



University of St.Gallen

---

---

# Narratives in Finance

---

---

MASTER'S THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF  
MASTER OF ARTS IN QUANTITATIVE ECONOMICS AND FINANCE

AUTHOR

CORINNE KNÖPFEL

WIESEN 2488, HERISAU

11-613-676

CORINNE.KNOEPFEL@STUDENT.UNISG.CH

SUPERVISOR

DR. PETER GRUBER

INSTITUTE OF FINANCE

UNIVERSITÀ DELLA SVIZZERA ITALIANA

DATE OF SUBMISSION: SATURDAY 2<sup>ND</sup> FEBRUARY, 2019

# Abstract

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Monetary Policy and Interest Rates</b>	<b>2</b>
2.1	Excess Sensitivity Puzzle . . . . .	2
2.2	Existing Research and Explanations . . . . .	5
2.3	New Insights Through Narrative Research . . . . .	7
<b>3</b>	<b>Narratives and Decision Making</b>	<b>10</b>
3.1	What Narratives Are . . . . .	10
3.1.1	McAdams Research on Narratives . . . . .	10
3.1.2	Social Psychology Background . . . . .	10
3.2	How Narratives can help . . . . .	10
3.2.1	Bayesian Brain and Predictive Coding . . . . .	10
3.2.2	Influence and Change on Human Beings . . . . .	10
3.3	Narrative Research . . . . .	10
<b>4</b>	<b>Topic Analysis</b>	<b>11</b>
4.1	Probabilistic Latent Semantic Analysis . . . . .	11
4.1.1	Mixture Model / Generative Model . . . . .	12
4.1.2	Model Fitting with Expectation-Maximization . . . . .	15

4.1.3	Adding a Background Language Model . . . . .	18
4.1.4	Expectation Maximization . . . . .	19
4.1.5	PLSA with background model . . . . .	20
4.1.6	PLSA . . . . .	20
4.1.7	Latent Dirichlet Allocation . . . . .	21
4.2	LDA . . . . .	21
4.2.1	Notes . . . . .	22
4.3	Sensitivity Analysis . . . . .	22
<b>5</b>	<b>Data and Methodology</b>	<b>23</b>
5.1	Financial Data . . . . .	23
5.2	Text Data . . . . .	25
5.3	Methodology . . . . .	27
5.3.1	Text Preprocessing . . . . .	27
5.3.2	Application of Topic Analysis . . . . .	28
5.4	NOTES . . . . .	29
<b>6</b>	<b>Results</b>	<b>30</b>
<b>7</b>	<b>Conclusion</b>	<b>31</b>
	<b>References</b>	<b>32</b>
	<b>Appendices</b>	
<b>A</b>	<b>Target Rate and Yield Curves</b>	<b>35</b>
<b>B</b>	<b>Text data</b>	<b>38</b>
<b>C</b>	<b>Whatever may come...</b>	<b>40</b>
C.1	For Example... . . . . .	40

# List of Figures

4.1	An illustration of four topics (Steyvers & Griffiths, 2007, p.2).	13
4.2	The generative model and the problem of statistical inference (Steyvers & Griffiths, 2007, p.3).	14
5.1	Target rate and 3M treasury yield.	25
5.2	Wordcloud illustrating the most common words across all articles.	26
5.3	Dispersion of most common words across time.	27
A.1	Target rate and treasury yields of all maturities.	37
B.1	Token and article count for every policy day.	39

# List of Tables

4.1	Formal definition of topic modeling task. . . . .	12
A.1	FOMC meetings. . . . .	35
A.2	Target rate adjustments since January 1, 1998. . . . .	36

# Chapter 1

## Introduction

# Monetary Policy and Interest Rates

However little understood, the relationship between monetary policy and market interest rates is undeniable. Interest rates of all maturities react to changes in monetary policy, creating opportunities and risks for traders, challenges for policy makers, and puzzling effects for academics to study (Ellingsen & Söderström, 2001, p. 1594).

Target rate changes in particular have an impact on the bond market and on interest rates (Cook & Hahn, 1989, p. 332). Yet, the understanding of yield curve movements is incomplete at best. On average, the relationship between monetary policy and interest rates appears to be positive: An increase in the central bank's target rate leads to an increase in the interest rates of all maturities. However, there are many instances where this simple rule has proven false and interest rates of long maturities fell in response to an increase in the central bank's rate (Ellingsen & Söderström, 2001, p. 1594).

Chapter 2.1 gives an account of the puzzle posed by the inconsistent response of long-term rates, Chapter 2.2 touches on previous research and possible explanations, and Chapter 2.3 outlines how an investigation of narratives might be able to shed light on this puzzle.

## 2.1 Excess Sensitivity Puzzle

Cook and Hahn (1989) analyzed financial data from the late 70s and found that the U.S. Federal Reserve (Fed), by setting the target for the federal funds rate, had a strong influence on interest rate movements. While short-term rates reacted particularly strongly, changes in the target



rate also caused small but significant movements in long-term rates.

It is not surprising that short-term rates follow the target rate closely, after all the Fed keeps the overnight rate close to the target and thus directly influences the one-month rate (Ellingsen, Söderström, & Masseng, 2003, p. 1). The movements of the long-term rates are more ambiguous. Cook and Hahn (1989, p. 343–346) interpret the fact that, on average, 10-year and 30-year bonds co-move with the short-term rates as evidence for the expectation theory of the term structure of interest rates. According to the expectation theory, long-term rates are equal to short-term rates over the same period of time plus a term premium. Thus, an increase in the short-term rates is expected to drive up long-term rates as well, but to a lesser extent (Ellingsen & Söderström, 2001, p. 1594).

To Romer and Romer (2000), on the other hand, the response of long-term rates presents a puzzle. They argue that standard theory predicts a drop in inflation as short-term rates rise, which ought to lead to a reduction in long-term rates. The opposite can be observed, however: Interest rates for all maturities typically rise following an increase in the target rate. Romer and Romer (2000) explain this anomaly with information-asymmetry between the Fed and the general public. They find evidence that the Fed is in possession of private information, which it reveals to other market participants through its monetary policy. In response, market participants adjust their inflation expectations upwards, causing long-term rates to rise.

Dissecting the interest rate response in more detail led Skinner and Zettelmeyer (1995) to paint an even complexer picture. While the yield curve shifts upwards on average, they found a number of occasions where an adjustment to the target rate caused the yield curve to tilt: Long and short rates responded by moving in opposite directions (as cited in Ellingsen et al., 2003, p. 1). Skinner and Zettelmeyer came to the conclusion that these were not singular occurrences, but that such tilts made up a considerable portion of the yield curve responses and could be observed in all four of the big economies they studied, that is in France, Germany, the United Kingdom, and the United States (as cited in Ellingsen & Söderström, 2001, p. 1594). An example is the yield curve movement in 1994, where interest rates of long maturities fell after the Fed announced an increase in its target rate (Ellingsen & Söderström, 2001, p. 1594). So not only is the positive response of long-term rates difficult to explain, the response is not even consistent in its direction: long-term rates may move up or down when the Fed increases

the target rate.

Whether positive or negative, to Gürkaynak, Sack, and Swanson (2005b, p. 425) any response of long-term rates is in contradiction to standard macroeconomic models. They argue that models predict that short-term rates return quickly to their steady state and thus have only a transitory effect on the future path of interest rates. Therefore, one would expect long-term rates not to react to monetary policy changes. They refer to the fact that long-term rates move significantly in response to monetary policy decisions as *excess sensitivity* of long-term interest rates (Gürkaynak, Sack, & Swanson, 2003, p. 2).

Gürkaynak et al. (2005b, p. 426–427) focus on the response of forward interest rates as a different way of expressing the yield curve. They find that long-term forward rates move in the opposite direction as the monetary policy actions. As they note, this stands in sharp contrast to the findings of Cook and Hahn (1989) and Romer and Romer (2000), who observed a movement of long-term rates in the same direction. Gürkaynak et al. put this down to their use of forward rates, which they consider a better measure for sensitivity. Additionally, they criticize previous research for the usage of raw change in the target rate, neglecting to differentiate between expected and unexpected policy moves. In their opinion, only the unexpected components of a monetary policy action can be expected to influence the term structure (Gürkaynak et al., 2005b, p. 430–431).

Since Gürkaynak et al. observe a negative response of the long-term forward rates, they suggest that such a response is not an anomaly but has a very natural explanation. Standard macroeconomic models assume that long-run levels of inflations and real interest rates are relatively fixed and known by all market participants (Gürkaynak et al., 2005b, p. 425). Gürkaynak et al. argue that models might be misspecified and long-run inflation expectations are not as perfectly anchored as assumed. They see the most plausible explanation for the observed term structure movements in the fact that monetary policy surprises lead market participants to adjust their expectations of the long-run level of inflation (Gürkaynak et al., 2005b, p. 434–435).

Even though Gürkaynak et al. (2005b) are able to account for the negative response of long-term forward rates to an increase in the target rate, Ellingsen and Söderström (2004, p. 2) maintain that their model is unable to explain the positive response of long-term yields observed

by other researchers. Thus, Gürkaynak et al. (2005b) fail to solve the puzzle as to why the yield curve shifts on one occasion but tilts at another when provoked by apparently identical monetary policy actions. Ellingsen et al. address this shortcoming in their own theoretical model (2001) and provide empirical support for their hypotheses (2003).

## 2.2 Existing Research and Explanations

Ellingsen and Söderström (2001) use a simple dynamic macroeconomic model where shocks to output and inflation exhibit some persistence and monetary policy actions have a lagged effect on output and inflation. The central bank is assumed to minimize deviations of inflation and output from their long-run averages, while market participants form rational expectations concerning the future target and short rates. On the basis of this model, Ellingsen and Söderström (2001, p. 1599–1602) make several predictions:

- *Proposition 1*: If there is symmetric information, economic shocks are observed by all market participants and affect interest rates directly. Policy actions by the central bank reveal no new information and thus will not affect the term structure of interest rates.
- *Proposition 2*: If the central bank has private information about shocks to supply or demand, market participants will infer this information from the central bank's policy actions. Thus, the yield curve of market interest rates will respond by moving in the same direction as the target rate change.
- *Proposition 3*: If the central bank has private information about changes in its own inflation preferences, market participants will infer these changes by observing the central bank's reaction to an economic shock. Consequently, they will adjust their expectations about future interest rate targets. This causes the yield curve to tilt as long rates move in the opposite direction as the target rate change.

Thus, the yield curve moves for two reasons: either the Fed reacts to new, possibly private information about the economy (what Ellingsen and Söderström call *endogenous*, outlined in proposition 2), or the Fed's policy preferences change (what Ellingsen and Söderström call *exogenous*, outlined in proposition 3). They predict that interest rates of all maturities move

in the same direction after an endogenous policy action, but that short and long-rates move in opposite directions after an exogenous change (2001, p. 1594–1595).

In a second paper, Ellingsen et al. (2003) analyze empirical data to find evidence for their model. In order to determine whether a policy action is endogenous or exogenous, they analyze reports on U.S policy in the *Credit Market* column of the *Wall Street Journal*. This text basis is supposed to capture the traders' opinions to a policy move and not the central bank's intention behind it, as it is the traders' opinions that move the bond prices (Ellingsen et al., 2003, p. 2). Ellingsen et al. used the articles on the day of the Fed move, as well as on the day before and the day after. They found publications on the days following a policy action to be the most informative (2003, p. 8).

They estimate the following regression (Ellingsen et al., 2003, p. 13):

$$\Delta i_t^n = \alpha + (\beta_n^{NP} d_t^{NP} + \beta_n^{Ex} d_t^{Ex} + \beta_n^{End} d_t^{End}) \Delta i_t^{3m} + v_t^n, \quad (2.1)$$

where  $\Delta i_t^n$  is the change in the interest rate of maturity  $n$  on day  $t$ ;  $d_t^{NP}$ ,  $d_t^{Ex}$ , and  $d_t^{End}$  are dummies for non-policy, exogenous policy, and endogenous policy days respectively; and  $\Delta i_t^{3m}$  is the change in the 3-month treasury bill rate on day  $t$ .

The one-day change in the 3-month T-bill rate is taken as a measure of unexpected monetary policy action (regressor in eq.2.1). Ellingsen et al. (2003, p. 13) argue that the 3-month rate is sufficiently short to be determined by policy actions, but also sufficiently long to avoid noise from expectation errors. If the target rate remains unchanged, that is on non-policy days, the change in the 3-month rate measures the adjustment of expectations about future monetary policy actions provoked by the day's new information. If the target rate changes, that is on policy days, any change in the 3-month rate is interpreted as the unexpected component of the policy action (Ellingsen et al., 2003, p. 12).

The main hypothesis of Ellingsen et al.'s model is that long-term interest rates respond positively to endogenous policies and negatively to exogenous policies:

$$H_0 : \text{For large } n: \beta_n^{Ex} < 0 < \beta_n^{End} \quad (2.2)$$

Using data from October 1988 to December 2001, Ellingsen et al. (2003, p. 16) find

significant positive responses of the the 6-month and 1-year rate to endogenous and exogenous policy actions. For the 10-year and the 30-year rate, on the other hand, the coefficients are significant and positive for endogenous changes, and negative for exogenous changes. Ellingsen et al. conclude that their model finds strong support in U.S. data.

Yet, the author of this thesis cannot help but note that the explained variation ( $R^2$ ) is rather small for long rates. While the model is able to account for up to 60% of the variation in short rates, this ratio drops to 15% for 10-year rates and 10% for 30-year rates (Ellingsen et al., 2003, p. 16). Additionally, Ellingsen et al. (2003, p. 20) admit that their results might be dependent on the classification of a few pivotal events. Since the classification was done manually, it is quite subjective. This could explain why von Krosigk (2017) was not able to replicate their results using text mining techniques. Von Krosigk analyzed data for the time period of January 2002 to June 2017 and found only positive coefficients, especially for exogenous events, with the only significant effect pertaining to the 6-month rate (2017, p. 36). This stands in sharp contrast to Ellingsen et al.'s results and raises doubts concerning the robustness of their findings.

## 2.3 New Insights Through Narrative Research

It is striking that Ellingsen et al. (2003), in order to find data in support of their model, naturally chose a narrative approach. In their model, they explicitly assume that the yield curve's response depends "on market participants' interpretation of the policy move" (Ellingsen & Söderström, 2001, p. 1603). They aim at classifying policy events as they are perceived by financial investors "since it is the investors' beliefs that determine the interest rate response" Ellingsen and Söderström (2001, p. 1604). They analyze newspaper articles not to determine the central bank's intentions underlying a policy move, but rather the traders' opinions. In their view it is "irrelevant whether a target change is in fact driven by policy preferences or by economic events. At any given point in time it is traders, and not the Fed, that determine the price of long-term bonds" (Ellingsen et al., 2003, p. 2). Thus, the effect on market interest rates is not driven by policy actions, but by the opinions and views market participants form about such actions. In other words, it's not the target rate change that influences the yield curve, but the stories surrounding it.

Likewise, Cook and Hahn (1989) used newspaper articles to analyze the reaction of the

yield curve to target rate movements. They focused on perceived changes in the target rate as reported by the Wall Street Journal on the day after a target rate change to determine its magnitude and direction. Interestingly, Cook and Hahn (1989, p. 337) mention that the Journal sometimes used "speculative language" which hampered their ability to isolate the bare facts of the policy action. In their quest to determine the facts of the policy move, they did their best to strip the articles of all other information, including the manner in which the facts were presented and the interpretative value of the "speculative language."

Gürkaynak, Sack, and Swanson (2005a, pp. 86–87) drive the point home by saying that "previous studies estimating the effects of changes in the federal funds rate on bond yields [...] have been missing most of the story." Their research revealed that reactions on the financial market were at least partially driven by the statements accompanying a policy action. Announcements of the FOMC, the Federal Open Market Committee of the Fed which regulates the funds rate target, account for at least three quarters of the variation in the movement of longer term Treasury yields around a FOMC meeting.

Similarly, Goetzmann, Kim, and Shiller (2016) support the view that market participants are highly influenced by narrative statements, especially by the financial press. A survey over a 26 year period revealed that investors generally hold an exaggerated assessment of the risk of a stock market crash and that their assessments were influenced by the news stories, in particular the front page stories, they have read. According to Goetzmann et al., newspaper articles make market returns, especially negative developments, more salient and thus influence investor behavior. Other researchers, such as Engelberg and Parsons (2011), Kräussl and Mirgorodskaya (2014), and Yuan (2015), support the view that the financial press plays an important role in focusing investor attention and thus influences their behavior.

Consequently, the author of this thesis hypothesizes that it is the interpretation of a policy event, that is the narrative surrounding a target rate change as it is perceived by the market participants, that determines the response of the financial markets and thus the movement of the long-term interest rate. Even though Ellingsen et al. (2003) employ a narrative approach, it remains closely tied to a macroeconomic model and only allows for certain predetermined aspects of a potentially much bigger narrative. Thus, it stands to reason that opening the focus of the analysis to include any type of narrative that could potentially influence a market

participant's action will yield more robust results. To this end, the author proposes the following model:

$$\Delta i_t^n = \alpha + (\beta_n^{NP} d_t^{NP} + \beta_n^{N_1} d_t^{N_1} + \beta_n^{N_2} d_t^{N_2}) \Delta i_t^{3m} + v_t^n, \quad (2.3)$$

where  $\Delta i_t^n$  is the change in the interest rate of maturity  $n$  on day  $t$ ;  $d_t^{NP}$  is a dummy for non-policy days,  $d_t^{N_1}$  and  $d_t^{N_2}$  are dummies for policy days that were classified as being dominated by either narrative one ( $N_1$ ) or narrative two ( $N_2$ ); and  $\Delta i_t^{3m}$  is the change in the 3-month treasury bill rate on day  $t$ .

Ideally, an examination of newspaper articles with regards to narratives surrounding a target rate change will allow the identification of two distinct narratives that are able to account for the inconsistent reaction of the long-term rates. Thus, the main hypothesis stipulates that narrative one leads to a negative reaction of the long-term rate while narrative two provokes a positive reaction:

$$H_0 : \text{For large } n: \beta_n^{N_1} < 0 < \beta_n^{N_2} \quad (2.4)$$

Chapter 3 outlines what narratives are and why there is reason to believe that they have a strong influence on human behavior and thus warrant more attention in financial and economic research. To circumvent the problem of subjectivity faced by previous research when it comes to the identification of narratives, this thesis uses Natural Language Processing techniques rather than manual evaluation of text data. Chapter 4 gives an overview of different methods and the extent to which they are able to identify narrative structures.

Keep in mind the check Ellingsen et al use to check for just general news related movements in the yield curve, do the same if necessary

Also: if possible, generate testing sample and try hand at out of sample prediction – see how that goes!

# Chapter 3

## Narratives and Decision Making

### 3.1 What Narratives Are

#### 3.1.1 McAdams Research on Narratives

#### 3.1.2 Social Psychology Background

### 3.2 How Narratives can help

#### 3.2.1 Bayesian Brain and Predictive Coding

Here, there could be a direct link to the algorithms that are used in Machine Learning, AI, and NLP.

#### 3.2.2 Influence and Change on Human Beings

Akerlof and Shiller understand narratives as a convention, but it is more than that, it changes how people think and perceive the world. Akerlof and Snower (2016)

### 3.3 Narrative Research



# Chapter 4

## Topic Analysis

In this chapter, I take a closer look at topic mining and analysis, a field of natural language processing that aims at analyzing the content of text data. To that end, I introduce unsupervised text mining techniques called probabilistic topic models that discover latent topics in the text data. Zhai and Massung (2016, p. 329) define a topic as "the main idea discussed in the text data, which may also be regarded as a theme or subject of a discussion or conversation."

The reason for the use of topic analysis in this thesis is obvious: News articles that present different narratives on the target rate adjustment will do so by discussing different themes or topics concerning such an adjustment. On an analytical level, we can expect that articles reporting along the lines of different narratives will also employ a different vocabulary. This is exactly what a probabilistic topic modeling with its bag-of-words method is able to pick up on. Probabilistic Latent Semantic Analysis (PLSA) is introduced in Chapter 4.1 as a first probabilistic topic model, followed by Latent Dirichlet Allocation (LDA), a development of PLSA, in Chapter 4.1.7.

### 4.1 Probabilistic Latent Semantic Analysis

Probabilistic Latent Semantic Analysis (PLSA) was first introduced by Hofmann (1999). Blei, Ng, and Jordan (2003, p. 994) called Hofmann's model a "significant step forward" in probabilistic topic modeling. The main achievement of PLSA was to supplement the theory of Latent Semantic Analysis with a sound statistical foundation and to introduce a proper generative

model of the data (Hofmann, 1999, p. 289). It is based on the idea that documents are mixtures of topics and the generative model specifies a probabilistic procedure by which documents are assumed to be generated (Stein & Griffiths, 2007, p. 2). As Blei et al. (2003, p. 994) explains, PLSA "models each word in a document as a sample from a mixture model, where the mixture components are multinomial random variables that can be viewed as representations of 'topics'." Let's take a closer look at the generative process via such mixture models.

#### 4.1.1 Mixture Model / Generative Model

As input a topic modeling task takes a collection of text documents and a specification of the number of topics, as output it produces the topics as well as the coverage of the topics in every document (Zhai & Massung, 2016, pp. 330–331), as illustrated in Table 4.1.<sup>1</sup>

Input	
• A collection of $N$ text documents	$C = \{d_1, \dots, d_N\}$
• Number of topics	$k$
Output	
• Coverage of topics in each document $d_i$	$\{\pi_{i1}, \dots, \pi_{ik}\}$ , with $\sum_{j=1}^k \pi_{ij} = 1$
• $k$ topics	$\{\theta_1, \dots, \theta_k\}$

**Table 4.1** – Formal definition of topic modeling task.

In the context of topic modeling, a topic is represented as a probability distribution over words (or terms). That is, a topic is a distribution that assigns each word in the vocabulary set a probability. If we were to sample from this distributions, words closely associated with the topic are more likely to come up as they are given a higher weight in the distribution. In general, all words in the vocabulary set may have a non-zero probability in a given word distribution as it is always possible that a unrelated word shows up in an article on the topic (Zhai and Massung 2016, pp. 335–337; Blei et al. 2003, p. 994). Figure 4.1 illustrates four topics, for each of which the 16 words with the highest probability are listed. Based on these words, the topics could be labeled drug use, colors, memory, and health care (Stein & Griffiths, 2007, p.2). The aim of probabilistic topic models is to discover such word distributions in the text data.

<sup>1</sup> Please note that this thesis follows the notation of Zhai and Massung (2016).

**Figure 4.1** – An illustration of four topics (Steiyvers & Griffiths, 2007, p.2).

word	prob.	word	prob.	word	prob.	word	prob.
DRUGS	.069	RED	.202	MIND	.081	DOCTOR	.074
DRUG	.060	BLUE	.099	THOUGHT	.066	DR.	.063
MEDICINE	.027	GREEN	.096	REMEMBER	.064	PATIENT	.061
EFFECTS	.026	YELLOW	.073	MEMORY	.037	HOSPITAL	.049
BODY	.023	WHITE	.048	THINKING	.030	CARE	.046
MEDICINES	.019	COLOR	.048	PROFESSOR	.028	MEDICAL	.042
PAIN	.016	BRIGHT	.030	FELT	.025	NURSE	.031
PERSON	.016	COLORS	.029	REMEMBERED	.022	PATIENTS	.029
MARIJUANA	.014	ORANGE	.027	THOUGHTS	.020	DOCTORS	.028
LABEL	.012	BROWN	.027	FORGOTTEN	.020	HEALTH	.025
ALCOHOL	.012	PINK	.017	MOMENT	.020	MEDICINE	.017
DANGEROUS	.011	LOOK	.017	THINK	.019	NURSING	.017
ABUSE	.009	BLACK	.016	THING	.016	DENTAL	.015
EFFECT	.009	PURPLE	.015	WONDER	.014	NURSES	.013
KNOWN	.008	CROSS	.011	FORGET	.012	PHYSICIAN	.012
PILLS	.008	COLORED	.009	RECALL	.012	HOSPITALS	.011

Going back to the formal definition in Table 4.1, each  $\theta_i$  is a word distribution. Thus,

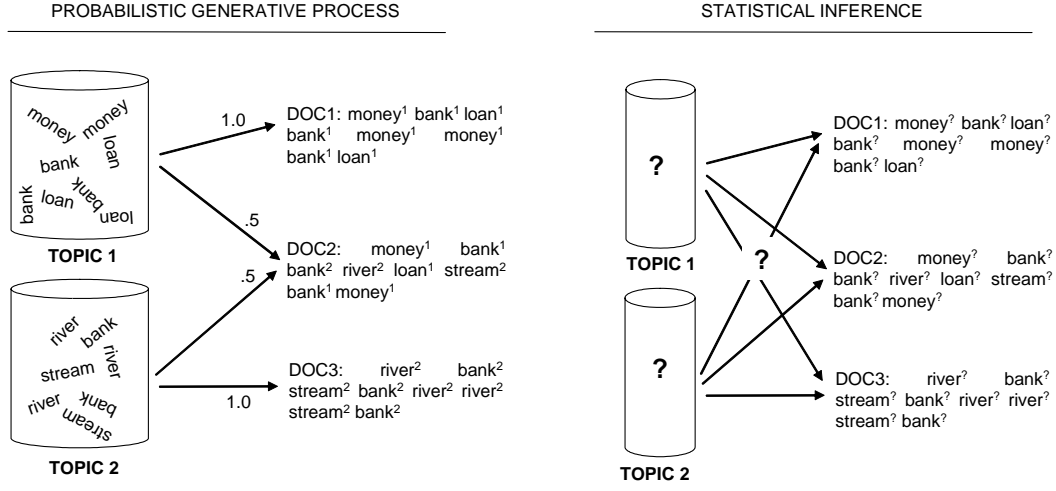
$$\sum_{w \in V} p(w|\theta_i) = 1,$$

where  $p(w|\theta_i)$  is the probability of word  $w$  in the word distribution  $\theta_i$  with  $w$  being a unique word in the vocabulary set  $V = \{w_1, w_2, \dots, w_M\}$ . The vocabulary set is the set of unique words in a document or a collection  $C$  (Zhai & Massung, 2016, pp. 338).

The generative models underlying topic models are based on probabilistic sampling rules and specify how the words in documents are generated on the basis of latent variables. Given the definition of topics as word distributions, the model assumes that every word in a document is drawn from a topic. From which topic a word is to be drawn is determined by a distribution over topics. As such, documents with different content are generated by choosing different distributions over topics (Steiyvers & Griffiths, 2007, p. 2–3). Figure 4.2 illustrates the process of generating three documents from two topics. While two of the documents are generated exclusively from one topic, one document is an equal mixture of both topics. Note that words can be part of more than one topic, allowing the model to capture the multiple meanings of polysemies (Steiyvers & Griffiths, 2007, p. 2–3). [list more upsides](#)

The generative process can be inverted to appear as a problem of statistical inference (see Figure 4.2): When fitting the generative model, the aim is to identify the latent variables, here the latent topics, that are best able to explain the observed data. Thus the model is able to infer the probability distributions over words and the distribution over topics for each document

**Figure 4.2** – The generative model and the problem of statistical inference (SteYvers & Griffiths, 2007, p.3).



from the text data (SteYvers & Griffiths, 2007, p. 3). While the inferred distributions over words are interpreted as topics, the probability distribution over topics can be usefully thought of as the extent to which a topic accounts for the content of a document, that is what fraction of words in document  $d_i$  is generated by topic  $\theta_j$ . Note that the probabilities of document  $d_i$  covering topic  $\theta_j$  sum to one across all topics:

$$\sum_{j=1}^k \pi_{ij} = 1.$$

Thus, the topics  $\{\theta_1, \dots, \theta_k\}$  as inferred by the topic model account for every word in the document, with no words being attributed to other topics (Zhai & Massung, 2016, pp. 338).

There is one key assumption underlying the generative model explained above. It assumes that the order of the words in a document as well as the order of the documents in a collection can be neglected. The model picks up on the frequencies of words, but completely ignores their position in the text. Should the order of the words contain useful information, such information is discarded by probabilistic topic models. This assumption is known as the “bag-of-words” assumption, an assumption of exchangeability of the words in a document (Blei et al. 2003, p. 994; SteYvers and Griffiths 2007, p. 3). Hofmann (1999, p. 290) himself admits that the “key assumption is that the simplified ‘bag-of-words’ [...] representation of documents will in many cases preserve most of the relevant information.” In Figure 4.2, this principle is captured

by illustrating topics as bags containing different distribution over words. The position of the words is arbitrary.

#### 4.1.2 Model Fitting with Expectation-Maximization

As outlined above, a topic model is a mixture model that consists of several (latent) variables, i.e. word distributions. An estimation of the model's variables is obtained via Maximum Likelihood (ML) estimation. If a mixture model consists of several components, that is more than just one topic, there is no analytical solution to the ML estimation and a numerical optimization algorithm must be employed. The Expectation-Maximization algorithm (EM) is a family of useful algorithms to obtain an ML estimate of mixture models (Zhai & Massung, 2016, p. 359) According to Hofmann (1999, p. 290; 2001, p. 181), EM is the "standard procedure for maximum likelihood estimation in latent variable models."

In a first step, the ML estimation problem is to be defined. Based on the generative model outlined in Chapter 4.1.1, the likelihood function is derived. Recall that  $p(w|\theta_j)$  is the probability of word  $w$  in the word distribution  $\theta_j$  and that  $\pi_{d,j}$  is the coverage of topic  $\theta_j$  in document  $d$ . When faced with the problem of statistical inference,  $\pi_{d,j}$  can be thought of as the probability of topic  $\theta_j$  generating word  $w$ . Then, the probability of observing the sequence of words that make up document  $d$  is:

$$p(d) = \prod_{w \in V} \left( \sum_{j=1}^k \pi_{d,j} p(w|\theta_j) \right)^{c(w,d)} \quad (4.1)$$

$$\log p(d) = \sum_{w \in V} c(w, d) \log \left( \sum_{j=1}^k \pi_{d,j} p(w|\theta_j) \right) \quad (4.2)$$

with  $w$  being a unique word in the vocabulary set  $V = \{w_1, w_2, \dots, w_M\}$  and  $c(w, d)$  being the count of word  $w$  in document  $d$ . If we consider the entire collection of  $N$  documents  $C = \{d_1, \dots, d_N\}$ , the log likelihood function is:

$$\log p(C|\pi_{d,j}, \theta_j) = \sum_{d \in C} \sum_{w \in V} c(w, d) \log \left( \sum_{j=1}^k \pi_{d,j} p(w|\theta_j) \right) \quad (4.3)$$

A few words of explanation.  $\sum_{j=1}^k \pi_{d,j} p(w|\theta_j)$  denotes the probability of word  $w$  occurring

once in document  $d$ . It is the probability of observing the word regardless of which topic is used. We assume independence in generating each word, hence the probability of the document equals the product of the probability of each word in the document (see Eq. 4.1). Eq. 4.2 is the log likelihood function for document  $d$ , just as Eq. 4.3 is the log likelihood for the entire collection  $C$  (Hofmann, 1999; 2001; Steyvers & Griffiths, 2007; for notation see Zhai & Massung, 2016, p. 340–377).

With the likelihood function defined, we are faced with a constrained optimization problem:

$$\arg \max_{\pi_{d,j}, \theta_j} p(C|\pi_{d,j}, \theta_j) \quad (4.4)$$

$$\text{s. t. } \sum_{w \in V} p(w|\theta_j) = 1, \quad j \in [1, k] \quad \sum_{j=1}^k \pi_{dj} = 1, \quad d \in C \quad (4.5)$$

All that is left to do is to solve the maximization problem. If we knew from which topic a word is generated it would be straightforward to calculate the ML estimate. In such a case, the word distributions would simply be the normalized word frequencies (see Chapter XXXX for elaborations on unigram language models). However, the partitioning of the words among the topics is not known, that is we do not know from which topic a word is generated, thus we have to fall back on an iterative algorithm to solve the maximization problem. The EM algorithm proceeds by guessing from which distribution a word is generated and making a tentative estimate of the parameters. Based on the assumed partitioning, the estimate of the parameters is updated. This, in turn, allows an improved inference of the partitioning, leading to an iterative hill-climbing algorithm that improves the estimate of the parameters until it reaches a local optimum (Zhai & Massung, 2016, p. 360). The algorithm proceeds in two steps: In the expectation step (E), posteriori probabilities for the latent variables are computed based on current estimates. In the maximization step (M), the parameters are updated (Hofmann, 1999, p. 290; 1999, p. 181–182).

In the E-step, the algorithm uses Bayes rule to infer the topic that has been used to generate a word. We introduce a hidden variable  $z_{d,w} \in \{1, 2, \dots, k\}$  to capture this information. The value of this hidden variable is inferred based on a tentative set of parameters (Hofmann, 1999,

p. 290; 2001, p. 182; Zhai & Massung, 2016, p. 362–374):

$$p(z_{d,w} = j) = \frac{\pi_{d,j}^{(n)} p^{(n)}(w|\theta_j)}{\sum_{j=1}^k \pi_{d,j}^{(n)} p^{(n)}(w|\theta_j)} \quad (4.6)$$

Eq. 4.6 shows the E-Step of the EM algorithm for PLSA, where  $p(z_{d,w} = j)$  is the probability that word  $w$  in document  $d$  is generated from topic  $\theta_j$ . Note that this probability depends on the document  $d$ , i.e. whether a word has been generated from a specific topic depends on the document. As a result, each document will have a different topic distribution,  $\pi_{d,j}$ , indicating the varying emphasis on specific topics across documents. I will use this fact to classify articles according to different narratives (see Chapter XXXX). The probability value of  $z_{d,w}$  is calculated for every unique word in each document by computing the product of the probability of word  $w$  given the selected topic and the probability of selecting a topic. The product is normalized to ensure the constraints in Eq. 4.5 hold. The superscript  $^{(n)}$  indicates the generation of parameters in the iteration (Zhai & Massung, 2016, p. 374–376).

In the M-step we calculate an ML estimate of the parameters  $\pi_{d,j}$  and  $p(w|\theta_j)$  using the estimate obtained in step E. We use the estimated partitioning of the words among the topics to adjust the word count  $c(w, d)$ , that is we obtain a discounted word count  $c(w, d)p(z_{d,w} = j)$  which can be understood as the expected count for the event that word  $w$  is generated from  $\theta_j$ . Remember that the ML estimation could not be solved analytically because we did not know the partitioning of the words. Having obtained a tentative guess of the partitioning, we can easily estimate  $\pi_{d,j}$  (the probability of document  $d$  covering topic  $\theta_j$ ) and  $p(w|\theta_j)$  (the probability of word  $w$  for topic  $\theta_j$ ) (Hofmann, 1999, p. 290; 2001, p. 182; Zhai & Massung, 2016, p. 364–375):

$$\pi_{d,j}^{(n+1)} = \frac{\sum_{w \in V} c(w, d) p^{(n)}(z_{d,w} = j)}{\sum_{j \in k} \sum_{w \in V} c(w, d) p^{(n)}(z_{d,w} = j)} \quad (4.7)$$

$$p^{(n+1)}(w|\theta_j) = \frac{\sum_{d \in C} c(w, d) p^{(n)}(z_{d,w} = j)}{\sum_{w \in V} \sum_{d \in C} c(w, d) p^{(n)}(z_{d,w} = j)} \quad (4.8)$$

As Eq. 4.7 and Eq. 4.8 illustrate, the computation of the parameter estimates amounts simply to aggregating the the expected word counts and normalizing them among all topics or among all words, respectively. The normalization must ensure that the constraints in Eq. 4.5 hold. The new generation of parameters is used to adjust the probabilities of the  $z_{d,w}$  values,

which subsequently can be used to compute a next generation of parameters. The EM algorithm continues to iterate over the E- and M-step until the likelihood converges. Instead of using a convergence condition, a stopping rule can be employed. In this case, the algorithm stops updating the parameters once a sufficient performance, as defined in the stopping criterion, is reached (Hofmann, 2001, p. 182–183).

As mentioned before, EM is a hill-climbing algorithm that starts with an initial guess of the parameter values and then successively improves it. In the process of improving the estimate, the EM algorithm is guaranteed to converge to a local, but not a global maximum. To account for this, Zhai and Massung recommend applying the algorithm repeatedly with changing initial values for the unknown parameters and using the run with the highest likelihood value (2016, p. 363–368).

### 4.1.3 Adding a Background Language Model

In the original PLSA Hofmann (1999) there was no background topic. The aim of a background topic is to capture the common words in the text data so that the other topics can capture the words of interest. If a topic model does not include a background model, such as the original PLSA, common words will have a high probability in the learned topics. As a result, entire learned topics could consist mainly of stopwords.

Behavior of a mixture model muss auch hier rein

The simplest topic model is the unigram language model (more on the topic in Chapter xxxx-). Adding a background language model. setting background model powerful tool to inject some domain knowledge in estimator – setting very strong prior in Bayesian estimation Mostly, topic models are mixture models of at least two topic.

First, a topic can be represented as a word distribution (or a term distribution) and second a text document is a sample of words drawn from a probabilistic model

- ONE TOPIC: unigram language model, MLE with some prior belief, so Bayesian estimation of parameters
  - p. 342 / model:  $p(w_i|\theta)$  for  $i \in (1, M)$
  - likelihood function:  $\prod_{i=1}^M p(w_i|\theta)^{c(w_i,d)}$  with  $c(w_i, d)$  being the count of unique word



$w_i$  in document  $d$

– now maximize, that is find the word probabilities  $p(w_i|\theta)$

- Adding a background language model, p. 347
  - $p(\theta_i)$  is probability of choosing word distribution  $i$ , generative model with some uncertainty as to which word distribution will be chosen, must sum to one for all  $\theta_i$
  - set  $p(\theta_b)$  to indicate how many words to factor out // how to set  $p(\theta_i)$ ?
  - likelihood function:  $\prod_{i=1}^M [p(\theta_d)p(w_i|\theta_d) + p(\theta_b)p(w_i|\theta_b)]^{c(w_i,d)}$  with  $c(w_i,d)$  being the count of unique word  $w_i$  in document  $d$
- background model  $\theta_b$  needs to be preset to bias the word distribution towards common words p. 352! setting background model powerful tool to inject some domain knowledge in estimator – setting very strong prior in Bayesian estimation
- 
- 
- 
- 

#### 4.1.4 Expectation Maximization

- infer which word is from which distribution in a document, based on tentative estimate of parameters, iterative hill-climbing algorithm p. 360
- use Bayes rules, prior is  $p(\theta_i)$ , the probability of partitioning, belief before we observe the text
- binary latent variable  $z$ , to denote which topic a word is from
- posteriori probability  $p(z = 0|w = \text{text})$ , guesses at which probability has been used to generate the word, proportional to  $p(\theta_d)p(w_i|\theta_d)$  // E-Step / helps us figure out which word has been attributed to which topic, but does not make it final
- E-Step: how likely is  $w$  from  $\theta_d$ :  $p^{(n)}(z = 0|w) = \frac{p(\theta_d)p^{(n)}(w|\theta_d)}{p(\theta_d)p^{(n)}(w|\theta_d) + p(\theta_b)p^{(n)}(w|\theta_b)}$

- M-Step:  $p^{(n+1)}(w|\theta_d) = \frac{c(w,d)p^{(n)}(z=0|w)}{\sum_{w' \in V} c(w',d)p^{(n)}(z=0|w')}$
- we introduce the latent variables because their existence makes the ML trivial to compute, because we can now normalize over all the terms that are of  $z = 0$
- M-step uses the fact, that all occurrences of  $w$  have been split between the distributions,  $c(w,d)p^{(n)}(z=0|w)$  is a discounted count of  $w$ , expected number of occurrences in topic  $z = 0$ , and  $c(w,d)p^{(n)}(z=0|w) + c(w,d)[1 - p^{(n)}(z=0|w)] = c(w,d)$ , that is the total count in the document
- for each iteration we can calculate the likelihood value

#### 4.1.5 PLSA with background model

here can implement own algorithm with background model, created myself adding a background language model

#### 4.1.6 PLSA

- probability of observing a word:  $p_d(w) = \lambda_B p(w|\theta_b) + (1 - \lambda_B) \sum_{j=1}^k \pi_{d,j} p(w|\theta_j)$
- Likelihood function for all words in document  $d$ :  $\sum_{w \in V} c(w,d) \log[\lambda_B p(w|\theta_b) + (1 - \lambda_B) \sum_{j=1}^k \pi_{d,j} p(w|\theta_j)]$
- Likelihood function for all words in collection  $C$ :  $\sum_{d \in C} \sum_{w \in V} c(w,d) \log[\lambda_B p(w|\theta_b) + (1 - \lambda_B) \sum_{j=1}^k \pi_{d,j} p(w|\theta_j)]$
- Unknown parameters:  $\pi$  and  $\theta$
- use the EM model to compute the ML estimates for PLSA, more hidden variables in the E step, p. 374, probabilities that word  $w$  and doc  $d$  is created by model  $j$  or  $B$ , estimating the latent variables  $z$
- $p(z_{d,w} = j) = \frac{\pi_{d,j}^{(n)} p^{(n)}(w|\theta_j)}{\sum_{j'=1}^k \pi_{d,j'}^{(n)} p^{(n)}(w|\theta_{j'})}$
- $p(z_{d,w} = B) = \frac{\lambda_B p(w|\theta_b)}{\lambda_B p(w|\theta_b) + (1 - \lambda_B) \sum_{j=1}^k \pi_{d,j}^{(n)} p^{(n)}(w|\theta_j)}$
- M Step, probability of  $d$  covering topic  $j$ , and probability of word  $w$  for topic  $j$

- $\pi_{d,j}^{(n+1)} = \frac{\sum_{w \in V} c(w,d)(1-p(z_{d,w}=B))p(z_{d,w}=j)}{\sum_{j'} \sum_{w \in V} c(w,d)(1-p(z_{d,w}=B))p(z_{d,w}=j')}$
- $p^{(n+1)}(w|\theta_j) = \frac{\sum_{d \in C} c(w,d)(1-p(z_{d,w}=B))p(z_{d,w}=j)}{\sum_{w'} \sum_{d \in C} c(w',d)(1-p(z_{d,w'}=B))p(z_{d,w'}=j)}$
- p. 376, first need to initialize all the unknown parameters randomly,  $\pi$  and the  $p(w|\theta)$

#### 4.1.7 Latent Dirichlet Allocation

- p. 378 impose some prior knowledge about the data set to be estimated
- parameters are  $\Lambda$  und prior distribution is  $p(\Lambda)$
- using Maximum A priori estimation
- MAP:  $\Lambda^* = \operatorname{argmax}_{\Lambda} p(\Lambda)p(\text{Data}|\Lambda)$
- $p(\Lambda)$  as a conjugate prior distribution
- the topic coverage distribution (a multinomial distribution) for each document is assumed to be drawn from a prior Dirichlet distribution, so are the word distributions representing the latent topics assumed to be drawn from another Dirichlet distribution - thus they are no longer parameters, the only parameters of the model are the ones characterizing the Dirichlet distributions (two kinds),  $\alpha_1, \dots, \alpha_k$  and  $\beta_1, \dots, \beta_M$ , with  $M$  being the number of unique words

## 4.2 LDA

PLSA - The linear growth in parameters suggests that the model is prone to overfitting and, empirically, overfitting is indeed a serious problem (Blei et al., 2003, p. 1001)

First introduced by Blei et al. (2003)

”While Hofmann’s work is a useful step toward probabilistic modeling of text, it is incomplete in that it provides no probabilistic model at the level of documents.” (Blei et al., 2003, p. 994)

here use package, just include for completeness, prob. difficult to implement myself with background model

### 4.2.1 Notes

Different ways to define topics are available: topics as a single term, topics as word distribution, unigram language model,, use prob distribution over words to fin tpic, use MLE, problem: common words with giving little information are given high values, ' add background lagnuage model.

While Topic Analysis can be a powerful tool to evaluate text data, there are also problematic aspects. issues are obvious. Human judgment is needed in defining what exactly constitutes a topic

Hoffman, M., Bach, F. R., & Blei, D. M. (2010)

Steyvers and Griffiths (2007)

Blei et al. (2003)

Asuncion, A., Welling, M., Smyth, P., & Teh, Y. W. (2009)

here: general topics, document specific word distributions, corpus wide background distribution

Chemudugunta, C., Smyth, P., & Steyvers, M. (2007)

Bishop (2006)

Darling (2011)

Another problem: where the document stands does not matter, but some days have a lot more articles than others, shall we randomly select only a few as to keep the balance? Make several iterations? Questions is: how can topic model pick up on different vocabulary?

## 4.3 Sensitivity Analysis

# Chapter 5

## Data and Methodology

### 5.1 Financial Data

Data on target rate adjustments and FOMC meetings was retrieved from the Fed’s website (Federal Reserve System, 2018, 2013; Federal Open Market Committee, 2018a; 2018b) and summarized in table A.1 and A.2 in Appendix A.

The FOMC holds eight regularly scheduled meetings during the year. Additional, unscheduled meetings are called when necessary (Federal Open Market Committee, 2018b). In April 2011, the Fed has taken up the practice of holding quarterly press conferences where it comments on its policy decisions, including its treatment of the target rate. Usually, the press conferences take place after every other meeting. In June 2018, the Fed announced that starting January 2019 it will hold a press conference after every meeting (Federal Open Market Committee, 2018c). Table A.1 in Appendix A lists all 195 FOMC meetings that have taken place over the last 20 years. If a meeting lasted two days, only the last day is listed. Unsurprisingly, certain years necessitated more emergency meetings than others: In 2008, the FOMC held a total of 14 meetings, 6 more than usual. In 2001, the FOMC held 13 meetings, two of which were conference calls shortly after the events of 9/11. While the market anticipates the scheduled meetings and forms expectations about potential policy actions, the same is not possible for unscheduled emergency meetings.

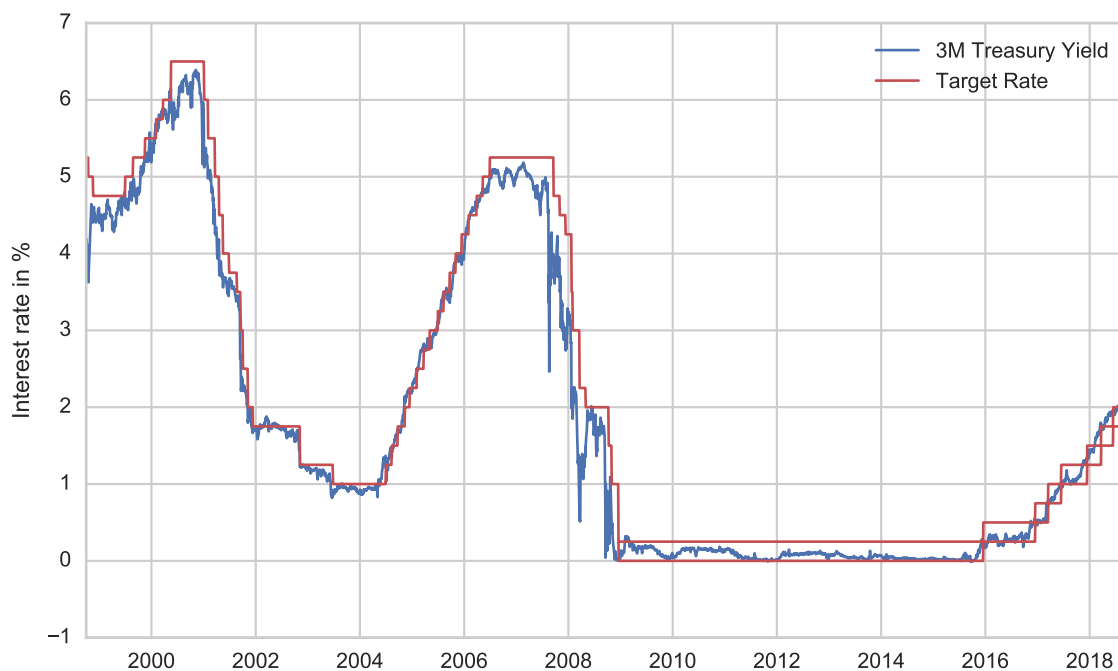
Table A.2 in Appendix A gives an overview of the changes in the target rate over the past 20 years. From January 1998 to September 2018, the target rate was adjusted on 57

occasions. Only six of the 57 adjustments happened after unscheduled meetings. Most notably, two surprise adjustments took place during 2008 and three during 2001, one of them shortly after 9/11. Until 2008, the Fed used to decide and implement the new target rate on the very same day. The practice was changed after 2008 and the target rate was subsequently adjusted on the day following the FOMC meeting.

The development of the target rate over time is characterized by periods of stark increase and decrease. In May 2000, the target rate was at its highest with 6.5%. From January 2001 to June 2003, the target rate decreased steadily until it reached a low point of 1%. Mid-2006, the target rate was again at 5.25% but was lowered drastically in 2007 and 2008 until it reached its all-time low of 0% in December 2008. At the same time, the FOMC introduced a target range and defined the target rate no longer as a discrete number but with the help of an upper and lower bound. For seven years, until december 2015, the FOMC kept the target rate in the range of 0% to 0.25%. Since then, it has slowly increased the target rate, announcing a range of 2%–2.25% in September 2018.

The daily yield curve of the US Treasury bills, notes, and bonds for the period of October 1, 1998 to September 30, 2018 was retrieved from Thomson Reuters Datastream. Figure 5.1 illustrates the development of the 3-month treasury yield as well as the target rate over the 20-year period. As explained in Chapter 2.2, Ellingsen et al. approximate unexpected monetary policy actions with the change in the 3-month T-bill rate. They argue, that the 3-month rate is sufficiently short to be determined by the target rate, but also sufficiently long to avoid noise from expectation errors (Ellingsen et al., 2003, p. 13). Indeed, Figure 5.1 shows that the 3-month T-bill rate and the target rate seem to move in tandem.

The treasury yields for all other maturities are depicted in Figure A.1 in Appendix A. Please note that for the 1-month rate the data series starts on July 31, 2001 and for the 7-year rate the series starts on May 26, 2009. Due to data availability, the 20-year rate is given as a constant maturity rate while the rates of the other maturities are given as bid yields. As expected, while the short term yields (up to 1 year) move quite closely with the target rate, the longer the maturity the more it emancipates itself from the target rate.

**Figure 5.1** – Target rate and 3M treasury yield.

## 5.2 Text Data

Articles are collected from the Dow Jones Factiva Database (<https://global.factiva.com>) by use of the search terms *Federal Reserve* and *interest rate*. Only articles that appeared in the *United States* on the subject of *interest rates* in a window of three days around each target rate adjustment (the day before, of, and after an adjustment as listed in Table A.2) are taken into account. The articles are mainly taken from the *The Wall Street Journal*, *Financial Times*, *Reuters*, *The Associated Press*, *Market News International*, *Dow Jones Institutional News*, *Agence France*, and *AFX*, as these newspapers seem to publish the most articles on the topic.

From October 1, 1998 to September 30, 2018, 56 target rate adjustments have taken place, for which a total of 2'318 articles have been extracted. Since the FED changed its policy from undertaking a target rate change on the same day as a FOMC meeting to only doing so on the following day, articles  $\pm 1$  day around the official target rate change have been collected. This ensures that the articles capture any information, speculation, and interpretations that abound directly after the meeting, on the day of the target rate change as well as on the following day. On rare occasions, the number of articles ran in the several hundreds and only the most relevant have been selected.

**Figure 5.2** – Wordcloud illustrating the most common words across all articles.

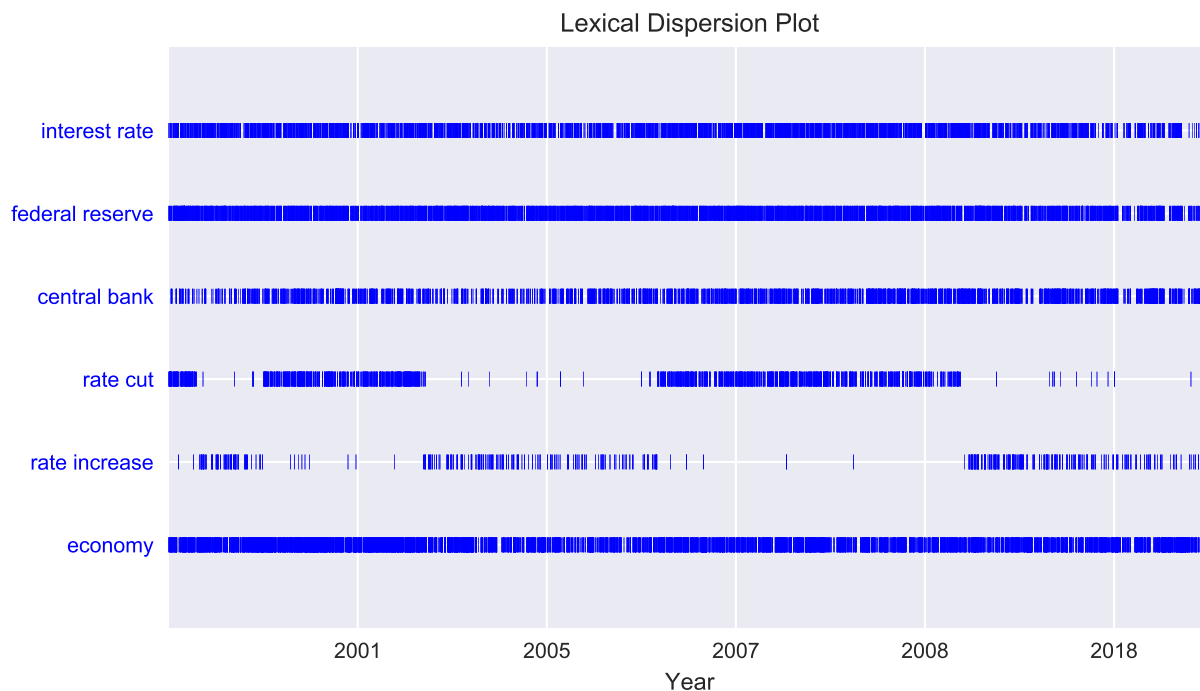


The final sample comprises between 14 and 97 publications for every policy day. In total, over 1'600'000 tokens are extracted from these articles. After stop words have been removed, the token count drops to roughly 1'100'000. (For more information on text preprocessing, see Chapter 5.3.1). Figure B.1 in Appendix B illustrates the spread of the text data across policy days and shows that the token count fluctuates quite drastically. More data is available for recent target rate adjustments, less for more historic adjustments.

Looking at the most common words in the entire text data base, as illustrated in Figure 5.2, yields no surprises. As one might expect, the articles make heavy use of context specific vocabulary such as "interest rate", "federal reserve", "economy", but also of terms appropriate for a financial environment such as "basis point", "percentage point", or "investor". Even analyzing just the headlines of the articles yields an almost identical word usage. Thus, headlines appear to be just as factual and technical as the general text body. Overall, this is a first indication that while there is a set vocabulary to talk about the facts of a target rate change, there is no similarly systematic vocabulary to express interpretations and sentiments surrounding such a change.

A closer look at the dispersion of the most common words reveals that their usage is consistent over time (see Figure 5.3). The frequently used terms are just as likely to be used in



**Figure 5.3** – Dispersion of most common words across time.

older articles as in newer publications. As one might expect, the articles talk about "rate cut" in times where the Fed is lowering the target rate, and about "rate increase" when the Fed is in the process of raising the target rate.

## 5.3 Methodology

### 5.3.1 Text Preprocessing

For almost all purposes of computational linguistics, the texts have to be processed and prepared. To that end, text data first needs to be segmented into words, that is the sequence of characters that make up a text needs to be broken down to locate the word boundaries. Words identified thus are referred to as tokens and the process is known as tokenization (Palmer, 2010, p. 10). I apply the word tokenizer of the nltk package (Bird, Klein, & Loper, 2009), as this application is prepared to deal with frequently occurring character sequences appertaining to the English language, such as contractions. Palmer (2010, pp. 16-19) rightly points out that there exists plenty of tokenization ambiguity, even in a language where the words are generally

space-delimited. Some of this ambiguity is hard to resolve, such as the use of apostrophes for the genitive form of a noun, for the plural form, and for verbal contractions. **Could give a (code) example in the appendix**

In a next step, frequent words that carry little information, commonly referred to as stop words, are removed from the text.

In a next step, Porter stemmer

especially concerning punctuation, already needs to address the ambiguity that is inherent in natural language. there is a lot of ambiguity in natural language that

Depending on what we need for further processing, the text needs to be prepared In a first step, the text data must be prepared for analysis. To that end, the text is split into meaningful tokens. I used my own tokenizer for this task, Porter stemmer, Preprocessing of text: - tokenization, how and which one chosen and why? - stemmer -stop word removal - nltk.tokenize.mwe module

### 5.3.2 Application of Topic Analysis

For our purposes, topic analysis is used to identify the topics contained in the articles reporting on the target rate adjustment, the hypothesis being that different topics will emerge for different interpretations of the Fed's policy move.

I could use LDA when doing out of sample prediction - because then I can predict documents I have not seen before, because I train an LDA model, but when I use all documents, I could just as easily do the mixed model approach with several unigram models???

tf-idf term weighting: Apply Term Frequency Inverse Document Frequency normalization to a sparse matrix of occurrence counts. ,bag of words methodology, feature extraction has a big influence on topics that we will find, corpus specific stopwords, preprocessing with vectorizer of do your own

**EM hill climbing algorithm, only reaches local maximum, thus initialize several times with different RV!!**

## 5.4 NOTES

Besprechung - 24.09.2018 —————

- Frage Juan Pablo Ortega ob er Korreferent sein will - nur zwei Narrative finden, ohne Daten vorgeben (Texte nach Meeting verwenden, weil sonst ja nicht Interpretation gefunden wird), dann schauen geht die Kurve beim einen Narrativ hoch beim anderen runter - es sollten auch die non-target rate adjustments verwendet werden, weil ansonsten j schon eine Selektion stattfindet - ABER: stimmt das wirklich, weil wenn kein adjustment, dann bewegt sich doch die Kurve nur gemäss neue Infos auf dem Markt, - also vielleicht doch besser keine adjustment heisst non-policy day?

- Example: nach nine eleven gab es tatsächlich ein paar unangemeldet meetings und daher komische effekte weil wirklich überraschende Verschiebungen in der interest rate

- modell ist gut, unsupervised learning verwenden, nicht vorher sagen, wo geht's hoch und wo runter, und dann ev. auch out-of sample probieren, aber das wäre Paradedisziplin, keine Garantie, dass das funktioniert

—my thoughts before meeting

all absolute Fed target rate changes during the sample period – ev. sind 10 Jahre nicht genug, vor allem weil es dann nur die extraordinary years sind - 20 Jahre? training and testing samples? aber dann müsste man annehmen, dass die Narrative über die Jahre gleichbleiben? oder aber man nimmt einzelne Datenpunkte aus dem sample raus? einzelne Tage (wohl zu wenige Observations) - einzelne ARTikel - sagt das was aus?

# Chapter 6

## Results

# Chapter 7

## Conclusion

# References

- Akerlof, G. A., & Snower, D. J. (2016). Bread and bullets. *Journal of Economic Behavior & Organization*, 126, 58–71.
- Asuncion, A., Welling, M., Smyth, P., & Teh, Y. W. (2009). On smoothing and inference for topic models. In *Proceedings of the twenty-fifth conference on uncertainty in artificial intelligence* (pp. 27–34). AUAI Press.
- Bird, S., Klein, E., & Loper, E. (2009). *Natural language processing with python. Analyzing text with the natural language toolkit*. O'Reilly Media. Retrieved from <http://www.nltk.org/book/>
- Bishop, C. M. (2006). *Pattern recognition and machine learning*. New York, NY: Springer.
- Blei, D. M., Ng, A. Y., & Jordan, M. I. (2003). Latent dirichlet allocation. *Journal of Machine Learning Research*, 3(Jan), 993–1022.
- Chemudugunta, C., Smyth, P., & Steyvers, M. (2007). Modeling general and specific aspects of documents with a probabilistic topic model. In *Advances in neural information processing systems* (pp. 241–248).
- Cook, T., & Hahn, T. (1989). The effect of changes in the federal funds rate target on market interest rates in the 1970s. *Journal of Monetary Economics*, 24(3), 331–351.
- Darling, W. M. (2011). A theoretical and practical implementation tutorial on topic modeling and gibbs sampling. In *Proceedings of the 49th annual meeting of the association for computational linguistics: Human language technologies* (pp. 642–647).
- Ellingsen, T., & Söderström, U. (2001). Monetary policy and market interest rates. *American Economic Review*, 91(5), 1594–1607.

- Ellingsen, T., & Söderström, U. (2004). Why are long rates sensitive to monetary policy? *SSRN Electronic Journal*.
- Ellingsen, T., Söderström, U., & Masseng, L. (2003). Monetary policy and the bond market. *Stockholm School of Economics. Photocopy*.
- Engelberg, J. E., & Parsons, C. A. (2011). The causal impact of media in financial markets. *The Journal of Finance*, 66(1), 67–97.
- Federal Open Market Committee. (2018a). *Historical materials by year*. Retrieved 2018-10-04, from [https://www.federalreserve.gov/monetarypolicy/fomc\\_historical\\_year.htm](https://www.federalreserve.gov/monetarypolicy/fomc_historical_year.htm)
- Federal Open Market Committee. (2018b). *Meeting calendars, statements, and minutes (2013-2018)*. Retrieved 2018-10-04, from <https://www.federalreserve.gov/monetarypolicy/fomccalendars.htm>
- Federal Open Market Committee. (2018c). *Transcript of chairman powell's press conference june 13, 2018*. Retrieved 2018-10-04, from <https://www.federalreserve.gov/mediacenter/files/FOMCpresconf20180613.pdf>
- Federal Reserve System. (2013). *Open market operations archive*. Retrieved 2018-10-04, from [https://www.federalreserve.gov/monetarypolicy/openmarket\\_archive.htm](https://www.federalreserve.gov/monetarypolicy/openmarket_archive.htm)
- Federal Reserve System. (2018). *Open market operations*. Retrieved 2018-10-04, from <https://www.federalreserve.gov/monetarypolicy/openmarket.htm>
- Goetzmann, W., Kim, D., & Shiller, R. J. (2016). *Crash beliefs from investor surveys* (Working Paper No. w22143). National Bureau of Economic Research.
- Gürkaynak, R. S., Sack, B. P., & Swanson, E. T. (2003). The excess sensitivity of long-term interest rates: Evidence and implications for macroeconomic models. *Finance and Economics Discussion Paper*.
- Gürkaynak, R. S., Sack, B. P., & Swanson, E. T. (2005a). Do actions speak louder than words? the response of asset prices to monetary policy actions and statements. *International Journal of Central Banking*, 1(1), 55–93.
- Gürkaynak, R. S., Sack, B. P., & Swanson, E. T. (2005b). The sensitivity of long-term interest rates to economic news: Evidence and implications for macroeconomic models. *American Economic Review*, 95(1), 425–436.
- Hoffman, M., Bach, F. R., & Blei, D. M. (2010). Online learning for latent dirichlet allocation.

- In *Advances in neural information processing systems* (pp. 856–864).
- Hofmann, T. (1999). Probabilistic latent semantic analysis. In *Proceedings of the fifteenth conference on uncertainty in artificial intelligence* (pp. 289–296). Morgan Kaufmann Publishers Inc.
- Hofmann, T. (2001). Unsupervised learning by probabilistic latent semantic analysis. *Machine Learning*, 42(1/2), 177–196.
- Kräussl, R., & Mirgorodskaya, E. (2014). *News media sentiment and investor behavior* (Working Paper No. 492). Center for Financial Studies.
- Palmer, D. D. (2010). Text preprocessing. In N. Indurkha & F. J. Damerau (Eds.), *Handbook of natural language processing* (pp. 9–30). Boca Raton, FL: CRC Press.
- Romer, C. D., & Romer, D. H. (2000). Federal reserve information and the behavior of interest rates. *American Economic Review*, 90(3), 429–457.
- Steyvers, M., & Griffiths, T. (2007). Probabilistic topic models. In T. Landauer, D. McNamara, & Dennis, S., & Kintsch., W. (Eds.), *Latent semantic analysis: A road to meaning* (pp. 424–440). Lawrence Erlbaum.
- von Krosigk, M. (2017). *Classification of monetary policy decisions through text mining techniques* (Unpublished master’s thesis). University of St. Gallen, St. Gallen, Switzerland.
- Yuan, Y. (2015). Market-wide attention, trading, and stock returns. *Journal of Financial Economics*, 116(3), 548–564.
- Zhai, C., & Massung, S. (2016). *Text data management and analysis: A practical introduction to information retrieval and text mining* (First edition ed., Vol. 12). New York, NY and San Rafael: Association for Computing Machinery and Morgan & Claypool Publishers.



# Appendix A

## Target Rate and Yield Curves

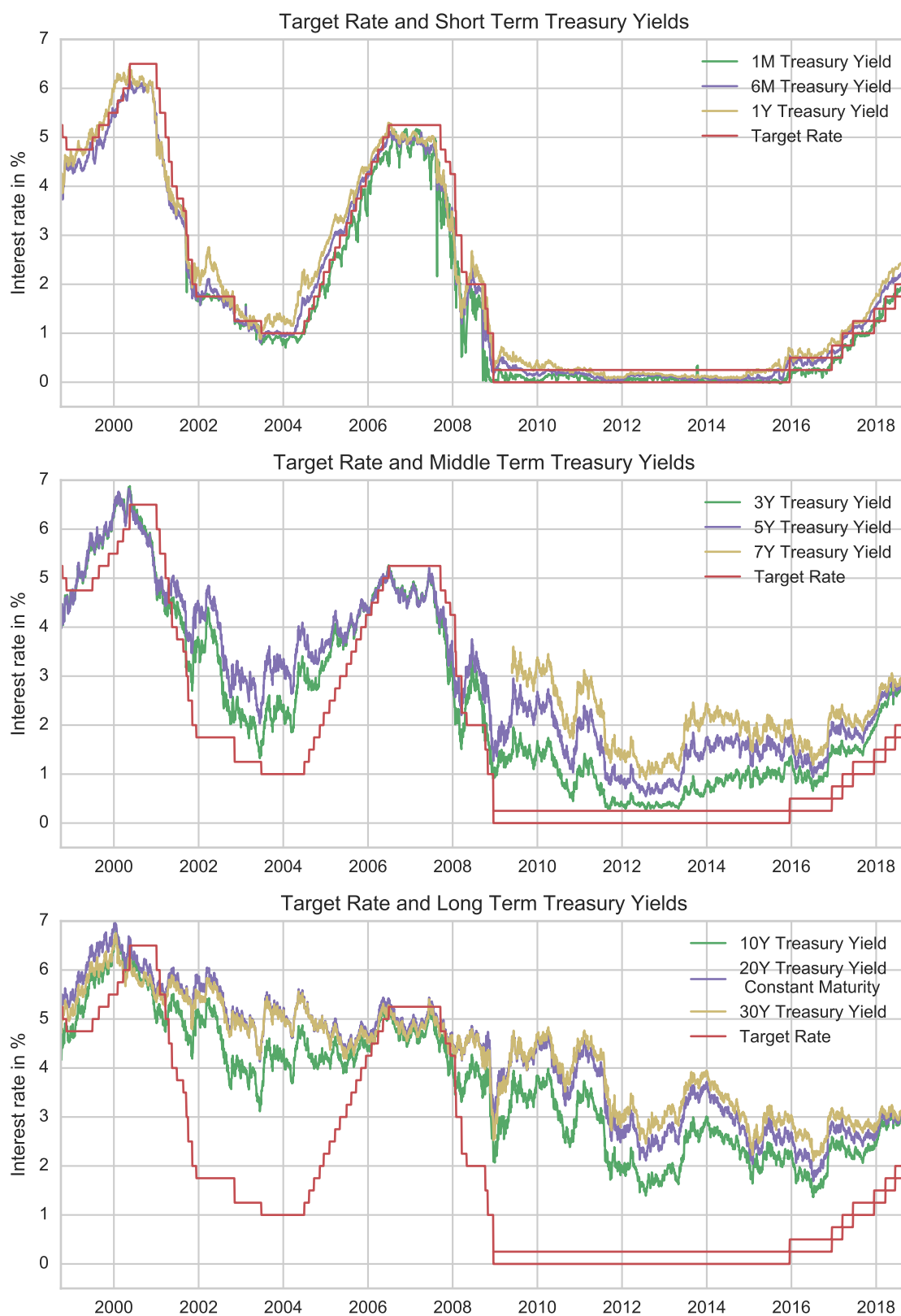
Dates of all FOMC meetings since January 1, 1998						
26.09.2018	18.03.2015	13.12.2011	*07.02.2009	12.12.2006	12.08.2003	31.01.2001
01.08.2018	28.01.2015	*28.11.2011	28.01.2009	25.10.2006	25.06.2003	*03.01.2001
13.06.2018	17.12.2014	02.11.2011	*16.01.2009	20.09.2006	06.05.2003	19.12.2000
02.05.2018	29.10.2014	21.09.2011	16.12.2008	08.08.2006	*16.04.2003	15.11.2000
21.03.2018	17.09.2014	09.08.2011	29.10.2008	29.06.2006	*08.04.2003	03.10.2000
31.01.2018	30.07.2014	*01.08.2011	*07.10.2008	10.05.2006	*01.04.2003	22.08.2000
13.12.2017	18.06.2014	22.06.2011	*29.09.2008	28.03.2006	*25.03.2003	28.06.2000
01.11.2017	30.04.2014	27.04.2011	16.09.2008	31.01.2006	18.03.2003	16.05.2000
20.09.2017	19.03.2014	15.03.2011	05.08.2008	13.12.2005	29.01.2003	21.03.2000
26.07.2017	*04.03.2014	26.01.2011	*24.07.2008	01.11.2005	10.12.2002	02.02.2000
14.06.2017	29.01.2014	14.12.2010	25.06.2008	20.09.2005	06.11.2002	21.12.1999
03.05.2017	18.12.2013	03.11.2010	30.04.2008	09.08.2005	24.09.2002	16.11.1999
15.03.2017	30.10.2013	*15.10.2010	18.03.2008	30.06.2005	13.08.2002	05.10.1999
01.02.2017	*16.10.2013	21.09.2010	*10.03.2008	03.05.2005	26.06.2002	24.08.1999
14.12.2016	18.09.2013	10.08.2010	30.01.2008	22.03.2005	07.05.2002	30.06.1999
02.11.2016	31.07.2013	23.06.2010	*21.01.2008	02.02.2005	19.03.2002	18.05.1999
21.09.2016	19.06.2013	*09.05.2010	*09.01.2008	14.12.2004	30.01.2002	30.03.1999
27.07.2016	01.05.2013	28.04.2010	11.12.2007	10.11.2004	11.12.2001	03.02.1999
15.06.2016	20.03.2013	16.03.2010	*06.12.2007	21.09.2004	06.11.2001	22.12.1998
27.04.2016	30.01.2013	27.01.2010	31.10.2007	10.08.2004	02.10.2001	17.11.1998
16.03.2016	12.12.2012	16.12.2009	18.09.2007	30.06.2004	*17.09.2001	*15.10.1998
27.01.2016	24.10.2012	04.11.2009	*16.08.2007	04.05.2004	*13.09.2001	29.09.1998
16.12.2015	13.09.2012	23.09.2009	*10.08.2007	16.03.2004	21.08.2001	*21.09.1998
28.10.2015	01.08.2012	12.08.2009	07.08.2007	28.01.2004	27.06.2001	18.08.1998
17.09.2015	20.06.2012	24.06.2009	28.06.2007	09.12.2003	15.05.2001	01.07.1998
29.07.2015	25.04.2012	*03.06.2009	09.05.2007	28.10.2003	*18.04.2001	19.05.1998
17.06.2015	13.03.2012	29.04.2009	21.03.2007	16.09.2003	*11.04.2001	31.03.1998
29.04.2015	25.01.2012	18.03.2009	31.01.2007		20.03.2001	04.02.1998

\* indicates an unscheduled meeting/conference call

**Table A.1** – FOMC meetings.

FOMC Meeting on										FOMC Meeting on									
Date	$T_{gt_{low}}$	$T_{gt_{up}}$	$\Delta T_{gt_{low}}$	$\Delta T_{gt_{up}}$	day prior	same day	Date	$T_{gt_{low}}$	$T_{gt_{up}}$	$\Delta T_{gt_{low}}$	$\Delta T_{gt_{up}}$	day prior	same day						
27.09.2018	2.00%	2.25%	25	-	1	0	14.12.2004	2.25%	-	25	-	0	1						
14.06.2018	1.75%	2.00%	25	-	1	0	10.11.2004	2.00%	-	25	-	0	1						
22.03.2018	1.50%	1.75%	25	-	1	0	21.09.2004	1.75%	-	25	-	0	1						
14.12.2017	1.25%	1.50%	25	-	1	0	10.08.2004	1.50%	-	25	-	0	1						
15.06.2017	1.00%	1.25%	25	-	1	0	30.06.2004	1.25%	-	25	-	0	1						
16.03.2017	0.75%	1.00%	25	-	1	0	25.06.2003	1.00%	-	-25	-	0	1						
15.12.2016	0.50%	0.75%	25	-	1	0	06.11.2002	1.25%	-	-50	-	0	1						
17.12.2015	0.25%	0.50%	25	-	1	0	11.12.2001	1.75%	-	-25	-	0	1						
16.12.2008	0.00%	0.25%	-75	-100	0	1	06.11.2001	2.00%	-	-50	-	0	1						
29.10.2008	1.00%	-	-50	-	0	1	02.10.2001	2.50%	-	-50	-	0	1						
*08.10.2008	1.50%	-	-50	-	1	0	*17.09.2001	3.00%	-	-50	-	0	1						
30.04.2008	2.00%	-	-25	-	0	1	21.08.2001	3.50%	-	-25	-	0	1						
18.03.2008	2.25%	-	-75	-	0	1	27.06.2001	3.75%	-	-25	-	0	1						
30.01.2008	3.00%	-	-50	-	0	1	15.05.2001	4.00%	-	-50	-	0	1						
*22.01.2008	3.50%	-	-75	-	1	0	*18.04.2001	4.50%	-	-50	-	0	1						
11.12.2007	4.25%	-	-25	-	0	1	20.03.2001	5.00%	-	-50	-	0	1						
31.10.2007	4.50%	-	-25	-	0	1	31.01.2001	5.50%	-	-50	-	0	1						
18.09.2007	4.75%	-	-50	-	0	1	*03.01.2001	6.00%	-	-50	-	0	1						
29.06.2006	5.25%	-	25	-	0	1	16.05.2000	6.50%	-	50	-	0	1						
10.05.2006	5.00%	-	25	-	0	1	21.03.2000	6.00%	-	25	-	0	1						
28.03.2006	4.75%	-	25	-	0	1	02.02.2000	5.75%	-	25	-	0	1						
31.01.2006	4.50%	-	25	-	0	1	16.11.1999	5.50%	-	25	-	0	1						
13.12.2005	4.25%	-	25	-	0	1	24.08.1999	5.25%	-	25	-	0	1						
01.11.2005	4.00%	-	25	-	0	1	30.06.1999	5.00%	-	25	-	0	1						
20.09.2005	3.75%	-	25	-	0	1	17.11.1998	4.75%	-	-25	-	0	1						
09.08.2005	3.50%	-	25	-	0	1	*15.10.1998	5.00%	-	-25	-	0	1						
30.06.2005	3.25%	-	25	-	0	1	29.09.1998	5.25%	-	-25	-	0	1						
03.05.2005	3.00%	-	25	-	0	1													
22.03.2005	2.75%	-	25	-	0	1													
02.02.2005	2.50%	-	25	-	0	1													
$\Delta T_{gt}$ are given in basis points							* indicates a target rate adjustment following an unscheduled meeting												

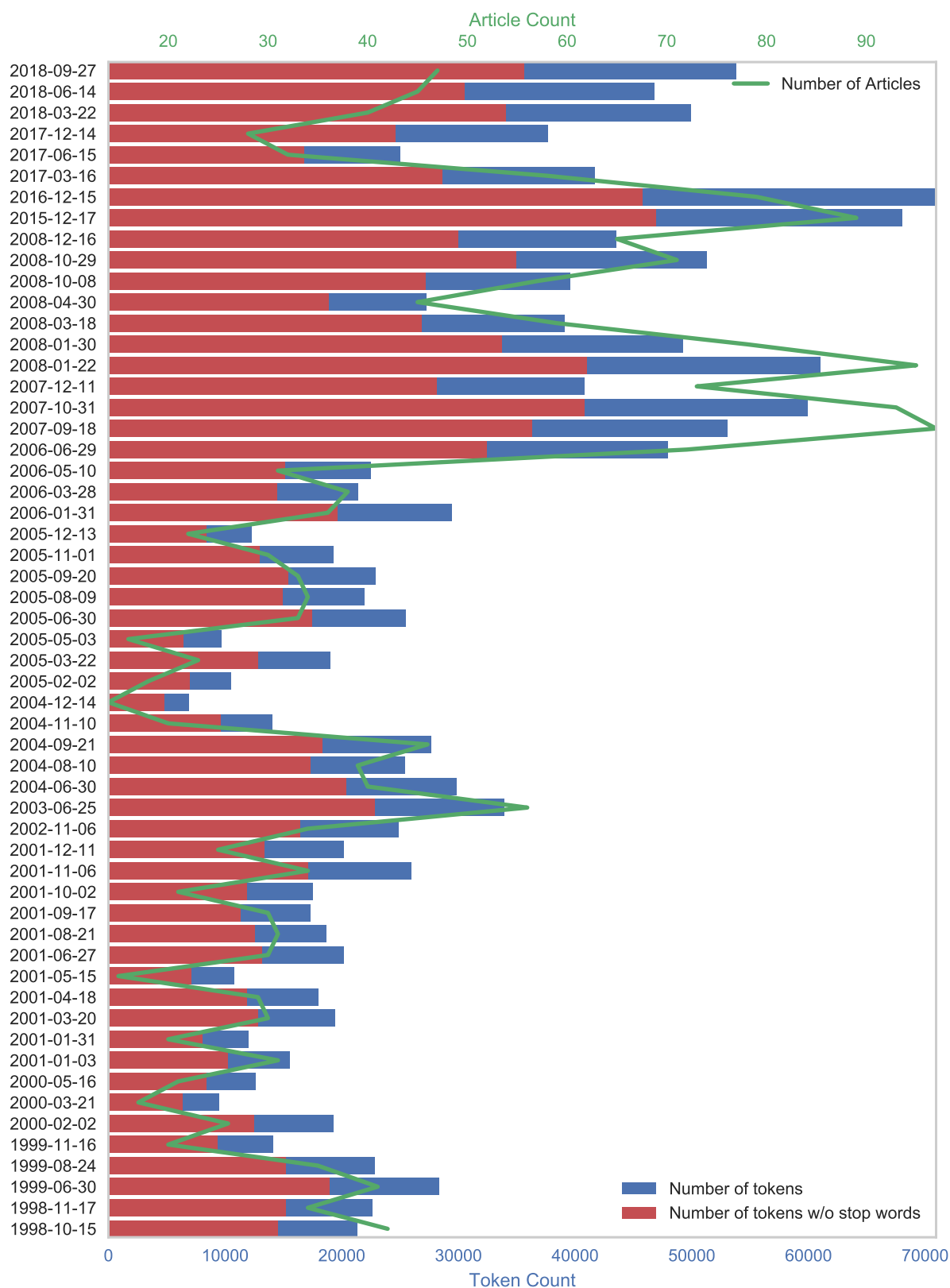
**Table A.2** – Target rate adjustments since January 1, 1998.

**Figure A.1** – Target rate and treasury yields of all maturities.

# Appendix B

Text data

**Figure B.1** – Token and article count for every policy day.



# Appendix C

## Whatever may come...

### C.1 For Example...

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac

pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio. Integer vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetur at, consectetur sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui. Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis, ultrices a, dui.

# Declaration of Authorship

"I hereby declare

- that I have written this thesis without any help from others and without the use of documents and aids other than those stated above;
- that I have mentioned all the sources used and that I have cited them correctly according to established academic citation rules;
- that I have acquired any immaterial rights to materials I may have used such as images or graphs, or that I have produced such materials myself;
- that the topic or parts of it are not already the object of any work or examination of another course unless this has been explicitly agreed on with the faculty member in advance and is referred to in the thesis;
- that I will not pass on copies of this work to third parties or publish them without the University's written consent if a direct connection can be established with the University of St.Gallen or its faculty members;
- that I am aware that my work can be electronically checked for plagiarism and that I hereby grant the University of St.Gallen copyright in accordance with the Examination Regulations in so far as this is required for administrative action;
- that I am aware that the University will prosecute any infringement of this declaration of authorship and, in particular, the employment of a ghostwriter, and that any such



infringement may result in disciplinary and criminal consequences which may result in my expulsion from the University or my being stripped of my degree.”

.....

Location, Date

.....

Signature

By submitting this academic term paper, I confirm through my conclusive action that I am submitting the Declaration of Authorship, that I have read and understood it, and that it is true.