively, a dummy variable $UMPM$ is coded 1 and 0 otherwise. A comprehensive list of the resulting 34 press conference can be found in Table A1 in the Appendix.

[7] ECB press conference transcripts with introductory statements and Q&A sessions are available at: https://www.ecb.europa.eu/press/pressconf.

3.3 Measuring Complexity of Introductory Statements

To quantify the latent dimension of comprehensibility, we follow the linguistic approach of Hernández-Murillo and Shell (2014) and Smales and Apergis (2017a, 2017b) and use the Flesch-Kincaid Grade Level (Kincaid, Fishburne, Rogers, and Chissom, 1975) to measure complexity in the introductory statements.[8]

The Flesch-Kincaid Grade Level score (FK) is a linear function in the average sentence length and the average word length measured in syllables. Technically, for a document i it is calculated as:

$$FK_i = 0.39\,\frac{total\ words_i}{total\ sentences_i} + 11.8\,\frac{total\ syllables_i}{total\ words_i} - 15.59.$$

It is supposed to be equivalent to the US grade level of education and indicates the required years of education to be able to understand the respective text. The Flesch-Kincaid grade level approach can be applied to documents of arbitrary length. Consider for instance, the following – rather complex – sentence from Mario Draghi's introductory statement to the ECB press conference on 4 September 2014: 'The Eurosystem will purchase a broad portfolio of simple and transparent asset-backed securities (ABSs) with underlying assets consisting of claims against the euro area non-financial private sector under an ABS purchase programme (ABSPP)'[9]. With 37 words and 68 syllables, the Flesch-Kincaid grade level score of this sentence is $0.39\frac{37}{1} +$

[8] This approach is also applied in other fields of finance. For example, Smith and Taffler (1992), You and Zhang (2009), and Miller (2010) investigate the effect of complexity in corporate reports on subsequent trading volumes and stock-price movements. Loughran and McDonald (2016) discuss the use of textual analysis and linguistic measures in accounting and finance.

[9] https://www.ecb.europa.eu/press/pressconf/2014/html/is140904.en.html (accessed: 29 Aug 2020).

$11.8\,\frac{68}{37} - 15.59 = 21$, suggesting that a person needs to be a professional reader for full comprehension.

We calculate the Flesch-Kincaid Grade Level score for all introductory statements using the quanteda package in R (Benoit et. al., 2018). To reduce the potential influence of outliers, we define the variable $Complexity$ as the log of this score.

3.4 Measuring Trading Volume

To proxy financial market trading activity, we use trading volume of the EURO-STOXX-50 futures, since futures are highly liquid trading instruments that react quickly to new information (see, e.g., Kuttner, 2001; Bomfim, 2003). The underlying stock index, the EURO-STOXX 50 (ISIN: EU0009658145) with 50 large-cap constituents from the euro area, is one of the leading European stock indices. The corresponding future (ISIN: DE0009652388) is traded on the EUREX and, with a tick-size of 10, is widely considered the most liquid European stock index future.[10]

We retrieve trading volume at a 1-minute frequency from PortaraCQG and calculate $Volume_{Intro}$ as the natural logarithm of the mean trading volume (per minute) over the 15-minute window from 14:30–14:45 CET. This period reflects the start of the press conference and the average time span needed to read the introductory statement. Correspondingly, we define $Volume_{Q\&A}$ as the natural logarithm of the mean

[10] According to Eurex Daily Statistics from 30 December 2016 and 29 December 2017, the average annual trading volume of the EURO-STOXX-50 futures was roughly 328 million contracts, corresponding to €10,474bn and an average daily trading volume of 1.35 million contracts (Source: https://www.eurex.com/ex-en/data/statistics/trading-statistics, accessed 4 December 2020). In our sample, covering 2009-2017, the average trading during an introductory statement is some 4,600 contracts per minute, which is significantly more than the (time-of-the day pattern adjusted) average trading volume per minute (see Figure 1).

trading volume (per minute) measured during the roughly 60 minutes long Q&A-session (14:50–15:50 CET) and $Volume_{Conf}$ as the natural logarithm of the mean trading volume (per minute) over the period of the whole press conference (14:30–15:50 CET).

3.5 Descriptive Analysis

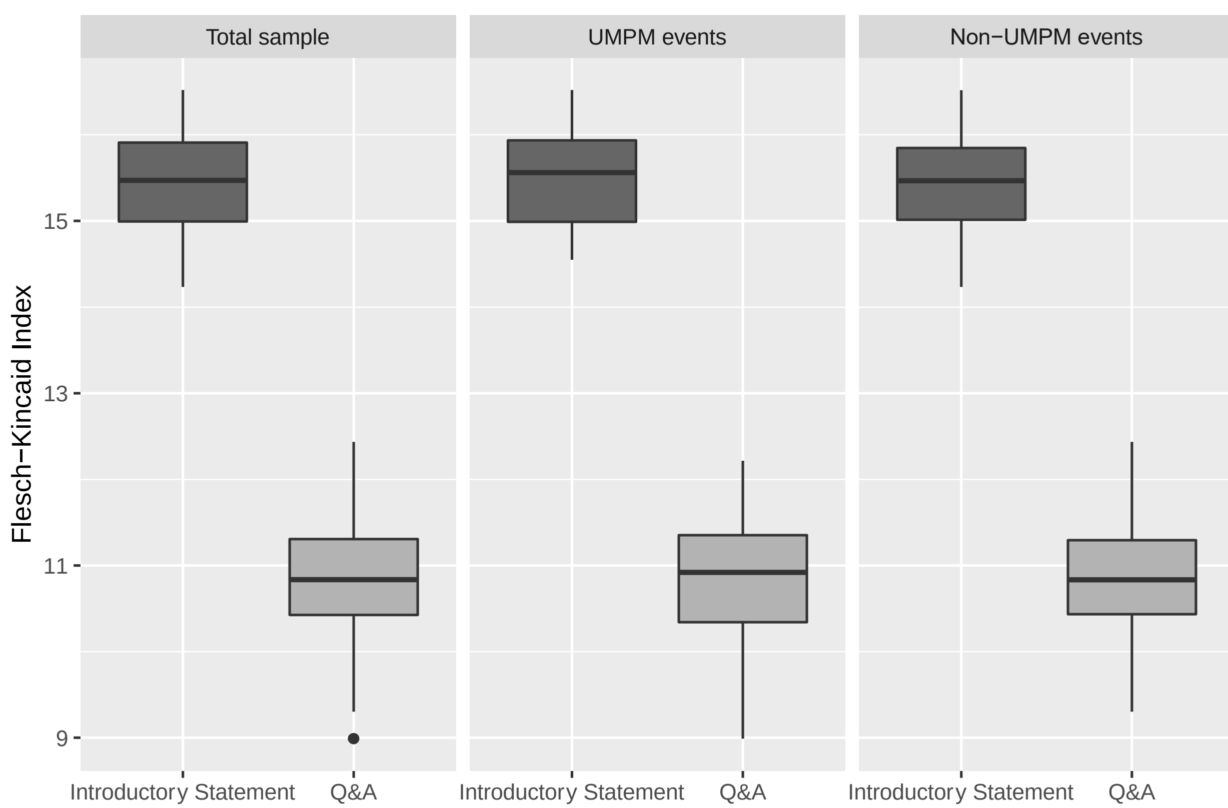
In this subsection, we provide descriptive statistics about the linguistic complexity of the introductory statements, as well as stylised facts and anecdotal evidence demonstrating the relevance of our hypotheses. Specifically, with regard to the later, we analyse (1) the trading activity around the press conferences, (2) the trading activity's temporal distribution, and (3) its relationship with respect to complexity of the introductory statements.

3.5.1 Linguistic Complexity of Introductory Statements

Calculating the Flesch-Kincaid Grade Level score for every introductory statement in our sample, we find a mean score of 15.4 with a standard deviation of 0.6. This can be roughly interpreted as 15 years of education are required to comprehend and follow an average introductory statement of the ECB. For all statements, the observed minimum and maximum values for the Flesch-Kincaid Grade Level are 14.2 and 16.5, respectively. These statistics correspond with the findings of Coenen et al. (2017) and demonstrate that the level of linguistic complexity of introductory statements is consistently high. A descriptive summary of the Flesch-Kincaid Grade Level is provided in Table A2 in the Appendix. Interestingly, we do not find a significant difference between UMPM-events (15.5) and non-UMPM events (15.4).

To illustrate the disparity in complexity between introductory statement and Q&A session, we also calculate the Flesch-Kincaid Grade Level score for the transcripts of the Q&A sessions. With an average Flesch-Kincaid Grade Level of above 15 for the introductory statement (independent of the type of event) and below 11 for the Q&A session (again, independent of the type of event), we discover a difference of more than 4 years of required education between the two forms of communication. Figure 1 shows these differences for all press conference, UMPM-events, and non-UMPM events, respectively.

Figure 1: Complexity distribution of the ECB's communication



Notes: Boxplot of Flesch-Kincaid Grade Level across introductory statements and Q&A sessions, with observed values illustrated as jitter plot. Differentiation between UMPM-events and non-UMPM events according to Table A1 in the Appendix.

We can see that in all three samples, statements are clearly more linguistically complex than Q&A sessions. Moreover, the most complex Q&A session is less complex than the least complex introductory statement. This supports our argument that communication in Q&A sessions is less formal and thus less complex, and thus may help to improve the flow of information and encourage trading.

3.5.2 Excess Trading Patterns

Next, we examine the EURO-STOXX-50 future trading activity during all GCM press conferences in our sample to understand its extent and temporal distribution. To exclude the effects stemming from common time-of-the-day patterns, we calculate *excess* trading volumes, defined as the difference between the mean trading volume per minute from all *event days* (i.e., press conference days) minus the mean volume per minute from *non-event days* (i.e., days without an ECB press conference). Figure 2 illustrates the mean excess trading volume for UMPM-events and non-UMPM events.

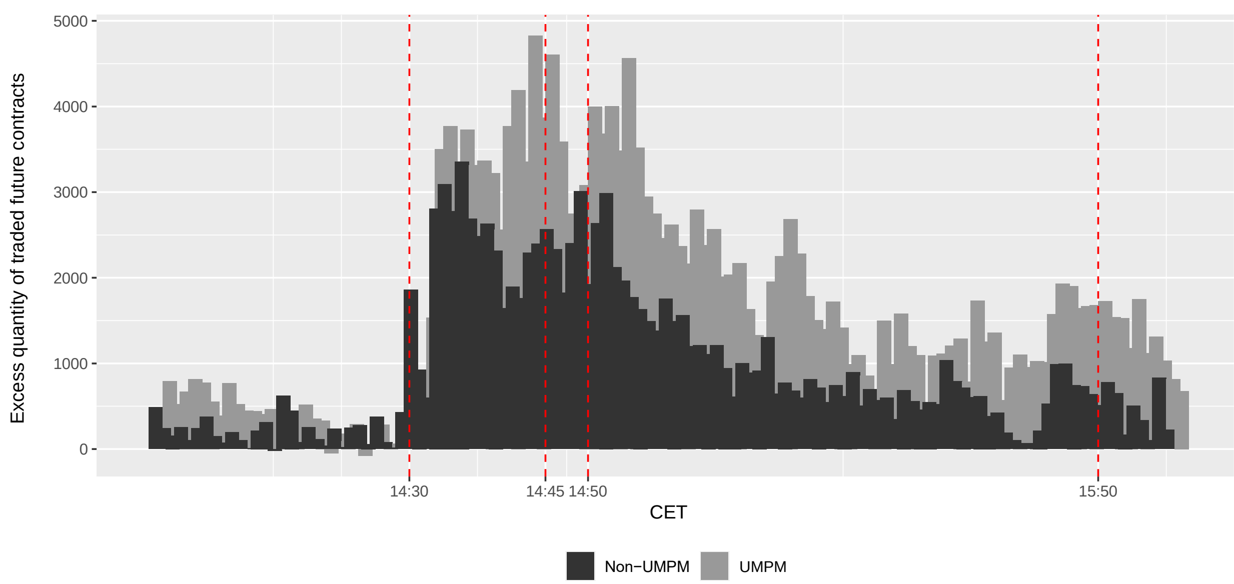
Three observations stand out. *First*, mean excess trading volume in stock index futures increases significantly a few minutes after the beginning of the GCM press conferences (14:30 CET). The pattern is consistent with previous work on the effects of ECB communication on financial markets (see, e.g., Andersson, 2010), and the view that the introductory statement conveys relevant news for financial markets.[11]

Second, following a decline at the end of the introductory statement (at around 14:45 CET), the volume rises again with the beginning of the Q&A session (at around 14:50 CET). This suggests that the Q&A session provides additional information to financial

[11] Note that these spikes in trading volumes are unlikely due to reactions to the Governing Council's interest rate decision, as the interest rate decision is communicated prior to the press conference at 13:45 CET.

market participants. From 15:00 CET onwards, trading volumes slowly decrease until the end of the Q&A session around 15:50 CET, when trading activity reverts to near normal levels.

Figure 2: Excess trading pattern



Notes: Mean excess trading volume in stock index futures during the analysed GCM press conferences. Calculation using mean excess trading volume for 1-minute intervals of the EURO-STOXX-50 Future across all GCM days between January 2007 and December 2017. Excess trading volume computed as mean EUREX trading volume across all GCM days minus mean EUREX trading volume on non-meeting days over the same period. Differentiation between UMPM-events and non-UMPM events according to Table A1 in the Appendix.

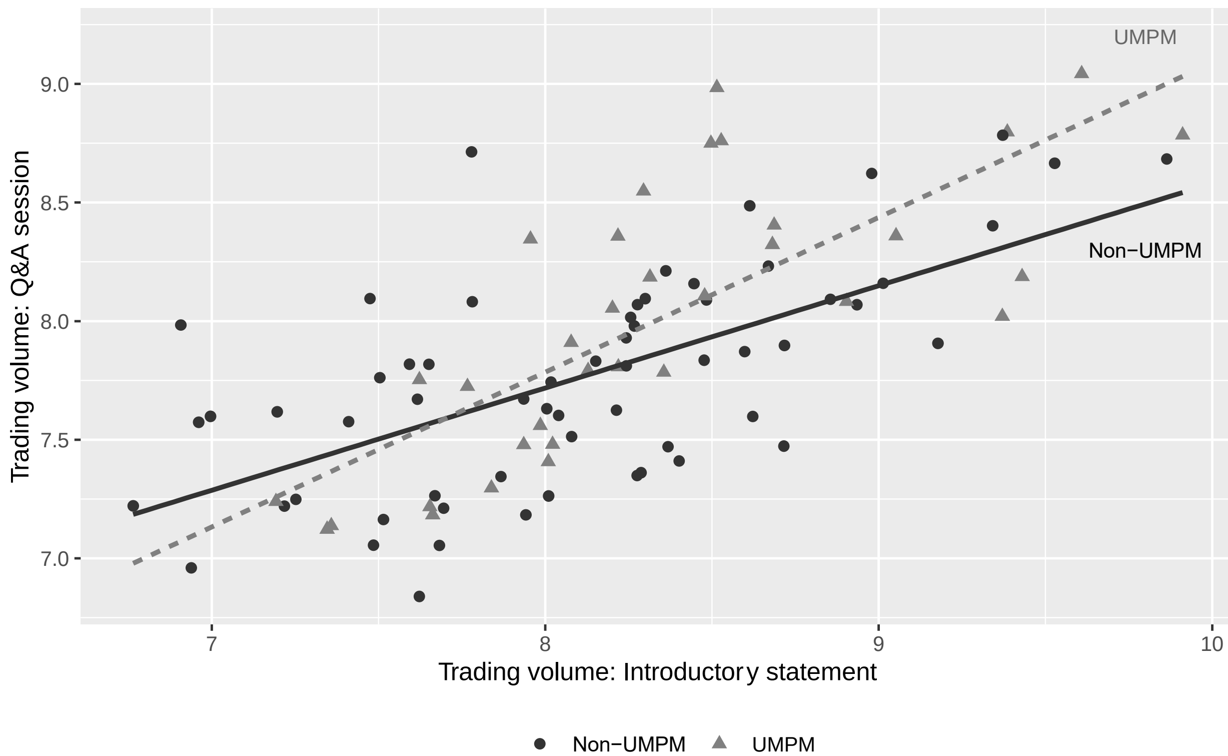
Third, Figure 2 highlights considerable differences between trading volume during UMPM-events (grey) and non-UMPM events (black). In addition, the following conclusions can be drawn: (i) trading volume tends to be higher during UMPM-events, (ii) trading peaks later during UMPM events, and (iii) during the Q&A session, excess trading volumes slow down faster for non-UMPM than for UMPM-events. This pattern is consistent with the view that financial market participants find UMPM-events relatively more difficult to understand than non-UMPM events, which is why they temporarily underreact. The hike in trading activity especially during UMPM-events suggests that the less complex Q&A session provides valuable information for market participants too.

3.5.3 Temporal Distribution of Trading Volumes

Next, we assess whether the temporal distribution of trading activity illustrated in Figure 2 is representative for all events in our sample or whether it is simply a product of aggregation over time. For each of our UMPM-events and non-UMPM events, Figure 3 plots the (logarithm of the) average trading volume during the Q&A session versus the (logarithm of the) average trading volume during the introductory statement as well as the corresponding event-specific regression lines.

Three main patterns are evident from Figure 2. *First*, there is a positive correlation between the trading volumes in the two periods. This relationship is statistically significant in both cases. *Second*, qualitatively, we find a steeper slope for the regression line representing UMPM-events, suggesting that financial markets react with delayed trading in case of UMPM events. *Third*, the quantitative relationship between trading volume during the introductory statement and during the Q&A session can vary substantially. This indicates that the relationship is not perfectly linear and, therefore, further variables appear to be relevant.

Figure 3: Temporal distribution of trading volumes



Notes: Cross-plot of trading volumes across introductory statements and Q&A sessions, with observed values and a fitted regression line. Calculated using the natural logarithm of average (mean) minute trading volume of the EURO-STOXX-50 Future on EUREX all GCM days between January 2009 and December 2017. Separation between 14:30–14:45 introductory statement and 14:50–15:50 Q&A session. Differentiation between UMPM-events and non-UMPM events according to Table A1 in the Appendix.

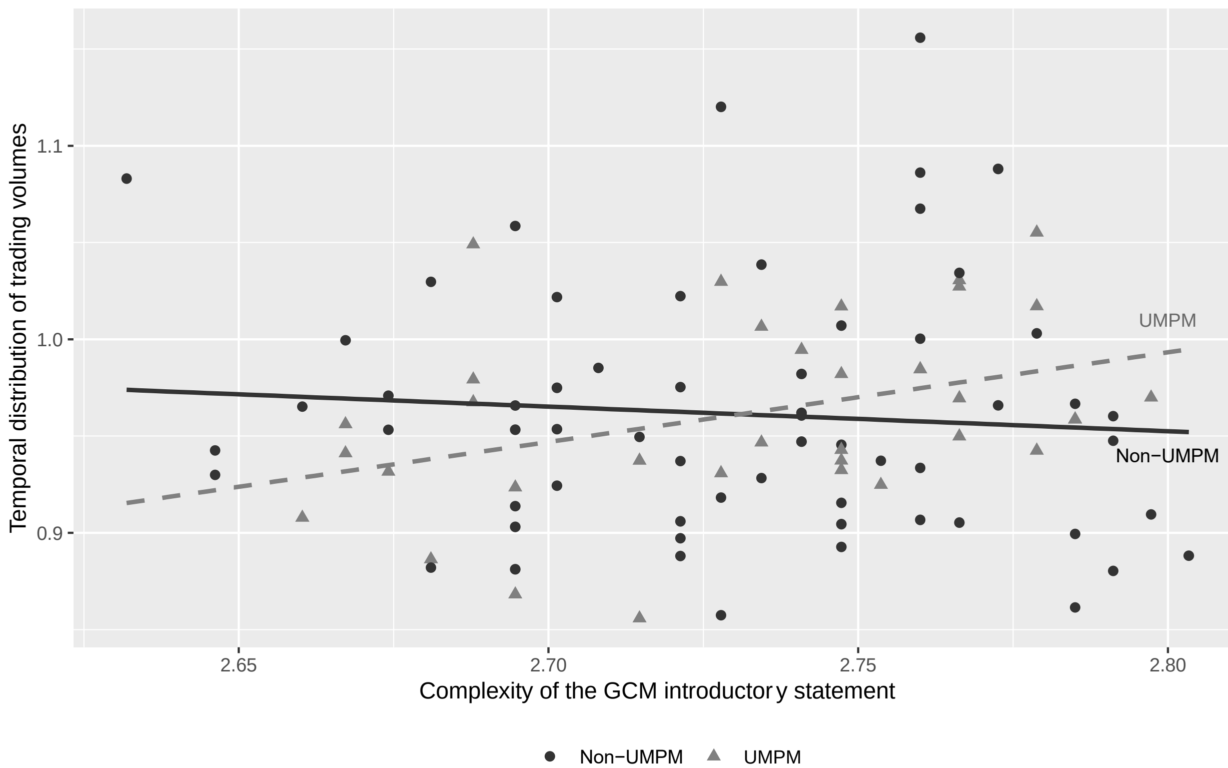
3.5.4 Trading Volumes and Complexity

Finally, we shift our focus to the ease of understanding of the transmitted information. We analyse whether there is a relationship between the temporal distribution of trading volumes and the linguistic complexity of introductory statements.

In order to capture the temporal distribution of trading volumes in a single variable, we calculate the difference of the logarithm of the average trading volume per minute during the introductory statement, $Volume_{Intro}$, to the respective value for the Q&A

session, $Volume_{Q\&A}$. Figure 4 plots this log difference against the linguistic complexity for each event.

Figure 4: Trading volumes and complexity



Notes: Temporal distribution of trading volumes and complexity. Calculation based on the ratio of average (mean) minute trading volumes of the EURO-STOXX-50 Future on EUREX over GCM days with during the 14:50–15:50 Q&A session divided by the 14:30–14:45 introductory statement, with the natural logarithm applied to the fraction. Communication complexity of GCM introductory statements is measured by the natural logarithm of the Flesch-Kincaid Grade Level. Differentiation between UMPM-events and non-UMPM events according to Table A1 in the Appendix.

For UMPM-events, the relationship between the complexity of the introductory statements and the temporal distribution of trading volumes is positive, whereas it is slightly negative for non-UMPM events. This pattern is consistent with the view of a positive association between complexity and delayed trading. In other words, we find evidence of an underreaction of the market in the case of UMPM-events.

4 Regression Analysis

4.1 Empirical Design

To formally test our hypotheses, we estimate versions of the following regression:

$$(1) \quad V_t = \alpha + \beta_1 \cdot Complexity_t + \beta_2 \cdot Complexity_t \cdot UMPM_t + \beta_3 \cdot UMPM_t + \gamma \cdot Controls_t + \varepsilon_t,$$

where V_t measures trading behaviour at the event t (i.e., the ECB press conference following the Governing Council Meetings), $Complexity_t$ the linguistic complexity of the event's introductory statement, and $UMPM_t$ the type of event. α represents a constant, $Controls_t$ a vector of control variables, and ε the error term. Table 1 provides further details of our variable definitions. The β_i's are our coefficients of interest. Specifically, arguing that UMPM-events are more complex in context and content, it is β_2, the coefficient of the interaction term, which is geared to reflect our argument that it is not only the linguistic complexity of the transcripts that matters, but also the complexity of the context and content.

We add three control variables to our regression. First, based on Kuttner (2001), we capture the surprise effect in conventional monetary policy by long-term Bond Returns. We use the log-return of the 10-year BUND future as traded on EUREX during 13:44–14:29 CET. Second, we use a Rate Change Dummy, which indicates whether the ECB announced a change in its de-posit facility rate at 13:45 CET. Third, we include ΔShadow Prime Rate, which captures monetary tightening as conveyed in the ECB's communications. In line with Hayo, Henseler, and Rapp (2019), we calculate this measure using the Wordscores approach (Laver, Benoit and Garry, 2003), calibrated by using introductory statement transcripts of GCM press conferences from 1999–2006 and corresponding changes in the deposit facility rate.

Table 1: Overview of variable definitions

Dependent variables		
V_t	$Volume_{Intro}$	ln(mean minute $volume_{14:30-14:45}$)
	$Volume_{Q\&A}$	ln(mean minute $volume_{14:50-15:50}$)
	$Volume_{Conf.}$	ln(mean minute $volume_{14:30-15:50}$)
D_t	$Volume_{Q\&A\text{-to-Intro}}$	ln((mean minute $volume_{14:50-15:50}$)/(mean minute $volume_{14:30-14:45}$))
	$Volume_{Q\&A\text{-to-Conf.}}$	ln((mean minute $volume_{14:50-15:50}$)/(mean minute $volume_{14:30-15:50}$))
Independent variables		
$Complexity_t$		Flesch-Kincaid Grade Level for GCM introductory statements, calculated as: 0.39 • WS + 11.8 • SW – 15.59 WS = Total number of words divided by total number of sentences SW = Total number of syllables divided by total number of words
Control variables		
$Controls_t$	Bond Return	ln(Price[14:29]/Price[13:44]), of EUREX traded EURO-BUND Futures
	Rate Change Dummy	Deposit facility rate change announced at 13:45 (yes=1/no=0)
	Δ Shadow Prime Rate	Calculated using *Wordscores*, calibrated based on introductory statement transcripts of GCM press conferences in 1999–2006 and corresponding changes in the deposit facility rate

Notes: A descriptive summary of all variables can be found in Table A2 in the Appendix.

4.2 Regression Analysis

To assess the first two hypotheses, we regress statement complexity on trading volume. Table 2 reports the results for two measures of trading behaviour, $Volume_{Intro}$ and $Volume_{Conf}$, *where* $Volume_{Intro}$ measures trading volume during the introductory statement and $Volume_{Conf}$ during the aggregate press conference.[12] For each of the volume measures, we estimate three specifications.

[12] We confirm the results presented here in unreported tests, where we use (i) corresponding measures of *excess* trading volume and (ii) an alternative measure for $Volume_{Intro}$, which we define as the logarithm of average trading volume defined over the period 14:35-14:45 CET aiming to get rid of potential noise trading and make sure we capture the effect of the introductory statement only.

The results can be summarised as follows. *First*, Specification (1) and (4) reveal that linguistic complexity of introductory statements is negatively (but insignificantly) correlated with contemporaneous trading activity. While this is consistent with our first hypothesis (H1), the coefficients are far from significant. Essentially, the results from these tow specifications suggest that overall for the period 2009-2017 linguistic complexity of introductory statements uncorrelated with contemporaneous trading activity, which is in contrast to the findings of Smales and Apergis (2017a, 2017b) for FOMC statements.

Table 2: Analysis of trading volume

	Dependent variable:					
	$Volume_{Intro}$			$Volume_{Conf}$		
	(1)	(2)	(3)	(4)	(5)	(6)
Complexity	-0.89	3.23	2.73	-0.67	1.92	1.46
	(1.74)	(2.00)	(1.98)	(1.34)	(1.56)	(1.51)
Complexity*UMPM		-12.42***	-9.87***		-7.90***	-5.57**
		(3.44)	(3.61)		(2.69)	(2.76)
UMPM		34.16***	27.12***		21.81***	15.35**
		(9.41)	(9.89)		(7.34)	(7.56)
Bond_Return			0.57			0.47*
			(0.35)			(0.27)
Rate_Change_Dummy			0.32			0.35**
			(0.20)			(0.15)
ΔShadow Rate			0.26			0.25*
			(0.19)			(0.14)
Constant	10.63**	-0.71	0.67	9.79***	2.63	3.89
	(4.76)	(5.47)	(5.41)	(3.67)	(4.27)	(4.14)

Observations	95	95	95	95	95	95
R^2	0.003	0.15	0.21	0.003	0.12	0.22

Notes: Coefficients are estimated using an OLS regression. Standard errors are displayed in parentheses. ***, **, * indicate significance at the 1, 5, and 10 per cent level, respectively.

Second, Specification (2) and (5) document an event-differentiated correlation of linguistic complexity with trading activity in financial markets. While the coefficient of $Complexity$ is positive (but insignificant), the coefficient of the interaction term $Complexity_t \cdot UMPM_t$ is negative and highly significant. The sum of the coefficients, i.e. $\beta_1 + \beta_2$, in Specification (2) is -9.13 (with a standard deviation of 2.47) and highly significant ($p < .01$).[13] This is not only consistent with You and Zhang (2009) and Miller (2010) who propose a negative relationship between information complexity and trading behaviour and our second hypothesis (H2), but also economically meaningful: Specifically, Specification (2) suggests that an increase in complexity by 1% is associated with a decrease in trading volume by up to 9%, or some 420 contracts per minute. Relatedly, a hike in the Flesch-Kincaid Grade Level index by one year beyond the average (i.e., from 15.4 to 16.4) is on average accompanied by a reduction in trading volumes by some 2,760 contracts per minute (about 75% of the standard deviation).

Third, Specification (3) and (6) document that these results remain intact, when we add our control variables. However, the coefficients of the interaction term decrease and thus the estimated correlation of linguistic complexity with trading activity in case of an UMPM event. Specifically, the sum of the coefficients β_1 and β_2 are -7.1 and -4.1

[13] For Specification (5) the coefficients add up to -5.98 with a standard deviation of 2.37, which is significant at the 5%-level.

in Specification (3) and Specification (6), respectively. *Finally*, looking at the coefficients β_2 and β_3 of Specification (2), we find, consistent with Figure 2, that for an UMPM-event of average $Complexity$, which is -2.7, contemporaneous trading volume is about 23% ($p < .10$) higher than for a non-UMPM event with similar $Complexity$.

In sum, the results from Table 2 are consistent with our argument that is not only the linguistic complexity of the transcripts that matters, but also the complexity of the context and content that matters and a market that underreacts to complex central bank communication.

To assess our third hypothesis, we turn to the temporal distribution of trading activity. Table 3 reports results for two measures of temporal distribution of trading activity, $Volume_{Q\&A-to-Intro}$ and $Volume_{Q\&A-to-Conf}$, which are defined as the difference between $Volume_{Q\&A}$ and $Volume_{Intro}$ and $Volume_{Q\&A}$ and $Volume_{Conf}$, respectively. Again, for each of the measures, we estimate three specifications.

The results can be summarised as follows. *First*, Specification (1) and (4) reveal that linguistic complexity of introductory statements is positively (but insignificantly) correlated with delayed trading activity. While this is consistent with our third hypothesis (H3), the coefficients are far from significant.

Second, again we find an event-differentiated correlation of linguistic complexity with trading activity in financial markets.[14] While in Specification (2) and (5) the coefficient

[14] We confirm the results presented here in unreported tests, where we also control for the complexity of Q&A statements and allow the complexity of Q&A statements to interact with $UMPM$.

of $Complexity$ is negative (but insignificant), the coefficient of the interaction term $Complexity_t \cdot UMPM_t$ is positive and significant. The sum of the coefficients, i.e. $\beta_1 + \beta_2$, in Specification (2) is 4.6 (with a standard deviation of 1.8) and significant ($p < .05$).[15] *Third*, Specification (3) and (6) document that these results remain intact, when we add our control variables. However, the coefficients of the interaction term are slightly lower. *Finally*, looking at the coefficients β_2 and β_3 of Specification (2), we find no significant difference between UMPM-events and non-UMPM events for average $Complexity$ ($p > .30$).

Table 3: Analysis of the temporal distribution of trading volume

	Dependent variable:					
	$Volume_{Q\&A\text{-}to\text{-}Intro}$			$Volume_{Q\&A\text{-}to\text{-}Conf.}$		
	(1)	(2)	(3)	(4)	(5)	(6)
Complexity	0.56	-1.49	-1.44	0.35	-0.18	-0.18
	(1.26)	(1.53)	(1.56)	(0.34)	(0.42)	(0.43)
Complexity*UMPM		6.05**	5.80**		1.53**	1.49*
		(2.63)	(2.85)		(0.71)	(0.78)
UMPM		-16.52**	-15.82**		-4.16**	-4.05*
		(7.17)	(7.80)		(1.95)	(2.12)
Bond_Return			-0.09			0.01
			(0.28)			(0.08)
Rate_Change_Dummy			0.02			-0.001
			(0.16)			(0.04)
ΔShadow Rate			-0.01			-0.01
			(0.15)			(0.04)
Constant	-1.88	3.72	3.59	-1.04	0.39	0.37

[15] For Specification (5) the coefficients add up to 1.35 with a standard deviation of 0.52, which again is significant at the 5%-level.

	(3.45)	(4.17)	(4.27)	(0.94)	(1.13)	(1.16)
Observations	95	95	95	95	95	95
R^2	0.002	0.06	0.06	0.01	0.06	0.06

Notes: Coefficients are estimated using an OLS regression. Standard errors are displayed in parentheses. ***, **, * indicate significance at the 1, 5, and 10 per cent level, respectively.

In sum, the results from Table 3 again are consistent with our argument that markets underreact to complex central bank communication and delay trading. Moreover, the results suggest that trading is not uniformly delayed, but – for UMPM events – gains momentum with the beginning of the Q&A session, which supports our third hypothesis (H3).

4.3 Additional Analysis

In this section, we aim to shed some light on the difference between UMPM-events and non-UMPM events. Therefore, we investigate whether UMPM-announcements contain more novel information than standard announcements, i.e. whether they are more 'unconventional'. Specifically, we employ Amaya and Filbien's (2015) similarity index to assess the degree of homogeneity between different statements.

To calculate the index, we (i) remove all numbers, dates, and stop words, and (ii) construct word bi-grams (two-word combinations) in order to capture combined expressions, for example, 'quantitative easing'. We calculate the cosine similarity of two subsequent introductory statements for all events in our sample, as follows:

$$Similarity_t = \frac{\sum_{b=1}^{B} \mathrm{fr}_{b,t} \cdot \mathrm{fr}_{b,t-1}}{\sqrt{\sum_{b=1}^{B} \mathrm{fr}_{b,t}^2} \cdot \sqrt{\sum_{b=1}^{B} \mathrm{fr}_{b,t-1}^2}},$$

where B represents the total number of unique bi-grams in all press releases and $fr_{b,t}$ and $fr_{b,t-1}$ are the frequencies of bi-gram b in press releases t and $t-1$, respectively.

To illustrate the idea of our similarity measure, consider the following two sentences: *'The Governing Council expects the euro area economy to grow at a moderate pace in 2010'* and *'We expect price stability to be maintained over the medium term, thereby supporting the purchasing power of euro area households'* from two intro-*ductory statements from 2010. They* contain one shared bigram (euro_area) and 34 unique bigrams (the_governing, governing_council, council_expects, …). The similarity index value of those two sentences is $\frac{1}{35} = 0.03$. Comparing longer texts tends to increase the value of the index, as the probability of recurring bigrams rises. In our sample, the similarity index has an average score of 0.44, indicating that 44% of all bigrams in an introductory statement occurred in the previous one too.

To assess whether UMPM announcements differ from non-UMPM announcements, we run the following regression:

$$(2) \quad Similarity(t\ and\ t-1)_t = \alpha + \beta \cdot UMPM_t + \gamma \cdot Similarity(t\ and\ t-2)_t + \varepsilon_t,$$

Note that Amaya and Filbien (2015) find that ECB introductory statements become more similar over time. To capture this development, we include a delayed sentiment index as a regressor. It is based on comparing the content of the current statement with the text of the statement in t-2. The Durbin-Watson Test supports our choice of the delayed sentiment term.

Table 4 reports the estimation results. The UMPM-Dummy is statistically significant and economically relevant. Statements with UMPM announcements are 3% less similar to the previous period statements than statements without UMPM announcements. Given an average of 1420 bigrams, this increases the number of unique bigrams by 45. Since UMPM announcements do not significantly differ in length from other announcements, they appear to contain more 'novel' information. Arguably, it is this new information that drives the previous results. That is, through the deviation from 'standard' announcements, complexity increases traders' cognitive costs, which causes them to postpone their trading decisions to the 'easier' Q&A session. These findings do not change when controlling for the previous event type (i.e. using a lagged UMPM-Dummy and interaction terms).[16]

Table 4: Similarity analysis

	Dependent variable:
	Similarity(t and t-1)
UMPM-Dummy	-0.03**
	(0.01)
Similarity(t and t-2)	0.87***
	(0.07)
Constant	0.14***
	(0.02)
Observations	96
R^2	0.66

Notes: Coefficients are estimated using an OLS regression. Standard errors are displayed in parentheses. ***, **, * indicate significance at the 1, 5, and 10 per cent level, respectively.

[16] All omitted results here and elsewhere in the paper are available on request.

In a next step, we analyse the similarity between introductory statement and Q&A session. First, there is a remarkably strong similarity between the two institutionalised forms of communication. Given that Figure 1 suggests considerable differences in linguistic structure, an average similarity index of about 0.2 provides empirical evidence that the substance of the Q&A session is close to the preceding introductory statement. Second, the degree of similarity between introductory statement and Q&A session does not differ during UMPM-events, which suggests that traders can generally rely on Q&A questions to clarify the more complex content of the introductory statement.

These findings complement our previous results, namely (1) linguistic complexity of Q&A sessions is lower than that of introductory statements, (2) for UMPM-events with high linguistic complexity trading is delayed to Q&A sessions, and (3) the similarity between subsequent press conferences is lower for UMPM-events. Thus, we discover empirical evidence supporting the following transmission process from statement complexity to financial market trading behaviour: Traders realise that introductory statements referring to UMPM's are complex and contain relatively more novel information. While this causes traders to underreact to the new information, the discussion and clarification of the cognitively costly content during the subsequent Q&A session mitigates this effect. An outcome of this process is that parts of the trading shifts from the statement phase to the Q&A phase of the ECB’s press conference.

5 Robustness of Results

As robustness tests, we (1) increase the time horizon, (2) address the concept of vagueness in our complexity metric, (3) consider alternative measures for the latent variable of complexity, and (4) determine complexity via factor analyses based on multiple complexity measures as well as further communication-related measures.

5.1 Time Horizon

To incorporate events prior to the period of the effective lower bound, we increase the observation period to January 2003 until December 2017. This extension roughly doubles the number of observations to around 163 press conferences. The estimation results for extending the sample are presented in Table 5 and demonstrate that our previous findings are robust. In addition to the earlier results and similar to the results of Smales and Apergis (2017a, 2017b) for the FOMC, for non-UMPM-events the relationship between complexity and trading volume is now statistically significant.

Table 5: Robustness check - Time horizon

	Dependent variables			
	$Volume_{Intro}$	$Volume_{Conf}$	$Volume_{Q\&A\text{-}to\text{-}Intro}$	$Volume_{Q\&A\text{-}to\text{-}Conf.}$
	H2		H3	
	(1)	(2)	(3)	(4)
Complexity	4.39***	3.16***	-1.72**	-0.49**
	(1.11)	(0.92)	(0.76)	(0.21)
Complexity*UMPM	-13.35***	-9.17***	5.99**	1.82***
	(3.58)	(2.96)	(2.44)	(0.68)
UMPM	37.14***	25.67***	-16.44**	-4.96***

	(9.79)	(8.09)	(6.68)	(1.86)
Bond_Return	0.53	0.35	-0.21	-0.03
	(0.34)	(0.28)	(0.23)	(0.06)
Rate_Change	0.21	0.26*	0.06	0.02
	(0.17)	(0.14)	(0.11)	(0.03)
ΔShadow Rate	-0.14	-0.13	0.01	0.01
	(0.19)	(0.16)	(0.13)	(0.04)
Constant	-4.32	-1.16	4.41**	1.25**
	(3.02)	(2.50)	(2.06)	(0.57)
Observations	163	163	163	163
R^2	0.24	0.24	0.07	0.06

Notes: Coefficients are estimated using an OLS regression. Standard errors are displayed in parentheses. ***, **, * indicate significance at the 1, 5, and 10 per cent level, respectively.

5.2 Complexity or Vague Talk

Next, we examine the possibility that the Flesch-Kincaid Grade Level metric may better be interpreted as an indicator for vagueness rather than complexity. We argue that complexity is a proxy for the cognitive cost of comprehending the content. However, vagueness also generates information that is difficult to follow, but originates from a lack of clarity. The Flesch-Kincaid Grade Level index consists of two components, the average length of a sentence (WS) and the average word length (SW):

$$FK_i = 0.39\underbrace{\frac{total\ words_i}{total\ sentence_i}}_{WS} + 11.8\underbrace{\frac{total\ syllables_i}{total\ words_i}}_{SW} - 15.59,$$

Longer sentences, i.e. higher WS, may be associated with both, more complexity and more vagueness, whereas the use of longer words, i.e. higher SW, should only affect comprehensibility. In other words, SW measures complexity but not vagueness, whereas WS is a representation of complexity and vagueness.

Disaggregating the Flesch-Kincaid Grade Level into these two components, we discover that the correlation between SW and the complete index is almost 90%, compared to around 10% for WS. Furthermore, if we include SW and WS in our regression model (see Table 6), we find that SW (i.e. 'complexity') appears to drive our results rather than WS ('vagueness'). Qualitatively, this conclusion holds for both hypotheses but only the estimates for H2 are statistically significant.

Table 6: Robustness check – Vague talk

	Dependent variable:							
	$Volume_{Intro}$		$Volume_{Conf}$		$Volume_{Q\&A\text{-}to\text{-}Intro}$		$Volume_{Q\&A\text{-}to\text{-}Conf.}$	
	H2				H3			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SW	1.76		1.49		-0.26		0.003	
	(1.39)		(1.04)		(1.09)		(0.30)	
WS		-3.48		-6.07		-2.59		0.001
		(6.81)		(5.08)		(5.31)		(1.44)
SW*UMPM	-5.71**		-3.90**		2.44		0.62	
	(2.59)		(1.95)		(2.04)		(0.56)	
WS*UMPM		-15.08		-7.51		11.30		3.74
		(14.47)		(10.80)		(11.29)		(3.06)
UMPM	18.47**	9.01	12.64**	4.51	-7.80	-6.68	-1.96	-2.18
	(8.34)	(8.61)	(6.28)	(6.42)	(6.57)	(6.72)	(1.79)	(1.82)
ΔShadow Rate	0.29	0.30	0.26*	0.23	-0.06	-0.08	-0.03	-0.02
	(0.19)	(0.20)	(0.14)	(0.15)	(0.15)	(0.16)	(0.04)	(0.04)
Bond_Return	0.71**	0.65*	0.55**	0.52*	-0.18	-0.13	-0.02	0.004
	(0.35)	(0.37)	(0.26)	(0.28)	(0.28)	(0.29)	(0.08)	(0.08)
Rate_Change_Dummy	0.34*	0.31	0.36**	0.35**	0.01	0.06	-0.005	0.01
	(0.20)	(0.21)	(0.15)	(0.16)	(0.16)	(0.16)	(0.04)	(0.04)
Constant	2.52	10.22**	3.12	11.53***	0.48	1.20	-0.12	-0.11
	(4.42)	(4.11)	(3.33)	(3.06)	(3.49)	(3.20)	(0.95)	(0.87)
Observations	95	95	95	95	95	95	95	95
R^2	0.18	0.16	0.22	0.21	0.03	0.02	0.04	0.04

Notes: Coefficients are estimated using an OLS regression. Standard errors are displayed in parentheses. ***, **, * indicate significance at the 1, 5, and 10 per cent level, respectively.

5.3 *Alternative Measures of Complexity*

Our operationalisation of the latent complexity variable in the form of the Flesch-Kincaid Grade Level follows Smales and Apergis (2017a, 2017b). To demonstrate that our results do not depend on this choice, we employ a variety of alternatives. The most common measures for linguistic complexity are the Flesch Reading Ease (Flesch, 1948), the Gunning Fog Index (Gunning, 1952), the SMOG Index (McLaughlin, 1969), the Coleman-Liau Index (Coleman and Liau, 1975), and the Automated Readability Index (Senter and Smith, 1967). Table 7 sets out the respective definitions.

Table 7: Definitions of Alternative Complexity Measures

Complexity measures	
Flesch Reading Ease (inverted)	$1/(206.835 - 1.015 \cdot \mathrm{WS} - 84.6 \cdot \mathrm{SW})$ WS = #words divided by #sentences; SW = #syllables divided by #words
Gunning Fog Index	$0.4 \cdot \mathrm{WS} + 40 \cdot \mathrm{CWW}$ WS = #words divided by #sentences; CWW = #complex words divided by #words
SMOG Index	$1.0430 \cdot \sqrt{\mathrm{PS} \cdot (30/S)} + 3.1291$ PS = #polysyllables (3 or more syllables); S = #sentences
Coleman-Liau Index	$5.88 * \mathrm{AL} + (0.296 * \mathrm{Nst} / \mathrm{Nw}) - 15.8$ AL = Average #letters per 100 words; AS = Average #sentences per 100 words
Automated Readability Index	$4.71 \cdot (\mathrm{C/W}) + 0.5 \cdot (\mathrm{W/S}) - 21.43$ C = #characters; W = #words; S = #sentences

Notes: We use the inverse of the Flesch Reading Ease, so as to ensure that for all indicators larger values represent a higher degree of complexity.

Table 8 reports the estimated coefficients for Equation (1) for the various complexity measures indicators. We include all control variables, but only report the coefficients for the interaction term between UCPM and the respective complexity measurement.

Regardless of the underlying complexity definition, the coefficients have the expected sign and most of them are significant at the 10% level or below. Thus, we conclude that our results are generally robust with regard to the definition of complexity.

Table 8: Coefficients for alternative measures of complexity

Specification	H2 $Volume_{Intro}$	H3 $Volume_{Q\&A\text{-}to\text{-}Intro}$
Flesch Kincaid Grade Level	-12.09***	5.42*
	(3.91)	(3.06)
Flesch Reading Ease	-5.83***	3.00*
	(2.04)	(1.59)
Gunning Fog Index	-12.69***	6.32*
	(4.23)	(3.29)
SMOG Index	-15.67***	7.73*
	(5.21)	(4.06)
Coleman-Liau Index	-7.65	1.37
	(5.66)	(4.33)
Automated Readability Index	-10.36***	3.69
	(3.23)	(2.54)

Note: Coefficients are estimated using an OLS regression. Standard errors are displayed in parentheses. ***, **, * indicate significance at the 1, 5, and 10 per cent level, respectively. All control variables are included (see Table 1).

Complexity Approximated via Factor Analyses

Since all indicators in the previous section are supposed to measure the same latent variable, it is appropriate to approximate complexity using factor analysis. We employ two sets of underlying variables. In a first step, we conduct a factor analysis using the six complexity measures discussed above and find two common factors (Eigenvalue > 1). In a second step, we conduct another factor analysis containing an additional set of variables quantifying communication. An overview of these additional variables is provided in Table 9. Combining the six complexity indicators with the seven additional variables, we find three common factors (Eigenvalues > 1). The six complexity indicators primarily load on the first factor. The communication indicators Future, Positive/Negative and Active/Passive mainly load on the second factor, while the remaining ones tend to load on the last factor.

Table 9: Additional Variables for Quantifying Communication - Related Aspects

Communication measures	
Future-Orientation	% future verbs
Uncertainty	% uncertainty verbs
Active/Passive	(% active verbs - % passive verbs)+1
Overstated/Understated	(% overstated verbs - % understated verbs)+1
Positive/Negative	(% positive verbs - % negative verbs)+1
Positive/Negative	(% positive verbs - % negative verbs)+1 [Loughran-McDonald definition]
Strong/Weak	(% strong verbs - % weak verbs)+1

We use both factors from the first factor analysis and the three factors from the second factor analysis to re-estimate Equation (1), with V_t defined as $Volume_{Intro}$ and $Volume_{Q\&A\text{-}to\text{-}Conf}$. The results are reported in Table 10.

Consistent with our previous results in Tables 2 and 3, the factor capturing complexity has a significantly negative coefficient for H2 and a significantly positive one for H3. In contrast, the two other factors reflecting the additional communication-related aspects are insignificant. We therefore conclude that our findings are also robust to complexity approximated via a factor analysis as well as with regard to other aspects of communication.

Table 10: Coefficients for complexity measures based on factor analysis

Panel A: Factor Analysis (Complexity Measures)		
Specification	H2 $Volume_{Intro}$	H3 $Volume_{Q\&A\text{-}to\text{-}Conf}$
Factor 1*UMPM-Dummy	-0.42***	0.06*
	(0.15)	(0.03)
Factor 2*UMPM-Dummy	-0.26	0.05
	(0.19)	(0.04)
Observations	91	91
R^2	0.21	0.08

Panel B: Factor Analysis: Complexity + Add. Measures)		
Specification	H2	H3
Factor 1*UMPM-Dummy	-0.48***	0.06*
	(0.16)	(0.03)
Factor 2*UMPM-Dummy	0.24	-0.03
	(0.15)	(0.03)
Factor 3*UMPM-Dummy	-0.05	0.03
	(0.16)	(0.04)
Observations	91	91
R^2	0.29	0.11

Notes: Coefficients are estimated using an OLS regression. Standard errors are displayed in parentheses. ***, **, * indicate significance at the 1, 5, and 10 per cent level, respectively. All control variables are included (see Table 1).

6 Conclusion

In this paper, we assess the effects of central bank communication complexity on trading behaviour of financial market participants. Our analysis covers the official ECB press conference following regular GCMs between January 2009 and December 2017, during which unprecedented UMPM substantially increased communication complexity. Examining the transcripts of the introductory statements and using high-frequency data on European stock index futures, we investigate whether complexity of ECB communication affects contemporaneous trading in financial markets.

Our findings can be summarised as follows. *First*, differentiating between UMPM-events and non-UMPM-events, we do not find evidence for any difference in the linguistic complexity of introductory statements. *Second*, we discover a negative relationship between ECB communication complexity and contemporaneous trading volume during events where unconventional monetary policy is discussed. This event-differentiated underreaction of the market suggests, that when the ECB shares information with financial markets, it is not only the linguistic complexity of the communication that matters, but also the complexity of the context and content. To support this view, we demonstrate that more 'novel' information is transmitted during UMPM-related press conferences than during other press conferences. These findings, which are in line with results reported by You and Zhang (2009) and Miller (2010) and consistent with the argument that investors underreact to cognitively costly/complex information (Hirshleifer, 2001; Hong and Stein, 1999; McEwen and Hunton, 1999), extent the findings of Smales and Apergis (2017a, 2017b) for the Federal Reserve.

Finally, we shed some light on the question of whether the ECB's Q&A-sessions may help to mitigate the underreaction of the market. Consistent with that view, we find a positive relationship between the complexity of ECB communication in UMPM-events and a shift of trading activity from introductory statement to Q&A session.

Going forward, promising future research could focus on the question of what drives complexity of central bank communication and whether, in case of the ECB, a shift of trading activity to Q&A sessions can be explained by Q&A sessions effectively mitigating complexity issues. In addition, it would be interesting examine whether our findings apply to other central banks and other forms of central bank communication.

This could help to identify best practices for central banks’ communication strategies vis-à-vis financial markets.

Acknowledgments

Funding: The academic work of Kai Henseler is financially supported by a scholarship from the Konrad-Adenauer Foundation.

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Appendix

Table A1: ECB's GCM press conferences included in the sample

No.	*Date*	*UMPM disclosure (predominant)*
1	07 May 2009	Asset Purchase Programme
2	04 Jun 2009	Asset Purchase Programme
3	06 Aug 2009	Swap Agreement
4	03 Dec 2009	Forward Guidance
5	04 Mar 2010	Allotment Policy
6	10 Jun 2010	Allotment Policy
7	02 Sep 2010	Allotment Policy
8	02 Dec 2010	Allotment Policy
9	03 Mar 2011	Allotment Policy
10	09 Jun 2011	Allotment Policy
11	04 Aug 2011	Allotment Policy
12	06 Oct 2011	Asset Purchase Programme
13	03 Nov 2011	Asset Purchase Programme
14	06 Jun 2012	Allotment Policy
15	02 Aug 2012	Asset Purchase Programme
16	06 Sep 2012	Asset Purchase Programme
17	06 Dec 2012	Allotment Policy
18	02 May 2013	Allotment Policy
19	05 Jun 2014	Allotment Policy
20	03 Jul 2014	Allotment Policy
21	04 Sep 2014	Asset Purchase Programme
22	02 Oct 2014	Asset Purchase Programme
23	22 Jan 2015	Asset Purchase Programme
24	10 Mar 2016	Asset Purchase Programme
25	21 Apr 2016	Asset Purchase Programme
26	02 Jun 2016	Asset Purchase Programme
27	21 Jul 2016	Forward Guidance
28	08 Sep 2016	Forward Guidance
29	20 Oct 2016	Forward Guidance
30	08 Dec 2016	Asset Purchase Programme
31	19 Jan 2017	Asset Purchase Programme
32	09 Mar 2017	Forward Guidance
33	27 Apr 2017	Forward Guidance
34	08 Jun 2017	Forward Guidance

Notes: ECB's GCM press conferences sampled following the 2008 financial crisis, when the ECB started conducting UMPM on a recurring basis, apparent by the announcement of ECB's first covered bond purchase programme on 07 May 2009, and covering the period until June 2017. Limitation to press conferences where details on UMPM are disclosed, i.e., details on Asset Purchase Programmes, Swap Agreements, Allotment Policy, and/or Forward Guidance.

Table A2: Descriptive summary

	UMPM (n=34)				Non-UMPM (n=61)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
<u>*Complexity Measures*</u>								
Flesch.Kincaid	15.5	0.55	14.6	16.5	15.4	0.56	14.2	16.5
Flesch	28.7	1.94	25.0	32.6	27.6	1.96	21.7	31.7
FOG	19.6	0.62	18.2	20.8	19.6	0.70	18.1	21.1
SMOG	17.1	0.44	16.2	17.9	17.1	0.50	16.8	18.2
Coleman Liau	13.8	0.35	13.3	14.7	14.1	0.39	13.2	14.8
ARI	15.8	0.66	14.6	17.0	15.6	0.73	13.9	17.1
<u>*Trading Volume*</u>								
$Volume_{Intro}$	8.3	0.67	7.19	9.9	8.1	0.72	6.6	9.9
$Volume_{Conf}$	8.1	0.56	7.14	9.2	7.9	0.49	6.6	9.1
$Volume_{Q\&A\text{-}to\text{-}Intro}$	-0.33	0.43	-1.4	0.47	-0.31	0.55	-1.3	1.2
$Volume_{Q\&A\text{-}to\text{-}Conf.}$	-0.08	0.13	-0.43	0.12	-0.1	0.14	-0.41	0.17
<u>*Control Variables:*</u>								
Bond Return	-0.04	0.20	-0.54	0.46	0.95	0.01	0.19	0.50
Shadow Rate	0.19	0.43	-0.99	0.92	-0.17	0.31	-0.78	0.50
Rate Change Dummy	0.12	0.33	0	1	0.08	0.28	0	1
Similarity	0.41	0.09	0.28	0.61	0.45	0.09	0.28	0.65
<u>*Robustness Check*</u>								
WS	25.0	1.34	22.9	27.2	24.2	1.49	20.80	27.50
SW	1.81	0.02	1.77	1.87	1.83	0.022	1.79	1.89
Future-Orientation	1.18	0.32	0.53	1.87	1.15	0.31	0.49	1.70
Uncertainty	0.68	0.26	0.15	1.19	0.75	0.22	0.30	1.24
Active/Passive	1.14	0.02	1.11	1.19	1.14	0.02	1.11	1.19
Overstated/Under-stated	1.05	0.01	1.03	1.07	1.05	0.01	1.03	1.08
Positive/Negative	1.03	0.01	1.01	1.06	1.03	0.01	1.02	1.06
Positive/Negative LM	1.00	0.01	0.98	1.01	1.00	0.01	0.99	1.01
Strong/Weak	1.11	0.01	1.09	1.14	1.11	0.02	1.08	1.15

Notes: Descriptive statistics of our variables based on a total of 95 observations.