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The ECB's monetary pillar after the financial crisis

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Abstract

We apply a structural topic model (STM) to analyze European Central Bank (ECB) communication regarding the monetary pillar of its monetary policy strategy. We do so by quantifying the transcripts of the ECB Presidents introductory statements at the press conferences that accompany the regular meetings of the ECB Governing Council. Our evidence shows that, within its monetary pillar, the ECB has gradually shifted its focus away from a genuine monetary analysis towards monitoring the stability of the European financial system. We go on to augment a standard Taylor rule by quantitative indicators obtained from the STM to assess whether the monetary pillar in general, and the shift in focus in particular, has had a measurable impact on the ECBs monetary policy stance. We find weak evidence that the monetary analysis has had a bearing on the ECBs interest rate setting in the early years of the ECB's existence, but this influence completely disappears in the latter years of the sample. We also find that after the financial crisis, the monetary policy response to its financial sentiment communication has been accommodative rather than "leaning against the wind".

Keywords: ECB, monetary policy, central bank communication, topic models
JEL: C11, E52, E58

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1. Introduction

The large macroeconomic costs associated with the unwinding of financial imbalances in the aftermath of the financial crisis of 2007-08 have made financial stability issues a major concern for central banks Borio (2016). However, there is no consensus on whether a financial stability goal be explicitly incorporated into central banks' monetary policy frameworks or be addressed exclusively by macroprudential policy instruments Smets (2014). According to the traditional (or clean separation) view proposed by Bernanke and Gertler (2000) and more recently advocated in IMF (2012), monetary policy should primarily focus on the price stability goal, whereas macroprudential policy is the main tool for maintaining financial stability. In particular, macroprudential instruments such as bank capital requirements or sector-specific loan-to-value ratios may be better suited to limit distress in financial markets as these instruments are sufficiently granular and can be employed in a much more targeted way in comparison to one-size-fits-all monetary policy measures. A contrasting view originally advocated by Borio and Lowe (2002) suggests that as long as macroprudential measures cannot fully control the financial cycle, central banks should "lean against the wind" in response to the emergence of financial imbalances by explicitly taking into account financial stability concerns as a secondary objective in their monetary policy strategy. As the financial cycle has a longer duration than the business cycle, such a policy stance requires a lengthening of the policy horizon of the monetary authorities beyond the medium term usually associated with the inflation targeting strategies espoused by most leading central banks.

The two-pillar approach of the European Central Bank (ECB) in effect incorporates such a longer-run policy horizon. Whereas the first (economic) pillar contains a broad-based assessment of the outlook for future price developments, the second (monetary) pillar monitors the components and counterparts of M3 growth in terms of the availability of credit to households and firms (ECB, 2003). The stated aim of this two-pronged strategy is to capture both the short- to medium-term economic determinants of inflation risk in the economic pillar as well as the longer-run monetary drivers of inflation pressure in the monetary pillar Issing (2011)).[1] Whereas the primary objective of the ECB is to maintain price stability, it also has a contributory role in maintaining financial stability, as laid out in Article 127 of the Treaty on the Functioning of the European Union. This contribution can be exercised through the ECB's monetary policy task or its supervisory task, but it does not establish a competence for independent and stand-alone action (Mersch, 2018). In particular, it clearly falls short of a financial stability mandate on an equal footing with the primary objective of price stability (Psaroudakis, 2018). Rather, financial stability issues only enter the monetary policy arena to the extent that the two-pillar approach comprises assessments of financial market developments (Lautenschläger, 2018).

A subtle shift in the characterization of the two-pillar approach appears to have taken place in the aftermath of the financial crisis of 2007-08, when the ECB began to place a stronger emphasis on financial stability issues. In particular, the ECB adjusted its definition of the monetary pillar in the direction of a more comprehensive discussion of the availability of credit to households and firms, analyses of the funding of credit institutions, variations in the composition of their balance sheets and the size of the interbank market (ECB, 2009). Reflecting on this perceived shift in the ECB's communication, Galí (2010) even suggested at the time to rethink the monetary pillar as a financial stability pillar.

In this paper we utilize recent advances in text-mining analysis to evaluate the importance of financial stability issues in the ECB's communication regarding its two-pillar approach. In particular, we analyze whether a shift in the ECB's communication through its monetary pillar can in fact be detected in the aftermath of the financial crisis. We also investigate the extent to which

[1] Right from its inception, the two-pillar monetary policy strategy has come under intense criticism in terms of both its theoretical underpinnings as well as its empirical usefulness. The major weakness identified in the literature concerns the lack of transparency regarding the relative weights attached to the economic and monetary analysis, particularly in situations when the two pillars give conflicting signals as to the risks of inflationary pressures (Svensson, 1999; Gerlach, 2004; Woodford, 2008).

financial stability communication has affected the monetary policy actions of the ECB. A number of previous studies have used word counts and constructed wording indicators for monetary rhetoric to study the ECB's communication with the public (Gerlach, 2007; Heinemann and Ullrich, 2007; Rosa and Verga, 2007; Berger et al., 2011). However, this literature is primarily concerned with assessing the importance the ECB has assigned to the monetary analysis during the early years of its operation, with no specific focus on the role of financial stability concerns. One of the major findings in these papers is that developments in the monetary sector only played a minor role in ECB communication and did not constitute an important determinant of ECB monetary policy actions. Whereas the text analyses in these early studies were conducted manually, recent approaches apply computer-automated algorithms to assist the collection and quantification of relevant central bank communication (see, e.g., Born et al. (2014)). A small but growing literature applies probabilistic topic models to analyze monetary policy data (Bailey and Schonhardt-Bailey, 2008; Schonhardt-Bailey, 2013; Fligstein et al., 2014; Hansen and McMahon, 2016). However, none of these papers investigates ECB communication in general or the two-pillar approach in particular.

We utilize the structural topic model (STM) proposed by Roberts et al. (2016) as a recent extension to the family of probabilistic topic models to quantify the transcripts of the ECB President's introductory statements at the press conferences that accompany the regular meetings of the ECB Governing Council. The introductory statements are regarded as the ECB's most important communication device in terms of its two-pillar monetary policy approach (Weidmann, 2018). To preview our results, we not only find strong evidence for an increasing prominence of financial stability issues in the communication of the monetary pillar, but we also establish that this shift has unfolded rather gradually starting well before the onset of the financial crisis. We go on to estimate an augmented Taylor rule incorporating this information to assess whether the monetary pillar in general, and the shift in focus in particular, has had a measurable effect on the ECB's monetary policy stance. We find weak evidence that the monetary analysis has had a bearing on the ECB's interest rate setting in the early years of the ECB's existence, but this influence completely disappears in the latter years of the sample. We also find that after the financial crisis, the monetary policy response to its financial sentiment communication has been accommodative rather than "leaning against the wind".

The remainder of the paper is structured as follows: Section 2 describes the structural topic model and the data set used, Section 3 uses the model to quantify the ECB's communication in terms of its two-pillar approach, Section 4 reports on Taylor rule estimates incorporating the quantitative indicators obtained from the STM, and Section 5 concludes.

2. Probabilistic model and data

2.1. The structural topic model

In order to analyze which policy stance the ECB takes in its policy communication, we begin by quantifying the transcripts of relevant public statements. We do so by resorting to the structural topic model (STM) proposed by Roberts et al. (2016). This model is a recent extension to the family of probabilistic topic models (e.g., Latent Dirichlet Allocation (LDA) by Blei et al. (2003) or the Correlated Topic Model (CTM) by Blei and Lafferty (2007)), which have proven highly effective in the automated analysis of text data. Topic models are unsupervised machine-learning algorithms that automatically classify texts within big collections of documents. This is achieved by revealing the hidden topics that run through the collection of texts and then computing the proportion for each topic within the documents (Blei, 2012).

The underlying principle of all topic models is the assumption that documents arise from a stochastic process. The outcome of this document-generating process is a collection of documents, indexed by $d \in \{1, \ldots, D\}$ and consisting of $n \in \{1, \ldots, N_d\}$ words ($\boldsymbol{w}_{d,n}$). Within a document, each word is *assigned* to one of K topics ($\boldsymbol{\beta}_k$). This word-topic assignment is denoted by $\boldsymbol{z}_{d,n}$. A topic itself is a distribution over a fixed vocabulary, indexed $\{1, \ldots, V\}$. By construction, documents contain all K topics but differ in the proportions for each topic ($\boldsymbol{\theta}_d$) (see, e.g., Blei et al., 2003, Blei and Lafferty, 2007; Blei, 2012).

The novelty of the STM is that the inference of topics ($\boldsymbol{\beta}_k$) and their proportions ($\boldsymbol{\theta}_d$) within each document is not only based on word counts and co-occurrences over these documents (as is the case for LDA and CTM), but also on additional document-specific information. This document-level metadata comprises observable covariates that add explanatory power to documents' content and thereby improve the classification of texts (Roberts et al., 2016).

The STM explicitly incorporates such document-level metadata, allowing the document-topic proportions ($\boldsymbol{\theta}_d$) or the observed words ($\boldsymbol{w}$) to vary with document-specific information rather than just corpus-wide information. Formally, the distribution over the document-topic proportions is referred to as topical *prevalence* prior and the topic-specific distribution over words as the *content* prior (Roberts et al., 2016).

To lend some intuition to the two document-level priors, consider a binary document-level covariate that indicates whether a monetary policy decision was communicated by a hawkish or a dovish central bank official. Knowing that the central banker is a hawk, we would expect her to emphasize the importance of price stability. If the central banker is known to be dovish, we would conceive her to talk more of monetary stimuli. Thus, the prior information on a speaker's hawkish-dovish attitude adds explanatory power to the *prevalence* of certain topics (*price stability* vs. *unemployment*) in her speeches. In addition, the same hawkish-dovish covariate may inform on a different use of words *within* the same topic. When talking about the topic *recession* and how monetary policy should react in such a state of the economy, a hawk will emphasize the risk of deflation, whereas a dove may advocate measures to fight rising unemployment. In this case, the document-level information explains differences with regards to the *content* or framing within the same topic.

The complete STM model consists of three building blocks. (1) The *language model* forms the core of the model, which governs the per-word topic assignments within documents. The two additional components are (2) the *topic* *prevalence model*, which conditions document-topic proportions on a matrix of observed document-level covariates ($\mathbf{X}$), as well as (3) the *topical content model*, which bases the topic-word distribution on a matrix of observed document-level covariates ($\mathbf{Y}$). Building blocks (2) and (3) are optional components of the STM model, which the researcher may choose to include in the analysis of texts depending on the specific research question.[2]

For our analysis, we apply a STM consisting of components (1) and (2) as we ask how the prevalence of monetary pillar topics have changed with the occurrence of the financial crisis of 2008/09. To give a schematic illustration of the STM as we apply it, Figure 1 depicts the assumed data-generating process as graphical model. In this representation, white nodes denote *latent* random variables, and shaded nodes represent the *observable* variables. Accordingly, only the documents' words ($\boldsymbol{w}_{d,n}$) and the provided document-level covariates ($\mathbf{X}$) are observable, while the topic proportions ($\boldsymbol{\theta}_d$), word assignments ($\boldsymbol{z}_{d,n}$), and topics ($\boldsymbol{\beta}_k$) comprise the latent structure that the algorithm seeks to infer. $\boldsymbol{\gamma}$ and $\boldsymbol{\Sigma}$ denote the priors for the corpus-wide topic prevalence coefficients and ξ denotes the prior for the corpus-wide topic distribution.

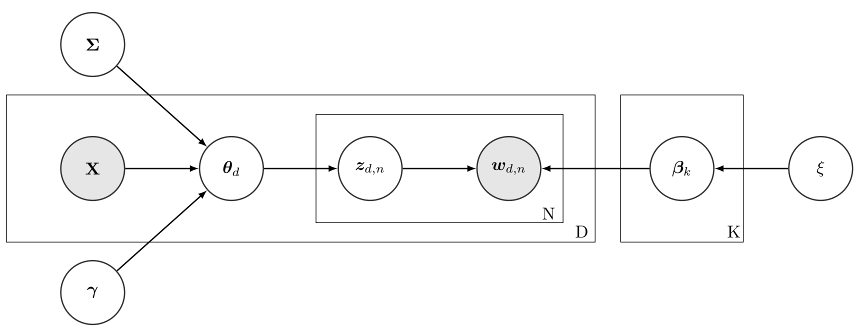

Figure 1: The graphical model represention of the STM based on Roberts et al. (2016).

To infer the latent parameters ($\boldsymbol{\theta}_d$, $\boldsymbol{z}_{d,n}$, $\boldsymbol{\beta}_k$) from observed documents and corresponding document-level data, STM reverses this generating-process, ask-

[2] In the absence of covariate matrices $\mathbf{X}$ and $\mathbf{Y}$, the STM essentially reduces to the CTM (Roberts et al., 2016).

ing which hidden structure most likely generated the observed documents (Blei, 2012). This is done via a *partially collapsed variational EM algorithm*, developed by Roberts et al. (2016), and implemented in the *stm-package* in R.[3]

2.2. Text data

We apply the STM on the ECB president's introductory statements held at the press conference that accompany the ECB's Governing Council regular meeting. The introductory statements are regarded as the ECB's most important communication device in regards to its two pillar monetary policy strategy (Weidmann, 2018). According to Berger et al. (2011), its importance stems from two traits. First, it conveys the position and views of the Governing Council to the public, agreed upon on a word-by-word basis by its members. Secondly, in comparison to the Economic Bulletin's Editorial (formerly Monthly Bulletin), it centers around the two pillars of the ECB's monetary policy strategy, i.e. the economic analysis and the monetary analysis.

As a first step, we apply an algorithm to collect all introductory statements from the ECB website's media section between May 2003 and July 2017. Together with the raw text, we also record relevant document-level metadata, such as the date and a unique ID that allow us to match further covariates to these documents for the *topic prevalence* analysis of the STM. The start of the sample period is selected to coincide with the ECB's re-evaluation of its monetary policy strategy on May 8, 2003. Whereas prior to this date, the introductory statements on the monetary pillar focused rather narrowly on measures of raw M3 growth, the ECB has since broadened its monetary analysis to include the components and counterparts of M3 growth in terms of loans to the private sector as well as measures of excess liquidity (ECB, 2003).

In our approach to reveal the latent topics that run through the introductory statements, we follow Hansen and McMahon (2016) and treat the individual sentences within the monetary and economic pillars as the unit of observation.

[3]For a more technical description of the STM model, see the Appendix A.1

This procedure is owed to the homogeneous content of our corpus. As all introductory statements contain paragraphs for the economic analysis and the monetary analysis, topics are less easily separable when performing STM on the document rather than the sentence level. While a multitude of sentences remain very similar even across the sentence-level corpus, the disaggregated view ensures sufficient heterogeneity within the corpus for the STM to reveal meaningful topics in terms of *semantic coherence* and *exclusivity* from the STM analysis.[4] This leaves us with three raw corpora based on the introductory statements on sentence level: (i) monetary analysis, (ii) economic analysis, and (iii) combined analysis.

On all three corpora we perform pre-processing routines, standard in computational linguistics. This includes the conversion of all words to lower letters, the stemming of words, the removal of punctuation, hyphens, separators, Unicode symbols, URLs, Twitter tags and characters that consist of numbers only. We also remove common stopwords, which add no topical meaning to texts (i.e., articles, conjunctions or common functional words such as *the*, *also*, or *because*).[5]

Table 1 contains summary statistics for the raw and prepared corpora. The combined pillars comprise 5,008 sentences over a collection of 157 introductory statements between 2003:05 and 2017:07. This amounts to a total of 135,896 words in the unprocessed combined corpus. The pre-processing reduces the complexity of the corpus in terms of its word count by roughly half. The mean word count per unprocessed document is 433, when combining the economic and monetary analyses. Viewed separately, the economic analysis is on average more elaborate than the monetary analysis, with 574 words per documents to 291 words per document, respectively.

[4] See Roberts et al. (2016) and Roberts et al. (2018) for a discussion of these two criteria in the context of topic interpretation and readability.

[5] The pre-processing was conducted using established routines from the R package *quanteda* by Benoit (2018).

Table 1: Descriptive statistics for the introductory statements corpora

	Economic and monetary analysis sentences				
	Sample	*No. documents (No. sentences)*	*Total words in corpus*	*Mean per document*	*Std.Dev. per document*
Raw	2003:05 – 2017:07	157 (5,008)	135,896	433	193
Prepared	2003:05 – 2017:07	157 (5,008)	65,140	207	90
	Economic analysis sentences				
	Sample	*No. documents (No. sentences)*	*Total words in corpus*	*Mean per document*	*Std.Dev. per document*
Raw	2003:05 – 2017:07	157 (3,402)	90,132	574	156
Prepared	2003:05 – 2017:07	157 (3,402)	42,880	273	72
	Monetary analysis sentences				
	Sample	*No. documents (No. sentences)*	*Total words in corpus*	*Mean per document*	*Std.Dev. per document*
Raw	2003:05 – 2017:07	157 (1,606)	45,764	291	102
Prepared	2003:05 – 2017:07	157 (1,606)	22,260	142	50

The number of unique words is $1,246$ in the pre-processed combined corpus (economic and monetary analysis), $1,004$ for the economic analysis sentences, and 839 for the monetary analysis sentences.

2.3. Choosing the number of topics

Before we can run a STM on our corpus and assess how the salience of certain topics has changed over time, we have to first provide the algorithm with a choice for K, i.e. the number of topics that STM shall reveal. As a general guideline, Roberts et al. (2018) suggest to choose K as a function of the number of documents in the corpus and conditional on the subject matter, with $K \in \{1, \ldots, 10\}$ for very short and specific corpora, and $K \in \{5, \ldots, 50\}$ for small to medium sized corpora (i.e. a few hundred documents).

Clearly, these suggestions for the appropriate choice for K can only serve as starting point for a decision that is more tailor-made for the specific corpus and research question at hand. Following Roberts et al. (2018) we base our choice for K on an evaluation of properties of the topic-word distributions. In other words, the choice for K has to result in semantically interpretable topics. Earlier research by Mimno et al. (2011) and Bischof and Airoldi (2012) suggests that topics tend to be semantically interpretable if they optimize the trade-off between *semantic cohesion* and *exclusivity*. Semantic cohesion describes the concept that the top words under a topic tend to co-occur in the same documents. Exclusivity of a topic is achieved if words with high probability under a certain topic have low probability under other topics. It was shown that models with an optimal semantic coherence-exclusivity trade-off correspond to topic evaluations by human experts in the subject matter (Roberts et al., 2018).

For our purpose we estimate models along the sequence $K = 4, \dots, 50$ and plot the computed values for exclusivity against the values for semantic cohesion. The result is depicted in Figure 2. The optimal K is identified along the semantic coherence-exclusivity "frontier" and cross-checked with the rules-of-thumb for approproate numbers of K provided by Roberts et al. (2018). This leaves us with a choice of $K = 12$ for the combined corpus of monetary and economic analysis sentences.[6]

3. Quantifying the ECB's introductory statements

3.1. STM model specification

As described earlier, the novel feature that separates the STM from other topic models is that it allows for the inclusion of document-specific covariates. Not only does the inclusion of additional information increase the prediction accuracy and interpretability of topics, but it enables to analyze the prevalence of topics conditional on the provided covariates (Roberts et al., 2016).

In our case, we add covariates according to theory-driven assumptions and prior knowledge of the ECB's introductory statements. First, we add a binary variable that denotes whether a sentence is part of the economic or the monetary pillar (see Section 2.2). As we will see below, this not only facilitates the interpretation of topics, but also validates the topic predictions from the STM

[6] Roberts et al. (2018) emphasize that the choice of K should not be based solely on this quantitative measure, but be accompanied by human judgment. Following this advice and having our relatively small and homogenous corpus in mind, we chose $K = 12$ over models with higher K (e.g., $K = 20$) that also lie close to the semantic coherence-exclusivity "frontier".

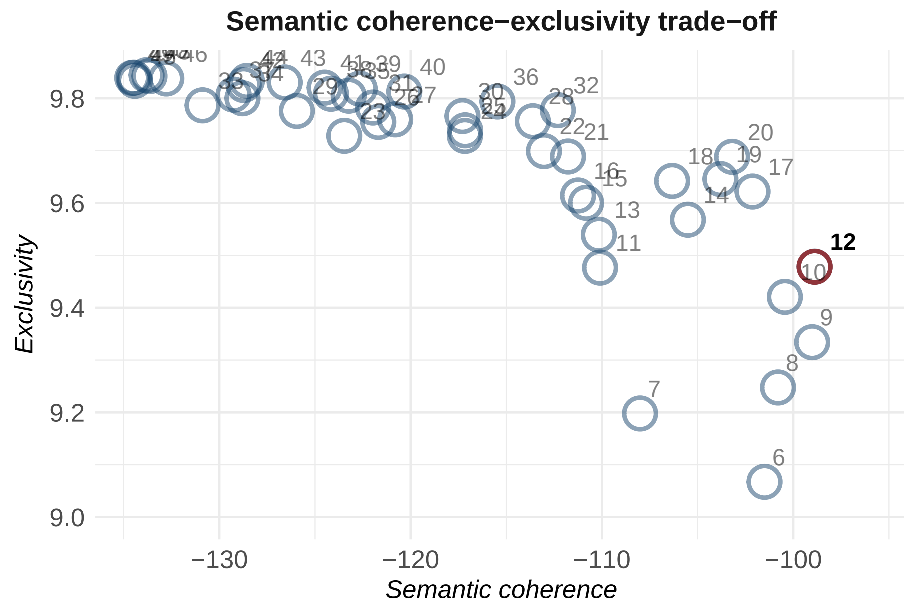

Figure 2: Trade-off between exclusivity and semantic cohesion evaluated along the sequence of models with $K = 4, \ldots, 50$. The choice for K falls on the model which is not strictly dominated by others in terms of exclusvity and semantic coherence (Roberts et al., 2018).

model. Second, we construct a dummy variable that takes the value 0 for all introductory statements held before the ECB's Monthly Bulletin 11/2009 and 1 for all documents thereafter. This reflects statements from the ECB, according to which it started making use of information from the traditional monetary analysis for financial stability assessments (ECB, 2009; Galí, 2010). Third, we follow Roberts et al. (2018) and index all documents by the number of days elapsed since the introductory statement held on May 8, 2003 (i.e. the first document in our corpus). The inclusion of this day index accounts for the possibility that some topics may go out of fashion while others start trending over the course of time. Finally, we include an interaction term of the day index and the monetary strategy dummy to account for the realistic assumption that topic prevalence neither shifted over night in November 2009, nor evolved gradually over time. Rather, there may have been a trigger in late 2009 that then changed the dynamics of the topic prevalence.[7]

We estimate $K = 12$ topics from the combined pillars of the introductory statements between 2003:05 and 2017:07 using a structural topic model with the four described covariates as prevalence priors. This is done via a *partially collapsed variational EM algorithm*, developed by Roberts et al. (2016), and implemented in the *stm-package* in *R*. The starting values for the algorithm are chosen by a robust moment-based estimator as suggested by Arora et al. (2013) and Roberts et al. (2016).[8]

3.2. Topic prevalence results

Table 2 shows the 12 topics revealed by the STM and the 12 most probable words for each topic in descending order. Since STM finds topics solely based on relational word occurrences, each topic is only given a number from 1 to 12 (topic order is irrelevant). It is up to the researcher to make meaning of each topic based on the coherence of words it contains with high probability (DiMaggio et al., 2013). According to this criterion, the words contained in the different topics revealed by STM suggests an association of topics 1, 8 and 10 with the monetary pillar. Checking individual sentences from the original documents corroborates this interpretation. In fact, the sentences identified by STM with the highest probabilities of belonging to one of these three topics all come from the monetary analysis section of the ECB president's introductory statements. Typical sentences for these three individual topics are summarized in Tables 3–5. In order to cross-check the suggested identification more rigorously, Figures 3 and 4 report the topic proportions separately for the monetary and economic analysis sections of the introductory statements. The results confirm that topics 1, 8 and 10 are indeed those topics most frequently communicated

[7]We follow Roberts et al. (2016) and allow for the day variable to have a non-linear relationship in the topic estimation stage. See Roberts et al. (2018) on how to implement this using spline functions within the stm-package.

[8]We refer to the articles for a detailed description of the EM algorithm and the initialization method as an outline is beyond the scope of this paper.

Table 2: Topics revealed by STM with $K = 12$

Topic 1 (*prob. .063*)		**Topic 2** (*prob. .101*)		**Topic 3** (*prob. .068*)		**Topic 4** (*prob. .052*)	
prob.	words	prob.	words	prob.	words	prob.	words
.071	bank	.082	risk	.053	support	.138	market
.056	credit	.080	term	.052	improv	.084	financi
.045	financi	.057	outlook	.051	condit	.068	develop
.027	reflect	.054	medium	.047	measur	.033	potenti
.025	sheet	.045	price	.045	demand	.030	tension
.024	balanc	.034	govern	.039	polici	.029	factor
.023	time	.031	council	.039	domest	.029	impact
.022	deposit	.031	stabil	.036	financ	.025	part
.020	continu	.030	remain	.034	euro	.023	condit
.019	sector	.026	develop	.034	strengthen	.020	affect
.016	ongo	.026	upsid	.033	area	.019	uncertainti
.016	lend	.026	line	.033	monetari	.018	number

Topic 5 (*prob. .084*)		**Topic 6** (*prob. .083*)		**Topic 7** (*prob. .098*)		**Topic 8** (*prob. .091*)	
prob.	words	prob.	words	prob.	words	prob.	words
.132	econom	.123	price	.078	rate	.090	monetari
.065	activ	.061	increas	.078	inflat	.040	growth
.060	continu	.039	pressur	.072	price	.037	m3
.059	remain	.036	wage	.036	energi	.030	analysi
.059	expect	.035	oil	.031	month	.030	rate
.045	recoveri	.028	stronger	.028	expect	.028	liquid
.031	sector	.026	indirect	.027	oil	.026	expans
.030	time	.024	develop	.027	level	.024	under
.025	balanc	.023	commod	.026	year	.024	continu
.024	gradual	.023	risk	.022	annual	.023	money
.023	dampen	.023	relat	.021	current	.022	strong
.022	moder	.023	effect	.020	reflect	.021	credit

Topic 9 (*prob. .080*)		**Topic 10** (*prob. .091*)		**Topic 11** (*prob. .104*)		**Topic 12** (*prob. .086*)	
prob.	words	prob.	words	prob.	words	prob.	words
.078	euro	.098	loan	.080	project	.118	quarter
.074	area	.087	annual	.047	annual	.101	euro
.055	global	.085	growth	.045	staff	.099	area
.048	economi	.065	rate	.045	hicp	.098	growth
.047	growth	.030	household	.043	inflat	.053	real
.030	real	.030	privat	.042	assess	.051	gdp
.027	export	.029	sector	.034	estim	.036	year
.025	support	.029	corpor	.033	eurostat	.029	survey
.023	incom	.025	financi	.029	analysi	.027	indic
.021	downsid	.024	remain	.029	macroeconom	.026	data
.021	consumpt	.022	increas	.029	econom	.023	recent
.020	demand	.021	month	.026	flash	.019	confirm

The table presents the 12 topics revealed by the STM, along with the proportions in which these topics occur in the combined corpus (i.e. the economic and monetary analysis). For each topic, we show the 12 most probable words in descending order.

in the monetary pillar. Moreover, all remaining topics are much less prevalent across the introductory statements, with some pertaining primarily to the economic pillar (5, 6, 7, 9, 11) and others being equally important for both pillars (2, 3, 4, 12).

Focusing on the three selected topics most relevant for the monetary pillar, topic 8 turns out to be closely associated with the ECB's traditional monetary analysis. In fact, the list of typical sentences contained in Table 4 conforms to the definition of the (broadened) monetary analysis as a comprehensive assessment of the liquidity situation in terms of the components and counterparts of M3 as well as concepts of excess liquidity, as defined in ECB (2003). In contrast, topics 1 and 10 are more in line with the ECB's consideration of financial stability issues laid out in ECB (2009). In particular, these include the availability of credit to households and firms as well as the funding of credit institutions. Whereas typical sentences in both of these topics fit this financial stability notion rather well, the statements in topic 1 feature some explicit crisis terminology, containing words such as "leverage", "credit standard", "credit risk" or "credit supply constraints". We thus interpret topics 8 and 10 as reflecting the primary monetary and financial stability analysis, respectively, and topic 1 as a potential measure of the ECBs crisis communication (see Tables 3 and 5).

Figure 5 highlights the prevalence plots associated with topics 1, 8 and 10 as shown in Figure 3. It turns out that the importance in the ECB's communication of the traditional monetary analysis reflected in topic 8 has steadily declined throughout the 10-year period from 2003-2013, while stabilizing at a comparatively low level over the most recent years. Conversely, statements associated with the financial stability analysis of topic 10 have increasingly become more frequent, particularly in the wake of the financial crisis of 2007-08. Finally, the third prevalence plot supports our interpretation of topic 1 as constituting a summary measure of the ECB's crisis communication. The statements in this category gain importance only after the onset of the financial crisis and the subsequent waves of the euro-area debt crisis, before receding over the last years of the sample.

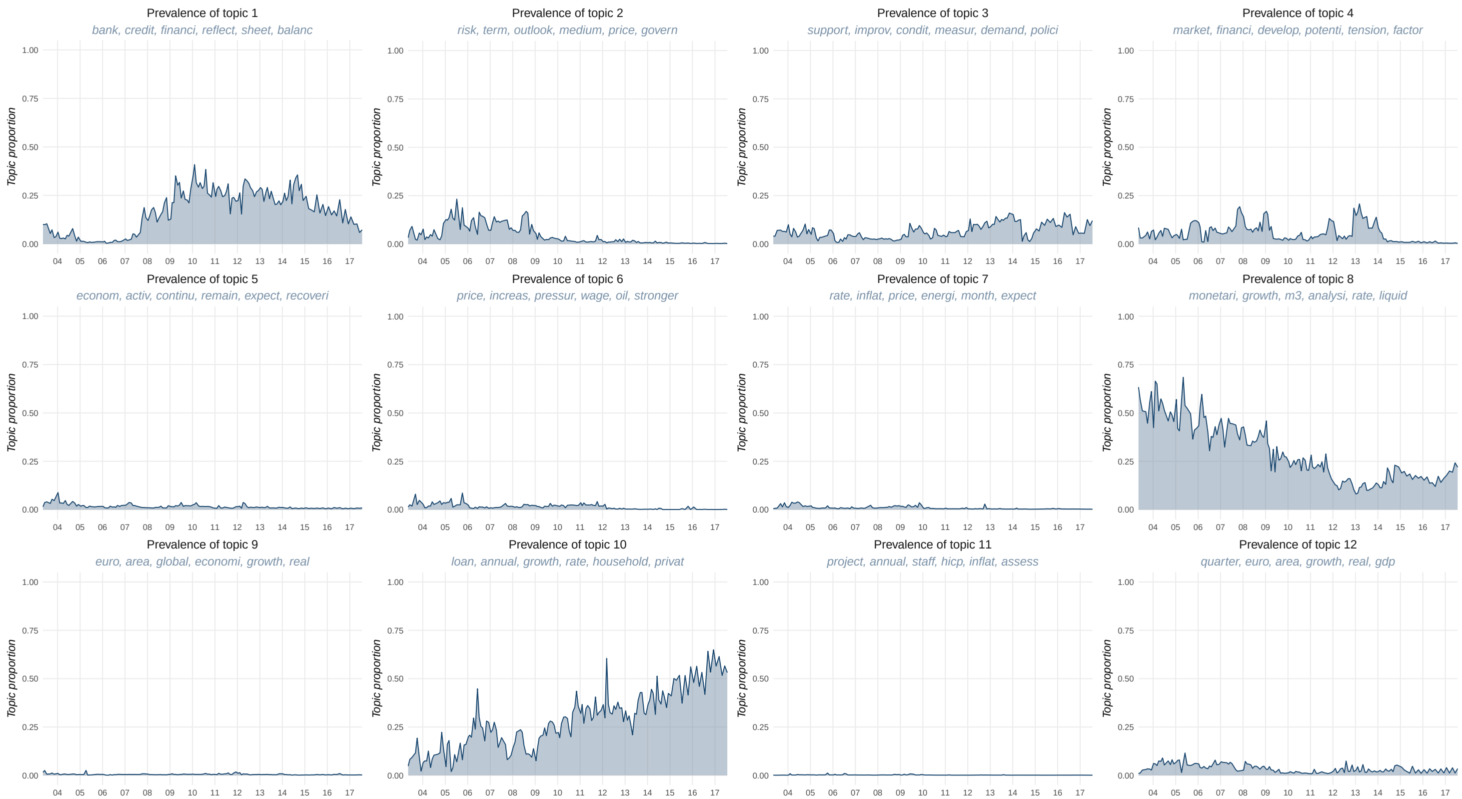

Figure 3: Prevalence of the $K = 12$ revealed topics within the *monetary* analysis sentences of the introductory statements (2003:05 to 2017:07). The topic prevalences were estimated by a STM on the combined pillars corpus (i.e., including monetary and economic analysis sections).

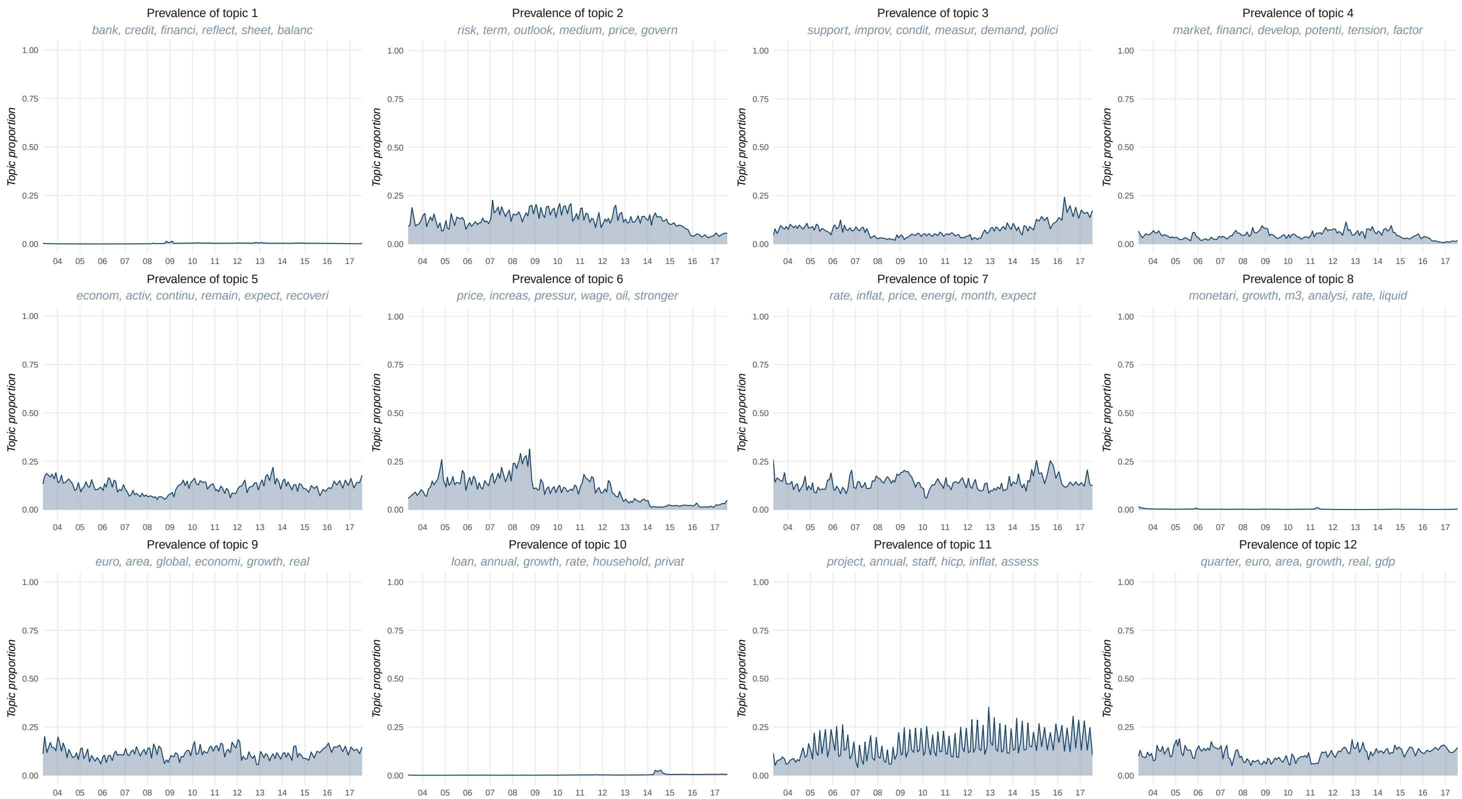

Figure 4: Prevalence of the $K = 12$ revealed topics within the *economic* analysis sentences of the introductory statements (2003:05 to 2017:07). The topic prevalences were estimated by a STM on the combined pillars corpus (i.e., including monetary and economic analysis sections).

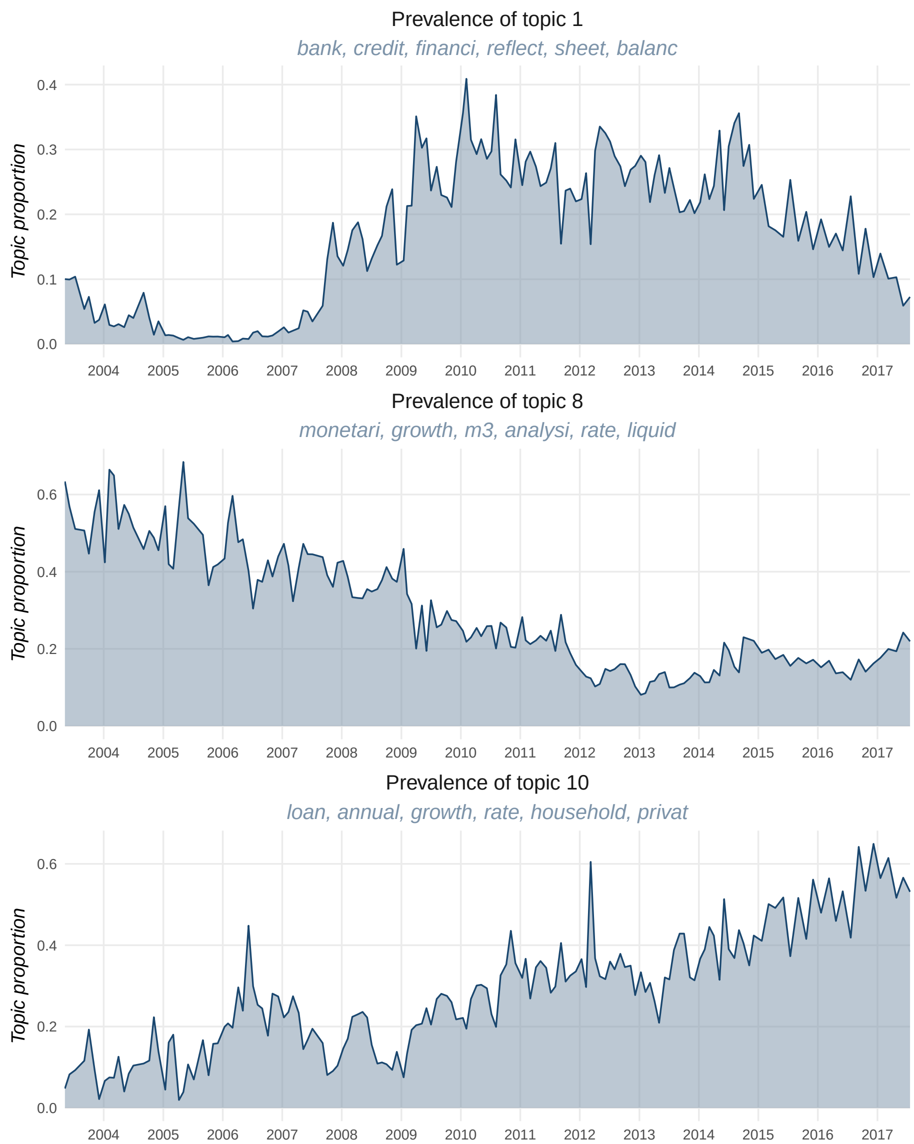

Figure 5: Close up: Prevalences of the identified monetary analysis topics within the monetary analysis sentences of the introductory statements (2003:05 to 2017:07).

Table 3: Characteristic quotes from topic 1

	Topic 1	
	Date	**Proportion of topic**
	April 2, 2009	.657
Quote	*"In this respect, developments over the past few months may in part reflect ongoing efforts of banks as well as the corporate and household sector to reduce the highly leveraged positions built up in past years."*	
	August 6, 2009	.637
Quote	*"However, according to the latest euro-area bank lending survey, lenders tightened their credit standards to a significantly lesser extent."*	
	December 3, 2009	.864
Quote	*"Banks are currently faced with the challenge of managing the size and structure of their overall balance sheets, and at the same time ensuring the availability of credit to the non-financial sector."*	
	June 6, 2012	.872
Quote	*"The soundness of banks' balance sheets will be a key factor in facilitating both an appropriate provision of credit to the economy and the normalisation of all funding channels."*	
	August 7, 2014	.891
Quote	*"Lending to non-financial corporations continues to be weak, reflecting the lagged relationship with the business cycle, credit risk, credit supply factors and the ongoing adjustment of financial and non-financial sector balance sheets."*	
	September 4, 2014	.835
Quote	*"Against the background of weak credit growth, the ECB is finalising the comprehensive assessment of banks' balance sheets, which is of key importance to overcome credit supply constraints."*	

The table presents selected sentences from the introductory statements, which have a high proportion of words from topic 1. Along with the quote, we show the date on which the introductory statement was released, and the proportion of words that are attributed to the respective topic.

Table 4: Characteristic quotes from topic 8

	Topic 8	
	Date	**Proportion**
	June 5, 2003	.868
Quote	*"This is confirmed by evidence from both the components and counterparts of M3."*	
	July 1, 2004	.802
Quote	*"While a significant part of the excess liquidity has accumulated as a result of past portfolio shifts, low interest rates have also fuelled the build-up of liquid assets."*	
	June 2, 2005	.898
Quote	*"The monetary dynamics are driven by the strong growth of the most liquid components of broad money contained in the narrow aggregate M1."*	
	January 11, 2007	.860
Quote	*"This has mainly taken the form of shifts among the components of M3 rather than constraining the overall expansion of M3 itself."*	
	June 6, 2013	.836
Quote	*"Turning to the monetary analysis, recent data confirm that the underlying pace of monetary and, in particular, credit expansion continues to be subdued."*	
	July 16, 2015	.834
Quote	*"Turning to the monetary analysis, recent data confirm robust growth in broad money (M3)."*	

The table presents selected sentences from the introductory statements, which have a high proportion of words from topic 8. Along with the quote, we show the date on which the introductory statement was released, and the proportion of words that are attributed to the respective topic.

Table 5: Characteristic quotes from topic 10

	Topic 10	
	Date	**Proportion of topic**
	November 4, 2004	.827
Quote	*"In particular, the growth rate of loans for house purchase continues to rise and is now approaching double digits."*	
	April 6, 2006	.837
Quote	*"Moreover, the annual growth rate of credit to the private sector has strengthened further over recent months, with borrowing by households - especially loans for house purchase - and non-financial corporations rising at a marked pace."*	
	September 3, 2009	.892
Quote	*"The flow of loans to households remained slightly positive, whereas in the case of non-financial corporations the flow of loans was negative again."*	
	February 3, 2011	.850
Quote	*"On the counterpart side, the annual growth rate of bank loans to the private sector continued to conceal differences in the magnitude of growth across sectors."*	
	May 3, 2012	.919
Quote	*"The volume of MFI loans to non-financial corporations and households remained practically unchanged compared with the previous month."*	
	October 20, 2016	.909
Quote	*"Loan dynamics followed the path of gradual recovery observed since the beginning of 2014."*	

The table presents selected sentences from the introductory statements, which have a high proportion of words from topic 10. Along with the quote, we show the date on which the introductory statement was released, and the proportion of words that are attributed to the respective topic.

4. Monetary policy analysis

4.1. Constructing tone measures from the monetary topics

In a next step, we ask whether the monetary pillar in general, and the shift in focus in particular, has had a measurable effect on the ECB's monetary policy stance. For this purpose, we construct tone-weighted measures by combining the topic prevalences of topics 1, 8, and 10 (see section 3.2) with dictionary analyses. This comprises (1) a measure for the hawkish-dovish tone within the classical monetary topic and (2) a measure for the financial stability sentiment conveyed in the financial crisis and stability topics. We adopt the hawkish-dovish dictionary from Bennani and Neuenkirch (2017) and the financial stability sentiment (FSS) dictionary from Correa et al. (2017). Both dictionaries provide lists of words for two categories. In Bennani and Neuenkirch (2017) the categories are *hawkish* and *dovish*. In Correa et al. (2017) categories are labeled *positive financial sentiment* and *negative financial sentiment*.

The hawkish-dovish tone of each sentence is then computed as follows

$$\phi_s^{HD} = \frac{w_{n,s}^{hawk} - w_{n,s}^{dove}}{w_{n,s}^{total}}, \tag{1}$$

where $w_{n,s}^{hawk}$ ($w_{n,s}^{dove}$) are the hawkish (dovish) word counts, and $w_{n,s}^{total}$ the total number of words within each document. Analogously, the financial stability sentiment tone of each sentence is given by

$$\phi_s^{FSS} = \frac{w_{n,s}^{pos} - w_{n,s}^{neg}}{w_{n,s}^{total}}, \tag{2}$$

where $w_{n,s}^{pos}$ ($w_{n,s}^{neg}$) are the positive (negative) financial stability word counts. Consequently, ϕ_s is placed in the interval $[-1, 1]$, where a sentence with a score $\phi_s^{HD(FSS)}$ close to 1 indicates a hawkish (positive financial stability sentiment) tone and a sentence with a score $\phi_s^{HD(FSS)}$ close to -1 a dovish (negative financial stability sentiment) tone.

As noted by Grimmer and Stewart (2013), dictionary methods only work well if the scores attached to words align closely with how the words are used in a specific context. This is why it is important not to simply apply the dictionary scores to the introductory statements as a whole, but to score each individual sentence according to its topical content. In other words, sentences that are about financial stability should be scored using the FSS dictionary, while traditional monetary pillar sentences are best scored using the hawkish-dovish dictionary. To take this into account, we use a similar approach as Larsen (2017) and multiply each sentence's dictionary score with that sentence's proportion for the topics 1, 8, and 10. After summing over all sentences within a document we obtain the following topic specific tone measures

$$\varphi_{d,k}^{j} = \sum_{s=1}^{S} \phi_s^j \theta_{s,k}^j, \qquad j \in \{HD, FSS\}, \quad k \in \{1, 8, 10\}. \tag{3}$$

These measures not only indicate how prominent an introductory statement touches on a specific topic, but also inform on the topic specific tone that it conveys. We standardize all topic specific tone measures and denote them as $\varphi_{d,1}^{FSS}$, $\varphi_{d,8}^{HD}$, and $\varphi_{d,10}^{FSS}$.[9]

4.2. Specifications and estimation of the Taylor rule

Our structural topic model reveals that the ECB communication in the monetary pillar has in fact shifted away from its previous focus on long-term inflationary pressures based on money growth rates towards monitoring more closely the stability of the European financial system. Our aim in this section is to assess whether this shift has had any measurable impact on the ECB's monetary policy stance. To this end we incorporate the tone-weighted topic prevalence measures into empirical estimates of a Taylor rule. Although originally intended as a rule-of-thumb indicator of monetary authorities' interest rate reaction function (Taylor, 1993), the Taylor rule is frequently used as an input in monetary policy deliberations and decision-making at central banks (Asso et al., 2010).

[9]Plots for the three topic specific tone measures are available upon request.

We use a standard specification of the Taylor rule with nominal interest rate smoothing given by:

$$i_t = \rho i_{t-1} + (1-\rho)\{\alpha + \beta_\pi(\pi_t - \pi^*) + \beta_y y_t\} + u_t. \tag{4}$$

The specification includes a lagged interest rate term, with ρ denoting the interest rate smoothing parameter. The actual Taylor rule appears within the curly brackets. Here π_t and π^* are observed inflation and the inflation target, and y_t constitutes the output gap, with β_π and β_y as the respective Taylor rule reaction coefficients. The constant term α corresponds to the sum of the long-run real interest rate, r^*, and the inflation objective, such that $\alpha = r^* + \pi^*$. Finally, u_t is the error term.

We will refer to (4) as our benchmark model, which we then compare to an augmented model specification. The augmented model additionally includes the tone-weighted communication measures from (3) for the different monetary policy topics:

$$\begin{aligned} i_t =& \rho i_{t-1} + (1-\rho)\{\alpha + \beta_\pi(\pi_t - \pi^*) + \beta_y y_t \\ &+ \delta_1 \varphi_{t,1}^{FSS} + \delta_8 \varphi_{t,8}^{HD} + \delta_{10} \varphi_{t,10}^{FSS}\} + u_t. \end{aligned} \tag{5}$$

All Taylor rule specifications are estimated by ordinary least squares (OLS). Coefficient inference is based on heteroskedasticity and autocorrelation consistent (HAC) standard errors in the vein of Newey and West (1987). Apart from full-sample OLS regressions for both models, we also run sub-sample regressions for the pre-crisis and post-crisis periods. The breakpoint that splits the sample is obtained by conducting the Bai and Perron (2003) structural break test for one breakpoint on the augmented model. The test reveals 2008:09 as the optimal breakpoint, which coincides with the bankruptcy of Lehman Brothers on September 20, 2008.

4.3. Data

To match the frequency of our ECB tone measures, we obtain data at monthly frequency from the ECB's Statistical Warehouse and the EU Commission's business and consumer surveys.[10] Our sample spans the time period from 2003:05 to 2017:07, amounting to 168 observations. For the nominal policy rate, we use the Euro OverNight Index Average (EONIA). We follow Sauer and Sturm (2007) and use forward-looking variables for inflation and the output gap for the euro-area. For inflation, we use one year ahead forecasts of the Harmonized Index of Consumer Prices (HICP), as published by Eurostat. The output gap is measured by the Economic Sentiment Indicator (ESI), from which the sample average has been subtracted. As shown by Sauer and Sturm (2007), the ESI is a good business cycle indicator for the EU. Despite some persistence in these time series, we follow the standard practice in this literature and disregard the possibility of unit roots in the interest rate and the inflation rate, as they seem implausible from an economic point of view for a credible central bank such as the ECB (Brüggemann and Riedel, 2011).

4.4. Regression results

Table 6 reports our estimation results for the benchmark case as well as the augmented version of the Taylor rule. We present results for the full sample and two subsamples comprising the pre-crisis and post-crisis periods. Our results indicate a substantial interest rate smoothing effect across all specifications, with values of the smoothing coefficient above 0.7, and reaching as high as 0.9 for the pre-crisis estimates. These values are at the upper end of the range of estimated Taylor-rule smoothing parameters for industrial countries, as reported in Hofmann and Bogdanova (2012). Furthermore, all regression results show significantly positive coefficients for both inflation and the output gap. Whereas

[10] As the ECB changed the frequency of Governing Council monetary policy meetings from every four weeks to six weeks starting in January 2015, we impute missing observations for $\varphi^{FSS}_{d,1}$, $\varphi^{HD}_{d,8}$, and $\varphi^{FSS}_{d,10}$ with the mean value of the observation prior to the missing value and the next available one. This gives us a monthly time series for the tone-weighted communication measures, which we denote $\varphi^{FSS}_{t,1}$, $\varphi^{HD}_{t,8}$, and $\varphi^{FSS}_{t,10}$

the output gap coefficients come out rather small, the inflation reaction coefficients are substantially larger, yet below unity throughout. These results are roughly in line with other recent estimates of Taylor rules for the ECB (see e.g. Bauer and Neuenkirch, 2017, Beckmann et al., 2017).

Table 6: Results of Taylor-rule regressions with Newey-West (HAC) standard errors

	Benchmark model			Augmented model		
	Pre-crisis	Post-crisis	Full sample	Pre-crisis	Post-crisis	Full sample
Intercept	0.314***	0.224***	0.272***	0.304**	0.201***	0.247***
	(0.086)	(0.068)	(0.086)	(0.119)	(0.061)	(0.071)
$E_t(\text{Inflation}_{t+12})$	0.748***	0.424***	0.553***	0.676***	0.306***	0.403***
	(0.143)	(0.109)	(0.141)	(0.133)	(0.112)	(0.112)
ESI_t	0.012**	0.012***	0.024***	0.007*	0.018***	0.027***
	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)	(0.005)
$FSS1_t$				0.073**	0.026	0.043 **
				(0.034)	(0.025)	(0.019)
$Hawk/Dove_t$				0.041	0.019	0.048**
				(0.026)	(0.043)	(0.021)
$FSS10_t$				0.032	-0.073***	-0.076***
				(0.050)	(0.018)	(0.023)
$EONIA_{t-3}$	0.898***	0.716***	0.878***	0.902***	0.734***	0.869***
	(0.035)	(0.066)	(0.042)	(0.048)	(0.066)	(0.037)
Adj.R^2	0.985	0.914	0.981	0.989	0.923	0.983
Obs.	62	106	168	62	106	168

The table reports the short-run reaction of the interest rate. The corresponding steady-state coefficients can be obtained by dividing the estimated Taylor-rule coefficients by $(1-\rho)$. Heteroskedasticity and autocorrelation consistent (HAC) standard errors in the vein of Newey and West (1987) are reported in brackets. *** indicate signifcance at 1% level, ** indicate significance at 5% level and * indicate significance at 10% level. The breakpoint 09:2008 was derived based on the augmented model by running the Bai and Perron (2003) structural break test for one breakpoint.

Turning to the communication variables of the augmented model, the hawkish/dovish measure has the expected positive sign. However, the estimated coefficient is significant only in the full sample, whereas it just misses the 10% significance threshold in the pre-crisis regression, and is clearly insignificant post-crisis. We interpret this result as a rather weak indication that monetary analysis, as reflected in the ECB's communication of its monetary pillar, may have informed monetary policy decisions to some degree in the early years of the sample. However, this influence vanishes completely in later years, confirming our previous finding of the fading importance of monetary developments in the ECB's public announcements. Conversely, the impact of the financial stability variable of topic 10 becomes significant only in the second half of the sample period, and like in the full sample, enters with a negative coefficient. This evidence suggests that the ECB has shown a tendency to reduce interest rates whenever conveying a positive financial sentiment in its communication with the public. The monetary policy response thus appears to be accommodative rather than "leaning against the wind". This impression is corroborated by the fact that the financial crisis variable of topic 1 is significant only in the first subperiod, but comes out insignificant for the period following the financial crisis.[11]

5. Conclusions

This paper is concerned with analyzing the importance of financial stability issues in the European Central Bank's (ECB) communication with the public. The ECB pursues a distinct monetary policy strategy in the form of a two-pillar approach. The first (economic) pillar assesses the short to medium-term determinants of price developments, with a focus on real activity in the economy. In contrast, the second (monetary) pillar focuses on the long-run link between money and prices by monitoring the components and counterparts of M3 growth and the availability of credit to households and firms. A subtle shift in the characterization of the monetary pillar appears to have taken place in the aftermath of the financial crisis of 2007-08, when the ECB began to focus more closely on the stability of the European financial system (ECB, 2009).

We utilize the structural topic model (STM) proposed by Roberts et al. (2016) as a recent extension to the family of probabilistic topic models to quantify the transcripts of the ECB President's introductory statements at the press conferences that accompany the regular meetings of the ECB Governing Coun-

[11]We have also run the Taylor rule regressions using the Wu-Xia EONIA shadow rate . As the differences in the results were all found to be minor, we only report the regression output for EONIA proper.

cil. We not only find strong evidence for an increasing prominence of financial stability issues in the communication of the monetary pillar, but we also establish that this shift has unfolded rather gradually starting well before the onset of the financial crisis.

We go on to estimate a Taylor rule augmented by our communication variables to assess whether the monetary pillar in general, and the shift in focus in particular, has had a measurable impact on the ECB's monetary policy stance. Our results suggest that monetary analysis, as reflected in the ECB's communication of its monetary pillar, appears to have exerted a weak impact on monetary policy decisions in the early years of the ECB's existence. However, this influence disappears in later years, thus mirroring the fading importance of monetary developments in the ECB's public announcements. Conversely, financial stability issues have affected the ECB's interest rate policy only in the years following the financial crisis. Moreover, we find the monetary policy response to be accommodative rather than "leaning against the wind", which may be taken as an indication of a possible lack of financial stability concerns informing the ECB's monetary policy decisions after the financial crisis.

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A. Appendix

A.1. The structural topic model

The structural topic model (STM) assumes that documents, indexed by $d \in \{1, \dots, D\}$, consist of $n \in \{1, \dots, N_d\}$ words ($\boldsymbol{w}_{d,n}$) that arise from a mixture of K topics ($\boldsymbol{\beta}_k$). Each word within a document is *assigned* to only one topic, denoted by $\boldsymbol{z}_{d,n}$, and topics are distributions over a fixed vocabulary, indexed $\{1, \dots, V\}$. Documents share all topics but differ in the proportions for each topic ($\boldsymbol{\theta}_d$). The topic proportions for each document depend on the P document-level covariates, contained in $\boldsymbol{X}$. According to this representation, documents resemble *bag of words*, in which the order of words is ignored. While this stark assumption would clearly rule out most reading comprehension of such generated documents, it proves highly effective when the primary goal is to uncover the thematic content of texts (Blei, 2012; Grimmer and Stewart, 2013).

The STM model we apply assumes that a document d arises from the following data-generating process. Provided K topics, $\boldsymbol{w}_{d,n}$ observed words, and the $D \times P$ data matrix $\boldsymbol{X}$, the algorithm can be summarized as follows:

$$\boldsymbol{\beta}_{1:K} \sim Dir(\xi), \quad \text{where } 0 < \xi < 1, \tag{A.1}$$

$$\boldsymbol{\gamma}_k \sim \text{Normal}_p(0, \sigma_k^2 I_p), \quad \text{for } k = 1, \dots, K-1, \tag{A.2}$$

$$\sigma_k^2 \sim \text{Inv-Gamma}(1, 1), \tag{A.3}$$

$$\boldsymbol{\theta}_d \sim \text{LogisticNormal}_{K-1}(\boldsymbol{\Gamma}'\boldsymbol{x}_d', \boldsymbol{\Sigma}), \tag{A.4}$$

$$\boldsymbol{z}_{d,n} \sim \text{Multinomial}_K(\boldsymbol{\theta}_d), \quad \text{for } n = 1, \dots, N_d, \tag{A.5}$$

$$\boldsymbol{w}_{d,n} \sim \text{Multinomial}_V(\boldsymbol{\beta}_{z_{d,n}}), \quad \text{for } n = 1, \dots, N_d, \tag{A.6}$$

where $\boldsymbol{\Gamma} = (\gamma_1, \dots, \gamma_K)$ is a $P \times (K-1)$ matrix of coefficients for the topic prevalence.

To generate correlated topic proportions for each document, $\boldsymbol{\theta}_d$ is drawn from a logistic normal distribution, which can be represented by drawing $\boldsymbol{\eta}_d \sim \text{Normal}_{K-1}(\boldsymbol{\Gamma}'\mathbf{x}_{\boldsymbol{d}}', \boldsymbol{\Sigma})$ and mapping this vector to the $K-1$ topic simplex. This is achieved by specifying $\theta_{d,k} = f(\eta_d) = \exp(\eta_{d,k})/(\sum_{i=1}^{K} \exp(\eta_{d,i}))$ and fixing $\eta_{d,K}$ to zero to obtain an identifiable model. Once the topic proportion vector is set, n words within the document d are generated by repeatedly drawing $\boldsymbol{z}_{d,n} \sim \text{Multinomial}_K(\boldsymbol{\theta}_d)$ and then, conditional on the n topic assignments, drawing from the respective distribution over terms $\boldsymbol{\beta}_{z_{d,n}}$ to obtain the word realizations.

To implement the document-specific prior for the topic prevalence, the mean vector of the logistic normal is given by a linear combination of the form $\boldsymbol{\mu}_d = \boldsymbol{\Gamma}'\boldsymbol{x}_d'$, where each element of $\boldsymbol{\Gamma}$ is sampled from a normal distribution with zero mean and shared variance parameter, or formally, $\boldsymbol{\gamma}_{p,k} \sim \text{Normal}(0, \sigma_k^2)$ and $\sigma_k^2 \sim \text{Inverse-Gamma}(1, 1)$.

To estimate the latent parameters from observed documents and corresponding document-level data, STM reverses the generating-process, asking which hidden structure most likely generated the observed documents. This is done via a *partially collapsed variational EM algorithm*, developed by Roberts et al. (2016), and implemented in the *stm-package* in *R*. The starting values for the algorithm are chosen by a robust moment-based estimator as suggested by Arora et al. (2013) and Roberts et al. (2016).