Monetary Policy and Financial Markets

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Thesis submitted for the degree of Doctor of Philosophy

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March 2021

For my father Jürgen, a hard-working and passionate carpenter, who passed away too early. Together with my mother Christiane, he encouraged and enabled me to pursuit my dreams.

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Acknowledgments

I am deeply grateful to my supervisors Lucio Sarno and Maik Schmeling and my de-facto supervisor Matteo Maggiori for their outstanding support and advise. I have benefited greatly from my visit to the Department of Economics at Harvard University, hosted by Matteo who has spared no effort to welcome and connect me to students and faculty.

I thank my co-authors Michael Ehrmann and Bauke Visser for their collaboration. I am also thankful to Adi Sunderam for his continued interest in my research and collaboration.

I very highly appreciate the support by Giovanni Cespa, Giacinta Cestone, Malla Pratt, and Abdul Momin. They all have always put a lot of effort to help me and made a big difference to the success of my studies. It was also a real pleasure to help teaching courses directed by Andrew Clare, Ian Marsh and Aneel Keswani. Thank you all so much.

My warm thanks also to all former collaborators and managers at the Bank of England, European Central Bank, Sveriges Riksbank, BlackRock and Deutsche Bank. I am especially thankful to Albina, Benjamin, David, Mark, Sylvain and Tobias. You have all contributed positively to my development as a researcher and economist.

My parents and my sisters deserve my deepest appreciation for their unwavering support, affection, and countless life lessons. Thank you for everything.

Finally, none of my progress and adventures would have been possible without my fiancée Anna. Stockholm, London, Frankfurt, Boston. At every time and place, you gave your full support and enthusiam, often at your personal detriment. I owe you endless gratidue.

A scholarship by City, University of London provided the funds for this research.

Declaration

I declare that this thesis has not been submitted as an exercise for a degree at the City, University of London or any other University and that this thesis is entirely my own and my co-authors' work.

Robin Tietz
March 2021

Thesis Abstract

This thesis comprises three essays on monetary policy and financial markets. The research uses micro data and textual analysis to answer questions in the intersection between finance and monetary economics. Simple and intuitive models complement the empirical analysis.

In the first essay, I present a large database of speeches by Federal Reserve officials that I assembled with web scraping algorithms. I parse the topic and tone of the speeches to provide empirical evidence on how Fed officials use their speeches to guide short-term interest rate expectations. Measures of misalignment between market and central bankers' expectations predict tone in speeches about monetary policy. If markets' near-term interest rate expectations are too high, central bankers' speak more negatively to signal that less interest rate hikes are coming. These effects are strongest for voting Fed Presidents and Chairs of the Fed Board of Governors. I study this policy of communicating in response to market expectations in a rational expectations model, in which the central bank communicates in a discretionary fashion between interest rate decisions and is averse to bond market volatility.

The second essay is co-authored with Michael Ehrmann and Bauke Visser and builds on the speech data and methods presented in the first essay. We use the Federal Open Market Committee as a setting to study how the right to vote affects behavior in a committee decision-making process, both during meetings and in between meetings. We find no evidence for a hypothesis maintaining that without the voting right, presidents use their public speeches and their meeting statements to compensate for this loss of formal influence; instead, the data support the hypothesis that with the voting right, presidents are more involved. Financial markets react less to presidents' public speeches in years they have voting rights than in years they have not. We argue that this is consistent with our evidence on the communication behavior of presidents.

The third essay provides firm-level estimates of the real effects of US monetary policy on investment in 36 countries. The key identification idea is that firms, that roll over US Dollar debt shortly after FOMC meetings, are more exposed than firms that do not. Reductions in business investment after US monetary tightening are largest in countries with pegged or managed exchange rates (non-floaters) but also significant in floaters. The stronger spillovers in non-floaters arise from firms with high leverage and are amplified by exchange rate fluctuations. A simple model of currency choice rationalizes my findings. Exchange rate management leads to higher financial vulnerability because it allows smaller and less productive firms to borrow in foreign currency, a conjecture which is confirmed in the data.

General Introduction

This introduction gives a broad context to the dissertation, which comprises three essays on monetary policy and financial markets. The order of the essays is chronological and thus reflects my development during the PhD program.

The first two essays, chapter 1 and 2, analyse from distinct and complementary viewpoints the public communications by the Federal Reserve System and its officials and the link between these communications and financial markets. Both essays use the same database of speeches that I assembled using webscraping tools. To the best of my knowledge, this database is still to date one of the most comprehensive databases of speeches by Federal Reserve officials that exists.

The two essays also share the method to parse the content of the speeches' texts. I first introduced this database and my application of the methods in my first working paper during the Ph.D. program (Tietz, 2018). The first essay is a newly revised version.

In the first essay, I focus on the role that very short-term market expectations concerning monetary policy decisions play in explaining the content of the Fed officials' speeches. A simple model assesses the implications of the empirical pattern under rational expectations. This essay has also brought to light heterogeneity in communication behaviour across different types of Fed officials.

The second essay, a slightly revised version of my co-authored work Ehrmann et al. (2020), is partly motivated by this heterogeneity across Fed officials and takes an in-depth approach to differences in behaviour and possible explanations. Together with my co-authors, we focus specifically on the implications of the voting right rotation among the regional Fed presidents on the FOMC.

Reflecting the different focus, new insights and additional resources, the second essay naturally complements the first one. We add new data, e.g. the texts of transcripts of the FOMC meetings, and the unit of analysis changes from individual speeches to intermeeting periods and Fed districts.

The third essay, chapter 3, turns to the *effects* of monetary policy and the analysis puts again emphasis on the role of financial markets. I estimate the real effects of US monetary policy outside of the United States that arise through spillovers to non-financial firms' financing conditions, with special focus on foreign currency corporate bonds. A basic corporate finance model rationalizes my findings.

Monetary policy and financial markets interact in manifold ways with feedback loops operating in both directions. Paying tribute to such complexity, my dissertation combines empirical analysis and simple models to enhance our understanding of these interactions.

Chapter 1

How does the Fed manage interest rate expectations?[1]

[1]This is a revised version of my working paper with the same title. I am thankful for comments by Itay Goldstein, Philipp König (discussant), Charles Martineau (discussant), Lucio Sarno, Maik Schmeling, Valentin Schubert Yannick Timmer, and Andreas Uthemann (discussant), discussions with Thorsten Beck, Michael Ehrmann, Jordi Galí, Sam Hanson, Peter Karadi, Greg Mankiw, Julien Pinter (discussant), Ricardo Reis, Jeremy Stein, Adi Sunderam, and participants at: EFA Annual Meeting (2019), CEBRA Annual Meeting (2019), Harvard Macro Lunch (2019), Bank of Canada Central Bank Communications Conference (2018), 6th Emerging Scholars Conference (2018) and Cass Business School Seminar (2018). Special thanks to Sylvain Champonnois who introduced me to computational textual analysis.

"...when policy expectations in the market seem to be out of alignment with our own expectations, I have done that myself: to give speeches in which I try to say things that will correct this misalignment."

Janet Yellen
Central Bank Communications Conference, ECB, November 2017

1.1 Introduction

How do central bankers manage interest rate expectations? Do they use their speeches to steer markets? Are they always successful in smoothening policy implementation?

To answer these questions, I assemble a comprehensive database of speeches by officials of the Federal Reserve System and parse their contents. I find that measures of misalignment between financial markets' and central bankers' expectations predict the tone and topic in speeches. If markets' short-term expectations regarding the Fed funds rate are higher than those of the Fed, FOMC members give speeches which are more negative in tone. Excessively hawkish (dovish) market expectations are followed by dovish (hawkish) signals from the FOMC members. This finding holds when measuring Fed expectations by assuming that FOMC members know the upcoming decision already few weeks in advance as well as when measuring Fed expectations with Greenbook projections.

I provide evidence for a causal link from misalignment to speeches by analyzing quantitatively the link between misalignment and the topic of speeches. Larger misalignment is associated with an increased probability that central bankers mention explicitly "market expectations" in their speeches. A direct link between misalignment and the speech topic makes it unlikely that the predictive power of misalignment for speech tone is driven entirely by the Fed's private information, or subject to reverse causality. I also provide a brief narrative analysis of FOMC transcripts, documenting the Fed's concerns about misaligned market expectations and their use of communication to address them (e.g. the above quote).

Since the roles on the FOMC vary across its members, I account for heterogeneity across different speaker types. I document that the predictive power of misalignment for speech tone is stronger a) for the Chair and Vice Chair of the Board of Governors and b) for the same Fed president when he or she has the right to vote on the FOMC than when not. These findings represent interesting stylized facts to be investigated in future research.[2]

My evidence on a link between misalignment and speeches is consistent with the quote by Janet Yellen above. The *occasional* existence of such link conforms well

[2]In follow-up work with Michael Ehrmann and Bauke Visser (Ehrmann et al., 2020), we investigate in-depth the voting rotation among Fed presidents and related mechanisms.

with conventional wisedom. More surprising is that such communication policy has been sufficiently systematic to be measurable with statistical significance. The difference between an occasional and systematic policy is crucial because systematic policies are easier to internalize by the private sector.

Intuition might suggest that such policy is socially optimal. If central bankers become aware of misconceptions by the market, it seems intuitive that they should try to reduce them. Yet, theoretical work on rational expectations indicates that policies responding directly to private sector expectations often induce instabilities, for example Bernanke and Woodford (1997). Rational agents understand that policy is set as a function of their expectations and re-optimize accordingly, creating a coordination problem between the beliefs of the central bank and the private sector.

Motivated by the systematic nature of the communication response to market expectations, I construct a 3 period model capturing the cycle from one FOMC meeting to the next. Following Stein and Sunderam (2017), policy is discretionary, the Fed is averse to bond market volatility and has private information about the level of the short-term nominal interest rate consistent with achieving its inflation and employment targets. The central bank sets interest rates at two consecutive meetings and releases a signal in the intermeeting period. The financial market tries to outguess the central bank, estimating its target rate using information contained in the nominal short rate and the intermeeting communication. Two types of equilibria arise. In the benign case, communication reduces expectational errors successfully. In the worst case, market expectations become self-fulfilling, policy outcomes and bond market volatility go haywire.

If the central bank is not averse to bond volatility, its intermeeting communication has a unique interpretation for the market: The central bank reacts to unexpected changes in financial conditions since the last meeting. If instead it is averse to bond volatility, it underadjusts to new private information attempting to smoothen out the implementation of the policy change. This creates an inference problem for the market. The market cannot be sure whether intermeeting communication responds to surprises in financial conditions or is part of a strategy. Market beliefs about motives for communicating can become self-fulfilling and the central bank might face a trade-off between moving the interest rate closer to target and not upsetting bond markets. Surrendering to market expectations will keep markets calm but leaves financial conditions off target.

Empirical evidence points to an increasingly good anticipation of upcoming monetary policy decisions. (Lange et al., 2003; Poole et al., 2002) And enhanced central bank transparency is a common explanation for the improvements. (Blinder et al., 2001; Blinder et al., 2008) At the same time, theory suggests that efficiency gains through central bank transparency are not unlimited. (Stein, 1989; Morris and Shin, 2002; Faust, 2016; Morris and Shin, 2018) Empirical insights about the effects and limits of transparency are still scant.

With this paper I aim to provide a first step towards filling this gap, adding to a recent strand of empirical papers on language-based central bank communication, see e.g. Hansen et al. (2017), Schmeling and Wagner (2017), or Lucca and Trebbi (2009). I make three contributions. First, the database of around 3800 speeches that I assemble is to the best of my knowledge one of the most comprehensive ones considered in the literature. Second, analyzing the speeches sentence by sentence allows me to adjust the widely-used dictionary developed in Loughran and McDonald (2011) conditional on the nouns mentioned in that sentence, making it more applicable to the central bank context while refraining from subjective word choices. Third, by identifying words characteristic of discussions about current monetary policy affairs, I offer a simple and objective way of filtering out irrelevant speeches.

I further contribute to the broader empirical literature on the workings of monetary policy. Krueger and Kuttner (1996), Lange et al. (2003) and Gürkaynak et al (2004, 2007b) develop a measure of unanticipated monetary policy changes used by the vast majority of empirical papers, e.g. Steinsson et al. (2018), Hanson and Stein (2015), Gorodnichenko and Weber (2016).

I make two contributions. First, while all papers above rely on asset price changes to infer signals about monetary policy, I use textual analysis of speeches by Fed officials. Second, my analysis turns around the usual perspective: Rather than explaining the impact of monetary policy on markets, I explain how central bankers react to market expectations. The insights from previous papers imply a challenge for that perspective. Financial markets might endogenously respond to monetary policy. This identification problem is treated most prominently in Rigobon and Sack (2003). Rigobon and Sack (2003) ask whether the Fed adjusts its stance in response to stock market movements while I analyze how implementation of a given desired stance interacts with financial market expectations.

The theoretical aspects of this paper relate to the public communication literature following Stein (1989) and Morris and Shin (2002). My model builds on the setup in Stein and Sunderam (2017) and adds explicit central bank communication. Contrary to most papers, the policy maker in my model sets the mean of the signal instead of its precision (the noise variance). This follows Banerjee and Liu (2014). A further departure from mainstream is that the policy maker communicates as well as takes policy action, as in James and Lawler (2011). A recent application of this literature to monetary policy is the paper by Morris and Shin (2018). It shares the idea that the central bank chooses how to weigh-in price-based signals into its reaction function. A key difference is that, in my model, the central bank has private information not the market and that the agents are not subject to herding incentives.

1.2 Data

1.2.1 Speeches

There is no exhaustive archive of speeches by senior Fed officials. I collect speeches from four different sources. The first one is an archive of speeches on the *webpage of the Federal Reserve Board of Governors*. The website contains speechs by members of the Federal Reserve Board of Governors, starting from 1996. The second source is the *BIS archive*, starting from 1997. The BIS archive provides speeches from central bankers wordwide. For the US, the BIS archive does not only cover speeches by members of the Board of Governors but also from presidents of regional Federal Reserve banks. The third source is *FedInPrint*, which indexes publications from the Federal Reserve System. Lastly, I visit the webpages of the 11 regional Federal reserve banks. The last source is crucial to gain sufficient coverage of speeches by the regional Fed presidents.[3]

From each of the sources, I download all speeches available and collect for each speech information on the exact date, location and the surname of the speaker. As the sources are partly overlapping, I subsequently delete all duplicates. The complete sample consists of 3846 unique speeches given between 1985 and 2018.[4] The pre-processing of the text involves the following steps. I split the speeches into sentences, remove all non-alphabetic characters, stopwords, words with less than 3 characters, and convert the remainder to lower case.

1.2.2 Asset price data for market expectations

The baseline market expectations are derived from daily time series of the prices of short-horizon Fed funds futures. These contracts cover the period of a given calendar month and are settled against the 30 day average of effective fed funds rate. Krueger and Kuttner (1996), Gürkaynak et al. (2007b) and Hamilton (2009) show that Fed funds futures have strong predictive power for near-term Fed policy.

[3]Federal Reserve Board: https://www.federalreserve.gov/newsevents/speeches.htm; BIS: http://www.bis.org/list/cbspeeches/index.htm; FedInPrint (does not host speech data but provides links): https://www.fedinprint.org/.

[4]Since the sample includes only 3 different speakers before 1995, I proceed with the around 3500 speeches from 1995 onwars. I also remove all speeches by current or past Fed officials that they gave while not being Fed official, e.g. speeches by Stanley Fischer during his governorship at the Bank of Israel. Analyzing the coincidence of surnames and speech location, I also detected instances of wrongly included speeches due to identical surnames, e.g. Esther George, President of the Federal Reserve of Kansas City, and Sir Edward George, Governor of the Bank of England, 1993-2003.

Figure A.6 plots the time series of futures-based expectations concerning the next policy decision together with the Fed target rate. Details of the construction are outlined below. Appendix Table A.5 lists the Bloomberg Tickers.[5]

A general concern about asset price based measures of expectations is that they might be conflated with risk premia. Piazzesi and Swanson (2008) find excess returns on Fed funds futures can be predicted with real-time data on non-farm payrolls.

Two arguments are crucial to understand this concern in the context of this paper. First, the return predictability/risk premium argument relies on the assumption of perfect information and rational expectations. However, asymmetric information is at the very heart of this paper. As Hamilton (2009) argues, non-farm payrolls might predict Fed futures' excess returns because they were driving Fed policy at times when the market did not fully incorporate them into their expectations.

Second, even if the return predictability was evidence for risk premia, they are likely irrelevant at the horizons I consider. Piazzesi and Swanson (2008) focuses on longer horizon contracts and returns at monthly frequency. For the contract most relevant to my study, 1 month ahead, they find an average excess return of only 2.9 basis points. Instead, Hamilton (2009) studies short-horizon contracts and finds that daily risk premia variations are negligible.

Lastly, I also control for the macro variables thought to drive risk premia.

1.3 Measuring misalignment and speech content

1.3.1 Misalignment

Here I define my measures of misalignment and its components. Let misalignment at date t concerning the upcoming interest rate decision at t^{fomc} be

$$misal_t = E_t^{\text{Market}}(r_{t^{fomc}}^{tar}) - E_t^{\text{Fed}}(r_{t^{fomc}}^{tar}),$$

where r^{tar} is the Fed funds target rate.[6] While E_t^{Market} can be derived with relative ease from market prices, measuring E_t^{Fed} is less straightforward. $E^{\text{Fed}}(r_{t^{fomc}}^{tar})$ is the benchmark used by central bankers to align market expectations with. My baseline

[5] One alternative to Fed funds futures are FOMC overnight index swaps (OIS). FOMC OIS cover exactly the periods between FOMC meetings and thus do not require a mapping from the time period of the contract to the FOMC cycle. However, the FOMC OIS are available only from 2007 and hence Fed funds futures remain the most-widely used gauge of market expectations. Appendix Figure A.7 shows that the two sources of market expectations are broadly consistent. Another alternative are Eurodollar futures, which are here not discussed for brevity. Unreported exercises suggest that the main findings remain largely unchanged.

[6] I will refer to the "target rate" even though from December 2008 onwards the Fed announces a target range. During that period, I will use the arithmetic average of the upper and lower bound of that range. Effects of excess reserves and related robustness checks are discussed below.

is to assume that central bankers have perfect foresight on the upcoming decision two (three, four..) weeks before the meeting. I also construct actual interest rate expectations by the FOMC based on the Greenbook supplements.

Market expectations. I derive market expectations $E_t^{\text{Market}}(r^{tar}_{t^{fomc}})$ about the level of the Fed funds rate *after* next FOMC meeting from Fed funds futures prices.

There are usually 8 FOMC meetings during the year, with intermeeting periods of around 6 weeks. Suppose next FOMC meeting takes place in the current month at date t^{fomc}. Let r_t be the effective Fed funds rate (EFFR) at date t. If there are D days in the month and the FOMC t^{fomc} is at the d-th day, the rate implied by the current month futures contract, shortly before t^{fomc}, will be

$$FF1_t = \frac{d}{D}\bar{r}_{t<d} + \frac{D-d}{D}E_t(\bar{r}_{t>d}). \tag{1.1}$$

$E_t(\bar{r}_{t>d})$ is the expected average funds rate after next FOMC meeting, $\bar{r}_{t<d}$ is the average funds rate that prevails until the FOMC meeting.[7] If the upcoming FOMC is in the next calendar month, I match it with the appropriate futures contract. Solving Eq. 1.1 for $E_t(\bar{r}_{t>d})$ yields the expected average Fed funds rate after the next FOMC

$$E_t^{\text{Market}}(r_{t^{fomc}}) \equiv E_t(\bar{r}_{t>d}) = \frac{D}{D-d}FF1_t - \frac{d}{D-d}\bar{r}_{t<d}. \tag{1.2}$$

Appendix A.1.2 contains a time series plot of $E_t^{\text{Market}}(r_{t^{fomc}})$ and robustness tests with respect to episodes of high EFFR volatility around settlement periods and structural changes in the position of the EFFR relative to the target rate (e.g. QE).

Central bankers' expectations: A) Perfect foresight. I employ two alternative measures of $E_t^{\text{Fed}}(r^{tar}_{t^{fomc}})$. The baseline $E_t^{\text{Fed,Fwd}}(r^{tar}_{t^{fomc}})$ assumes that any interest rate decision was known to the Fed speakers already two weeks before the meeting. The timing is varied in robustness tests. I compute $E_t^{\text{Fed,Fwd}}(r^{tar}_{t^{fomc}})$ as

$$E_t^{\text{Fed,Fwd}}(r^{tar}_{t^{fomc}}) = r_t^{tar} + \Delta r^{tar}_{t^{fomc}}. \tag{1.3}$$

So the target rate change $\Delta r^{tar}_{t^{fomc}}$ (at upcoming FOMC date) is added to the current Fed funds target rate r_t^{tar}[8] and the sample is restricted based on the assumed number of weeks of foresight. I denote the corresponding misalignment with

[7] I make two adjustments. First, to avoid that the weights are very big numbers, I use next month's future contract if the FOMC meeting is on one of the last 5 days in a month. Second, if date t is the $\hat{d}$-th day of the month, some time before the FOMC at d, the equation would be $FF1_t = \frac{\hat{d}}{D}\bar{r}_{t<\hat{d}} + \frac{d-\hat{d}}{D}E_t(\bar{r}_{\hat{d}<t<D}) + \frac{D-d}{D}E_t(\bar{r}_{t>d})$. In these cases I assume that market participants do not expect any target rate changes during the period before the next FOMC meeting.

[8] In a robustness test, I replace the future level of the target rate $E_t^{\text{Fed,Fwd}}(r^{tar}_{t^{fomc}})$ with the future level of the effective Fed funds rate, accounting for structural shifts in the position of the average effective Fed funds rate within the target range (e.g. those related to large excess reserves).

$misal_t^{Fwd}$.

Central bankers' expectations: B) Greenbook forecasts. To relax the assumption of perfect foresight, I derive an alternative measure of $E_t^{\text{Fed}}(r_{t^{fomc}}^{tar})$ based on the interest rate projections underlying the Greenbook forecasts prepared by the staff of the Federal Reserve Board.[9] These forecasts have been shown to carry significant private information by the Fed and explain a large share of the Fed's policy changes. (Romer and Romer, 2000, 2004) Romer and Romer (2008) further show that individual FOMC members' forecasts do not carry useful information beyond that contained in the Greenbooks.

The Greenbook projections forecast the quarterly average Fed funds rate, so usually covering two FOMC meetings. To keep focus on short-term expectations, I consider one and two quarter ahead forecasts.[10] For corresponding market expectations, I combine the appropriate future contracts to compute the futures implied average Fed funds rate over the forecasted quarter.

The misalignment concerning the average Fed funds rate in the coming quarter, $\bar{r}_{1Q}$, is then computed as

$$misal_t^{GB,1Q} = E_t^{\text{Market}}(\bar{r}_{1Q}) - E_{t^{GB}}^{\text{Fed,GB}}(\bar{r}_{1Q}), \tag{1.4}$$

for $t \in \{t^{GB}+1, ..., t^{fomc}, ..., t^{GB}+T\}$. So Greenbook forecasts delivered to FOMC members at date t^{GB} for the FOMC meeting at t^{fomc} are compared to the market expectations at dates $t > t^{GB}$. The choice of parameter T reflects the trade-off between a larger sample of subsequent speeches and the potential contamination through new information arrival after forecast preparation. The baseline results will be based on $t \in \{t^{fomc}, ..., t^{GB} + 3 \text{ weeks}\}$. Implications for identification will be discussed in more detail in Section 1.4.1.

Descriptive analysis of misalignment. Table 1.1 provides summary statistics for the misalignment measures. Average absolute misalignment in the last two weeks before the decision is around 5 basis points.[11] Measured against the usual step size of interest rate decisions, 25 basis points, misalignment of 5 basis points appears economically significant. Assuming the Fed wants to hike by 25 basis

[9]The Greenbook data is made available to the public with a 5 year lag. Since 2010, the Greenbook is called Tealbook (merged with Bluebook). Data and definitions can be found on the webpage of the Philadelphia Fed (here).

[10]Two remarks:1)I cannot use current quarter forecasts. The Greenbook forecasts are compared to the market expectations *following* the FOMC meeting, so the current quarter forecasts at the second meeting do not relate to future policy. The forecasts at the first meeting carry predictive content for *both* meetings but subsequent market expectations only for the second meeting. 2)For very few data points when GB interest rate projections are unavailable, I use inflation and output gap forecasts in an estimated forward-looking Taylor-Rule, details in Appendix A.1.4.

[11]Appendix Figure A.8 plots the empirical densities of misalignment. Misalignment is nearly symmetrically distributed around zero with a slightly negative skew, which is consistent with Cieslak (2018) who finds that markets tend to underestimate future monetary easing.

points, a -5bp misalignment says that the market is pricing only 20bp, thus assigning a 80% probability to a 25 bp hike.

	Perfect foresight, weeks before FOMC						Greenbook	
	0	1	2	3	4	5	1Q ahead	2Q ahead
Mean	0.053	0.056	0.059	0.064	0.067	0.073	0.186	0.279
Stdev.	0.084	0.089	0.094	0.099	0.103	0.116	0.233	0.343
Min.	-0.275	-0.285	-0.300	-0.365	-0.450	-0.510	-0.548	-0.759
Max.	0.401	0.460	0.455	0.480	0.460	0.470	0.899	1.469

Notes: Summary statistics for misalignment measures for scheduled FOMC meetings. Standard deviation, minima and maxima are computed on the raw, daily misalignment values, while the averages are computed on absolute values of misalignment. Misalignment was around 30 basis points one week ahead of unscheduled meetings.

Table 1.1: *Summary statistics of misalignment measures*

Misalignment exhibits additional intuitive features. First, its average absolute value and variability are decreasing as the upcoming FOMC gets closer, consistent with the idea that market expectations converge gradually to the outcome. Second, the average absolute value and variability increase with the underlying forecast horizon. For the 1 and 2 quarter ahead misalignment measures, the full-sample average absolute value is around 20 and 40 basis points respectively.

Figures A.4 and A.3 illustrate the time variation of both misalignment measures. Misalignment appears larger at meetings at which the target rate is changed, around turning points in the monetary policy cycle and during NBER recessions.[12] The magnitude of misalignment concerning the *upcoming* decision has decreased while interest rates were stuck at the zero lower bound (ZLB). Since this is the main focus of this paper, the baseline sample will exclude the ZLB period.

The size of one and two-quarter ahead misalignment has also decreased during the ZLB but stayed persistently positive at around 15-20 basis points. This is consistent with that financial markets were constantly expecting Fed hikes in the medium term between 2009 and 2011, see e.g. Cieslak (2018). Only after the introduction of calendar forward guidance in late 2011, rate expectations were pushed towards zero.[13]

Appendix A.4 provides a brief narrative analysis of FOMC transcripts and minutes that confirms the main features of misalignment and the Fed's consideration

[12] Due to the small number of these events in the sample, a rigorous statistical analysis is difficult.

[13] At the same time, extracting accurate market expectations from futures quotes has become more difficult during the ZLB period. Further analysisis provided in the Greenbooks (see e.g. page 48 in the June 2010 Greenbook, here) shows that market expectations exhibited later lift-off dates when measured at the mode than when measured at the mean. Also the NY Fed dealer survey suggested at times lift-off dates 1 to 2 quarters later than what market based expectations implied.

of it.

1.3.2 Parsing the content of speeches by Fed officials

Speech tone. As baseline measure of the tone in the speeches, I use the dictionary developed in Loughran and McDonald (2011) following Schmeling and Wagner (2017), with some adjustments for the central banking context (more below).[14]

For each sentence s in speech i, I obtain $N_{i,s}$, the number of words that are identified by Louhgran and McDonalds (LMcD) as conveying a negative meaning, and $T_{i,s}$, the total number of words. The list of negative words will vary slightly with the topic of sentence s (more below). I aggregate by summing over all sentences in a speech, $N_i = \sum_s N_{i,s}$ and $T_i = \sum_s T_{i,s}$. I then compute the tone of speech i as

$$\tau_i = 100 \times (1 - \frac{N_i}{T_i}). \tag{1.5}$$

Adjustments for central banking context. The LMcD dictionary was built in the context of company reports, which is similar but different from the central banking context. To check whether the "negative" words identified by LMcD make sense in the central banking context, Appendix Table A.1 lists for each year in the sample the 5 words of the LMcD dictionary that were used most often in the speeches.

The most frequent words are clearly associated with negative meaning in the central banking context, e.g. *loss* and *recession*. A special case is the word *unemployment*, which in many years is one of the most frequent words. Given its mandate to promote price stability and maximum employment, it is natural that Fed officials mention "unemployment" frequently, not necessarily with negative meaning.

The topic "unemployment" is further special in that some adjectives and verbs, which typically indicate negative meaning in the context of other topics, have a positive meaning for "unemployment." For example, "lower output growth" usually conveys a deterioration of economic conditions while "lower unemployment" indicates an improvement.

I address these concerns in two ways. First, I exclude the word "unemployment" from the list of negative words. Second, for all sentences that contain the word "unemployment" but not the words "inflation", "employment", or "growth", I delete "decline" and "declined" ("lower" is not included in LMcD) and add "higher" and "high" to the list of negative words.

Appendix A.1 contains summary statistics (Table A.2), a time series plot of average speech tone (Fig. A.2), and further background information.

Identifying speeches about monetary policy. Fed officials give speeches at a

[14] My findings are robust to using a simple bigram search as in Apel and Grimaldi (2012).

wide variety of occassions, including events entirely unrelated to monetary policy. Including speeches that talk exclusively about unrelated topics would introduce noise and hinder the analysis. I therefore implement a classification algorithm following Gentzkow and Shapiro (2010) to filter out relevant speeches.

I proceed in three steps. First, I infer pairs of words that occur often together ("bigrams") from the speeches' text.[15] This ensures that word pairs like "monetary policy" are treated as one phrase and has been shown to improve the performance of topic classification algorithms (Wang and Manning, 2012).

Second, I select 300 speeches manually which relate clearly to monetary policy, e.g. the speech given by Rosengren on 15th February 2017 "Monetary Policy as the Economy Approaches the Feds Dual Mandate." I then compute for any phrase p that occurs at least once in the speeches the statistic

$$\omega_{p,c} = \frac{(N_{p,c}N_{-p,-c} - N_{p,-c}N_{-p,c})^2}{(N_{p,c}+N_{p,-c})(N_{p,c}+N_{-p,c})(N_{p,-c}+N_{-p,-c})(N_{-p,c}+N_{-p,-c})}, \tag{1.6}$$

where $N_{p,c}$ is the number of occurrences of phrase p in documents labelled with $c \in \{\text{monetary policy relevant}, \text{not relevant}\}$. Analogously, $N_{-p,-c}$ is the number of occurrences of all phrases except phrase p in all documents not labelled c.

$\omega_{p,c}$ measures how characteristic word p is for label c, accounting for the word count conditional on c but also the frequency of occurrence in all non-c documents. Table A.4 lists the words that $\omega_{p,c}$ identifies as most representative of the monetary policy topic. The results are intuitive: Speeches about monetary policy contain more mentions of words like "inflation" and "monetary policy."

In the third and final step of the speech classification, I count for each speech the occurrences of the 200 words most characteristic for the monetary policy topic.[16] I then define an exogenous threshold, 10% of total words, that a speech has to exceed in order to be classified as "relevant to monetary policy."

In the regression analysis, I will subset on the speeches that are related to monetary policy according to this threshold. My findings are robust to other treshold values and the estimates change in an intuitive way (Table A.9).

[15]For this, I use the R-package "wordVectors," which implements a prominent algorithm presented in Mikolov et al. (2013).

[16]I delete only few words from the list like "regulatory" or "supervision" in order to reduce the chances of misclassification. The value added of determining the characteristic words statistically is of course that it is less arbitrary and it is easier to agree on a set of words to search for than to agree on every speech's topic individually. Appendix Figure A.1 plots the empirical distribution of the occurrences of the characteristic words across speeches.

1.4 Empirical analysis

1.4.1 Empirical strategy

Main regression specification. To analyse the relationship between speech tone and the misalignment measure, I estimate the equation

$$\tau_{jt} = \alpha_j + \beta \text{misal}_{t-1} + \theta \text{misal}_{t-1} \times \text{Status}_{jt} + \phi \text{Status}_{jt} + \gamma X_{t-1} + \epsilon_{jt}, \tag{1.7}$$

where τ_{jt} is the tone in the speech given by speaker j on day t (defined in Eq. 1.5). $misal_{t-1}$ is the 5-day rolling average of the misalignment measure on the day before the speech.[17] X_{t-1} is a vector of controls, including four economic surprise indeces (employment, inflation, output and macro sentiment) following Beber et al. (2015) and a dummy variable for the Asian, Russian, Dotcom, and 2008 financial crisis.

In my baseline, I control for speaker fixed effects to absorb time invariant variation in communication behaviour across speakers. Since the key regressor $misal_{t-1}$ is an aggregate variable and variations between FOMC periods are potentially important, I do not include FOMC fixed effects but control for macro variables (see above) and provide a robustness test. I use robust standard errors.[18]

Speaker heterogeneity. Since there are different types of FOMC members, I estimate Equation 1.7 separately for speeches by members of the Board of Governors ("governors") and regional Reserve Bank presidents ("presidents").[19] Within the groups of presidents and governors, the dummy Status_{jt} captures further heterogeneity. For the presidents' sample, Status_{jt} equals one if speaker j will be a voting member at the upcoming FOMC meeting and zero if non-voting. For the governors' sample, Status_{jt} equals one if the speaker is the chair or vice chair of the Fed Board.

Identification. To address identification challenges, I complement the speech tone regressions with an analysis of the relationship between the topic of the speeches and misalignment. This approach is similar in spirit to the one taken by Cieslak and Vissing-Jorgensen (2020). The results in Section 1.4.3 show that misalignment predicts not only the *speech tone* but also the *speech topic*. Larger misalignment raises the probability that the speeches contain explicit references to

[17] Speeches are unevenly spaced over time, so controlling for "lagged" speech tone is non-trivial (and inconsequential in experiments) and thus omitted in favour of simplicity.

[18] My choice follows the bias-variance trade-off argument applied to the estimator variance following Cameron and Miller (2015). Low within-cluster correlation and low number of "short"/unbalanced clusters favor a parsimonous specification, which applies especially to the governors. Thus, I use robust SEs throughout as baseline but report a robustness test. Table A.15 shows the main findings hold when clustering standard errors by speaker.

[19] The Board of Governors oversees the Federal Reserve System as a whole. Instead, the presidents essentially represent their home districts. The presidents are divided into four groups, within which the right to vote on the FOMC rotates with one year terms. The NY Fed has a permanent voting right and I therefore treat its presidents as governors.

market expectations. I now describe the main identification concerns and how the content analysis helps to alleviate them.

One main identification concern is that both misalignment and speech tone might be driven by the Fed's private information resulting in a correlation without causal link from misalignment to speech tone. In this case, central bankers would speak more hawkishly simply because they are more hawkish and, at the same time, the market is looking "too dovish" because they do not know the hawkish news yet. If this story was the sole driver of the misalignment-tone correlation, any significant link between misalignment and the *speech topic* would shed light on the subject of the Fed's private information. However, it is unlikely that the Fed has private information about market expectations because these are, by definition, determined in the private sector and generally publicly observable. From this perspective, any predictive power of misalignment for the "market expectation" topic suggests that the Fed is indeed reacting to misalignment. Such causal link from misalignment to speeches arises if central bankers want to reduce the misalignment to avoid a market surprise, the central hypothesis tested in this paper. An additional channel could be that misalignment has immediate consequences which the Fed seeks to prevent, even without consideration of the potential market surprise.[20] Since my main focus is on very short-term misalignment such effects are likely limited and I leave it for further research to explore.

A second challenge concerns reverse causality, that speech tone could drive misalignment and not vice versa. This problem is best discussed in terms of the two components of misalignment, market expectations and the Fed's future decision (misaligment based on perfect foresight) or the Fed's expectations (proxied by Greenbook forecasts). If the reverse causality was working through the first component of misalignment, i.e. through the effect of speeches on market expectations, the link between speech tone on misalignment should be positive[21], we would have $Corr\big(\tau_{jt}, misal_t\big) > 0$. My estimate is therefore a conservative one. Another manifestation of reverse causality could be that the finding is driven by the effect of speeches on the second component of misalignment, i.e. on future Fed decisions or the Greenbook forecasts. However, following the argument above about the omitted variable bias, the fact that misalignment predicts the mentioning of market expectations largely rules out that such reverse causality story would be the only driver of misalignment-tone correlation. For if it was the only driver, much of the

[20]For example, suppose market expectations are (excessively) hawkish and cause financial conditions to tighten. Suppose further that the Fed privately decides that the tightening of financial conditions warrants a relatively loose monetary policy at the next meeting. A related question is whether there were cases where misalignment was so large that it influenced the decision to be taken. Self-fullfilling market expectations will be explored in the model developed further below.

[21]If the expectation management is effective, we would expect that more positive speeches make market expectations more hawkish, that is $Corr\big(\tau_{jt}, E_t^{\text{Market}}(r_{t_{fomc}})\big) > 0$.

effect of these speeches on future decisions and staff forecasts would need to stem from issues dealing with market expectations.

Finally, in Appendix A.4 I provide a brief narrative analysis that confirms the FOMC's concern about misaligned market expectations and their use of communication to reduce them.[22]

1.4.2 Speech tone regressions

Tables 1.2 and 1.3 present the main estimates using the baseline misalignment measure with perfect foresight. Table 1.4 presents results using the Greenbook misalignment.

	Dependent variable: τ_{jt}			
	Presidents		*Governors*	
$misal_{t-1}$	-0.251^{***}	-0.244^{***}	-0.162^{**}	-0.157^{**}
	(0.051)	(0.053)	(0.064)	(0.063)
Speaker FE	Y	Y	Y	Y
Controls	N	Y	N	Y
Observations	589	589	289	289
R^2	0.237	0.239	0.098	0.116

Notes: *p<0.1; **p<0.05; ***p<0.01. OLS estimates of equation: $\tau_{j,t} = \alpha_j + \beta \text{misal}_{t-1} + \gamma X_{t-1} + \epsilon_{jt}$, where (j,t) indexes speaker and day of speech. misal_{t-1} is lagged 5-day rolling average misalignment, standardized by its standard deviation. "Presidents" ("Governors") denotes the sample of speeches by Fed presidents (Fed Board Governors). Standard errors are HC White-Hubert. Controls are data surprises for 51 macroeconomic variables at $t-1$ (see Appendix A.1.3) and dummies for the Asian, Russian, Dotcom and 2008 financial crisis. Sample includes speeches of the subset "MP10" (least 10% of all words are "monetary policy relevant words"), and within 5 weeks of the upcoming FOMC. ZLB period is excluded.

Table 1.2: *Effects of misalignment assuming perfect foresight*

Baseline estimates for presidents and governors. Table 1.2 starts with the most basic specification, a univariate regression of speech tone on average misalignment during last week. The negative sign of coefficient β means that if market expectations are too hawkish, the tone in speeches becomes more dovish (i.e. using more negative words). β can be interpreted as the negative of the percentage change in the number of negative words used in a given speech in response to a one standard deviation (∼9bp) increase in the misalignment measure. So in the first column, $\beta = -0.251$ implies that, if the market expects the Fed funds rate to be 9 basis points higher after the next FOMC meeting than it will actually be, the percentage number of negative words used in the speeches increases by

[22] For example, in very similar spirit as the quote of Janet Yellen in the introduction, Ben Bernanke said in August 2003: "the markets have largely missed this point [...] To the extent that we can sharpen our message [...], we should make every effort to do so."

around 25 basis points. In the sample, the average speech has around 1650 words, implying that the speaker will use around 4 more negative words which is 6% of the average number of negative words per speech. The full-sample standard deviation of speech tone is 1.64. Thus, in the baseline, misalignment explains circa 15% of the speech tone variation.

Voting right and chairs heterogeneity. Table 1.3 reports the estimates including the interaction of misalignment with the $Status_{jt}$-dummy. For the presidents' sample, $Status_{jt}$ equals one if the speaker has the right to vote at the upcoming meeting. For the governors' sample, $Status_{jt}$ equals one if the speaker is chair or vice chair of the Board of Governors.

I document the speaker heterogeneity here mainly as stylized facts and to ensure transparency of the headlines results. Section 1.4.4 will provide some deeper discussion of potential explanations and point out areas for future research and follow-up work.

	Dependent variable: τ_{jt}			
	Presidents		*Governors*	
$misal_{t-1}$	-0.177^{***}	-0.170^{***}	-0.060	-0.055
	(0.059)	(0.061)	(0.078)	(0.078)
$misal_{t-1} \times Status_{jt}$	-0.248^{**}	-0.250^{**}	-0.264^{**}	-0.273^{**}
	(0.110)	(0.111)	(0.123)	(0.121)
Speaker FE	Y	Y	Y	Y
Controls	N	Y	N	Y
Observations	589	589	289	289
R^2	0.244	0.247	0.118	0.122

Notes: *p<0.1; **p<0.05; ***p<0.01. OLS estimates of equation: $\tau_{j,t} = \alpha_j + \beta \text{misal}_{t-1} + \theta \text{misal}_{t-1} \times \text{Status}_{jt} + \phi \text{Status}_{jt} + \gamma X_{t-1} + \epsilon_{jt}$. misal_{t-1} is lagged 5-day rolling average misalignment, standardized by its standard deviation. "Presidents" ("Governors") denotes the sample of speeches by Fed presidents (Fed Board Governors). Standard errors are HC White-Hubert. Status_{jt} is a dummy equal to one if the speaker is a voting FOMC member (in the Fed presidents sample) or equal to one if the speaker is the chair/vice chair (in the Board of Governors sample). Controls are data surprises for 51 macroeconomic variables at $t-1$ (see Appendix A.1.3) and dummies for the Asian, Russian, Dotcom and 2008 financial crisis. Sample includes speeches of the subset "MP10" (at least 10% of all words are "monetary policy relevant words"), and within 5 weeks of the upcoming FOMC. ZLB period is excluded.

Table 1.3: *Effects of misalignment assuming perfect foresight, voting/chair dummy*

Table 1.3, left-hand panel, shows that the predictive power of misalignment for speech tone is more than twice as strong for presidents with voting right than without. In the right-hand panel, the effect for Fed governors is almost exclusively driven by the chairs and vice chairs.[23] For the specification including controls, the

[23] In the previous version, the right-hand panel reported (contrary to left-hand) the adjusted R^2.

estimated effect for voting presidents (chairs) is $\beta + \theta = -0.170 - 0.250 = -0.420$ (-0.328). Thus, voting members (chairs) use around 8 (5) more negative words in response to a 1 standard deviation increase in misalignment. This effect captures around 40% of the within-speaker variation in speech tone.

(a) *Presidents*

	Dependent variable: τ_{jt}			
	1Q ahead	1Q ahead	2Q ahead	2Q ahead
$misal_{t-1}$	-0.187	-0.026	-0.189^{*}	-0.013
	(0.123)	(0.171)	(0.105)	(0.144)
$misal_{t-1} \times Status_{jt}$		-0.436^{**}		-0.457^{**}
		(0.211)		(0.187)
Obs	205	205	200	200
R^2	0.363	0.373	0.370	0.383

(b) *Governors*

	Dependent variable: τ_{jt}			
	1Q ahead	1Q ahead	2Q ahead	2Q ahead
$misal_{t-1}$	-0.062	0.237	-0.103	0.156
	(0.161)	(0.183)	(0.144)	(0.183)
$misal_{t-1} \times Status_{jt}$		-0.848^{**}		-0.616^{**}
		(0.337)		(0.311)
Obs	102	102	100	100
R^2	0.293	0.330	0.290	0.315

Notes: *p<0.1; **p<0.05; ***p<0.01. Speech tone τ_{jt} is regressed on misalignment based on Greenbook projections betw 1996 and 2012, excl the Global Financial Crisis. Standard errors are HC White-Hubert. Misalignment compares market expectations at date t with the projections from the most recent Greenbook. $Status_{jt}$ equals one if the speaker is a voting president (presidents sample) or the chair/vice chair of Fed Board (governors sample). For each Greenbook, speeches up to 3 weeks after it was released to the FOMC are included. Periods between unscheduled and subsequent scheduled meetings are excluded. Controls are rolling 5-day averages of data surprises at $t-1$ (see A.1.3) and real-time estimates of previous quarters CPI inflation and real GDP growth obtained from the Greenbooks. Based on the subsets of speeches "MP10" with at least 10% of all words are "monetary policy relevant words."

Table 1.4: *Effects of misalignment based on Greenbook projections*

Estimates using Greenbook-based misalignment. To relax the assumption of perfect foresight, Table 1.4 reports estimates using misalignment based on Greenbook forecasts. Contrary to the misalignment measure based on perfect foresight, Greenbook-based misalignment exhibits patterns at business cycle frequency (see Fig. A.3). I therefore augment the Equation 1.7 with real-time estimates of previous quarter's real GDP growth and CPI inflation obtained from the Greenbooks.

The effect of misalignment on subsequent speech tone, β, is again negative.

The interaction of misalignment with $Status_{jt}$ shows that the effect is mostly driven by voting presidents and the chairs and vice chairs of the Fed Board. For voting presidents (chairs), the effects are $\beta^{1Q} + \theta^{1Q} = -0.462$ (-0.611) and $\beta^{2Q} + \theta^{2Q} = -0.470$ (-0.460), implying an increase of negative words by around 8 words. For the chairs of the Fed Board, the estimates imply around 10 and 8 more negative words. The magnitude of these effects must be assessed carefully.

The coefficients measure the change in speech tone τ_{jt} in response to a 1 standard deviation increase in misalignment. As shown in the summary statistics, misalignment at more distant horizons is on average larger and more volatile. When measured in terms of the same delta in misalignment, speeches react far less strongly to misalignment at more distant horizons.

This could be explained with higher uncertainty associated with more distant forecast horizons. At more distant horizons, risk-averse policy makers might then require larger misalignment to feel compelled to guide expectations.

In the current setup, the sample consists of speeches given in the 3-week periods starting from the delivery of the Greenbook to the FOMC. This typically includes 5-6 days before the FOMC meeting. There are two important considerations. First, due to the blackout period around FOMC meetings during which Fed officials are not allowed to deliberate on monetary policy,[24] the effective time period under consideration is closer to 2 weeks. Second, the period includes the FOMC meeting and associated announcements. Since monetary policy shocks at these meetings could affect both speeches and misalignment, Appendix Table A.10 reports the estimates controlling for them. The main findings do not change.

1.4.3 Speech topic regressions

1.4.3.1 Mentions of market expectations

To implement the content analysis motivated in Section 1.4.1, I identify speeches that explicitly discusss market expectations. Many of these speeches will be contained in the set of "monetary policy speeches." Since the targeted content is very specific, I here simply search all speeches for the phrases listed in Table 1.5. If a speech contains any of these phrases, it is labelled as "market expectations-speech." The selected search terms are a conservative choice in the sense that central bankers might react to market expectations not by explicitly mentioning them, but by providing guidance on the underlying issues. I find 240 speeches

[24]The effective timing of this period has varied. In the latest update in 2011, the FOMC states on its webpage (Statement can be found here: link) "The blackout period will begin at the start of the second Saturday [...] before the beginning of the meeting and will end at midnight [...] on the next day after the meeting." As FOMC meetings usually start on a Tuesday or Wednesday, the blackout period usually covers 10-11 days before the meeting.

market expectations	markets predict
markets expect	market participants anticipate
market expects	market participants anticipated
market expected	market participants foresee
market participants expected	market forsees
participants expect	markets forsee
fed funds futures	

Notes: List of phrases used to identify speeches that explicitly mention "market expectations."

Table 1.5: *Phrases identifying speeches discussing market expectations*

which mention at least one of the key words, around 7% of all speeches in sample (Table A.3).

1.4.3.2 Extensive margin of communication: Speech topic

Probit specification. To test for a link between the market expectations topic and misalignment, I first construct a panel data set that records the number of speeches (all speeches and topic-specific) for each speaker and week before scheduled FOMCs. Naturally, it is rare that a speaker gives more than one speech mentioning market expectations in the same week, and I therefore opt to model the occurrence of these speeches as binary variable. I then estimate the following probit equation, again separately for the presidents' and governors' samples,

$$\begin{aligned} Prob(\text{Topic} = \text{``Mexp''})_{jt} =& \phi\big[\beta \text{ abs}(misal)_{t-1} + \theta \text{ abs}(misal)_{t-1} \times Status_{jt} \\ &+ Status_{jt} + \phi \text{ abs}(misal)_{t-2} + X_{jt-1}\big] \end{aligned} \tag{1.8}$$

where (j, t) indexes speaker and week, Topic_{jt} = "Mexp" indicates whether a speech mentions market expectations, as defined in Table 1.5. $abs(misal)_{t-1}$ is the absolute value of misalignment. X_{jt-1} is a vector of controls that includes the absolute value of the average data surprise indeces described above and the number of speeches by speaker j in week t.[25] The baseline covers weeks 2 to 5 before each FOMC (if existent), and omits unscheduled FOMCs, crises and the ZLB period.[26] The main sample then covers 123 FOMCs between March 1994 and January 2018.

Misalignment drives speech topics. Table 1.6 reports estimates of Equation 1.8 for the market expectations topic and a broader outcome variable for the probability

[25] I do not include FOMC fixed effects because they would be a perfect predictor of the speech content probabilities in FOMC periods, in which no president mentions market expectations. A similar argument applies to speaker fixed effects, for speakers that never mentioned market expectations. I found that controlling for the number of speeches is a good alternative.

[26] The first/last weeks are omitted because they fall into the "Purdah period," during which Fed officials are not allowed to give policy-related speeches. Controlling for the lag of misalignment further constraints the sample since I rule out that the lagged value is from previous FOMC period.

	Dependent variable: Prob(Speech with Topic)$_{jt}$			
	Presidents		*Governors*	
$abs(misal)_{t-1}$	−0.261	0.243	−0.207	0.090
	(0.204)	(0.209)	(0.138)	(0.178)
$abs(misal)_{t-1} \times Status_{jt}$	0.227	0.440***	−0.023	0.505***
	(0.161)	(0.135)	(0.209)	(0.162)
Topic	MonPol	MarketExp	MonPol	MarketExp
Obs	4490	4490	3700	3700

Notes: *p<0.1; **p<0.05; ***p<0.01. Estimates from probit regressions $Prob(Topic = C)_{jt} = \phi[\beta \text{ abs}(misal)_{t-1} + \theta \text{ abs}(misal)_{t-1} \times Status_{jt} + Status_{jt} + \phi \text{ abs}(misal)_{t-2} + X_{jt-1}]$ where (j, t) indexes speaker and week, topic $C \in \{\text{MonPol}, \text{"Mexp"}\}$. "Presidents" ("Governors") denotes the sample of speeches by presidents (governors). Standard errors in parentheses. Sample includes weeks 5 to 2 before each FOMC. $abs(misal_{t-1})$ is the absolute value of misalignment. X_{t-1} is a vector of controls (see main text). $Status_{jt}$ equals one if the speaker is a voting president (presidents sample) or the chair/vice chair of Fed Board (governors sample).

Table 1.6: *Effect of misalignment on probability of speeches mentioning market expectations*

of speeches about monetary policy as used in the tone regressions.

Larger misalignment significantly raises the probability of the market expectations topic both for voting presidents and the chairs of the Fed Board. The effect of misalingment on the monetary policy topic is insignificant. The latter is not surprising since speeches about monetary policy are very frequent and there will be many monetary policy speeches at small misalignment, making it a poor predictor.

Table 1.7 reports the marginal effects to assess the economic magnitudes.

	ΔProb(Speech with "Mexp")$_{jt}$			
	Presidents		Governors	
$abs(misal)_{t-1}$	Voting	Non-voting	Chairs	Rest
5bp	0.081	0.039	0.085	0.026
	(0.038)	(0.054)	(0.033)	(0.044)
10bp	0.115	0.043	0.130	0.027
	(0.066)	(0.066)	(0.073)	(0.047)
15bp	0.151	0.048	0.180	0.028
	(0.096)	(0.078)	(0.109)	(0.051)

Notes: Table shows the change in Prob(Speech with "Mexp")$_{t}$ in response to an 10bp increase in misalignment, conditional on the (pre-existing) level of misalignment. Standard errors in parentheses. Prob(Speech with "Mexp")$_{jt}$ is the probability that in week t speaker j gives a speech mentioning market expectations. The control variables are held at their means plus one standard deviation, the second lag of misalignment is set equal to 0.

Table 1.7: *Marginal effects of misalignment on probability of market expectations topic*

At an pre-existing misalignment of 5 basis points, a 10 basis point jump in misalignment increases the probability of a speech mentioning market expectations by around 8 percentage points for both voting presidents and chairs of the Board. This effect is increasing in the level of misalignment. At higher levels of misalignment (10 and 15 bp), the marginal effects are economically large but with weak significance due to the small number of episodes with misalignment at these levels.

Further discussion. Table A.3 shows that around 7% of all speeches include explicit mentions of market expectations, suggesting that the speech topic might be considered a rare event. Probit estimates can be biased in such situation. Therefore, Appendix Table A.14 shows that the findings are robust to using the rare-events logistic regression model from King and Zeng (2001) which corrects for this bias.

One concern about the content analysis could be that the mentions of market expectations are not truthful in the sense that they are driven by private strategic considerations inconsistent with the Fed's objective.[27] Two remarks are important. First, to the extent that such private strategic incentives are distributed symmetrically around the FOMC consensus, or unrelated to it, the effects of such mechanism on my estimates will be negligible. Second, such intepretation would be hard to reconcile with the evidence from the tone regressions which suggests that Fed officials attempt to reduce misalignment.

1.4.4 Further discussion & robustness

Zero lower bound. The main sample excludes the ZLB period because the interest rate stopped being the main tool of monetary policy. I define the ZLB period as the three year period from 2010 to 2012. The starting and end points for this period are based on the general judgement that during this time there were zero to very little speculations that the Fed target rate would be changed at the upcoming meeting. It's important to stress that this regards expectations concerning the *upcoming* decision. During the first half of the ZLB period, up until late 2011, markets were quite persistently expecting Fed lift-off in the *upcoming quarters*. Regarding the end point, 2013 featured the Taper Tantrum and some policy makers were arguing that rates should be raised in 2013. These dating decisions are not unambiguous. For example, as early as April 2012, Jeffrey Lacker, President of the Richmond Fed, and James Bullard, President of the St. Louis Fed, publicly argued that rates

[27] For instance, imagine a Fed president who is, like the market, more hawkish than the rest of the FOMC. Her/his mentions of market expectations would be in an confirming sense. Another related argument is put forth by Vissing-Jorgensen (2019) who claims that Fed officials would systematically leak information to move market expectations, in an attempt to reduce the Fed's future policy flexibility in favor of their preference. Vissing-Jorgensen (2019) analyzes this problem in a game theoretic model and provides some narrative evidence for leakages and the Fed's concern that communication can reduce policy flexibility. Since I focus on the upcoming policy decision, concerns by the Fed about reducing market volatility are likely more important. The unobservable nature of informal leakages makes it impossible for me to examine the issue systematically.

should be raised in 2013.[28] Equally, while the Fed announced it would leave the Fed funds target range at 0-25 basis points for an "extended period" in March 2009, there were debates about whether the Fed would cut rates into negative territory.[29] Appendix Table A.15 shows that the negative correlation between speech tone and misalignment also holds if the ZLB period is included, though the link becomes weaker.

Unobserved updates to Fed expectations. I do not observe how the Fed's expectations evolve continously over time. If positive public news arrive, observed speeches and market expectations should rise instantly while *measured* Fed expectations remain constant until updated. This would result in a positive correlation between speech tone and misalignment and hence my estimates are conservative with respect to this concern.

Expected effective funds rate. In Table A.15, the perfect foresight misalignment is constructed by assuming perfect foresight concerning the effective fed funds rate, not the target rate. This can alleviate concerns that structural changes in the position of the effective fed funds rate within the Fed's target range could be driving the results, especially in the years where asset purchase programmes have altered the aggregate liquidity conditions.

Speech classification thresholds and tone measures. Table A.9 confirms that, as the classification threshold for monetary policy related speeches increases, the estimates become less noisy and the effect size increases. The same holds for the governors' sample.

Table A.13 shows that the results are robust to exchanging the basline measure of speech tone with the Loughran-McDonald or with the popular method of counting bigrams as in Apel and Grimaldi (2012).

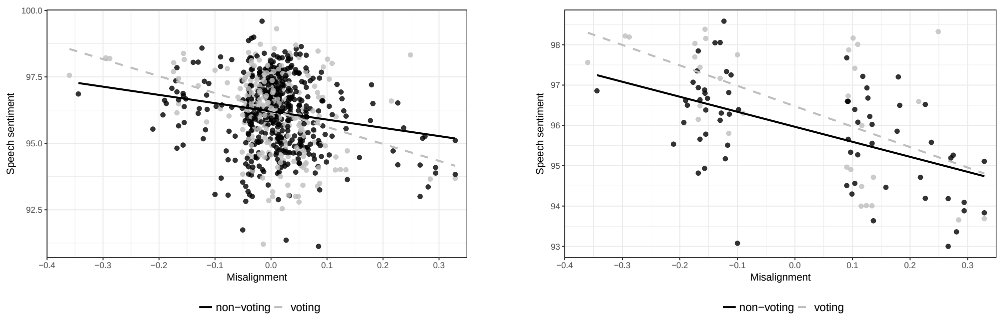
Effects by proximity to FOMC. Appendix Table A.11 suggests that the effect of misalignment weakens as the number of weeks before the upcoming FOMC meeting increases. For this purpose, the misalignment measure is interacted with week dummies. The positive coefficients suggest that the effect is strongest shortly before the FOMC, consistent with that policy makers need confidence about the upcoming decision and that this confidence grows as the meeting approaches.

Scatter plot. Figure 1.1 plots speech tone as a function of the misalignment error. Consistent with the summary statistics, misalignment is often relatively close to zero, within a 10 basis points range at either side. However, there are also observations of large misalignment. Figure 1.1b shows that the main finding is robust to excluding observations with small misalignment.

[28]See these Reuters articles (link and link) and this CNBC article (link).

[29]See e.g. Mankiw discussing the Fed going negative in this New York Times article (link). Media reports were especially steered by the fact that the Swedish central bank started implementing negative rates in this year (see e.g. link).

(a) *Full-sample* **(b)** *Excluding absolute misalignment <10bp*



Notes: The figure plots the speech tone measure τ_{jt} and the lagged 5-day moving average misalignment $misal_{t-1}^{Fwd,t^{fomc}}$, as used in the regressions, for speeches up to 5 weeks before the upcoming FOMC meeting. Colors refer to the voting status of the respective speaker at the upcoming FOMC meeting. Based on the subsets of speeches "MP10" with at least 10% of all words are "monetary policy relevant words."

Figure 1.1: *Relationship between speech tone and misalginment*

FOMC fixed effects. Table A.12 compares the baseline estimates with a specification including FOMC fixed effects, with and without the crisis year 2008. With FOMC fixed effects, the coefficients β and θ measure responses of speech tone to variations of misalignment within that period. Since the Fed's expectations (in the case of perfect foresight equal to the actual future decision) is a characteristic of the FOMC period, the fixed effects fully absorb this component of misalignment and the regression is therefore akin to regressing speech tone on only the market expectations component but controlling for the Fed's expectation. As expected, the estimates are less precise and somewhat smaller but the main effect holds and is significant for the voting presidents and the chairs of the Fed Board.

Voting rotation: Incentives, decision power and knowledge. Above I have documented that Fed presidents react more strongly to misalignment when they have the right to vote than when they do not. The voting right rotation between Fed presidents on the FOMC follows a pre-determined rule that is unrelated to macroeconomic and financial conditions.[30]

One could therefore argue, as in an earlier version of this paper, that the voting-right rotation offers an exogenous variation in the incentives of a speaker to engage in expectation management. Because he or she makes a formal and publicly recorded decision at the FOMC meeting, a voting president is more directly, and officially, associated with the decision. Viewed through the lens of the model in Holmström (1999),[31] the increased exposure induced by the voting right would

[30]Regional Fed presidents take turns for one year terms in their right to vote on the FOMC decision according to a fixed cycle announced by the Board of Governors.

[31]In the model, the agent exerts more effort if the principal becomes better informed about the

imply that the respective president puts more effort, which could manifest itself in an more eager expectations management.

Despite its intuitive appeal, the above identification argument requires auxiliary assumptions. While the rotation is exogenous, its effects on the presidents' incentives and information requires a whole separate analysis and is outside the scope of this paper. For the purpose of this paper, the heterogeneity between voting and non-voting presidents is simply presented as a stylized fact. It has motivated the follow-up work presented in Ehrmann et al. (2020).

1.5 Rational expectations model

The preceding empirical analysis is strongly suggesting that central bankers do indeed use their speeches to correct perceived expectational errors by the market. Theoretical work on policy rules under rational expectations suggest that a policy directly responding to market expectations might lead to instabilities, e.g. Bernanke and Woodford (1997).[32] The key insight is that such policy, if known to the public, creates a coordination problem. It raises a question concerning the efficacy of the type of policy that I have just provided empirical evidence for. Does intermeeting communication in response to expectational errors arise under rational expectations? If so, under what conditions? And, is it successful in equilibrium? I develop a simple analytical framework to answer these questions. The setup follows closely the model presented in Stein and Sunderam (2017).

1.5.1 Framework

The game's two players are the financial market and the central bank. Policy is discretionary. The central bank sets the nominal short-term interest rate and communicates, both in response to private information about the target interest rate i^*. i^* symbolizes the level of the nominal short rate at which inflation and output gap are at the values targeted by the central bank. The market's only action is to estimate i^* using its observations of the nominal short rate and central bank communication.

There are three periods $t = 1, 2, 3$. $t = 1$ and $t = 3$ represent two consecutive FOMC meetings, $t = 2$ is the inter-meeting period. In period 1, the Fed obtains private information e_1 about its target rate i^*_t. No new information arrives until the end of the game, at which point the private information is fully revealed to

agent. A similar argument is put forth by Hansen et al. (2017).

[32]See also Bernanke and Mishkin (1997). Bullard and Mitra (2002) argue the Taylor principle would be necessary and sufficient for expectational stability under forecast-based rules. Their finding is qualified by Preston (2006) who shows that it only holds if only one-period-ahead forecasts matter.

the market and the interest rate is set exactly at target value. The full revelation and implementation of private information at the end of the game is motivated by the focus on *short-term* monetary policy *implementation*. Equations 1.9 to 1.16 summarize all important relationships assumed in this model.

$$i_0^* = i_0 \qquad (1.9) \qquad i_1 = i_0 + k(i_1^* - i_0) + u_1 \qquad (1.13)$$

$$i_1^* = i_0^* + e_1 \qquad (1.10) \qquad i_2 = i_0 + \beta s_2 + u_2 \qquad (1.14)$$

$$i_2^* = i_0^* + e_1 \qquad (1.11) \qquad s_2 = \delta + \gamma \qquad (1.15)$$

$$i_3^* = i_0^* + e_1 \qquad (1.12) \qquad i_3 = i_3^*, \qquad (1.16)$$

Equations 1.9 and 1.16 state that the game starts and ends with the nominal interest rate at its target value. Equations 1.10 to 1.12 capture that the only new information arrives at $t = 1$, the target rate is constant thereafter.

The central bank sets interest rates at the FOMC meetings according to Equation 1.13 by choosing k which governs the strength of adjustment in the short rate in response to i^*.[33] I follow Stein and Sunderam by assuming that the central bank observes e_1 after deciding on k. This simplifies expressions below but preserves the commitment problem between time periods. In the inter-meeting period, $t = 2$, the central bank releases a noisy signal s_2 whose mean δ it picks (Eq 1.15).

Equation 1.14 signifies the assumption that central bank communication affects the nominal short rate (or financial conditions more broadly). This is crucial for two reasons. Firstly, it rules out cheap talk. Secondly, β allows for a directional interpretation of the signal. If $\beta > 0$, an increase in the signal implies a rise in the nominal short rate. Therefore an increase in s can be interpreted as more hawkish communication.[34] $u_t \sim N(0, \sigma_u^2)$ and $\gamma \sim N(0, \sigma_\gamma^2)$ are noise terms that materialize after the central bank moves but before the market moves, preventing the market to backout perfectly the private information.

Since e_1 is initially private information of the central bank, the market needs to estimate i_t^*, based on the signals it receives: The change in the nominal interest rate and the signal released in period 2. The market assumes that the target rate i^* follows a random walk,[35] $i_t^* = i_{t-1}^* + e_t$, and otherwise knows the entire

[33]Following Stein and Sunderam (2017), in this setting, the interest rate process is not recursive. Note that instead of $i_2 = i_1 + ...$ and $i_3 = i_2 + ...$, we have $i_1 = i_0 + ...$, $i_2 = i_0 + ...$ and $i_3 = i_0 + e$. The last condition reflects the fact that at the end of period 3, the nominal interest has to be on target. So the new information has to be fully impounded in financial conditions. Using $i_2 = i_0 + ...$ instead of $i_2 = i_0 + ...$ prevents the system to become recursive. If it was recursive, i_2 would become the fourth endogenous variable. In this sense, $i_2 = i_0 + ...$ is a simplifying assumption.

[34]In future work, it would be interesting to endogenize β and study whether and how it relates to the market's signal extraction problem. Since this requires a far more elaborate framework, it is outside the scope of this paper.

[35]This assumption simplifies the link between the time-t estimate of the target rate and the infinite horizon forward rate. Appendix A.3.3 details the relationship between the central bank's aversion to

structure of the economy except of k and δ. Instead, the market is using guesses K and D respectively. However, with rational expectation, the market will correctly conjecture $K = k$ and $D = \delta$. As will become clear shortly, the market's estimates matter to the central bank because they drive the infinite horizon forward rate, $i_t^\infty = E_t(i_t^*)$, and therefore bond market volatility.

Central bank loss function. As layed out above, the central bank's choice variables are the degree of interest rate adjustment in period 1, k, and the mean δ of the signal s_2 released in period 2. Period-by-period it minimizes the loss function

$$L_t = \sum_t^3 (i_t^* - i_t)^2 + \theta(\Delta i_t^\infty)^2. \tag{1.17}$$

$(i^* - i)^2$ captures the terms for the deviation of inflation and output gap from target values in the conventional loss function. The squared change in the infinite horizon forward rate, $(\Delta i^\infty)^2$, captures the central bank's aversion to bond market volatility. θ parametrizes the strength of this aversion. Stein and Sunderam (2017) introduce this type of loss function to explain *monetary policy gradualism*, the empirical pattern that central banks adjust policy rates slowly and in small increments.[36] An important distinction is that my model focuses on a phenomenon at higher frequency than the monetary policy inertia. Gradualist monetary policy is usually measured at quarterly frequency. Instead my model focuses on the implementation of the *upcoming* decision and the three dates span a typical FOMC period of around 6-7 weeks.

1.5.2 Solution

The model's solution is obtained by starting at the last decision made. Given the assumed full revelation and implementation of private information, there is no action in period 3. For exposition and without loss of generality, I set the initial interest rate i_0 to zero. Hence $i_1^* = i_2^* = i_3^* = e_1$.

Market expectations. This section derives the market's estimate of the Fed target rate in period 1 and 2, applying linear minimum mean squared error (LMMSE) technology to the observed signals.[37] In period 1, the only observed signal is the change in the nominal interest rate, Δi_1. Deriving the LMMSE estimator[38]

bond market volatility and the market's expectational errors.

[36]The large, positive coefficient on the autoregressive term in the Taylor-Rule has been subject to much debate. Rudebusch (2002, 2006) argues that it is due to persistence in omitted variables. Others argue that the Fed has an explicit desire to smoothen interest rates, for recent empirical support see Coibion and Gorodnichenko (2012). Stein and Sunderam (2017) deliver an economic rationale for such explicit desire to smooth interest rates. Other rationales include parameter uncertainty (Sack, 1998) or history-dependence as a expectation management tool (Woodford, 2003).

[37]One could think of the market's utility function being the negative of the mean squared error.

[38]χ is basically the OLS estimator from a regression of i^* on Δi.

gives

$$\widehat{e}_{1,t=1} = \underbrace{\frac{K\sigma_{\epsilon}^2}{K^2\sigma_{\epsilon}^2 + \sigma_u^2}}_{\chi} \Delta i_1. \tag{1.18}$$

In period 2, the market combines information contained in the rate change and in the central bank communication. (Below I provide an intuition for why the market would put a non-zero weight on a signal released already last period.) To derive at its optimal estimate $\widehat{e}_{1,t=2}$, the market uses a LMMSE of the form

$$\widehat{e}_{1,t=2} = \alpha_1 \Delta i_1 + \alpha_2 s_2. \tag{1.19}$$

Appendix A.3.1 goes through the derivations that yield the coefficients from the optimal estimate:

$$\alpha_1 = \frac{Var(s_t)Cov(i_t^*, \Delta i_t) - Cov(\Delta i_t, s_t)Cov(s_t, i_t^*)}{Var(s_t)Var(\Delta i_t) - Cov(s_t, \Delta i_t)^2} \tag{1.20}$$

$$\alpha_2 = \frac{Var(\Delta i_t)Cov(i_t^*, s_t) - Cov(\Delta i_t, s_t)Cov(\Delta i_t, i_t^*)}{Var(s_t)Var(\Delta i_t) - Cov(s_t, \Delta i_t)^2}. \tag{1.21}$$

By weighting the two signals, the market takes rational account of the variances of and co-variances between the two signals and their respective co-variation with the unknown target rate. As the market knows the structure of the economy except of the central bank parameters k and δ, Equations 1.20 and 1.21 can be brought to life by computing the theoretical moments. For the rational expectations solution, the central bank's choice for the mean of the signal needs to be derived first. I therefore postpone the development of analytical expressions to the next section.

Period 2. In period 2, the central bank solves:

$$\min_{\delta} L_2 = (i_2^* - i_2)^2 + \theta(\Delta i_2^{\infty})^2 + (i_3^* - i_3)^2 + \theta(\Delta i_3^{\infty})^2.$$

It chooses δ taking the market's expectation parameters α_1 and α_2 as given. The central bank does not internalize that the market understands its incentives and adjusts accordingly. The FOC yields

$$\hat{\delta} = E(\delta) = \frac{e_1\beta + \alpha_2\theta\left[e_1 - (2\alpha_1 - \chi)\Delta i_1)\right]}{\beta^2 + 2\theta\alpha_2^2} \tag{1.22}$$

$$= \underbrace{\frac{\beta + \alpha_2\theta(1 - (2\alpha_1 - \chi)K)}{\beta^2 + 2\alpha_2^2\theta}}_{v_1} e_1 - \underbrace{\frac{\alpha_2\theta(2\alpha_1 - \chi)}{\beta^2 + 2\alpha_2^2\theta}}_{v_2} u_1. \tag{1.23}$$

Again, under rational expectations, the market will understand that the central bank's optimal choice of δ is $\hat{\delta}$, $D = \hat{\delta}$. As $E(\gamma) = 0$, we have $E(\hat{s}) = \hat{\delta}$.

I can now develop analytical expressions for the coefficients of the market's forecast function. Using $\hat{\delta}$ and χ to compute analytical expressions in Equations 1.20 and 1.21, we have

$$\alpha_1 = \frac{\sigma_e^2\left[K(\sigma_\gamma^2 + \sigma_u^2 v_2^2) - \sigma_u^2 v_1 v_2\right]}{\sigma_u^2(\sigma_\gamma^2 + \sigma_e^2 v_1^2) - 2K\sigma_e^2\sigma_u^2 v_1 v_2 + K^2\sigma_e^2\left(\sigma_\gamma^2 + \sigma_u^2 v_2^2\right)} \tag{1.24}$$

$$\alpha_2 = \frac{\sigma_e^2\sigma_u^2(v_1 - Kv_2)}{\sigma_u^2(\sigma_\gamma^2 + \sigma_e^2 v_1^2) - 2K\sigma_e^2\sigma_u^2 v_1 v_2 + K^2\sigma_e^2\left(\sigma_\gamma^2 + \sigma_u^2 v_2^2\right)}. \tag{1.25}$$

The fact that v_1 and v_2 depend on α_1 and α_2 is crucial. It signifies that the agents understand that the central bank will communicate partly in response to their expectations. The latter implies that, as the agents' expectation formation varies, the *meaningfulness* of the central bank communication will vary as well. I define the *meaningfulness* as the covariation of the signal with the information of interest, e, which will be helpful to gain intuition for the equilibrium outcomes.

Period 1. With the central bank's optimal choice $\widehat{\delta}$, I can plug $E(\widehat{s}_2)$ into L_1 and differentiate with respect to k. Importantly, the expected choice of δ will affect the optimal value for k as $\widehat{s}_2$ is a function of Δi_1. Plugging in the optimal signal, multiplying out and evaluating the expectations, $E(u_1) = E(u_2) = E(e_1) = 0$, the expected loss function at $t = 1$ is

$$\begin{aligned} E(L_1) =& 2\alpha_1^2 k^2\sigma_e^2\theta + 2\alpha_1^2\sigma_u^2\theta - 2\alpha_1\chi k^2\sigma_e^2\theta - 2\alpha_1\chi\sigma_u^2\theta - 2\alpha_1 k\sigma_e^2\theta + 2\alpha_2^2\hat{s}^2\theta + b^2\hat{s}^2 \\ &+ 2\chi^2 k^2\sigma_e^2\theta + 2\chi^2\sigma_u^2\theta + k^2\sigma_e^2 - 2k\sigma_e^2 + \sigma_e^2\theta + 2\sigma_e^2 + 2\sigma_u^2. \end{aligned}$$

The FOC then gives the optimal k

$$\widehat{k} = \frac{1 + \alpha_1\theta}{1 + 2\alpha_1\theta(\alpha_1 - \chi) + 2\theta\chi^2}. \tag{1.26}$$

The fact that $\widehat{k}$ does not depend on α_2 reflects that the central bank sets the mean of the signal, which is zero at expected values, $E(e) = E(u) = 0$.

Finally, the model solution is pinned down by Equations 1.18, 1.24 and 1.25 specifying the market's estimators, Equation 1.26 for the central bank's choice of degree of adjustment to private information $\widehat{k}$, and imposing rational expectations.

Types of equilibria. Before analyzing the equilibrium outcomes, the different types of equilibria are characterized. First the edge case $\theta = 0$.

Proposition 1. If the central bank is not averse to bond market volatility, $\theta = 0$, the model has a unique equilibrium where the central bank adjusts fully to new information, i.e. $k = 1$. Nevertheless, if central bank communication is assumed to affect financial conditions, $\beta \neq 0$, the market will put, in period 2, a non-zero positive weight on both the past change in the nominal interest rate as well as on the central bank communication. We have $\alpha_1, \alpha_2 > 0$ as long as there is noise in the central bank's instruments $\sigma_u^2, \sigma_\gamma^2 > 0$.

The proof of Proposition 1 can be found in Appendix A.3.4. Why does the market put a non-zero weight on central bank communication even though the central bank reacts fully to its new information in the first place? The key is that, in period 1, the central bank decides on k based on $E(u)$, before u actually realizes. A surprise in u will therefore lead to a) a higher/lower nominal rate and b) consequently to higher/lower market expectations concerning i^*. In period 2, by sending a signal s, the central bank gets a chance to react to these misalignments. As long as $\theta = 0$, the central bank communication will unambigously cater the need to react to surprises in the noise term. There is no trade-off for the central bank between keeping markets calm (keeping Δi_t^∞ small) and achieving the inflation target (keeping i close to i^*).

However, if $\theta > 0$, the central bank underadjusts to its private information. Table 1.8 lists the equilibrium choices for k, α_1 and α_2 for different θ. As in Stein and Sunderam, as the central bank's aversion to bond market volatility (θ) increases, the degree k with which it reacts to new private information decreases. At the same time, the weight on the interest rate signal Δi in period 2 increases, and decreases for the communication signal.

Observation 1. For $\beta > 0, \theta > 0$, there is a critical threshold for the strength of aversion to bond market volatility, $\bar{\theta}$, which is decisive for the uniqueness of the model's solution. If $\theta < \bar{\theta}$, a unique equilibrium with $\alpha_1, \alpha_2 > 0$ and $0 < k < 1$ obtains. If $\theta > \bar{\theta}$, there are multiple equilibria.

Observation 2. For $\beta > 0$ and $0 < \theta < \bar{\theta}$, $\hat{k}$ is decreasing in θ : As the aversion to bond market volatility becomes stronger, the central bank reacts less and less to its private information, i.e. underadjustment increases.

The underadjustment can create a trade-off for the central bank between the two terms in its loss function: Financial conditions might be too tight ($i > i^*$) but market expectations regarding i^* too dovish ($\widehat{i^*} < i^*$). An easing of financial conditions would help achieving the inflation target but might confuse market expectations further. Moreover, when $k < 1$, central bank communication can have two motives. The central bank might use s as a strategic complement to its underadjustment in period 1: Having "misguided" markets in period 1, it aims to gently correct expectations in period 2, thereby smoothing the process of impounding e. At the same time, the central bank could also be reacting to realized noise in the short rate. As the market does not observe e and u, it faces uncertainty whether central bank communication is reacting to incoming data surprises or whether it is a strategic move to steer market expectations. The trade-off and uncertainty about motives for communication create a coordination problem between beliefs by the central bank and the market. Higher values of θ exacerbate this coordination problem and at some point introduce multiple equilibria. This is summarized in Observation 1. Depending on its beliefs, the market might want to put a positive or a negative weight on the signal. The expected covariation of the signal s_2 with i^* ("meaningfulness") and the beliefs about which values for u and e have realized determine the market's expectations.

Observation 2 characterizes the first type of the equilibria in which the behaviour of the market and the central bank is the same as in the unique equilibrium: The market puts a positive weight on both the interest rate signal and the communication, and the central bank's underadjusts more if the aversion to volatility is higher. The two last rows from Table 1.8 show that entirely different outcomes are possible too: In this scenario, the market puts a negative weight, $\alpha_2 < 0$, on s_2 and the central bank adjusts more to the private information. This is the outcome of self-fulfilling expectations. As suggested above, if $\theta > 0$, the market faces an identi-

θ	Unique	k	α_1	α_2
0	Yes	1	0.010	0.098
0.1	Yes	0.960	0.041	0.092
0.2	Yes	0.929	0.058	0.088
0.4	Yes	0.881	0.078	0.082
0.6	No	0.845	0.090	0.079
0.6	No	0.959	0.294	-0.316
0.6	No	0.944	0.260	-0.361

Notes: The table shows equilibrium values of α_1, α_2 and k for different values of θ, the central bank's aversion to bond market volatility. Apart of θ, all solutions share the same calibrations: $\sigma_u^2, \sigma_\gamma^2, \sigma_e^2 =$ 1 and $\beta = 0.1$

Table 1.8: *Equilibrium outcomes across θ values*

fication problem: Is the central bank trying to correct expectational errors resulting from surprises to the noise term of the interest rate process or is its communication reflecting the continuation of a gradualist strategy where the central bank attempts to impound its private information smoothly into the market?

Key to the outcomes are market beliefs about the correlation of the signal with its forecast target i^* and, equally important, the central bank's beliefs about the market's weights. If the market assumes the correlation between s and i^* is negative, it should put a negative weight on s. If the central bank thinks that the market will put a negative weight on its communication, but the directional impact of s on i_2 is pretermined at $\beta > 0$, the central bank faces a trade-off. By setting $s < 0$, the central bank could try to counteract $\alpha_2 < 0$, thereby ensuring that the market's estimate of i^* is updated in the right direction. Instead, the central bank could keep $s > 0$ and hence move financial conditions towards target.

An increase in the strength of volatility aversion of the central banker has two effects: Firstly, the increased degree of underadjustment makes the motives for communicating in period 2 more ambiguous and therefore increases the room for speculation. Secondly, once caught up in speculations about its motives, the higher the aversion to volatility, the more likely that the central bank gives in and makes expectations self-fulfilling.

In Appendix A.3.5, I derive the threshold $\bar{\theta}$ numerically. I also show that $\bar{\theta}$ is decreasing in the variance of the interest rate noise relative to the variance of the private information. The intuition for this is that as the variance of the interest rate noise term increases, the margin of error for the market's estimate in period 1 increases. The increased uncertainty makes multiple equilibria possible for lower degrees of aversion to bond market volatility. The opposite holds for the variance of the noise term in the signal s. As the noisiness of communication in period 2 increases, agents put less weight on it and therefore the interpretation of it becomes less important.

1.5.3 Expectation management in equilibrium

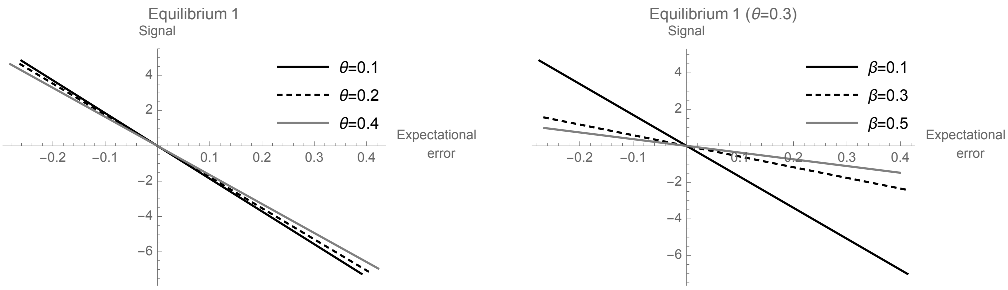
With the solutions to the model, I now turn to the initial questions. Is a signal as a function of expectational errors obtainable under rational expectations? And if so, does it improve on policy outcomes.

Comparative statics. Figure 1.2 shows that, in the unique equilbria, the signal is in a negative, linear relationship with the expectational error in period 1. The expectational error is defined as $\chi\Delta i_1 - e_1$, the difference between the market's estimate and the actual e_1.

Figures 1.2a and 1.2b then illustrate that the slope flattens if θ or β increase, respectively. A flatter slope means that central bank's response to expectation errors gets weaker. The effect of θ can be explained by the endogenous response of the market's forecast function to the central bank's increased volatility aversion. Instead, a higher β corresponds to a larger impact of the communication on the nominal short term interest rate. A stronger market impact of communication implies that the potential tradeoff between minimizing expectational errors and bringing financial conditions on target gets stronger. As a result, the equilibrium link between expectational error and communication gets weaker. Assessing these predictions empirically is an interesting avenue for future research.

Comparing outcomes across equilibria. In the unique good equilibrium $\theta = 0.2$, market expectations move gradually towards the correct value for the new

(a) *Varying volatility aversion* **(b)** *Varying market impact*



Notes: The figures plot the equilbrium relationship between the value of the signal s and $\chi\Delta i_1 - e_1$, the expectational error made by the market with its estimate of period 1. 1.2a and 1.2b vary θ and β respectively. To generate the errors, the model was simulated for a series of realizations of e_1 while the noise to the nominal interest rate and the signal itself were set equal to zero, i.e. $u, \gamma = 0$. The baseline calibration was used $\sigma_u^2, \sigma_\gamma^2, \sigma_e^2 = 1$ and $\beta = 0.1$.

Figure 1.2: *Response of intermeeting communication to expectational errors*

target rate $i^* = 0.75$. (Appendix Table A.16a tabulates the key variables.) The expectational error opened up by the underadjustment in period 1 is reduced through the intermeeting communication.

Instead, the outcomes are less benign in the case of high aversion to bond market volatility $\theta = 0.6$. (Appendix Table A.16b) The losses due to derailed short rates as well as the loss due to bond market volatility are dramatically higher than in the low θ equilibrium. In this case, the central bank surrenders to the market's expectations that its communication will be negatively correlated with e, and sets its actually negative in order to move market expectations in the right direction. The central bank is successful in doing so: The market revises its estimate of e upwards in period 2. However, it also pushes the nominal short rate away from the target. The high value of θ makes the central bank prioritize the correctness of the market's estimate at the expense of inappropriate levels of the nominal short rate.

1.6 Conclusion

This paper provides evidence that Fed officials react with their speeches to misalignment between their own and financial market expectations. The effects are strongest for the chairs and vice chairs of the Board of Governors and voting Fed presidents.

To address identification challenges, I show that larger misalignment also predicts more frequent mentions of market expectations in the speeches. I also provide a brief narrative analysis, confirming the Fed's concern with misaligned expectations and use of communication to reduce it.

While the occasional existence of such link conforms well with conventional wisedom, it is an important insight that such communication policy has been sufficiently systematic to be measurable with statistical significance. Systematic policies are easier to internalize by the private sector. Consistent with earlier papers, my simple model shows that the direct response of central bank communication to private sector expectation can induce multiple equilibria, some with undesirable properties. The model yields further predictions that will be promising to evaluate empirically.

Increased central bank transparency over the last two decades has made monetary policy considerably more predictable. This paper provides new evidence on the mechanics of expectations management in the run-up to decisions.

Importantly, my paper constitutes a first step towards understanding empirically and theoretically the intricate feedback loops between central banks and private sector expectations. Future work on this issue seems promising.

Chapter 2

Voting right rotation and the behaviour of committee members – a case study of the U.S. Federal Open Market Committee[1]

[1]Co-authored with Michael Ehrmann and Bauke Visser. Ehrmann: European Central Bank and CEPR, michael.ehrmann@ecb.int. Visser: Erasmus University Rotterdam and Tinbergen Institute, bvisser@ese.eur.nl. This chapter is a slightly edited version of the working paper Ehrmann et al. (2020). The latter has earlier been circulated under the title "Strategic interactions in preparing for committee meetings." It presents the authors' personal opinions and does not necessarily reflect the views of the ECB or the Eurosystem. We would like to thank Klodiana Istrefi, participants at the EEA Annual Congress 2019, the 2019 Deutsche Bundesbank Macro Workshop and seminars at the ECB and Erasmus University Rotterdam for helpful comments.

2.1 Introduction

The effect of decision rights on behaviour plays an important role in the design and evaluation of decision-making processes, both private and public. The incomplete contracts approach argues that agents seek to compensate the loss of a decision right, e.g. by investing less in relationship-specific assets (Grossman and Hart, 1986; Hart and Moore, 1990). A common form of a decision right is a voting right. Voting rights are important when groups of decision makers, like shareholders and committee members, need to reach agreement.[2]

We study the effect of voting rights on behaviour of individual members of a decision-making committee in a context that allows for causal inference. We exploit the rotation of voting rights among Federal Reserve Bank presidents on the Federal Open Market Committee (FOMC), the monetary policy committee of the United States. We are interested in the way rotation affects presidents' behaviour, both during FOMC meetings as documented in the verbatim transcripts, and in-between meetings as witnessed by their speeches. We also study whether voting status matters to how financial markets react to speeches, and whether it does so in ways consistent with the observed changes in behaviour.

While monetary policy is set in a centralised manner for the United States as a whole, it is the role of the Reserve Bank presidents to gather intelligence about the prevailing economic conditions in their respective Reserve district and to bring this intelligence to the discussion on monetary policy at the FOMC.

The FOMC meets eight times per year. It is attended by the Reserve Bank presidents of the 12 Fed districts and the 7 governors of the Board of Governors of the Federal Reserve System. Of these 19 persons, at any meeting, only 12 cast a vote: the 7 governors, the president of the New York Fed and 4 of the remaining 11 presidents. Which 4 is determined by a scheme that has not changed since 1942. The 11 districts are assigned to three groups of three districts and one group of two. Within each group, the voting right rotates on a yearly basis. In any district, presidents are appointed for a five-year period that is renewable. As a result, presidents typically experience years with the right to vote – when they are FOMC members – and years without the right to vote – when they are FOMC participants. We exploit this exogenous variation to investigate how the voting status affects behaviour of presidents in the meeting and in between meetings.

We formulate two hypotheses. First, the loss-compensation hypothesis is that in years without the right to vote, a president uses speeches during the intermeeting

[2]Research by Gompers et al. (2010) on dual-class firms (firms that have issued shares with and without voting rights) shows that firm value is decreasing in insider voting rights. Li et al. (2008) find that the unification of dual-class shares into a single class by granting voting rights to all shareholders, attracts institutional investors.

period and interventions during the meeting to compensate for the loss of voting right. Under this hypothesis, we expect that during years without the right to vote, the number of speeches, the length of the interventions at the meeting and the tone of either react more strongly to the differences between the economic performance of the president's home district and the U.S. economy.

Second, the involvement hypothesis maintains the opposite. Having the right to vote makes Bank presidents more involved. As a result, they will make their speeches and interventions more dependent on gaps between the regional economy and the U.S. economy when they have voting status. This may have a variety of reasons, including signalling their sensitivity as a decision maker to regional interest, using speeches as an indication of what is on their mind and may guide their votes, and as a test ground of lines of argumentation.

To test these hypotheses empirically, we parse the texts of a comprehensive set of documents prepared by the Federal Reserve System. For the intermeeting period, we focus on presidents' speeches; for the meetings themselves, we study the content of the FOMC meeting transcripts. This allows us to analyse, within one unified framework, multiple stages of the FOMC decision process. Speeches appear a natural place to start an analysis of intermeeting periods. Fed officials and the public see them as potentially influential and previous empirical research has shown that speeches can indeed influence markets (Blinder et al., 2008). Moreover, other ways of influencing – e.g. telephone conversations among presidents or meetings with journalists– are harder or impossible to observe.

We measure communication behaviour along two dimensions. First, the extensive margin is covered through the number of speeches in a given intermeeting period and through the length of interventions made during the meeting. Second, at the intensive margin, we measure the tone of the speeches or meeting interventions. Our main empirical analysis relates these measures to regional economic conditions (in particular the gap between the unemployment rate at the Fed district level and the national unemployment rate), the voting status of the speaker and interactions thereof.

The patterns in the data consistently support the involvement hypothesis. Our findings can be organised in three sets. The first set of findings concerns communication behaviour in the intermeeting period. We find that in years when Bank presidents have voting rights, they give more speeches, the larger is their regional unemployment gap. In years without voting rights, there is no such dependence on the regional economic situation. Also the tone of their speeches reacts in line with the involvement hypothesis, in that speech tone becomes more negative as the regional unemployment gap gets worse, but only so if they have voting rights.

We furthermore find that the speeches of voting presidents react to local conditions only before the publication of the Beige Book, a report that contains mostly anecdotal, qualitative information about regional economic conditions gathered by each Federal Reserve Bank and is published two weeks before each FOMC meeting. We argue that the Beige Book's publication marks a reduction in information asymmetry about regional conditions in the Fed districts and take this to suggest that the desire to signal private information about local deviations from the U.S. average is underlying some of the observed pattern.

The second set of findings relates to behaviour during the meeting. The tone of the presidents' opening interventions becomes more negative as regional unemployment gaps worsen. This relationship is present for all presidents, but it is stronger in their voting years. This suggests that they use their opening interventions at the meeting to signal district-specific information. At later stages of the meeting, after the economy go-round, when the discussion moves on from discussion the economic situation to the implications for monetary policy decisions, the regional unemployment gap loses its significance, which points towards a convergence process wherein regional conditions become less important as the meeting progresses (El-Shagi and Jung, 2015).

The third set of findings analyses the financial market reaction to the speeches. We find that markets respond systematically less to speeches by voting presidents than to speeches by non-voting presidents. This might seem surprising - after all, having a voting right might make them more influential in deciding the outcome of the meeting. However, if the speeches by presidents with voting rights give more emphasis to regional economic conditions, market participants will find it relatively easier to extract relevant information about the upcoming monetary policy decisions from the speeches by presidents without voting rights. This could explain why more involved committee members might be influencing markets less.

Do our findings say anything on whether or not the final outcome of FOMC meetings gives an exaggerated weight to regional conditions? It is important to note that this paper cannot shed any light on this question. Regional information is important in coming to an assessment of the overall economy, and actively sought for by all central banks. Whether our findings imply too much or too little influence on the final outcomes is impossible to say; this paper only provides descriptive evidence on behavioural patterns of committee members. Jung and Latsos (2015) provide a normative analysis and show that even though interest rate preferences of Reserve Bank presidents are affected by regional conditions, this did not impede the Fed's capacity to set interest rates with a nationwide focus.

Related literature. Our paper lies in the intersection of two (largely separate) strands of literature that focus on i) public communication by policy makers and ii) decision making in committees, respectively.

The literature on central bank communication has provided ample evidence that speeches by committee members are followed closely by the media and financial markets, and have the potential to move asset prices (see the literature survey by Blinder et al., 2008). Interestingly, most research on the market reaction takes the communication decisions of the policy makers as given, even though the latter have been shown to be used strategically to prepare the public for the upcoming meeting: speaking activity intensifies before committee meetings in which policy rates are changed (Ehrmann and Fratzscher, 2007), and the tone expressed in these speeches responds to market misperceptions about upcoming decisions (Tietz, 2018). Further evidence that communication is used strategically is provided by Vissing-Jorgensen (2019), who argues that committee members compete for the attention of financial markets in order to move market expectations and therefore influence the policy decision, via public appearances and through informal communication channels.

As to the second strand of literature on committee design, the reason why decisions are delegated to committees is that the aggregation of diverse information and the possibility to discuss possible actions should lead to better outcomes than decisions made by one individual. This is the focus of a large literature on committee design with prominent contributions such as Li et al. (2001), Prat (2005), Visser and Swank (2007) and Levy (2007). Still, substantive empirical evidence shows that the decision-making process in committees is subject to frictions such as uncertainty about preferences, herding or reputational concerns (Gerling et al., 2005).

A substantial body of literature looks at these questions for central banks (inter alia, Blinder, 2007; Riboni and Ruge-Murcia, 2014; Sibert, 2003; Swank et al., 2008), on the one hand because of the importance of central bank decisions for the economy and financial markets, and on the other hand because central bank committees have become increasingly transparent and often make their deliberations as well as their voting records available to the public, thereby giving researchers the chance to study the processes at work.

Our main focus is on the comparison of presidents' communication behaviour in voting and non-voting years. This distinction has been shown to matter. Tillmann (2011) shows that non-voting members of the FOMC overpredict (underpredict) inflation relative to the consensus forecast if they favour tighter (looser) policy, suggesting that non-voting member use their forecast in an attempt to influence policy. Tietz (2018) finds that voting members react more strongly to misperceptions by the market about upcoming policy decisions. Still, most papers, empirical and theoretical alike, focus on other forms of heterogeneity, importantly on the role of the chairman or the distinction between presidents and governors. (Chappell et al., 2004; Riboni and Ruge-Murcia, 2010, 2014). We view these comparisons as important and complementary to our analysis.

Several papers study the regional representation of the FOMC setup. Hayo and Neuenkirch (2013) show that speeches by FOMC members reflect regional economic conditions,[3] and Meade and Sheets (2005) find that Reserve Bank presidents from districts with higher (lower) unemployment rates than the U.S. aggregate are more likely to dissent in favour of looser (tighter) monetary policy in the deliberations of the committee. At the same time, El-Shagi and Jung (2015) argue that this tendency is already reduced in the second round of comments at the meeting, pointing to a consensus-enhancing factor being at work.

Despite the tendency to dissent in the discussion stage at the FOMC meetings, Meade (2005) shows that verbal dissents often do not result in actual dissents in the official vote. Still, a role for regional information has also been detected at the voting stage, e.g. by Eichler et al. (2018) who show that if a district's banking sector weakens, the associated Reserve Bank president is more likely to vote for looser monetary policy.

The difference between the discussion stage (where disagreement is voiced) and the voting stage (where dissent is rare), as well as the fact that more disagreement is voiced in the first than in the second round of discussions during the meeting are in line with the notion of a conformity bias (Visser and Swank (2007)), a notion that is supported empirically by evidence on the FOMC: once committee members became aware that transcripts of their discussions would be made public, less disagreement has been voiced in the FOMC meetings (Meade and Stasavage, 2008, Swank et al., 2008). Hansen et al. (2017) also provide empirical evidence for the conformity bias for the FOMC, and furthermore document a discipline effect, whereby agents exert more effort in equilibrium when their actions become more easily observable to the principal (Holmström, 1999).

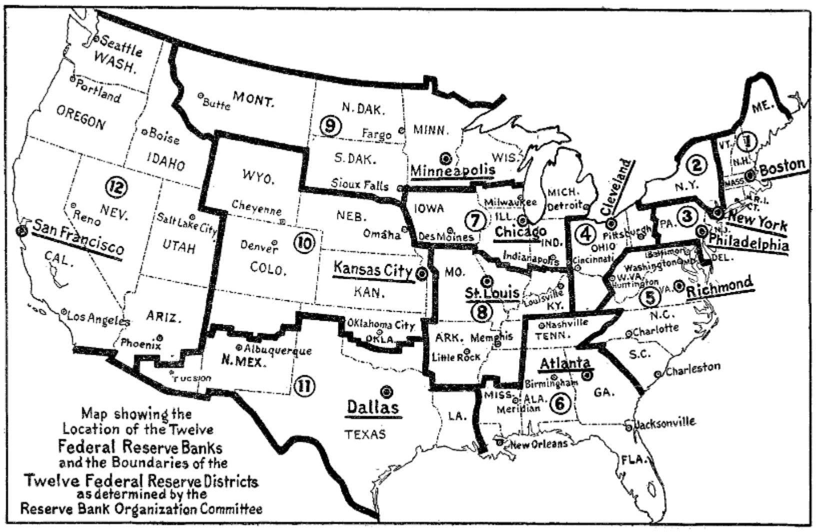
Organisation of the paper. The remainder of this paper is organised as follows. Section 2.2 provides an historic account of the decision making process at the Federal Reserve System, in particular the voting rotation. Section 2.3 develops our hypotheses how the voting rotation affects behaviour, before Section 2.4 discusses what data we employ to test these hypotheses. The empirical analysis is presented in Section 2.5. Section 2.6 concludes.

[3] Hayo and Neuenkirch (2013) also discuss the possibility that speeches by voters and non-voters respond differently to regional economic conditions, but do not test whether differences are significant.

2.2 Historical background

Governance. The Federal Reserve Act of 1913 created the Federal Reserve System, made up of a Federal Reserve Board and Federal Reserve banks, each bank with its own Federal Reserve city and district. After a series of depressions and financial panics in the preceding decades, the wish was to start an institution performing central banking functions to support the liquidity and stability of the banking system, while addressing various fears: fear for such an institution being dominated by New York, Wall Street and Eastern elites; fear for government control over money; and fear for bankers' interests prevailing over public interests (Meltzer, 2003).

The act allowed for the nomination of eight to twelve Federal Reserve cities. The committee that was tasked with the System's actual formation, the Reserve Bank Organization Committee, decided in 1914 there would be twelve districts. Figure 2.1, taken from the Committee's report, shows the boundaries of the districts and, for each district, the location of the Federal Reserve Bank in the underlined city.



Notes: Federal Reserve cities are underlined. Source: Reserve Bank Organization Committee (1914).

Figure 2.1: *Map of the Federal Reserve districts*

For any district considered, the committee took into account the size of its banking sector, its sectoral and geographical economic connections, its transport and communication infrastructure, and the likelihood that a Reserve bank located in a Reserve city would be able to perform its functions at the service of the district. As such, the districts reflected the early-twentieth century U.S. society. Meltzer (2003, p.1) characterises the U.S.A. of the time as "a developing country, with agriculture its largest occupation." By and large, the district boundaries have remained the same to this date.

The 12 Federal Reserve banks formed a confederation, supervised by the Board. The resulting Federal Reserve System lacked concentrated decision-making authority. At the time, lending to depository institutions through the "discount window" was more important than open market operations. As a result, Reserve banks were free to sell and purchase in the open market subject to the rules and regulations of the Board and were otherwise free to behave independently as they saw fit.

With the emergence of a national financial market and in light of the special position of the Federal Reserve Bank of New York because of the size of its banking sector and its role in the international financial system, struggles for power resulted, both among the Reserve banks, and between the Reserve banks and the Board. Despite several changes to the governance structure in the 1920s, these frictions continued to impede the efficient functioning of the Federal Reserve System.

The Great Depression and banking crises of the 1920s and early 1930s were taken as proof that the U.S. central banking system had failed and needed to be re-assessed radically. The Banking Act of 1933 gave legal status to an open market committee that included all Reserve banks as members and called it the Federal Open Market Committee.

The Banking Act of 1935 ended the semiautonomous nature of the Reserve banks and moved the locus of power to the Board in Washington. The chief executive officers of the Reserve Banks lost the title of Governor and became Presidents. The act, by and large, formed the FOMC as it still is today.

Since 1935, it consists of 12 seats, 7 seats for Board members and 5 seats in total for 12 Reserve Banks. It is chaired by a Board member. Reserve Bank districts are grouped and one seat is assigned to each group. In 1942, the Federal Reserve Bank of New York obtained a permanent seat on the FOMC, and Boston, the district with which New York had formed a group until then, was assigned to another group.

Since 1942, the groups of districts are Boston, Richmond and Philadelphia; Cleveland and Chicago; Atlanta, St. Louis and Dallas; and Minneapolis, Kansas City and San Francisco. To accommodate two or three districts with one seat, within each group, FOMC membership rotates on a yearly basis. Initially, rotation was a practical solution; in 1942 it became enshrined in law. Nonvoting Reserve Bank presidents do "attend the meetings of the Committee, participate in the discussions, and contribute to the Committee's assessment of the economy and policy options."[4]

Voting procedure. The official decision at the FOMC meeting is taken by a formal vote at the end of the meeting. The chairperson proposes the policy action

[4]Quote from https://www.federalreserve.gov/monetarypolicy/fomc.htm,accessed September 29, 2020.

based on the preceding discussion and every member casts her or his vote through voicing approval or not. The outcome is decided with a simple majority rule (Chappell et al., 2004). Historically, the vote count has always led to the approval of the proposed policy decision. In the (rare) event of dissent, there are usually only 1 or 2 dissenting votes. This, however, likely understates the true extent and frequency of controversy because members often vote approvingly even though they preferred a different policy decision (Meade, 2005).

The role of regional information and the Beige Book. The FOMC's mandate from Congress is "to promote maximum employment, stable prices, and moderate long-term interest rates in the U.S. economy."[5] Each Federal Reserve Bank systematically collects information about its district. Part of this information is anecdotal and is obtained "through reports from [Federal Reserve] Bank and Branch directors, plus phone and in-person interviews with and online questionnaires completed by businesses, community contacts, economists, market experts, and other sources." Regional information is regularly reviewed during an FOMC meeting. In the economy go-round, the first part of a meeting, Bank presidents discuss and comment on regional conditions. Furthermore, this anecdotal information is presented in the Beige Book, the Summary of Commentary on Current Economic Conditions by Federal Reserve District.

In 1970, then-Chairman Arthur Burns initiated the compilation of the first Beige Book, at the time called Red Book. Burns intended the Beige Book to replace parts of the presidents' verbal reporting about regional conditions during the meeting, and thus make the gathering of opinions and judgements from the districts more efficient and effective (FOMC minutes of May 5, 1970). In the Beige Book, each regional Fed summarises economic conditions in its district. Starting from May 1983, the Beige Book was made public. Its release date was set to two weeks before the FOMC meeting, in an attempt to downplay its significance for policy decisions. Still, since the 1987 stock market crash, the Beige Book started to be referenced frequently by the press (Fettig et al., 1999).

This brief recap of the historical background of the FOMC clarifies the special role of the Reserve Bank presidents. While monetary policy is set in a centralised manner for the United States as a whole, it is their role to gather intelligence about the prevailing economic conditions in their respective Reserve district and to bring this intelligence to the discussion on monetary policy at the FOMC – via the Beige Book and during the meeting. At the same time, they are subjected to a voting rotation that has been decided several decades ago and is exogenous to economic conditions today. How this voting rotation affects their behaviour is the question

[5] This quote is from the front matter that can be found in any recent Beige Book, see https://www.federalreserve.gov/monetarypolicy/beige-book-default.htm.

we study in this paper.

2.3 Two hypotheses about how the voting right affects presidents' behaviour

The rival hypotheses that we test maintain that the strength of the relationship between regional economic conditions and Bank president behaviour varies systematically with their voting status on the FOMC. To motivate these hypotheses, we begin by arguing that, by design, regional conditions influence how Bank presidents act and decide on the FOMC.

The previous section has already highlighted that Bank presidents collect and present intelligence about regional economic conditions, during the meeting and in the Beige Book. In addition, the governance of the Federal Reserve System has a strong regional component. Presidents of Reserve Banks are accountable to a Reserve Bank's board of directors. These boards have strong ties with regional financial industry, businesses and the community in general.

Earlier literature has already demonstrated that regional conditions do in fact influence the policy preferences expressed by presidents in the policy go-round in the meeting, their actual votes and the content of their speeches given in between meetings. Chappell Jr et al. (2008), Jung and Latsos (2015) and Bennani et al. (2018) find that an increase in regional unemployment is associated with a voiced preference for a lower target rate. While Tootell et al. (1991) finds no evidence that regional variables explain actual votes, Gildea (1992) and Meade and Sheets (2005) find that an increase in regional unemployment is associated with an increased probability of voting in favour of lower target rates, even if this implies a dissenting vote. Hayo and Neuenkirch (2013) find that employment, housing, production and financial conditions in the Fed district are reflected in the presidents' speeches.

Note that when we write that regional conditions matter, this should typically be taken to mean that differences between regional and national conditions matter. As our hypotheses claim that the strength of the relationship between regional economic conditions and president's behaviour changes systematically with a president's voting status, we must first formulate hypotheses about the sign of the relationship. Inspired by the research just cited, we assume that a president gives more speeches in between meetings and discusses at greater length in the meeting, the larger is the absolute difference between regional and U.S. average unemployment. Also, we assume that the tone of presidents' speeches and of their discussion in the meeting becomes more negative, the larger is unemployment in their district.

The loss-compensation hypothesis. The loss-compensation hypothesis maintains that in years without the right to vote, a president uses speeches during the intermeeting period and discussions in the meeting to compensate for the loss of voting right. The larger the absolute difference between regional and U.S. unemployment, the more the loss of voting power is felt. The loss-compensation hypothesis predicts that, to compensate for this loss, the number of speeches and the length of the discussions react more strongly to these differences in years that a president cannot vote than in years that he can.

The tone of a speech and of the discussion reacts to regional unemployment. The more extreme regional unemployment is relative to national unemployment, whether high or low, the more the loss of voting power is felt. The hypothesis predicts that, to compensate for this loss, the tone of a speech and of contributions to the discussion reacts more strongly to the regional conditions in years that a president cannot vote than in years with a right to vote.

All else equal, the loss in voting power should be more costly in periods when there are conflicting views within the FOMC, or when uncertainty about the right decision is large. The loss-compensation hypothesis predicts that in these instances, the number and tone of speeches of non-voters react more strongly to local economic conditions than otherwise.

The involvement hypothesis. The involvement hypothesis maintains that in years when presidents can vote, their speeches during the intermeeting period and discussions in the meeting reflect that they matter more to the decision. Given that it is a president's assignment to collect regional information and bring it to the FOMC, they use their speeches in between meetings and their interventions during meetings to signal their sensitivity as a decision maker to regional circumstances and use speeches both as an indication of what is on their mind and may guide their votes and as a test ground of lines of argumentation.

These considerations are more important, the more regional economic conditions differ from those in the U.S. aggregate. The hypothesis predicts that, because of this greater involvement, the number of speeches, the length of the meeting interventions as well as their tone react more strongly to these economic differences in years when a president can vote.

All else equal, the involvement will be stronger in periods of conflicting views within the FOMC or uncertainty about the right decision, i.e. when more is at stake. The hypothesis predicts that in these instances, the number and tone of speeches and the length and tone of interventions of voters react more strongly to local economic conditions than otherwise.

That is, the two hypotheses make opposite predictions concerning the change in responsiveness of presidential behaviour to regional economic conditions as a reaction to a change in a president's voting status. Both hypotheses make the same prediction concerning the change in responsiveness of presidential speech behaviour as a reaction to a change in the character of the preceding meeting, conditional on voting status. We use both the across-voting status and the within-voting status predictions to test the hypotheses.

2.4 Data

To empirically test our hypotheses, we collect data from various sources.

Speeches. We use the database of speeches originally presented in Tietz (2018). Speeches were collected from the webpages of the Federal Reserve Banks, the Board of Governors of the Federal Reserve System, BIS archive of central bank speeches and from FedInPrint, which provides an index of publications by the Federal Reserve System.[6] The final sample consists of 2887 unique speeches given between 1994 and 2013.

We collect the entire text of the speeches and construct a measure of the economic tone that gets expressed, separately for each speech. Before the analysis, we split the speeches into sentences, remove all non-alphabetic characters, stop words and words with less than 3 characters, and convert the remainder to lower case. To obtain a measure of tone, we follow Schmeling and Wagner (2017) and use the dictionary constructed in Loughran and McDonald (2011). Sentence-by-sentence, we count the number of negative words as classified by Louhgran and McDonald, N, and the total number of words T. Counting the words at the sentence level allows improving the accuracy of the tone measure.

We follow Tietz (2018) and adjust the dictionary to account for the jargon specific to the central banking context. Loughran and McDonald (2011) developed their dictionary using company reports. While company reports share much of the financial jargon typically used in central banking, the two contexts are different, and some complications make further adjustments desirable. The Federal Reserve aims to create economic conditions consistent with price stability and maximum sustainable employment. Therefore, the word "unemployment" will be used more often than in company reports and need not necessarily carry a negative connotation. The word "unemployment" is also special because many adjectives and verbs that otherwise have a negative meaning have a positive meaning for "unemployment." For example, declining inflation, output growth or stock markets typically convey a worsening of economic conditions, while declining unemployment indicates an upturn. We deal with this by excluding the word "unemployment" from the list of negative words. Furthermore, for all sentences that include "unemployment" but none of the words "inflation",

[6] For links see data description 1.2 of chapter 1

"employment", or "growth", we remove "decline", "declining" and "declined" from the list of negative words and add "higher" and "high."

We then aggregate the word counts for each speech and compute the tone measure τ_i for speech i as[7]

$$\tau_i = 100 \times (1 - N_i/T_i). \tag{2.1}$$

We also follow Tietz (2018) by removing speeches that are unrelated to monetary policy affairs, using a method from supervised machine learning. Based on 300 speeches labelled manually in Tietz (2018), we follow Gentzkow and Shapiro (2010) and compute for each phrase p that occurs at least once in the speeches the statistic $\omega_{p,c}$. $\omega_{p,c}$ measures how characteristic the phrase p is for topic $c \in \{\text{monetary policy relevant, not relevant}\}$, taking into account the conditional word counts.[8]

A simple threshold rule is then devised to filter out irrelevant speeches. For each speech, we count the number of occurrences of the 200 most representative words, i.e. with the 200 largest values of $\omega_{p,c}$. An exogenous threshold (5%, 7.5% and 10% of total words) is defined, which a speech has to exceed in order to be classified as "relevant to monetary policy." We use the 7.5% threshold as our baseline, but check our results for robustness.[9]

The last step in the preparation of the speech data for our econometric analysis is to aggregate them to the FOMC meeting frequency. The FOMC meets eight times a year. For each meeting period and each speaker, we calculate the number of speeches given in the inter-meeting period and the tone as simple average of the tone expressed in each individual speech. Appendix Table B.1 provides a set of summary statistics for the resulting variables.

Interventions made during the FOMC deliberations. As done, for instance, in Baerg and Lowe (2020) and Cieslak and Vissing-Jorgensen (2020), we also assemble a dataset that measures the interventions made by each FOMC member during the deliberation stage at the FOMC meetings. For that purpose, we subject the

[7] An alternative way of measuring the tone of speeches is by constructing net positivity as the share of positive words minus the share of negative words. Following the earlier literature (e.g. Schmeling and Wagner, 2017), the measurement is restricted to negative words, in particular because positive words are more frequently negated than negative words, therefore making the measurement of tone relatively more noisy.

[8] The statistic is $\omega_{p,c} = \frac{(N_{p,c}N_{-p,-c} - N_{p,-c}N_{-p,c})^2}{(N_{p,c}+N_{p,-c})(N_{p,c}+N_{-p,c})(N_{p,-c}+N_{-p,-c})(N_{-p,c}+N_{-p,-c})}$, where $N_{p,c}$ ($N_{-p,-c}$) is the number of occurrences of phrase p (all but p) in speeches labelled with topic c (all topics but c). A phrase is either a single word or a bigram. For more background, see Tietz (2018) or the original paper by Gentzkow and Shapiro (2010).

[9] Given the focus of this paper, the breadth of topics relevant to our analysis is somewhat wider than in Tietz (2018). That is why we use a slightly lower threshold value as baseline.

FOMC transcripts to the same procedure as the speeches and calculate measures of the length and tone of the comments, after separating the comments by each individual. The transcripts are released with a 5-year lag, which determines the end of our sample period in 2013. Given that the transcripts provide a verbatim record of the deliberations, there are many instances of very short remarks. To test for robustness of our results, we have therefore also calculated the number of words and the tone of the interventions only counting the longest intervention by each speaker or only including interventions that contain at least 50 words.

Dissents. Further to pre-meeting speeches and the interventions during the meeting, we also collect information whether an individual member decided to dissent in the decision stage. This information is provided on the website of the Board of Governors of the Federal Reserve System. Of course, this variable is only available for FOMC members with a voting status.

Regional economic data. The regional economic data cover unemployment, and for robustness furthermore inflation and return on assets of the financial sector. District-level unemployment rates are readily available for download from FRED. The data are computed by the Federal Reserve Bank of St. Louis based on statistics released by the Bureau of Labor Statistics.[10]

District-level CPI inflation rates are constructed by mapping data for Metropolitan Statistical Areas (MSAs) to districts. We focus on year-on-year inflation rates to avoid seasonality issues. If one Federal Reserve district contains more than one MSA for which we have inflation data, we weigh the MSAs with their respective population obtained from the 2010 Census figures. Data sources, their frequency and the mapping from MSAs to districts are summarised in Appendix Table B.2; Table B.1 in the appendix also provides summary statistics for the resulting variables. Finally, we also retrieve data on return on assets for banks geographically located in each Fed district, which are directly available from FRED.

The original time series for unemployment and inflation are monthly, those for return on assets quarterly. We aggregate them to FOMC meeting frequency (recall that the FOMC meets eight times a year) as follows: For each series, we identify the release dates, which allows us to trace the most recently available data at each point in time. Based on these, we construct a weighted average over the entire FOMC intermeeting period, where each release gets weighted with the relative number

[10]These data were discontinued in 2015. For a robustness test where we extend the speech data to 2018, we construct regional unemployment by mapping U.S. states to Federal Reserve districts based on population weights, which are tabulated in Appendix Table B.3. Over the common sample, the district-level unemployment rates computed by us and thos obtainable through FRED are near-perfectly correlated, with a correlation coefficient of 99%.

of days during which it represented the most recent available data. This implies that our economic conditions relate to the publicly available data at the time of the speaking engagements. Note that our dataset does not account for revisions and is therefore subject to the critique by Orphanides (2001). However, to the best of our knowledge, no real-time dataset can be constructed based on the publicly available data. Also, while we would ideally want to have forward-looking data, these are not available.

Beige Book. Finally, we collect information on the content of the Beige Book, as an alternative measure of regional economic conditions. For that purpose, we calculate the tone of the Beige Book, in the same way as for speeches and meeting interventions. We do so separately for each Fed district, following the structure of the Beige Book, which contains a separate section for each district.

2.5 Results

2.5.1 Testing the exogeneity of voting status

Our identification strategy rests on the assumption that voting status varies exogenously and is uncorrelated with economic conditions. Given that the voting scheme became standard practice in 1935-1936, well before the beginning of our sample period, we expect no correlation between the voting status of a Reserve Bank president and contemporaneous economic conditions.

	Voting status
Regional inflation	0.016
	(0.026)
Regional unemployment	0.036
	(0.023)
Regional return on assets	0.048
	(0.070)
Observations	1,735

Notes: The table shows marginal effects of a probit model that explains voting status with district-level inflation, unemployment and return on assets of the financial sector. Numbers in brackets are standard errors. No parameter is estimated to be statistically significant at the 10% level.

Table 2.1: *Testing the exogeneity of the voting scheme*

We test this formally in a simple probit model, in which we explain voting status with regional inflation, unemployment and financial sector return on assets. Table 2.1 reports the estimates of the marginal effects. There is indeed no systematic relationship between voting status and any of the three economic conditions, confirming the exogeneity of the voting scheme.

2.5.2 Difference in speech behaviour in the intermeeting period

Summary statistics. The summary statistics in Table 2.2 suggest that the average behaviour of voters and non-voters is very similar over the sample. In around 65% of all inter-meeting periods, Reserve Bank presidents do not deliver any monetary policy-related speech, a share that is virtually identical for voters and non-voters. The table also shows that there is a minimum of 0 and a maximum of 4 speeches that Reserve Bank presidents have delivered in inter-meeting periods covered by our sample. This motivates us to estimate an ordered probit model.

	Total		Non-voters		Voters	
# speeches	Obs	Share (in %)	Obs	Share (in %)	Obs	Share (in %)
0	1,149	66.22	733	66.39	416	65.93
1	359	20.69	235	21.29	124	19.65
2	172	9.91	106	9.60	66	10.46
3	48	2.77	26	2.36	22	3.49
4	7	0.40	4	0.36	3	0.48
Sum	1,735	100.00	1,104	100.00	631	100.00

Notes: The table shows how many speeches individual Fed presidents have delivered in the various inter-meeting periods as well as the share of each category, for all Fed presidents in the voting rotation (Total) and separately for voting and non-voting Fed presidents. "Obs" reports the number of observations.

Table 2.2: *Number of speeches by Fed presidents per inter-meeting period*

Number of speeches. We first test the hypotheses on the responsiveness of the number of speeches to regional economic conditions across years, with and without the right to vote. We do this based on the following ordered probit regression equation:

$$Pr(N_{i,t} = n) = \Pr\left(\begin{array}{l} \kappa_{n-1} < \mu_i + \mu_t + \beta_u^N |u_{d_it} - u_{\text{US},t}| \\ +\beta_v^N v_{d_it} + \gamma^N |u_{d_it} - u_{\text{US},t}| v_{d_it} + \epsilon_{it} \leq \kappa_n \end{array} \right) \tag{2.2}$$

We explain the number of speeches $N_{i,t}$ by Reserve Bank president i in intermeeting period t with president fixed effects μ_i, period fixed effects μ_t, the absolute difference between the economic conditions in district d of president i and U.S. economic conditions, $|u_{d,t} - u_{US,t}|$ (which we call the regional gap), the voting status of the

Reserve Bank $v_{d,t}$ and the interaction of regional economic conditions with the voting status.

President fixed effects control for the possibility that time-invariant characteristics of the president, like personality, affect speech behaviour. Malmendier et al. (2017) and Bordo and Istrefi (2018) find that policy preferences are shaped by the background of individuals. While the fixed effect controls for time-invariant characteristics, it cannot account for time variation in preferences as identified by Istrefi (2019). Period fixed effects remove all variation that is common across all presidents in an intermeeting period, the general economic situation being an important example. We cluster standard errors by Reserve Bank president.[11]

On the basis of the literature we expect presidents of either type to deliver more speeches, the larger regional gaps are, i.e. $\beta_u^N > 0$ and $\beta_u^N + \gamma^N > 0$. The key parameter to test our hypotheses is γ^N, as it measures the difference in responsiveness of the number of speeches to regional economic conditions across voting status. The loss-compensation hypothesis predicts $\gamma^N < 0$, while the involvement hypothesis predicts $\gamma^N > 0$.

Table 2.3 reports the results of the estimation. The first specification, without presidents' voting status, shows that regional unemployment matters for the speech activities of the Reserve Bank presidents: they tend to give more speeches, the larger is the gap between regional and U.S. unemployment. This is in line with the earlier evidence. The benchmark estimation in column 2 differentiates voters and non-voters. It shows that a president's speech activity reacts more strongly to the regional unemployment situation in years with voting rights than in years without. When they vote on the FOMC, their estimated reaction to regional unemployment is almost twice as large. This reaction is statistically significant at the 1% level, as can be seen by the sum of the two estimated coefficients, $\beta_u^N + \gamma^N$, provided in the middle panel of Table 2.3. In Appendix Table A.4, we report the marginal effects. In years a president is voting, an increase in the unemployment gap by one percentage point reduces the probability that the president does not deliver a speech by 13%. In non-voting years, that probability is reduced by only around 6% (and is statistically insignificant). The voting status itself does not affect the propensity to deliver speeches, consistent with the summary statistics.

These findings support the involvement hypothesis and go against the loss-compensation hypothesis. Presidents' speeches respond more strongly to regional conditions in years they vote, rather than in the years they do not.

These results are robust to redefining the threshold for relevant speeches from

[11] Note that the equation uses district-level macroeconomic variables and voting status. Given that there is always at most one president per Reserve Bank for each FOMC meeting, and given that there is no single individual who has been president of several Reserve Banks in our sample, we could also use a notation whereby macroeconomic variables and voting status are indexed with i rather than d.

7.5% to 5% or 10% (columns 3 and 4). The effect of regional economic conditions also holds for speeches covered by Reuters, i.e., speeches that are apparently deemed relevant for a more national audience (column 5). The most relevant margin seems to be whether or not a Reserve Bank president decides to deliver a speech. Conditioning on speaking, there is no further effect on the number of speeches (column 7) and estimating a probit model would in principle have been sufficient for our purposes (column 8). Another robustness test in column 9 shows that removing period fixed effects and instead controlling for the number of speeches given by all other members on the FOMC (but excluding those by the respective president) does not alter our findings in a substantive manner. Results are also unaltered when we add regional inflation and the financial sector return on assets (column 10), which by themselves do not affect the propensity to give speeches.[12] Another robustness test is provided in column 11, where we extend the sample of speeches until 2018. Restricting the sample to 2013 due to the availability of the FOMC meeting transcripts does not change the picture in an important way.

The last three columns of Table 2.3 extend the analysis to include different aspects of the Beige Book. Column 12 shows that the pattern identified above also exists if we proxy regional economic conditions with the content of the Beige Book. This is comforting evidence in two ways. First, it suggests that our measurement of the tone of the Beige Book captures economic conditions. Second, it also implies that our use of unemployment as a sole proxy for regional economic conditions is not biasing our results.

Columns 13 and 14 provide a subsample analysis. Here, regional economic conditions are once more proxied by unemployment, but we split the sample into the period before the release of the Beige Book, and the (shorter) period afterwards. Our behavioural pattern is exclusive to the first subsample, suggesting that the increased involvement relates in particular to the period in which the Reserve Banks gather regional information, and where this information has not yet been widely shared.

[12] There could be various reasons why we find that regional unemployment affects speech behaviour, but regional inflation and returns on asset do not, which is recurrent in the literature (Meade and Sheets, 2005; Hayo and Neuenkirch, 2013; Eichler et al., 2018). Unemployment is more salient as it is measured at the district level. Moreover, Fed staff talks to companies, and while it is relatively easy to aggregate information on hiring and firings, it appears considerably harder to aggregate data on price setting and changes. Also, unemployment tends to be a good proxy for the business cycle and the output gap and so is highly relevant. Finally, unemployment data is released relatively early.

	(1) Without voting	(2) Benchmark	(3) 5% threshold	(4) 10% threshold	(5) Reuters coverage	(6) No Reuters coverage	(7) Conditional on speaking	(8) Probit model	(9) Control for # of others' speeches	(10) Add inflation and RoA	(11) Until 2018	(12) Tone of beige book proxies for economy	(13) Pre-beige book release	(14) Post-beige book release
Absolute UE gap (β_u^N)	0.357**	0.277	0.255	0.335*	0.186	0.602	0.299	0.253	0.264*	0.277	0.253	-6.007	0.365*	-0.308
	(0.174)	(0.186)	(0.163)	(0.172)	(0.184)	(0.393)	(0.268)	(0.227)	(0.150)	(0.177)	(0.176)	(6.060)	(0.210)	(0.254)
Absolute UE gap × voting (γ^N)	–	0.264*	0.340***	0.253	0.323*	0.091	-0.030	0.337**	0.261*	0.232	0.232*	18.445**	0.277**	0.405
		(0.158)	(0.123)	(0.163)	(0.183)	(0.329)	(0.238)	(0.131)	(0.152)	(0.156)	(0.131)	(8.038)	(0.138)	(0.334)
Voting (β_v^N)	–	-0.028	-0.111	-0.036	-0.036	0.015	0.391**	-0.123	-0.037	-0.127	0.029	-0.044	-0.090	-0.105
		(0.115)	(0.095)	(0.099)	(0.127)	(0.292)	(0.177)	(0.123)	(0.129)	(0.177)	(0.102)	(0.119)	(0.136)	(0.192)
Speeches by other members	–	–	–	–	–	–	–	–	0.064***	–	–	–	–	–
									(0.011)					
Absolute Infl gap (non-voting)	–	–	–	–	–	–	–	–		0.099	–	–	–	–
										(0.111)				
Absolute Infl gap × voting	–	–	–	–	–	–	–	–		0.142	–	–	–	–
										(0.140)				
Absolute RoA gap (non-voting)	–	–	–	–	–	–	–	–		-0.096	–	–	–	–
										(0.231)				
Absolute RoA gap × voting	–	–	–	–	–	–	–	–		0.039	–	–	–	–
										(0.271)				
Abs. UE gap, voting ($\beta_u^N + \gamma^N$)	–	**0.550*****	**0.632*****	0.628***	**0.546*****	0.700	0.315	**0.589*****	**0.521*****	0.523***	**0.485****	**12.438***	**0.642*****	0.096
		(0.184)	(0.182)	(0.177)	(0.174)	(0.580)	(0.241)	(0.218)	(0.161)	(0.170)	(0.210)	(6.932)	(0.197)	(0.27)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
President FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,735	1,735	1,735	1,735	1,735	1,735	586	1,570	1,735	1,735	2,084	1,735	1,735	1,735

Notes: The table shows coefficient estimates for the effect of regional macroeconomic conditions and voting status on the number of speeches given by FOMC members in the rotation scheme, based on an ordered probit model following Eq. 2.2. UE stands for unemployment, Infl for inflation. Column (1) includes unemployment without allowing for a differential effect for voters. Column (2) is the benchmark model. Columns (3) and (4) are for monetary policy speeches identified at a 5% and 10% threshold, respectively. Columns (5) and (6) differentiate speeches depending on whether or not they were covered by Reuters. Column (7) tests for the number of speeches given, conditional on a speaker giving at least one speech in a given inter-meeting period. Column (8) excludes time fixed effects and replaces these with the number of speeches given by all other members on the FOMC. Column (9) reports results for a probit model. Column (10) includes regional inflation and financial sector return on assets. Column (11) extends the sample to 2018. Column (12) proxies regional economic conditions with the tone of the relevant section of the Beige Book. Columns (13) and (14) split the sample into the period before and after the release of the Beige Book. Standard errors are in brackets. Coefficients in bold are statistically significantly different from the top row coefficients at least at the 10% level. ***/**/* denote statistical significance at the 1%/5%/10% level.

Table 2.3: *Determinants of the number of speeches given*

	(1) Without voting	(2) Benchmark	(3) 5% threshold	(4) 10% threshold	(5) Reuters coverage	(6) No Reuters coverage	(7) Control for tone of others' speeches	(8) Adding inflation and RoA	(9) Until 2018	(10) Tone of beige book proxies for economy	(11) Pre-beige book release	(12) Post-beige book release
Regional UE (β_u^τ)	-0.148	-0.112	-0.123	-0.235	0.011	-0.831	-0.083	-0.181	-0.230**	9.568*	-0.167	0.808
	(0.118)	(0.119)	(0.135)	(0.170)	(0.120)	(1.323)	(0.063)	(0.111)	(0.110)	(5.279)	(0.162)	(0.870)
Regional UE × voting (γ^τ)	–	-0.156**	-0.138**	-0.196**	-0.192***	-0.102	-0.150***	-0.231***	-0.105	-2.448	-0.202***	-0.100
		(0.062)	(0.059)	(0.073)	(0.059)	(0.515)	(0.047)	(0.070)	(0.063)	(7.674)	(0.061)	(0.444)
Voting (β_v^τ)	–	1.139**	1.015**	1.435***	1.410***	0.831	1.056***	2.007***	0.752*	2.480	1.556***	-0.097
		(0.425)	(0.413)	(0.483)	(0.400)	(3.100)	(0.320)	(0.628)	(0.406)	(7.454)	(0.401)	(4.180)
Speeches by other members	–	–	–	–	–	–	0.587***	–	–	–	–	–
							(0.071)					
Regional Infl (non-voters)	–	–	–	–	–	–	–	-0.043	–	–	–	–
								(0.076)				
Regional Infl × voting	–	–	–	–	–	–	–	0.049	–	–	–	–
								(0.082)				
Regional RoA (non-voters)	–	–	–	–	–	–	–	-0.105	–	–	–	–
								(0.154)				
Regional RoA × voting	–	–	–	–	–	–	–	-0.443*	–	–	–	–
								(0.226)				
Regional UE, voting ($\beta_u^\tau + \gamma^\tau$)	–	**-0.268****	**-0.262***	**-0.431***	**-0.180**	-0.934	**-0.233*****	**-0.412*****	-0.335**	7.120	**-0.369****	0.708
		(0.127)	(0.127)	(0.205)	(0.138)	(1.359)	(0.062)	(0.130)	(0.125)	(4.934)	(0.178)	(1.150)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
President FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	586	586	714	471	510	85	586	586	745	586	470	116
R2	0.615	0.625	0.574	0.612	0.624	0.792	0.393	0.632	0.596	0.618	0.665	0.864

Notes: The table shows coefficient estimates for the effect of regional macroeconomic conditions and voting status on the tone of speeches given by FOMC members in the rotation scheme, following Eq. 2.3. UE stands for unemployment, Infl for inflation. Column (1) includes unemployment without allowing for a differential effect for voters. Column (2) is the benchmark model. Columns (3) and (4) are for monetary policy speeches identified at a 5% and 10% threshold, respectively. Columns (5) and (6) differentiate speeches depending on whether or not they were covered by Reuters. Column (7) excludes time fixed effects and replaces these with the tone of speeches given by all other members on the FOMC. Column (8) includes regional inflation and financial sector return on assets. Column (9) extends the sample to 2018. Column (10) proxies regional economic conditions with the tone of the relevant section of the Beige Book. Columns (11) and (12) split the sample into the period before and after the release of the Beige Book. Standard errors are in brackets. Coefficients in bold are statistically significantly different from the top row coefficients at least at the 10% level. ***/**/* denote statistical significance at the 1%/5%/10% level.

Table 2.4: *Determinants of the tone of speeches*

Speech tone. To investigate the extent to which the tone expressed in the speeches depends on a president's voting status, we estimate the relationship

$$\tau_{i,t} = \mu_i + \mu_t + \beta_u^\tau u_{d_i t} + \beta_v^\tau v_{d_i t} + \gamma^\tau u_{d_i t} v_{d_i t} + \epsilon_{it} \quad (2.3)$$

As before, we include president and period fixed effects and cluster standard errors by president. Appendix Table B.1 provides basic summary statistics for the speech tone.

We expect the tone of a speech of a president of either type to be negatively related to regional unemployment, $\beta_u^\tau < 0$ and $\beta_u^\tau + \gamma^\tau < 0$. The parameter of interest for a test of the hypotheses is γ^τ, as it measures the difference in responsiveness of the tone to regional economic conditions across voting status. The loss-compensation hypothesis predicts $\gamma^\tau > 0$, i.e. the relationship between tone and regional unemployment is more negative for non-voters, while the involvement hypothesis predicts the opposite, $\gamma^\tau < 0$.

We present the estimation results in Table 2.4. The first specification shows that a president tends to use a more negative tone, the larger is the unemployment gap, but that this relationship is not statistically significant. The benchmark estimation in column 2 differentiates voters and non-voters. It shows that presidents' tone reacts more strongly to the regional unemployment situation when they have voting rights: their estimated reaction to regional unemployment is more than twice as large. This reaction is statistically significant at the 5% level, as can be seen by the sum of the two estimated coefficients, $\beta_u^\tau + \gamma^\tau$, provided in the middle panel of Table 2.4. The estimate implies that a 1 percentage point increase in regional unemployment relative to the U.S. figure lowers the tone of the speeches given by the voting Reserve Bank presidents by one fourth of its standard deviation.

The findings on speech tone again support the involvement hypothesis and go against the loss-compensation hypothesis.

We subject these findings to the same robustness tests as before, by changing the threshold for identifying monetary policy-related speeches, by separating speeches that are covered by Reuters and those that are not, by removing meeting fixed effects and instead controlling for the tone of the speeches by all other FOMC members, by adding regional inflation and the financial sector return on assets, and by extending the sample to 2018. Results are robust.[13]

[13] As an additional robustness check, we estimate the effects on the number of speeches and speech tone jointly in a Heckman model. The underlying idea is that we observe the sentiment of the speeches by Reserve Bank presidents who decide to deliver a speech, but that we cannot observe the sentiment of those who do not. If the decision to give a speech is not random, it could introduce a sample selection bias in our estimates. The Heckman procedure corrects for such potential bias. The procedure involves a two-stage estimation method. In the first stage (selection), the probability of being included in the sample (in our application, the decision to deliver a speech or not) is estimated by way of a probit model. In the second stage (option), the sentiment expressed in the speeches is

As before, we also relate our estimation to the Beige Book. Using the content of the Beige Book as an alternative proxy for regional economic conditions yields largely insignificant results (note that we would expect the relationship between Beige Book tone and speech tone to be positive, which is what we find). When splitting the sample into pre-Beige Book release and post-release, we once more find that the pattern identified in our benchmark estimation stems exclusively from the pre-release window.

Intermeeting speech behaviour following dissent or a surprise decision. Moving on, we now test the predictions concerning speech behaviour in periods of conflicting views within the FOMC or uncertainty about the right decision. Recall that both hypotheses make the same prediction concerning the change in responsiveness of presidential speech behaviour as a reaction to a change in the character of the preceding meeting, conditional on voting status.

We say that a meeting is characterised by conflicting views if at least one FOMC member dissented in that meeting. Furthermore, we proxy uncertainty about the right decision through periods when the committee took a surprising decision. In particular, we measure market surprises with the high-frequency responses in Fed funds futures around the FOMC announcements provided in Steinsson et al. (2018). We classify a meeting as surprising if the associated monetary shock is larger than the top 75th or smaller than the bottom 25th percentile of the shocks' distribution.

We run separate tests for each situation. In either case, we extend the speech and tone regression models by a dummy, P_t, that equals one if the previous meeting has the characteristic. We interact this dummy with the regional economic conditions, the voting status and with both variables. For the number of speeches, the model becomes

$$Pr(N_{i,t} = n) = \Pr\begin{pmatrix} \kappa_{n-1} < \mu_i + \mu_t + \beta_u^N |u_{d_i t} - u_{\text{US},t}| + \beta_v^N v_{d_i t} \\ +\gamma_{uv}^N |u_{d_i t} - u_{\text{US},t}| v_{d_i t} + \gamma_{uP}^N |u_{d_i t} - u_{\text{US},t}| P_t \\ +\gamma_{vP}^N v_{d_i t} P_t + \delta^N |u_{d_i t} - u_{\text{US},t}| v_{d_i t} P_t + \epsilon_{it} \le \kappa_n \end{pmatrix} \tag{2.4}$$

while the model for the tone of speeches turns into

$$\begin{aligned} \tau_{i,t} =& \mu_i + \mu_t + \beta_u^\tau u_{d_i t} + \beta_v^\tau v_{d_i t} + \gamma_{uv}^\tau u_{d_i t} v_{d_i t} \\ &+ \gamma_{uP}^\tau u_{d_i t} P_t + \gamma_{vP}^\tau v_{d_i t} P_t + \delta^\tau u_{d_i t} v_{d_i t} P_t + \epsilon_{it} \end{aligned} \tag{2.5}$$

The loss-compensation hypothesis predicts $\gamma_{uP}^N > 0$ for speech number and $\gamma_{uP}^\tau < 0$ for speech tone; the involvement hypothesis predicts $\delta^N > 0$ for speech number

explained. The estimation of our model is conveniently identified, given the exclusion restriction that the absolute deviations of regional economic conditions from the U.S. average affect the number of speeches but do not affect the sentiment contained in the speeches. The results of this exercise, which we do not reported for brevity, show that our results are highly robust, both quantitatively and qualitatively.

and $\delta^{\tau} < 0$ for speech tone.

Dissent. Consider intermeeting periods that follow an FOMC meeting characterised by dissent first.

	Event at previous meeting (P_t)	
	Dissent	Large surprise
	(1)	(2)
Absolute UE gap (β_u^N)	0.197	0.252
	(0.212)	(0.196)
Absolute UE gap × voting (γ_{uv}^N)	-0.053	0.173
	(0.142)	(0.203)
Absolute UE gap $\times P_t$ (γ_{uP}^N)	0.164	0.065
	(0.228)	(0.156)
Absolute UE gap $\times P_t \times$ voting (δ^N)	0.585**	0.208
	(0.228)	(0.219)
Voting (β_v^N)	0.192	0.066
	(0.125)	(0.147)
Voting $\times P_t$ (γ_{vP}^N)	-0.447***	-0.204
	(0.161)	(0.194)
Abs. UE gap, voting, $P_t = 0$ ($\beta_u^N + \gamma_{uv}^N$)	0.144	0.425**
	(0.234)	(0.181)
Abs. UE gap, $P_t = 1$, non-voting ($\beta_u^N + \gamma_{uP}^N$)	0.361	0.317
	(0.227)	(0.202)
Abs. UE gap, $P_t = 1$, voting ($\beta_u^N + \gamma_{uv}^N + \gamma_{uP}^N + \delta^N$)	**0.894*** **	**0.698*** **
	(0.188)	(0.226)
Period FE	Yes	Yes
President FE	Yes	Yes
Observations	1,735	1,735

Notes: The table shows coefficient estimates for the effect of regional macroeconomic conditions and voting status on the number of speeches given by presidents in the rotation scheme, based on an ordered probit model following Eq. 2.4 augmented with dummy variable P_t and its interaction terms. The latter allow for differential effects for voting members depending on whether there has been dissent in the previous meeting (Column 1) or a relatively large surprise in the previous meeting (Column 2). UE stands for unemployment. Standard errors are in brackets. Coefficients in bold are statistically significantly different from the top row coefficients at least at the 10% level. ***/**/* denote statistical significance at the 1%/5%/10% level.

Table 2.5: *The number of speeches after dissent or a surprise decision*

Column 1 in Tables 2.5 and 2.6 show the results for the number of speeches and their tone, respectively. For presidents in non-voting years, there is no statistically significant evidence that the link between speech behaviour and regional conditions depends on whether the last meeting's decision was characterised by dissent or not. The relevant coefficients for the number of speeches and for the tone of speeches are statistically insignificant. However, in years in which presidents are voting, there is statistically significant evidence that the number of speeches and the tone of their speeches react more strongly to regional economic circumstances after a dissent than after a unanimous vote.

The middle part of Table 2.5 reports the sum of corresponding coefficients for the number of speeches, which allows for a straightforward comparison of the various cases. The reaction by a voting president after an FOMC meeting with dissent, at 0.894, is more than four times as large as the estimated coefficient for a non-voting president after a consensual FOMC meeting. The middle part of Table 2.6 shows that the difference in the reaction of speech tone to regional circumstances is also around 4 times larger (-0.426 versus -0.099).

	Event at previous meeting (P_t)	
	Dissent	Large surprise
	(1)	(2)
Regional UE (β_u^τ)	-0.099	-0.087
	(0.129)	(0.109)
Regional UE * voting (γ_{uv}^τ)	-0.086	-0.123
	(0.076)	(0.098)
Regional UE $\times P_t$ (γ_{uP}^τ)	-0.033	-0.056
	(0.124)	(0.134)
Regional UE $\times P_t \times$ voting (δ^τ)	-0.207*	-0.051
	(0.101)	(0.153)
Voting (β_v^τ)	0.620	0.818
	(0.510)	(0.693)
Voting $\times P_t$ (γ_{vP}^τ)	1.634**	0.542
	(0.750)	(0.979)
Regional UE, $P_t = 0$,voters ($\beta_u^\tau + \gamma_{uv}^\tau$)	-0.185	-0.210
	(0.125)	(0.127)
Regional UE, $P_t = 1$,non-voting ($\beta_u^\tau + \gamma_{uP}^\tau$)	-0.132	-0.143
	(0.137)	(0.162)
Regional UE, $P_t = 1$,voting ($\beta_u^\tau + \gamma_{uv}^\tau + \gamma_{uP}^\tau + \delta^\tau$)	**-0.426*** **	**-0.317***
	(0.148)	(0.169)
Period FE	Yes	Yes
President FE	Yes	Yes
Observations	586	586
R2	0.630	0.626

Notes: The table shows coefficient estimates for the effect of regional macroeconomic conditions and voting status on the tone of speeches given by presidents in the rotation scheme, following Eq. 2.5, augmented with dummy variable P_t and its interaction terms. The latter allow for differential effects for voting members depending on whether there has been dissent in the previous meeting (Column 1) or a relatively large surprise in the previous meeting (Column 2). UE stands for unemployment. Standard errors are in brackets. Coefficients in bold are statistically significantly different from the top row coefficients at least at the 10% level. ***/**/* denote statistical significance at the 1%/5%/10% level.

Table 2.6: *The tone of speeches after dissent or a surprise decision*

Surprise decision. The relationship between speech behaviour and regional economic circumstances does not seem to depend on whether the previous FOMC decision has caused a market surprise. The relevant coefficients for voters and non-voters are estimated to be statistically insignificant.

However, the middle part of Table 2.5 shows that the overall effect of regional unemployment on the number of speeches for a voter after a surprise decision is, at 0.698, close to three times as large as the estimated coefficient for a non-voter after an unsurprising decision. Similarly, the middle part of Table 2.6 shows that the difference in the reaction of speech tone to regional circumstances is even larger across these two categories (-0.317 versus -0.087).

The findings on speech behaviour after dissenting votes provide further support for the involvement hypothesis, and no support for the loss-compensation hypothesis; the findings on speech behaviour after a surprising decision do not favour any of the hypotheses.

2.5.3 Voting status and deliberation in the FOMC meeting

The results so far have provided compelling evidence supporting the involvement hypothesis with regard to communication behaviour in the intermeeting period. We will now test whether this behavioural pattern prevails during the deliberation stage at the FOMC meetings. Recall that the FOMC meeting starts with an economy go-round, where all participants discuss the economic situation. In this round, Reserve bank presidents discuss, inter alia, the regional economic conditions. Subsequently, the discussion moves on to the implications for the monetary policy decisions. Since monetary policy is set for the U.S. aggregate economy, we would expect regional economic conditions to be playing a lesser role in this part of the meeting. This meeting structure naturally suggests that it will be important to analyse the first intervention of each president separately from their entire set of interventions.

For brevity, we have relegated all results regarding the length of the interventions to the appendix. Appendix Table B.5 shows that hardly any of our regression variables exert statistically significant effects. The absence of a relationship between the length of interventions and regional economic conditions or the number of speeches may be explained with procedural limits of individual presidents' speaking time. Not every president will be able to freely choose how long he or she deliberates, which suggests that the intervention length may be a censored outcome variable.

Studying the tone of the interventions yields more interesting results. We start our analysis with the analogous regression to the tone of speeches, based on Eq. 2.3, i.e. we test whether the tone of the meeting interventions responds to regional unemployment, and whether there are differences between voters and non-voters. The results are shown in column (1) of Table 2.7 for the tone of the first intervention of a president at the meeting. They are, once more, supportive of the involvement hypothesis: the tone of the interventions becomes more negative, the larger the regional unemployment gap. This is the case for all speakers, but significantly more so for the voters.

We then expand our analysis to test to what extent speech behaviour and the interventions at the meeting are linked, first by relating the tone of the intervention to the tone of the intermeeting speeches and by differentiating the effect for voters and non-voters, and then by including both regional conditions and speech tone in our regression, which in this most expanded version is formulated as

$$T_{i,t} = \mu_i + \mu_t + \beta_u^T u_{d_i t} + \beta_v^T v_{d_i t} + \gamma_{uv}^T u_{d_i t} v_{d_i t} + \beta_\tau^T \tau_{d_i t} + \gamma_{\tau,v}^T \tau_{d_i t} v_{d_i t} + \epsilon_{it} \tag{2.6}$$

As always, we allow for president and meeting fixed effects and cluster standard errors by president. As these regressions are conditional on presidents having given speeches in the intermeeting period, we first repeat the earlier analysis that relates intervention tone to regional unemployment, but condition on the observations with intermeeting speeches.

	First intervention				All interventions			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Regional UE (β_u^T)	-0.425***	-0.583*	–	-0.599**	-0.052	-0.154	–	-0.158
	(0.150)	(0.304)		(0.281)	(0.084)	(0.127)		(0.121)
Regional UE × voting (γ_{uv}^T)	-0.135*	-0.282**	–	-0.193	-0.042	-0.094	–	-0.057
	(0.073)	(0.130)		(0.141)	(0.035)	(0.058)		(0.058)
Speech tone (β_τ^T)	–	–	-0.243	-0.240	–	–	-0.071	-0.070
			(0.202)	(0.199)			(0.049)	(0.049)
Speech tone × voting ($\gamma_{\tau,v}^T$)	–	–	0.501*	0.368	–	–	0.178**	0.139*
			(0.254)	(0.281)			(0.073)	(0.072)
Voting (β_v^T)	0.550	1.756*	-0.048	1.224	0.269	0.780*	0.181*	0.555
	(0.437)	(0.916)	(0.230)	(0.976)	(0.252)	(0.432)	(0.097)	(0.434)
Regional UE, voting ($\beta_u^T + \gamma_{uv}^T$)	**-0.560*****	**-0.865*****	–	-0.792***	-0.094	-0.248*	–	-0.215
	(0.141)	(0.272)		(0.280)	(0.084)	(0.138)		(0.139)
Speech tone, voting ($\beta_\tau^T + \gamma_{\tau,v}^T$)	–	–	**0.258**	0.128	–	–	**0.107**	**0.069**
			(0.226)	(0.240)			(0.065)	(0.057)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
President FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.145	0.333	0.331	0.339	0.472	0.568	0.569	0.572
Observations	1,714	582	582	582	1,714	582	582	582

Notes: The table shows coefficient estimates for the effect of regional macroeconomic conditions, the tone of speeches and voting status on the tone of meeting interventions, based on an OLS model following Eq. 2.6. Columns (1) and (5) include all observations for meeting interventions, all other columns are conditional on the speaker at the meeting also having delivered at least one intermeeting speech. The left panel relates to the tone of the first intervention at the FOMC meeting, the right panel to the tone of all interventions together. Standard errors are in brackets. Coefficients in bold are statistically significantly different from the top row coefficients at least at the 10% level. ***/**/* denote statistical significance at the 1%/5%/10% level.

Table 2.7: *Determinants of the tone of interventions at the FOMC meeting*

The results, reported in columns (2) of Table 2.7, confirm our evidence in favour of the involvement hypotheses, even at higher levels of statistical significance. For voters, there is also a somewhat stronger relationship between the tone of the intermeeting speeches and the tone of the meeting intervention than for non-voters (see column (3)).

The right panel of Table 2.7 reports results for the tone of all interventions made by each president during the entire meeting. The relationship with regional unemployment is absent, as we had expected, given that the regional economic conditions are primarily discussed in the first go-round. What is interesting, though, is that the tone of the speeches held in the intermeeting period is more strongly correlated with the tone of the entire set of interventions for voting presidents than for the non-voters, suggesting that the intermeeting speeches are more likely to already provide an indication of the monetary policy inclination of the voters.

2.5.4 Market reaction

The goal of this section is to understand whether the reaction of financial markets to a speech depends on the voting status of the president delivering the speech. As before, we limit attention to speeches about monetary policy. To ensure clean inference, we further restrict our analysis to days on which only a single speech was given, leaving us with 585 observations. We measure the market reaction as the absolute daily asset price change, where we focus on constant maturity Treasury yields with maturities ranging from 3 months to 5 years (for maturities beyond 5 years, we do not find any statistically significant results).

To test for differential market reaction, we regress the absolute value of the daily change in Treasury yields, $|dR|_t$, on the voting dummy

$$|dR|_t = \mu_i + \mu_{dow} + \beta v_{d,t} + \epsilon_{it} \tag{2.7}$$

controlling for president fixed effects μ_i and day-of-the-week fixed effects, μ_{dow}.

The top panel of Table 2.8 presents the benchmark estimates. These show some first evidence that market moves are smaller on days with speeches by voting presidents than on days with speeches by non-voting presidents, albeit at low levels of statistical significance. A regression coefficient of 0.005 implies a change of half a basis point. To put the size of this difference into perspective, Table 2.8 also reports the average absolute daily change for the various maturities, and the fraction by which the reaction to a speech by a voting president differs. The fractions tend to be substantial, ranging from more than 25% for 3-month rates to slightly above 10% for 5-year rates.

	3-month	6-month	12-month	2-year	5-year
Panel A: benchmark					
Voting	-0.006*	-0.004	-0.005*	-0.006*	-0.005
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
Average absolute change	0.023	0.021	0.026	0.036	0.045
Fraction	0.260	0.188	0.191	0.168	0.111
Observations	585	585	585	585	585
R-squared	0.064	0.134	0.163	0.118	0.072
Panel B: pre-Beige Book					
Voting	-0.008**	-0.007***	-0.008**	-0.008**	-0.007
	(0.004)	(0.003)	(0.003)	(0.004)	(0.005)
Average absolute change	0.022	0.021	0.026	0.036	0.045
Fraction	0.357	0.335	0.311	0.225	0.157
Observations	483	483	483	483	483
R-squared	0.069	0.144	0.176	0.128	0.070
Panel C: post-Beige Book					
Voting	-0.003	0.005	-0.001	-0.009	-0.006
	(0.009)	(0.007)	(0.008)	(0.009)	(0.011)
Average absolute change	0.026	0.023	0.029	0.036	0.046
Fraction	0.114	0.219	0.035	0.247	0.130
Observations	102	102	102	102	102
R-squared	0.325	0.365	0.341	0.403	0.346
Panel D: beyond 2013					
Voting	-0.005**	-0.004**	-0.004*	-0.006**	-0.006*
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Average absolute change	0.021	0.019	0.023	0.032	0.042
Fraction	0.244	0.213	0.174	0.186	0.142
Observations	769	769	769	769	769
R-squared	0.069	0.142	0.165	0.128	0.081
Panel E: speeches on Reuters					
Voting	-0.008**	-0.006**	-0.005*	-0.006	-0.005
	(0.004)	(0.003)	(0.003)	(0.004)	(0.005)
Average absolute change	0.023	0.020	0.024	0.034	0.045
Fraction	0.355	0.306	0.206	0.175	0.112
Observations	438	438	438	438	438
R-squared	0.057	0.135	0.166	0.123	0.079
Panel F: speeches from FOMC speak					
Voting	-0.001	-0.002**	-0.003**	-0.002	-0.005**
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Average absolute change	0.011	0.010	0.012	0.021	0.032
Fraction	0.091	0.195	0.243	0.097	0.156
Observations	568	568	568	568	568
R2	0.082	0.102	0.136	0.103	0.073

Notes: The table shows coefficient estimates for the effect of speeches on the daily absolute change in constant maturity treasury yields, following Eq. 2.7. Panel A shows results for all speeches on days with only one speech. Panels B and C split this sample into pre- and post-Beige Book release. Panel D extends the speech sample until 2018. Panel E restricts the sample to speeches reported upon by Reuters. Panel F uses speeches with a time stamp as recorded in the "FOMC speak" database. Rows "average absolute change" report the average absolute change of the dependent variable for the full sample. Rows "fraction" report the absolute value of the estimated coefficient on the voting dummy as a fraction of the average absolute change of the dependent variable. Numbers in brackets are standard errors. ***/**/* denote statistical significance at the 1%/5%/10% level.

Table 2.8: *Effect of speeches on Treasury rates on the day of speech*

We also split our sample into the period prior and following the release of the Beige Book. In our pre-Beige Book sample (panel B), the differences are larger (up to 36% at the 3-month maturity) and also more significant statistically. In contrast, no difference is observed for the post-Beige Book sample (panel C), in line with our earlier evidence. For robustness, we extend our sample to include all monetary policy speeches until 2018, and replicate our earlier findings, at higher levels of statistical significance (panel D). Statistical and economic significance also increase when we condition on speeches that are reported on Reuters (panel E).

Finally, we try to deal with the issue that our speech data does not contain time stamps, hence we only know the day of a speech, but not the exact time when it was delivered. Market closing for the treasury yields is at 15:30 Eastern Time, implying that any speech delivered afterwards affects yields on the subsequent day. To address this, we rely on "FOMC speak," an alternative speech dataset provided by the Federal Reserve Bank of St Louis,[14] which contains the time stamp of a large number of speeches. This allows us to appropriately time the speeches.

However, the "FOMC speak," dataset does not differentiate monetary policy speeches and other speeches. The results in panel F for 568 speeches delivered in the years 2011-2019 confirm our earlier findings.

We also exploit the around-the-clock nature of currency trade to measure the impact of speeches. We calculate the absolute change of the Japanese Yen-U.S. Dollar exchange rate between London fixing and Tokyo close of business, times that correspond to 11 am Eastern Time and midnight Pacific Time (or 1am Pacific Time during U.S daylight saving time), respectively.[15] The results (not shown for brevity) show that presidents move also this market less in years they vote. The difference in impact (estimated at the 10% significance level), compared to the average absolute daily change in the exchange rate, is, at 20%, substantial.

Consistency of market reaction and presidents' behaviour. Why do markets react less to speeches by presidents in years they vote than when they do not vote? We suggest an explanation based on the type of information conveyed in the speeches. The speeches in our sample convey information about economic conditions, but also help understanding how the upcoming FOMC meeting will evolve, e.g. what will be contentious topics, which side will prevail, and hence what decision will be taken. Both information types are ultimately important for asset prices, but we argue that the first type is directly relevant for markets, whereas

[14] https://www.stlouisfed.org/fomcspeak/viewbydate.

[15] Based on the speeches with time stamp from "FOMC speak," the time window for the treasury yields appropriately allocates 68% of all speeches (and wrongly allocates the speeches given later in the day). The exchange rate time window would allocate 63% of all speeches correctly, and generates a mismatch for the speeches given early in the day. The two time windows do therefore nicely complement one another, as they capture the set of speeches that is missing from the other time window.

the second type matters indirectly, through the monetary policy decision resulting from the meeting deliberation.

If the second, indirect influence were dominant, one would expect presidents to influence markets more in years they vote; after all, their influence on the FOMC decision is more direct thanks to their votes. However, the market reacts less to the speeches of voting presidents. This would either imply that the market behaves irrationally, and consistently so, or that this indirect influence is not dominant.

This leaves the possibility that the first, direct influence of a speech is dominant, i.e. markets are primarily looking for signals about the state of the economy. We argue that this may explain why markets consistently pay more attention to presidents' speeches in years they do not vote. The argument relies on the assumption that markets for U.S. government securities and foreign exchange are more interested in national than in regional information. Thus, market participants need to distinguish national from regional information when they digest a speech – they face a signal extraction problem. Speech characteristics – their tone and number – reflect both types of information, whether a president votes or not.

	Benchmark (1)	No meeting FE (2)
Absolute UE gap (β_u^N)	0.277	0.255*
	(0.186)	(0.134)
Absolute UE gap × voting (γ^N)	0.264*	0.245
	(0.158)	(0.150)
Voting (β_v^N)	-0.028	-0.028
	(0.115)	(0.133)
Absolute UE gap, voters ($\beta_u^N + \gamma^N$)	**0.550*****	0.500***
	(0.184)	(0.156)
Period FE	Yes	No
President FE	Yes	Yes
Observations	1,735	1.735

Notes: Estimates of ordered probit model for number of speeches. See notes to Table 2.3. Column (1) replicates the benchmark specification (Eq. 2.2) in column (2) of that table. Column (2) is based on the benchmark specification, but without meeting fixed effects.

Table 2.9: *What does the market learn from the number of speeches?*

Consider Table 2.9, with two regressions for the number of speeches that presidents give during intermeeting periods. Column 1 is the benchmark model from Table 2.3; column 2 uses the same specification, except that we removed the period fixed effects. Period fixed effects capture what is common to all districts in an intermeeting period, including the general, U.S.-wide economic situation. A comparison with the benchmark results in column 1 suggests that the speech activity of non-voting presidents is driven by regional economic conditions that, by and large, move in tandem with U.S.-wide economic conditions. Instead, in years that they vote, their speech activity is driven both by economy-wide conditions and by idiosyncratic regional conditions.

	Benchmark (1)	No meeting FE (2)
Regional UE (β_u^τ)	-0.112	-0.186**
	(0.119)	(0.071)
Regional UE × voting (γ^τ)	-0.156**	-0.214***
	(0.062)	(0.047)
Voting (β_v^τ)	1.139**	1.434***
	(0.425)	(0.369)
Regional UE, voting ($\beta_u^\tau + \gamma^\tau$)	**-0.268****	**-0.400*****
	(0.127)	(0.076)
Period FE	Yes	No
President FE	Yes	Yes
Observations	586	586
R2	0.625	0.303

Notes: Speech tone is the dependent variable. See notes to Table 2.4. Column (1) replicates the benchmark specification (Eq. 2.3) in column (2) of that table. Column (2) is based on the benchmark specification, but without meeting fixed effects.

Table 2.10: *What does the market learn from the tone of speeches?*

Without the period fixed effects, regional unemployment determines the tone of presidents' speeches, albeit to different degrees, whether they vote or not. The introduction of the period fixed effects shows that in years in which they do not vote, the tone of their speeches does not react to idiosyncratic regional unemployment, whereas in years in which they vote, it does to a significant extent.

This implies that market participants who are interested in learning about general economic conditions from the speeches of a president face a harder signal extraction problem in years that the president votes than in the other years. It is then rational for markets to react less to a speech in such years.

2.6 Conclusion

Committee decision-making is ubiquitous, in the economy as well as in politics. Some committees exhibit a changing membership or rotation of voting rights among the membership. In this paper, we have investigated empirically whether the right to vote affects the behaviour of committee members, using the FOMC as a case study. We exploit the rotation of voting rights among Federal Reserve Bank presidents on the FOMC, as it is exogenous to economic conditions and therefore allows for a causal analysis. It is the role of the Federal Reserve Bank presidents to gather intelligence about economic conditions in their Federal Reserve district, and to bring this information to the FOMC meeting, as a basis for the ultimate monetary policy decisions.

It is ex ante unclear in what direction the voting rotation affects behaviour. On the one hand, there could be loss-compensation behaviour, which would imply that during years without the right to vote, the inter-meeting speeches and interventions at the meeting react more strongly to the regional economic conditions. On the other hand, having the right to vote could make Bank presidents more involved, such that their speeches and interventions would be more dependent on regional economic conditions when they have voting status.

Our empirical results support the involvement hypothesis, both when studying intermeeting speeches and interventions at the meeting. In addition, the evidence shows that financial market participants react less strongly to presidents' speeches when they are voting. While this might seem counterintuitive at first, our findings help to explain why: the stronger emphasis on regional conditions by voting presidents implies that it is more difficult for the market to extract signals on U.S.-wide economic conditions and monetary policy.

Our empirical results allow the following conclusions. First, the design of rotation schemes for voting rights deserves special attention because the committee members adjust their behaviour endogenously according to voting status. Further research should assess to what extent this change in behaviour is desirable and, if not, how it could be mitigated. Second, strategic behaviour of committee members is already at play in the run up to the meeting. While this aspect is studied in some theoretical papers (e.g. Swank et al., 2008), the empirical literature largely ignores this aspect. Further research on this topic seems promising. Third, consistent with investor rationality, financial markets appear to internalise the communication decisions by committee members. Our findings suggest that future research on the financial market reaction to public announcements might benefit from considering the communication choices of policy makers.

Chapter 3

Dollar borrowing by non-financial firms and the real effects of US monetary policy abroad[1]

[1] I am extremely thankful for uncountable discussions with and superb advise by Matteo Maggiori, Lucio Sarno and Maik Schmeling. I also thank Markus Ibert, Valerio Nispi Landi, Jesper Lindé, Ian Marsh, Elisa Pazaj, Cosimo Petracchi, Valentin Schubert, Adi Sunderam, Yannick Timmer, and participants at Brown University PhD Macro Lunch (2020), Capital Fund Management (2020) and Cass PhD Research Days (2020).

3.1 Introduction

The Mundell-Fleming Trilemma states that floating exchange rates ensure independence of domestic monetary policy under free capital flows. If a country wants to fix its exchange rate, it would need to impose capital controls or give up its monetary policy independence. Financial globalization has worsened these trade-offs (Rey, 2013; Obstfeld, 2015). Recent research on the topic focuses on the role of global banks and asset prices. At the same time, non-financial firms make increasing use of international bond markets, even in pursuit of financial returns (Bruno and Shin, 2017; Calomiris et al., 2019) or to avoid capital controls and taxes (Coppola et al., 2020).

The contribution of this paper is to identify the real effects of US monetary spillovers and shed light on the role of non-financial firms' balance sheets and trade activities. I apply a corporate finance identification scheme to quarterly data for firms in 36 countries between 2003 and 2017. I estimate how real investment by these non-US firms responds to US monetary surprises.

I find that reductions in investment after US monetary tightening, dubbed real spillovers, are significant even in countries with floating exchange rates (floaters) and considerably larger in countries with managed or pegged exchange rates (non-floaters). The stronger spillovers in non-floaters, relative to floaters, arise from a relatively stronger response by firms with high leverage. Exchange rate fluctuations contribute to the heterogeneity because they amplify spillovers for non-floaters but dampen it for floaters. I rationalize my findings in a basic framework of endogenous currency choice. It highlights how limited exchange rate flexibility allows smaller and less productive firms to borrow in foreign currency, which magnifies financial vulnerability resulting from high leverage.

The identification idea employed in this paper is that firms which have debt denominated in US Dollars (USD) maturing *shortly after* FOMC announcements are more exposed to the monetary policy changes than firms that do not. This effect arises in a simple theoretical framework in which firms finance investment and maturing debt through new borrowing. New borrowing faces a net worth constraint because not all future income is pledgeable to investors. In the setup, interest rate increases do not affect the net worth of firms whose debt structure is constant because the present values (PV) of assets and debts fall equally. Instead, firms with maturing debt see the PV of debts decline by less than the PV of assets, leading to a drop in net worth and feasible borrowings.[2] I combine this insight with the argument that the exact timing of debt maturity within a given FOMC period,

[2]Below I discuss related cash flow effects, working through higher interest expenses or discrepancies between repayment values and issuance amounts, which could strengthen these effects.

whether it occurs before or after the FOMC, is plausibly exogenous if the debt is not short-term. Similar arguments on the timing of maturing debt have been used in earlier studies. For instance Almeida et al. (2012), Duval et al. (2020), Casas et al. (2020) and Benmelech et al. (2019) exploit pre-existing refinancing needs during financial crises.[3]

To implement my identification approach, I assemble globally comprehensive corporate bond data, the union of issuance data sets by Mergent, SDC and Dealogic, and merge it with quarterly accounting data on non-US firms from Compustat Global and Worldscope. I further complement this data with Capital IQ, for details on firms' debt composition, and firms' exporter status from Worldscope and Orbis.

The combined data set allows me to identify, for every quarter, firms that have debt maturing shortly after FOMC announcements and those that do not. I then regress quarterly physical investment on an interaction of the maturing variable with the US monetary policy shock, controlling for firm and country×date fixed effects and an array of firm characteristics.

It is crucial to stress that the maturing-debt-identification captures effects on investment due to *changes in financing conditions caused by US monetary policy*. Non-financial spillovers, such as direct effects of changes in aggregate US demand or information released by the FOMC, that affect all firms equally, are absorbed in the fixed effects. My main estimate, the semi-elasticity of investment with respect to monetary shocks, thus measures the real effects of a *firm-financing-spillover channel of US monetary policy*.

My analysis yields four main findings. The first key finding is that US monetary spillovers to investment are significant even in countries with floating exchange rates (floaters) but considerably larger in countries with managed or pegged exchange rates (non-floaters). I estimate that, after a 25 basis point surprise monetary policy tightening in the US, non-US firms with maturing USD debt reduce their investment relative to those without maturing debt by -2.5% in floaters and -6.5% in non-floaters, which corresponds to 30% and 75% of the overall standard deviation in the quarterly growth rate of physical capital. For comparison, the average effect for firms with USD debt (without the maturing-debt dummy) implies that they reduce their investment on average by -1.3%, relative to firms without USD debt. The stronger investment responses in non-floaters, relative to floaters, persist when controlling for differences in financial development. Stricter capital controls are associated with smaller, yet statistically and economically significant spillovers.

My investment-shock elasticities can be decomposed into a) sensitivity of

[3]In ongoing follow-up work, Schubert, Tietz, and Timmer (2020) use a similar argument to mine to identify the real effects of credit market frictions in the United States.

financing conditions and b) sensitivity of investment to financing conditions. In a two-stage least squares framework, using daily country-level corporate bond yields, I show that the two factors explain each around half of the stronger spillovers in non-floaters:[4] First, consistent with the empirical literature, the US monetary shocks cause larger fluctuations in corporate bond yields in non-floaters than in floaters. Second, and more puzzlingly, a unit change in financing conditions (bond yields) is associated with larger investment reductions by firms in non-floaters than in floaters.

For my second key finding, I estimate the investment responses on sub-samples capturing the two main candidate firm dimensions: Balance sheet health, which I measure as net leverage (debt minus cash over assets), and trade activity, for which I classify firms as exporters and non-exporters based on whether they report international sales or not.

The stronger spillovers in non-floaters are due to a relatively stronger response of highly leveraged firms. While high-leverage firms are more responsive than low-leverage firms within both country groups, the gap is significantly larger among them. The differential response by non-floaters, relative to floaters, does not differ significantly between exporters and non-exporters.

My third key finding is that exchange rate fluctuations contribute to the stronger spillovers in non-floaters relative to floaters because they amplify the firm-financing spillover channel for non-floaters but dampen it in floaters. I show this by augmenting the baseline specification with an interaction of the maturing-dummy and the exchange rate change over FOMC announcement days. This interaction captures how spillovers via firm financing conditions depend on the exchange rate change.

The effect of interest rate shocks on investment increases in magnitude for floaters and gets smaller for non-floaters. In other words, in floaters (non-floaters), a surprise US tightening without ensuing home currency depreciation leads to stronger (weaker) investment reductions than a hike with home depreciation.

For non-floaters, the maturing×depreciation coefficient is estimated to be negative. Investment reductions caused through the financing channel are larger if the home currency depreciates. These adverse effects are concentrated in high-leverage firms and non-exporters, which points to negative net worth effects consistent with recent evidence (Aguiar, 2005; Salomao and Varela, 2018; Banerjee et al., 2020).

Instead, for floaters, the maturing×depreciation coefficient is estimated to be positive, which is concentrated in non-exporters. This could be consistent with

[4] I instrument the firm financing costs with the monetary shock. The exclusion restriction is that, for the firms with maturing debt, the US monetary shocks affect investment only through their effect on financing costs. I verify the 1st stage estimates of stronger asset price responses in non-floaters in a range of robustness exercises, regressing aggregate and bond-level corporate yields, and sovereign bond yields on the monetary shocks.

that firm financing conditions reflect improved sales prospects for non-exporters. Improvements in sales by non-exporters following home depreciations are predicted under USD trade-invoicing (Goldberg and Tille, 2008; Gopinath, 2015) thanks to expenditure switching by domestic importers towards local products (Boz et al., 2017; Casas et al., 2017), a conjecture I confirm in the data. The absence of similar exchange rate effects for exporters is equally consistent with USD invoicing, precluding competiveness gains and adverse net worth effects alike.

My fourth and final finding rationalizes the stronger spillovers in non-floaters (finding 1) being driven by high leverage firms (finding 2) and amplified by exchange rate fluctuations (finding 3). In a simple theoretical framework, I find that limited exchange rate fluctuation allows fundamentally weaker firms to borrow in foreign currency, which results in higher sensitivity to foreign monetary policy that, in turn, is increasing in firm leverage.

My framework is based on the model of borrowing currency choice presented in Maggiori et al. (2018). In a small open economy, firms that borrow in USD (the foreign currency) are larger and more productive compared to home-currency-only borrowers, because issuing debt in USD requires a fixed cost. In addition, tapping the Dollar market implies exposure to additional types of shocks, which more productive firms can cope better with. These firm-type selection channels find empirical support in Maggiori et al. (2018) and Salomao and Varela (2018). I argue that exchange rate pegs impinge on the firm-type selection by reducing the variation of exchange rates which lowers the ex-ante likelihood of adverse exchange rate moves.[5] The relative difference in size and productivity between USD- and home-currency-only borrowers is therefore smaller in countries with lower (expected/announced) exchange rate variability. I confirm this conjecture in the data. Size and productivity gaps between USD- and home-currency-only borrowers are smaller in non-floaters than in floaters. The smaller size/productivity gaps in non-floaters raises sensitivity to foreign monetary policy at the intensive margin (through weaker balance sheets) as well as at the extensive margin (higher prevalence of USD borrowers).

In summary, my findings suggest that financial frictions strengthen the Trilemma, which helps to explain in two ways how the traditional Trilemma is consistent with the global financial cycle (Rey, 2013). First, in my framework and in the data, exchange rate management is associated with an endogenous rise in foreign currency borrowing and financial vulnerability, leading to a higher sensitivity to the global

[5]While I consider risk-neutral firms, changes in the variance of the exchange rate matter because the exchange rate is log-normally distributed. Concerning the investors' view, I assume that consequent changes in the relative prices of corporate bonds do not offset the direct effects on firm incentives. This assumption is supported by the finding that the special role of the USD (Maggiori, 2017; Jiang et al., 2018) extends to the market of corporate bonds (Liao, 2020; Maggiori et al., 2020).

financial cycle. Second, exchange rate fluctuations impinge on the international transmission of financing conditions, in ways that are consistent with import-driven expenditure switching, USD invoicing and adverse balance sheet effects. Overall, exchange rates then amplify the global financial cycle for non-floaters and dampen it for floaters.

In this argument, managed exchange rates are associated with stronger spillovers, not only because local monetary policy is highjacked by the implementation of exchange rate management, but because they exacerbate financial vulnerability and forgo benefits from exchange rate adjustments. These conclusions bear important consequences for economic theory and policy makers.

For theory, my findings suggest to further integrate the literature on financial globalization and its consequences with traditional, non-financial, arguments about the benefits of exchange rate flexibility. One avenue is to shed light on the asset pricing implications of exchange rates for liabilities by exporters vs non-exporters.

For policy makers, my findings provide a balanced view on the cost and benefits of exchange rate flexibility. On the one hand, my estimates are in line with the traditional Trilemma: Exchange rate management must be expected to entail stronger monetary spillovers while a freely floating exchange rate will absorb at least partly foreign shocks. On the other hand, the stronger spillovers are driven by highly leveraged firms, which respond adversely to home currency depreciations. Exchange rate pegs beget inadequate currency mismatch and fear of floating (Calvo and Reinhart, 2002) thus becomes self-justifying. For monetary policy as well as financial stability objectives, policy tools such as macroproduential regulation and lending standards might be needed to reduce spillovers.

Non-financial firms tapping international bond markets imply that shoring up the banking sector is insufficient to insulate an economy from foreign monetary shocks. The extensive and sophisticated use of tax havens (Coppola et al., 2020) further means that even capital controls might prove illusive in the future.

Related literature. My paper contributes to the literatures on the international transmission of monetary policy and the consequences of financial globalization.

There is a broad range of macro-empirical studies analyzing international monetary spillovers. One strand focuses on spillovers to asset prices, mostly interest rates. Klein and Shambaugh (2015), Bluedorn and Bowdler (2010), and Kearns et al. (2020) find that interest rates in peggers are more responsive to foreign monetary policy. Kearns et al. (2020) show that spillovers are strongest at the long-end of the yield curve and increase with financial openness. Obstfeld et al. (2019) find that peggers are more sensitive to global financial shocks. Kalemli-Özcan (2019) shows that local credit conditions in Emerging Markets depend relatively more on capital inflows and that floating exchange rates help mitigate related monetary spillovers.[6]

Another strand examines spillovers on economic activity. Di Giovanni and Shambaugh (2008) find that peggers experience stronger spillovers than floaters while Dedola et al. (2017) do not find a significant difference. Iacoviello and Navarro (2019) find stronger spillovers for peggers within Advanced Economies but not within Emerging Economies. Ca'Zorzi et al. (2020) document financial and real spillovers from the US to Europe and vice versa. All of these studies find that US monetary tightening is associated with a drop in economic activity abroad. To the contrary, Ilzetzki and Jin (2013) find that, between 1990 and 2007, US monetary tightening was associated with a rise in foreign industrial production, in Advanced and Emerging Economies alike. I contribute to this macro-empirical literature with novel micro-data estimates of the real effects of spillovers, focusing on non-financial firms, and firm-level channels to explain heterogeneity across countries.

The micro-empirical literature on monetary spillovers focuses mostly on financial variables. Bräuning and Ivashina (2019), Temesvary et al. (2018), Morais et al. (2019), Giovanni et al. (2017) show that US monetary policy drives significantly foreign bank credit and bond issuances. Instead, I provide estimates of the real effects for a broad set of countries. Also analyzing firm-level data but focusing on the effects of exchange rates in general, Banerjee et al. (2020), Salomao and Varela (2018), Casas et al. (2020) and Bruno and Shin (2019) provide evidence that home currency depreciations affect firms adversely through balance sheet channels.

Contractionary effects of home currency depreciations have long been studied in macro theory, often with a financial accelerator-type mechanism and motivated by currency crises. (Krugman, 1999; Aghion et al. 2001, 2004; Céspedes et al., 2004) Akinci and Queralto (2018) find large monetary spillovers in a DSGE, in which weaker local balance sheets lead to larger UIP deviations, amplifying the financial accelerator.

Organization of paper. Section 3.2 describes the data. Section 3.3 introduces the empirical setup. Section 3.4 presents the main results on macro heterogeneity. Section 3.5 explores which firm-types drive the macro heterogeneity. Section 3.6 presents a simple conceptual framework to resolve the remaining puzzle and back-up the empirical findings. Section 3.7 revists the Trilemma debate. Section 3.8 concludes.

[6] Other important papers are Gilchrist et al. (2019), Burger et al. (2017), Albagli et al. (2019), Bekaert et al. (2020), Shah (2017), Bowman et al. (2015), Fratzscher et al. (2018), Ehrmann et al. (2011), Uribe and Yue (2006), and Bredin et al. (2010).

3.2 Data description

I create a quarterly firm-panel that combines Compustat Global and Worldscope data with several bond issuance data sets. On each part, Appendix C.3 contains details.

Firm-level variables. Following Ottonello and Winberry (2018), my main measure of investment is the quarterly log-change in physical capital $\Delta k_{p,t}$, where $k_{p,t}$ is the capital stock net of depreciation. I further construct standard variables such as book leverage (total debt divided by total assets), cash flow over total assets, and sales growth. Where appropriate I convert values to home currency units and deflate using the local GDP price index.

I complement the standard accounting data in two ways. First, I use Capital IQ data to enrich the information on firms' liability structure, in particular keeping track of foreign currency debt and debt issued at variable interest rates. Second, I flag firms as exporters if they report sales outside of their home country, using Worldscope's annual geographic segment data or Orbis if the former is not available.

Bond issuance data. The bond-level data is the union of three sources: Mergent Fixed Income Securities Database (FISD), SDC Platinum New Issues and Dealogic. Bond information includes dates of issuance and maturity, issuance amount, coupon, yield to maturity and currency denomination.[7] I merge the bond data with the firm-quarter panel so that I observe the bonds issued or maturing for each firm-quarter.

Country classifications. I classify countries, at quarterly frequency, as floating, managed, or pegged exchange rate regimes against the US Dollar based on the de facto scheme by Ilzetzki et al. (2019). For example, I treat the Euro, as well as currencies pegged to the Euro, as floating. In my regression analysis, I distinguish between floaters and non-floaters (managed and pegged), because I find that results for countries in the "managed" category are much closer to the "pegged" category than to floaters.[8]

For capital account policies, I use the index provided in Chinn and Ito (2006). For financial development, I use the IMF's financial development index.

Sample summary statistics. The final sample covers 10431 firms from 36 countries. From these countries, 23 are classified as high income countries and 19 as floaters (at the end of sample).[9] The number of firms per country range from 15

[7]My global bond data set is similar to and extends the ones presented in Gozzi et al. (2012), Gozzi et al. (2008), Calomiris et al. (2019), Bruno and Shin (2017).

[8]My choice of a de-facto scheme is based on the evidence in Calvo and Reinhart (2002) that actual exchange rate policy often deviates from the official one. It is also important to note that even countries with de facto pegs experience exchange rate fluctuations.

[9]Table C.19 in Appendix C.3.1 provides details. The countries are Argentina, Brazil, Chile, China, Croatia, Cyprus, Denmark, Finland, France, Germany, Greece, Hong Kong, India, Indonesia, Ireland,

	$\Delta k_{p,c,t}$		Assets(USD,m)		Debt/TA		(Mat-Debt)/Debt	
	Not-Float	Float	Not-Float	Float	Not-Float	Float	Not-Float	Float
Mean	1.83	0.41	760.5	1527.4	27.51	25.14	15.96	16.50
p25	−1.65	−1.63	100.5	136.6	13.85	11.56	1.37	1.24
p50	0.44	−0.29	264.9	387.3	26.52	23.24	5.79	6.01
p75	4.47	1.88	741.0	1313.3	39.68	36.82	22.24	23.16
SD	9.14	6.32	1447.5	3405.3	16.73	16.48	21.79	24.07

Notes: All growth rates/ratios expressed in percentage points. (Mat-Debt)/Debt is the maturing amount of USD denominated debt over liabilities, statistics computed conditional on non-zero values. TA is book value of total assets. Debt is book value of debt. $\Delta k_{p,c,t}$ is the quarterly log-change in net property, plant and equipment. The full sample standard deviation of $\Delta k_{p,c,t}$ is 8.3%. Quarterly firm data from 2003 to 2016, crises (author's update of Reinhart and Rogoff, 2009) excluded.

Table 3.1: *Summary statistics by exchange rate regime*

in Cyprus to 1201 in China, the latter contributing around 10% of total observations. Table C.5 in Appendix C.1 shows that my main finding is robust to excluding any particular country.

On average, a firm remains in the sample for 20 quarters. Utilities, financial and public sector firms are excluded. The sample starts in 2003 Q1 and ends in 2016 Q4 (limited by availability of high-frequency monetary shocks). I exclude years and countries flagged as crises by Reinhart and Rogoff (2009) and quarters with unscheduled FOMC meetings.

Tables 3.1 provides summary statistics of key firm fundamentals. Consistent with country-level data, firms in non-floaters exhibit higher, more volatile investment rates, higher leverage and are generally smaller than in floaters. The maturing debt for a given quarter and firm accounts on average for around 15% of total debt, even though the median size is smaller, around 5%. The size of maturing debt, and its distribution, appears roughly of similar size in floaters and non-floaters.

3.3 Empirical setup: Identifying real effects of spillovers

Why are firms with maturing debt more exposed? Consider the effects of an interest rate increase in a setup in which firms finance investment and maturing debt through new borrowing which is subject to a borrowing constraint. Firms whose debt structure is constant see the present values (PV) of their assets and debts fall equally. Their net worth is constant. Now consider firms that have debt maturing just at the moment of the interest rate increase, and who have to

Israel, Italy, Japan, Luxembourg, Malaysia, Mexico, Netherlands, Norway, Peru, Philippines, Poland, Singapore, South Korea, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Turkey, United Kingdom, Vietnam.

refinance at higher rates. For those firms, the PV of debts declines by less than that of assets because the newly issued debt reflects the rate change. Firms with maturing debt thus experience a drop in net worth and feasible borrowings, relative to those without maturing debt. I formalize this argument in a simple theoretical framework in Section 3.6. I combine this with the insight that the exact timing of debt maturity *within a given quarter*, whether it occurs before or after the FOMC, should be exogenous as long as it is not short-term debt.[10] The tentative FOMC schedule (link) is known usually for one year in advance (always for the "next year"), and corporate bonds usually have original maturities between 5-8 years. In addition, there are several other factors that appear more important for the exact issuance timing (and, given fixed maturity, also the exact timing of maturity), including market conditions, rebalancing of bond indices, and requirements by the deal-managing banks.[11] Figure C.2 in App. C.2.2 shows that the corporate bond maturity is approximately uniformly distributed over the FOMC cycle. Lastly, my use of monetary policy *shocks* adds an additional layer of identification as they capture the unanticipated part of monetary policy announcements.

Appendices C.4.1 and C.2.2 provide direct evidence on the effect of monetary shocks on corporate bond issuances. I show that corporate bond yields of issuances after FOMC announcements are significantly affected by the associated monetary shocks and that maturing debt raises significantly the probability of bond issuances.

Capturing maturing debt in regressions. I define a dummy variable that indicates for each firm-quarter whether the firm has debt maturing in different sub-periods of the quarter. As baseline, the dummy for firm p is defined as

$$\text{Mat}^{\$}_{p,t-1} = \begin{cases} 1 \text{ if USD debt matures between FOMC2}_{t-1} \text{ and FOMC1}_t \\ 0 \text{ otherwise} \end{cases} \tag{3.1}$$

where FOMC2_{t-1} and FOMC1_t denote the last FOMC in previous quarter and the first FOMC in the current quarter respectively. My main focus is on debt denominated in US Dollars, but I also report results based on home-currency debt. In Table C.1 in Appendix C.1, I show that my main finding is robust to varying the timing assumption.[12]

Measure of monetary policy. My baseline measure of *unexpected* changes in

[10] I am not the first one to use this timing argument. Duval et al. (2020), Almeida et al. (2012) exploit refinancing needs during the 2008 crisis and Benmelech et al. (2019) during the Great Depression. More broadly, refinancing channels of monetary policy have been studied in Greenwood (2002), Eichenbaum et al. (2018) and Wong (2019).

[11] Based on conversations with market participants involved in corporate bond issuances in London. Contacts available upon request.

[12] In defining this time period, there is a trade-off between a) capturing all firms with increased exposure (lengthening the period), b) ensuring a sharp measure focused on the FOMC announcement (shortening the period) and c) the lag with which economic consequences of financial shocks materialize. Equation 3.1 aims to offer a balanced solution.

US monetary policy, mp_t, is the high frequency response in fed funds futures around FOMC announcements provided in Jarociński and Karadi (2020). These shocks are based on *3-month-ahead* future contracts, and measure changes in policy expectations at slightly longer horizon than the traditional Kuttner (2001)-style shocks based on *current-month* futures. I find that mp_t remains highly relevant during the zero-lower bound period. During the ZLB, mp_t continues to explain roughly the same share of variation in 2-year US Treasury yields (R^2) over FOMC announcement days and, crucially, the variation in 2-year yields declined only marginally during that period relative to before 2009. (Table C.23, Appendix C.1)

Specification. I regress firm-level investment on the monetary policy shock and an interaction of the maturing debt dummy with the monetary policy shock. Equation 3.2 presents the baseline regression specification.

$$\Delta k_{p,c,t} = a_p + a_{c,t} + b_1 \text{ mp}^{\$}_{t-1} + b_2 \text{ Mat}^{\$}_{p,t} + \beta \text{ mp}^{\$}_{t-1} \times \text{ Mat}^{\$}_{p,t-1} + \tau_1 X_{p,t-1} + \tau_2 \text{ mp}^{\$}_{t-1} \times X_{p,t-1} + \epsilon_{p,t} \tag{3.2}$$

where $\Delta k_{p,c,t}$ is the quarterly log-change in net property, plant and equipment of firm p from $t-1$ to t (end of quarters) standardized by its overall standard deviation. $\text{Mat}^{\$}_{p,t-1}$ is the maturing-debt dummy defined in Equation 3.1. $\text{mp}^{\$}_{t-1}$ is the US monetary policy shock measured at FOMC2_{t-1}, the last FOMC meeting of quarter $t-1$. $X_{p,t-1}$ is a vector of controls measured at previous quarter: real sales growth, cash flow over assets, log of total assets, book leverage (debt over assets), cash holdings, variable-rate debt (both over assets), and a dummy equal to 1 if firm p has USD debt outstanding at any point over the sample. I do not control for Tobin's Q in my baseline to avoid losing observations (Appendix Table C.4 reports a robustness test). a_p and $a_{c,t}$ are firm and country×date fixed effects respectively.

Between- and within-group effects of maturing debt. Table 3.2 introduces the maturing-debt scheme. Column 1 reports benchmark results. The link between the monetary shocks and investment unconditional on firm variables is insignificant. The insignificance is not surprising because monetary policy affects investment through multiple, potentially offsetting, channels (e.g. financing, information, trade).

In column 2, the monetary shock is interacted with a dummy for USD debt and includes country×date fixed effects, absorbing all observed and unobserved quarterly fluctuations at the country level. The estimates imply that, after a 1pp surprise monetary tightening, firms with USD debt outstanding reduce their investment by 0.6 standard deviations, relative to firms without USD debt. This amounts to a -5% drop in the quarterly percentage change in physical capital. Columns 3 and 4 show that investment reductions by firms with maturing Dollar

	Dep-var: $\Delta k_{p,c,t}$			
	(1)	(2)	(3)	(4)
$\text{mp}^{\$}_{t-1}$	-0.652			
	(0.545)			
$\text{mp}^{\$}_{t-1} \times \text{USDfirm}_p$		-0.625^{**}	-0.583^{**}	-0.158
		(0.249)	(0.242)	(0.278)
$\text{Mat}^{\$}_{p,t-1}$			-0.022	-0.021
			(0.019)	(0.019)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$			-1.537^{***}	-1.586^{***}
			(0.483)	(0.505)
Country×date FE	N	Y	Y	Y
Int-Controls	N	N	N	Y
Obs	208,479	208,479	208,479	208,479
Adjusted R^2	0.148	0.173	0.180	0.181

Notes: Estimates of equation: $\Delta k_{p,c,t} = \beta\, \text{mp}^{\$}_{t-1} \times\ \text{Mat}^{\$}_{p,t-1} + \tau\, \text{mp}^{\$}_{t-1} \times \text{USDfirm}_p + \vec{a}_{p,t} + \epsilon_{p,t}$, $\Delta k_{p,c,t}$ is the log change in net PPE, normalized by its standard deviation. $\text{Mat}^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same FOMC in pp. (from Jarociński and Karadi, 2020). All specs include $\vec{a}_{p,t}$, denoting firm-, fiscal-quarter-FE and firm controls. Firm controls (at previous quarter) are real sales growth, cash flow, log assets, leverage, cash/TA, variable-rate debt/TA. Int-controls are interactions of $\text{mp}^{\$}_{t-1}$ with the latter four controls. Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises (update of Reinhart and Rogoff, 2009) excluded.

Table 3.2: *Investment, monetary shock, and maturing debt: The financing spillover channel*

debt, relative to those without, are considerably larger, on average around 1.5 standard deviations.

My estimates isolate the financing channel and do not imply that the level of investment changes by the same amount. Since the monetary shocks might work through other channels, the total effect on investment may be a smaller reduction or even an increase in investment.

Including interactions of the firm controls with the monetary shock renders the USDfirm_p-shock interaction insignificant, while it hardly changes the coefficient of the maturing×shock interaction. It highlights that the differential response by firms with USD debt per se is endogenous and that it is captured well by the interaction controls. It validates the maturing-debt-timing variable as capturing an exogenous increase in exposure.[13]

[13] Table C.13 in Appendix C.1 provides an additional exogeneity test, verifying that the firm characteristics are not significantly related to the debt maturity timing.

3.4 Macro heterogeneity

3.4.1 Heterogeneity across country groups

Table 3.3 investigates how the financing spillover channel varies across key macroeconomic dimensions: Exchange rate regime, financial openness and development.

Spillovers strongest for non-floaters with open capital account. The classic Trilemma predicts that, under free capital flows (also dubbed open capital account or financial openness), exchange rate management implies loss of monetary independence and stronger influence of foreign monetary policy.

I first assess the role of financial openness. Column 2 augments the baseline specification with a triple interaction of maturing×shock with an index of financial openness $\text{KO}_{c,t}$ from Chinn and Ito (2006). $\text{KO}_{c,t}$ is normalized such that an increase means a lower degree of openness (stronger capital controls). The coefficient on $\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$ then captures spillovers to investment conditional on openness. The estimates show that spillovers are smaller in economies that are less financially open, confirming the notion that capital controls help to insulate the economy.

In column 3, I then include a triple interaction with a dummy capturing non-floaters. $\mathbb{1}^{\text{nflt}}_{c,t}$ equals 1 if firm p's home country c does not have a floating exchange rate against the US Dollar.[14] My normalization of $\text{KO}_{c,t}$ ensures that the coefficient on $\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$ captures the hypothesis posed by the Trilemma: Conditional on financial openness, non-floating exchange rates should lead to stronger spillovers. To focus on this hypothesis, I will adhere to this specifiction in all of the remaining analysis.

In column 3, the large and negative coefficient on $\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$ confirms the hypothesis that, conditional on openness, non-floaters experience stronger spillovers. Investment reductions by firms with maturing USD debt, relative to those without, are markedly stronger in countries with non-floating exchange rates than in those with floating exchange rates. Equally important, the spillovers to floaters with open capital account (coefficient on $\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$) is still statistically and economically significant. The latter contradicts the Trilemma and confirms Rey (2013)'s argument that the global financial cycle implies that countries will always experience strong influences from US monetary policy. Importantly, these estimates identify the financing spillover channel and are not driven by e.g. correlated business cycles.

Financial development does not explain it all. A country's exchange rate

[14]"Not-floating" groups together pegs and managed exchange rates. Table C.3 shows that the effect for the sample of managed exchange rates alone lies between those for floaters and pegs, albeit clearly more closely to the peggers. I therefore keep together managed exchange rates and pegs as "non-floating."

	Dep-var: $\Delta k_{p,t}$				
	(1)	(2)	(3)	(4)	(5)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$	-1.586^{***}	-1.763^{***}	-1.268^{**}	-2.624^{***}	-2.208^{**}
	(0.505)	(0.319)	(0.621)	(0.745)	(0.956)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \text{KO}_{c,t}$		0.329	0.993^{***}	1.283^{*}	1.694^{**}
		(0.396)	(0.259)	(0.757)	(0.652)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$			-1.754^{***}		-1.234^{**}
			(0.610)		(0.551)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \text{FinDev}_{c,t}$				-1.252^{**}	-1.143
				(0.574)	(0.931)
Obs	208,479	208,479	208,479	208,479	208,479
Adjusted R^2	0.181	0.182	0.182	0.181	0.182

Notes: Estimates of Eq.: $\Delta k_{p,c,t} = \beta\, \text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} + \gamma\, \text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times Z_{c,t} + \vec{a}_{p,t} + \epsilon_{p,t}$, $\Delta k_{p,c,t}$ is the log change in net PPE, normalized by its standard deviation. $Z_{c,t} \in \{\text{KO}_{c,t}, \mathbb{1}^{\text{nflt}}_{c,t}, \text{FinDev}_{c,t}\}$. $\text{KO}_{c,t}$ measures capital openness (Chinn and Ito, 2006;higher values=less open). $\text{FinDev}_{c,t}$ is IMF yearly financial development index (higher values=less developed). $\text{KO}_{c,t}$ and $\text{FinDev}_{c,t}$ are standardized by their standard deviations. $\mathbb{1}^{\text{nflt}}_{c,t}$ equals 1 if country c has a de-facto not-floating exchange rate (from Ilzetzki et al., 2019). $\text{Mat}^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same FOMC in pp. (from Jarociński and Karadi, 2020). All specs include firm-, fiscal-quarter-, and country×date FE; and firm-, and interaction controls. Firm controls (at previous quarter) are real sales growth, cash flow, log assets, leverage, cash/TA, variable-rate debt/TA, USD-debt-dummy. Int-controls are interactions of $\text{mp}^{\$}_{t-1}$ with the latter five controls. Standard errors two-way clustered by firm and date. Quarterly data from 2003 to 2016, crises (update of Reinhart and Rogoff, 2009) excluded.

Table 3.3: *Estimates of the financing spillover channel by exchange rate regime, financial openness and financial development*

regime choice and its development status are linked endogenously. The stronger response in non-floaters might therefore simply be a reflection of different levels of financial development. In columns 4 and 5 of Table 3.3, I regress investment simultaneously on two triple interactions, the maturing×shock interacted with a dummy for non-floaters and the IMF's financial development index. The estimates show that a country's exchange rate regime remains a statistically and economically significant determinant of spillover strength when controlling for financial development.

Persistence, asymmetry, ZLB and other robustness checks. Appendix C.1 offers various robustness checks. First, to check whether the effects on investment reverse in the subsequent quarters, I estimate dynamics in the maturing×shock coefficient using local projections á la Jordà (2005). Figure C.1 in the Appendix shows that the effects are estimated to be negative consistently over time and stay statistically significant over 3 to 4 quarters. Second, Table C.12 suggests that the effects have become stronger in the ZLB period but the difference is statistically insignificant. The base effect for the pre-ZLB period remains significant. Third, tightening shocks are associated with somewhat stronger effects than easing shocks, but this difference is also statistically insignificant. Fourth, in Table C.5 I drop each country in the sample one by one. Fifth, in Table C.1 I vary the timing assumption regarding maturing debt and FOMC meetings. In both cases the main findings are robust. Sixth, Table C.2 shows that my findings remain unchanged if I estimate the maturing interaction separately on sub-samples corresponding to the country groups and normalizing the dependent variable with its country-specific standard deviation. Appendix C.2.1 offers additional discussion of results (incl. unconventional monetary policy).

3.4.2 Higher sensitivity to or of financing conditions?

Last section showed that real spillovers in non-floaters are considerably larger than in floaters, even controlling for financial development. This section highlights that my main measure of spillover strength $\widehat{\beta}^R$, the semi-elasticity of investment w.r.t. the monetary shock, summarizes multiple steps in the transmission of monetary policy.

The real spillover heterogeneity can be attributed to two factors. First, differences in the sensitivity of financing conditions. US monetary shocks cause bigger fluctuations in financing conditions for non-floaters. Second, differences in sensitivity of investment to financing conditions. Firms in non-floaters react more strongly to a unit change in financing conditions. The following stylized regression framework illustrates the point formally.

$$\text{reduced form:} \qquad \text{investment} = \beta \times \text{monetary shock} + e \tag{3.3}$$

$$\text{true model I:} \qquad \text{investment} = \kappa \times \text{financing cost} \tag{3.4}$$

$$\text{true model II:} \qquad \text{financing cost} = \theta \times \text{monetary shock} \tag{3.5}$$

$$\text{I \& II} \implies \qquad \text{investment} = \kappa \times \theta \times \text{monetary shock} \tag{3.6}$$

Equation 3.3 is a simplification of my main regression. Equation 3.4 captures that what matters for firms' investment decision is not the monetary shock itself but their actual cost of financing. In both equations, I abstract from other drivers of investment because the maturing-debt approach isolates effects due to Fed-induced changes in financing conditions. Equation 3.5 describes how US monetary policy affects financing conditions. Equation 3.6 thus concludes that, at least conceptually, my reduced-form estimates $\widehat{\beta}^R$ can be decomposed into the product

$$\beta^R = \kappa^R \times \theta^R.$$

My finding of heterogeneity in the reduced form estimates of real spillovers

($\widehat{\beta}^{\text{nflt}} < \widehat{\beta}^{\text{float}}$) could be the result of heterogeneity in the sensitivity of financing costs to US monetary shocks ($\theta^{\text{nflt}} \neq \theta^{\text{flt}}$), heterogeneity in the firms' reaction to a unit change in the financing costs ($\kappa^{\text{nflt}} \neq \kappa^{\text{flt}}$) or a combination of both.

I investigate the decomposition empirically in two exercises. First, I estimate the equations using a two-stage least square (2SLS) estimator, using country-level corporate bond yields to measure financing costs around FOMCs (see Appendix C.3 for data details). Second, I use the bond-level data used to construct the maturing-debt dummy to estimate the relationship between the yields at issuance and the US monetary policy shocks.[15]

The specification for the 2SLS incorporates the insights from the stylized framework into the previous reduced form specification. I instrument the firm financing costs with the monetary shock.[16] The exclusion restriction is that, for the firms with maturing debt, the US monetary shocks affect investment only through their effect on the financing costs. The country-level indices track local currency corporate bonds. Therefore, I broaden the definition of my maturing dummy to capture also maturing debt denominated in home currency, denoted as $\text{Mat}^{all}_{p,t-1}$. The estimated effects are smaller but significant when using the dummy only based on USD debt (consistent with correlated asset prices).

2SLS estimates of spillovers. Table 3.4 reports 2SLS-estimates. Panel 3.4a shows that the reaction to a unit change in financing costs by firms in non-floaters is still considerably larger than in floaters ($\widehat{\kappa}^{\text{nflt}} < \widehat{\kappa}^{\text{flt}}$). The second stage thereby rejects the idea that the heterogeneity in investment elasticities is entirely the result of stronger asset price reaction. The 2SLS estimates are about 3.5 times larger than the OLS estimates, which is modest according to the meta-study of IV-estimates in Jiang (2017). In economic terms, the 2SLS estimates are expected to exceed the OLS estimates as endogenous variations in the corporate bond yields are likely to bias downward the OLS coefficient on $\Delta \text{fc}_{p,t} \times \text{Mat}^{\text{all}}_{p,t-1}$.[17]

[15] For 2SLS, I cannot use the corporate bond issuance yields for two reasons. First, it only includes yields of newly issued bonds, not of those alreay trading. This means that, for each firm, I do not observe its financing costs in quarters in which it did not issue a bond. Second, since I capture financing conditions only conditional on issuance, these yields are biased because I miss the "counterfactual issuances" by firms that decided not to issue or were not able to issue, e.g. due to market conditions.

[16] Technically, because of the fixed effects in my specification, I instrument the interaction between the maturing-debt dummy and firm financing costs with the interaction between the maturing-debt dummy and the monetary shock.

[17] For example, consider the arrival of positive news about the economy's prospect. A direct effect is that firms raise investment because they expect higher demand. This will apply to all firms. The coefficient on $\Delta \text{fc}_{p,t} \times \text{Mat}^{\text{all}}_{p,t-1}$ reflects the indirect effect of the news on investment via its impact on financing conditions (felt more strongly by firms with maturing debt). First, the direction of the indirect effect is ambiguous. Yields might rise if monetary tightening is anticipated, or fall if risk premia compress. Second, if the direct and indirect effects work in the same direction, it will depend on their relative magnitude. Thus, the effect of $\Delta \text{fc}_{p,t} \times \text{Mat}^{\text{all}}_{p,t-1}$ is more ambiguous if $\Delta \text{fc}_{p,t}$ is not

(a) *Second stage: $\widehat{\kappa}^R$, investment response to instrumented financing costs*

	Dep-var: $\Delta k_{p,c,t}$			
	OLS	2SLS	OLS	2SLS
$\Delta \text{fc}_{t-1,c} \times \text{Mat}^{\text{all}}_{p,t-1}$	-0.357^{**}	-1.269^{**}	-0.602^{***}	-2.052^{**}
	(0.146)	(0.599)	(0.182)	(0.805)
Country	Float	Float	Non-Float	Non-Float
Obs	70,604	71,774	135,401	136,705
Adjusted R^2	0.167	0.161	0.196	0.194

(b) *First stage: $\widehat{\theta}$, response of financing costs to US monetary shock*

	Dep-var: $\Delta \text{fc}_{c,t}$	
$\text{mp}^{\$}_t$	0.684^{***}	1.129^{***}
	(0.099)	(0.375)
F-stat	895.47	87.85
Country(R)	Float	Non-Float
Adjusted R^2	0.213	0.130

Notes: 2SLS estimates of Eq.: $\Delta k_{p,c,t} = \kappa^R \Delta \text{fc}_{t-1,c} \times \text{Mat}^{all}_{p,t-1} + \vec{a}_{p,t} + \epsilon_{p,t}$, $\Delta \text{fc}_{t-1,c}$ denotes the change in domestic corporate bond yields of country c over the last FOMC announcement of previous quarter. $\Delta k_{p,c,t}$ is the log change in net PPE, normalized by its standard deviation. $\text{Mat}^{all}_{p,t-1}$ is a dummy equal to 1 if firm p had debt maturing after the last FOMC in previous quarter. mp_t is the monetary shock from same FOMC in pp (from Jarociński and Karadi, 2020). Includes triple interaction with openess index $\text{KO}_{c,t}$ (Chinn and Ito, 2006), thus estimates of maturing interactions are conditional on financial openness. All specifications include $\vec{a}_{p,t}$, denoting firm-, fiscal-quarter-, country×date FE; and firm-, and interaction controls. Null of weak instruments is rejected if the F-Stat exceeds the critical value 16.38 (Stock and Yogo, 2002,10% maximal relative bias, 1 endogenous regressor, 1 instrument). Standard errors two-way clustered by firm and quarter. Quarterly data from 2003 to 2016, crises (update of Reinhart and Rogoff, 2009) excluded.

Table 3.4: *2SLS estimates of investment response to financing costs*

Panel 3.4b presents the 1st stage estimates. The null of weak instruments is strongly rejected. Surprise US monetary tightening is associated with significant increases in local curency corporate bond yields. The reaction is stronger for non-floaters $\widehat{\theta}^{\text{nflt}} > \widehat{\theta}^{\text{flt}}$, confirming the notion that the heterogeneity in investment elasticities ($\widehat{\beta}^{\text{nflt}} < \widehat{\beta}^{\text{float}}$) is partly due to stronger sensitivity of financing costs. I confirm the finding in analog regressions using a country×FOMC panel, in Table C.22 in Appendix C.4. At the same time, the monetary shock explains a higher share of the variation in financing costs in floaters, which can be attributed to more volatile yields in non-floaters. Even though the Fed-induced yield variation is smaller, relative to total variation, in non-floaters than in floaters, it has a stronger impact on investment in the second stage. The difference in R^2 thus supports the economic argument why the 2SLS-estimates exceed OLS.

instrumented.

Spillovers to yields of USD-denominated corporate bonds. Due to data constraints, I have to assume in the 2SLS exercise that the reaction of financing conditions is the same for all firms within a given country. I further have to focus on the yields of local currency bonds because long time series on yields of USD-denominated corporate bonds are sparse even at the country-level. To alleviate concerns arising from these assumptions, I estimate the relationship between the monetary shocks and corporate bond yields at time of issuance from my bond issuance data set. Appendix C.4.1 reports the results and details. I find that the yields of USD-denominated corporate bonds react significantly to the US monetary shocks. The relationship appears stronger for non-floaters, but the relationship is noisy and statistically insigificant. Even when taking the estimates at face value, they imply that the stronger asset price response would not be enough to explain away the heterogeneity in reduced-form estimates of the investment elasticities.

Appendix C.4.4 summarizes several papers that provide evidence related to θ and how it varies across country groups. While these studies mostly examine spillovers to government bond yields, they support the notion that asset price reaction is stronger in non-floaters (and in EMEs as is often the focus) but that the relative magnitude is too small to match the heterogeneity in investment elasticities.

3.5 Macro-firm heterogeneity

Real spillovers are around 3 times larger in non-floaters than in floaters (Section 3.4.1). Two factors explain each around half of the stronger spillovers in non-floaters (Section 3.4.2): First, US monetary shocks cause larger fluctuations in financing conditions. Second, and more surprisingly, a unit change in financing conditions is associated with larger investment reductions.

In this section, I investigate why firms in non-floaters react more strongly than firms in floaters, even after accounting for the stronger asset price response. I estimate the real effects conditioning simultaneously on firm characteristics and the exchange rate regime. The two natural candidate dimensions to investigate are firm balance sheets and international trade activity.

I will do so in terms of the reduced form estimates of investment semi-elasticities β, not κ, for two reasons. First, my data on the financing costs is at the country-level and therefore insufficient to estimate the decomposition by firm-type. Second, the empirical literature suggests that the stronger asset price reaction in certain country groups is an aggregate phenomenon. While investors differentiate between Emerging markets with strong and weak fundamentals, they categorically increase and reduce exposure to certain country types as an asset class. (Burger et al., 2015; Burger et al., 2017) This notion is further supported by the large body of evidence emphasizing the importance of global factors in driving capital flows. (Forbes and Warnock, 2012; Rey, 2013; Miranda-Agrippino and Rey, 2015)

Balance sheets and trade exposure. I estimate the coefficient on the triple interaction $\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$ on different subsamples of firms based on leverage and exporter status. Since I also control for the triple interaction with $\text{KO}_{c,t}$, $\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$ captures the hypothesis posed by the Trilemma: Conditional on financial openness, non-floating exchange rates should lead to stronger spillovers.

Firm type classifications. I label firms as "high leverage" if their net leverage (debt minus cash over assets) was above the median net leverage computed over all firms. The complement set of firms are labelled as "low leverage." As baseline, I sort on the lagged 4-quarter rolling average of net leverage (Appendix Table C.6 shows robustness under alternatives).

I label firms as exporters if, at any point during the sample period, they report sales abroad.[18] Non-exporters are firms that do not report international sales. I discuss below that both exporters and non-exporters can be importers. Utility firms (usually non-exporters) are excluded, ensuring that they do not bias the comparison.

The sample covers 50 quarters (without unscheduled FOMCs) and around 9400 cases of maturing USD debt (51% in floaters, 49% in non-floaters). Thus, on average 94 per quarter and regime, allowing for accurate estimates of the heterogeneity.

Leverage drives stronger spillovers in non-floaters. Table 3.5a shows that the stronger response by non-floaters visible in Table 3.3 is driven by firms with high net leverage. While firms with high leverage react more strongly under both exchange rate regimes, the difference is considerably larger in non-floaters. I find that the result is neither driven by different country compositions across subsamples (Table C.6), nor by shares of short-term debt, bond debt or cash holdings (Table C.10). The stronger responses by high-leverage firms, relative to low leverage firms, is consistent with Jeenas (2018)'s evidence for US data. Ottonello and Winberry (2018) show that the opposite holds for *within-firm* leverage variations.

Table 3.5b shows that both exporters and non-exporters reduce their investment significantly after US tightening, which holds for floaters and non-floaters alike. Unlike the sample split by leverage, it is not clear that one particular subset of firms (exporters or non-exporters) is driving the floater-vs-non-floater gap. The fact that the empirical distribution of leverage is similar for exporters and non-

[18]Regional sales splits are often reported irregularly and in non-standardized ways, making a time-varying measure infeasible. International trade relationships require fixed costs, thus it is unlikely that firms switch exporter status often.

exporters (Table C.17) helps to explain why the floater/non-floater gap is more similar between exporters and non-exporters. The leverage results holds also within exporters. The floater/non-floater gap is larger among high leverage exporters than for low leverage exporters.

The dominance of leverage is not obvious. One might argue that, since the maturing-debt identification isolates the *financing spillover channel*, it is natural that leverage turns out to be the key firm characteristic. However, leverage is the result of firm optimization and it is not obvious that firms with high leverage are more vulnerable. This holds particularly true for foreign currency borrowing, which may entail additional costs such as financial exposure to exchange rate fluctuations.

The financing spillover channel and exchange rates. I have so far neglected that exchange rates react significantly to US monetary surprises (see Appendix C.4 for evidence). Table 3.5 reports estimates of a specification that includes interactions of the maturing-debt dummy with the exchange rate responses, $\text{mp}^{ER}_{c,t-1} \times \text{Mat}^{\$}_{p,t-1}$, where $\text{mp}^{ER}_{c,t-1}$ is the change of the bilateral exchange rate of country c vis-a-vis the US Dollar over the FOMC announcement day ($\text{mp}^{ER}_{c,t-1} > 0$ means USD appreciation).

Crucially, the coefficient on $\text{mp}^{ER}_{c,t-1} \times \text{Mat}^{\$}_{p,t-1}$ captures *how spillovers via firm financing conditions depend on the exchange rate change*. Consequences of exchange rate fluctuations are captured only through their immediate impact on firm financing conditions because the maturing-identification isolates the *effects due to changes in financing conditions* caused by US monetary policy. Exchange rate channels unrelated to financing conditions are absorbed in the fixed effects.

Changes in coefficients on maturing×monetary shock. Controlling for the exchange rate adjustment has interesting implications for the main coefficient β on $\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$. Generally, the effects of interest rates on investment become larger in magnitude for floaters and smaller for non-floaters. The increase in magnitude of the maturing×shock coefficient for floaters means that, US tightening without home depreciation leads to stronger investment reductions than a US tightening with home depreciation, suggesting that the respective firms benefit from the exchange rate adjustment. The benefits for floaters are particularly strong for low leverage firms, for which the interest-rate-maturing coefficient increases by 60%, from −0.943 to −1.528. Instead, for non-floaters, the effect of the monetary shock on investment becomes smaller when controlling for the exchange rate response. A Fed hike without home depreciation leads to smaller investment reductions than a Fed hike with home deprecation.

Exchange rate effects. In Table 3.5, the estimated coefficients on $\text{mp}^{ER}_{c,t-1} \times \text{Mat}^{\$}_{p,t-1}$ capture investment responses to a Fed-induced home depreciation by

(a) *sample splits by firm leverage*

	Dep-var: $\Delta k_{p,t}$			
	(1)	(2)	(3)	(4)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$	-1.769^{**}	-2.081^{**}	-0.943^{**}	-1.528^{**}
	(0.760)	(0.803)	(0.375)	(0.616)
$\text{mp}^{\text{ER}}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$		0.031		0.054
		(0.057)		(0.044)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$	-2.881^{***}	-1.783^{*}	-1.089	-0.354
	(0.805)	(0.898)	(1.183)	(1.382)
$\text{mp}^{\text{ER}}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$		-0.123^{**}		-0.082
		(0.048)		(0.073)
Firm group (R)	High Lev	High Lev	Low Lev	Low Lev
Obs	104,063	104,063	101,933	101,933
Adjusted R^2	0.169	0.169	0.218	0.218

(b) *sample splits by exporter status*

	Dep-var: $\Delta k_{p,t}$			
	(1)	(2)	(3)	(4)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$	-0.823^{**}	-1.199^{*}	-2.038^{**}	-2.489^{***}
	(0.356)	(0.648)	(1.004)	(0.710)
$\text{mp}^{\text{ER}}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$		0.048		0.089^{**}
		(0.060)		(0.038)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$	-1.920^{*}	-0.985	-1.714	-1.044
	(1.012)	(1.196)	(1.407)	(1.956)
$\text{mp}^{\text{ER}}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$		-0.095		-0.154^{**}
		(0.067)		(0.072)
Firm group (R)	Export	Export	Non-Export	Non-Export
Obs	115,229	115,229	93,250	93,250
Adjusted R^2	0.164	0.164	0.240	0.240

Notes: Estimates of Eq.: $\Delta k_{p,c,t} = \vec{\beta}^R \, \text{Mat}^{\$}_{p,t-1} \times \begin{pmatrix} \text{mp}^{\$}_{t-1} \\ \text{mp}^{\text{ER}}_{c,t-1} \end{pmatrix} + \vec{\gamma}^R \, \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t} \times \begin{pmatrix} \text{mp}^{\$}_{t-1} \\ \text{mp}^{\text{ER}}_{c,t-1} \end{pmatrix} + \vec{a}_{p,t} + \epsilon_{p,t}$

Columns 2 and 4 augment the baseline with $\text{mp}^{\text{ER}}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$, the home currency depreciation after FOMCs interacted with the maturing dummy. "High Lev" contains firms with net leverage above median; "Export" sample contains firms which report international sales. $\Delta k_{p,c,t}$ is the log change in net PPE, normalized by its standard deviation. $\mathbb{1}^{\text{nflt}}_{c,t}$ equals 1 if country c has a de-facto not-floating exchange rate (from Ilzetzki et al., 2019). $\text{Mat}^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. mp_{t-1} is the high-frequency response of fed futures from same FOMC in pp (from Jarociński and Karadi, 2020). Includes triple interaction of $\text{mp}^{\$}_{t-1}, \text{Mat}^{\$}_{p,t-1}$ with openess index $\text{KO}_{c,t}$ (Chinn and Ito, 2006), thus estimates of maturing interactions are conditional on financial openness. All specifications include $\vec{a}_{p,t}$, denoting firm-, fiscal-quarter-, country×date FE, firm controls and interactions thereof with $\text{mp}^{\$}_{t-1}$ and $\mathbb{1}^{\text{nflt}}_{c,t}$. Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises (updated Reinhart and Rogoff, 2009) excluded.

Table 3.5: *Investment response ($\widehat{\beta}^R$) by exchange rate regime and firm types*

firms with maturing debt, relative to those without. It is generally estimated negative for non-floaters and positive for floaters, confirming the conjecture that exchange rate fluctuations amplify the financing channel for non-floaters and dampen it for floaters. For interpretation, it is important to recall that I control for the interest rate shock and its interaction with the maturing-variable. Three observations stand out in the leverage- and trade-subsamples:

1) First, the negative effects of home depreciation in non-floaters are consistent with adverse net worth effects due to currency mismatch on firms' balance sheets (Aguiar, 2005; Salomao and Varela, 2018; Casas et al., 2020; Banerjee et al., 2020). This interpretation is supported by the fact that the effects are statistically significant only for non-exporters and high-leverage firms. It is also consistent with Alfaro et al. (2019) who finds that financial vulnerability to home depreciation is increasing with firm leverage.

2) Second, for exporters, the insigificance of exchange rate effects is consistent with evidence on USD invoicing (Goldberg and Tille, 2008; Ito and Chinn, 2013; Gopinath, 2015). Revenues invoiced in Dollars preclude benefits from competitiveness gains but provide a natural hedge for USD liabilities.

3) Third, non-exporters in floaters with maturing debt raise investment after the home depreciation, relative to non-exporters without maturing debt.

I argue that observation 3 is consistent with that non-exporters' financing conditions reflect improved sales prospects. To understand why non-exporters' sales might improve, consider the effects of a home currency depreciation (Dollar strength) if all international trade is invoiced in US Dollars. While the prices of and foreign demand for domestically produced export goods are unaffected, the price of imported goods increases in home currency terms as the Dollar strengthens. The importers will respond by switching towards domestic substitutes. This is the import-driven trade balance adjustment as argued for by the invoicing literature (Goldberg and Tille, 2008; Gopinath, 2015). By definition, non-exporters only have domestic sales and therefore benefit relatively more from the boost in demand for domestic goods than exporters whose international sales stagnate.[19] Indeed, Table C.16 in Appendix C.1, shows that, for floaters, home depreciations are associated with higher sales' growth for non-exporters relative to exporters and that this differential is increasing in the home country's share of imports invoiced in US

[19] Obstfeld (2001) suggests that substitution away from imports might be done not only by households but also by firms. If non-exporters are themselves importers, they will also experience an increase in their input costs and potentially switch to domestic substitutes too. If exporters have a relatively high share of domestic sales, and a low share of imported inputs, they might benefit more from such import-driven expenditure switching. This is unlikely however, in light of evidence that large exporters are often also large importers (Amiti et al., 2014).

Dollars. Note that the increased sales per se are common to all non-exporters and absorbed in the fixed effects. It is to the extent that financing conditions reflect the increased sales that firms with maturing debt are more affected by it.

Pegs vs crawls, financial development and homogenous fixed effects. Table C.7 shows that the exchange rate effects strengthen when excluding pegs, such that non-floaters represent only managed exchange rates.[20] Table C.8 shows that the leverage-result persists when controlling for financial development. Table C.9 shows the leverage result also holds when using an interaction term for high-leverage over the full sample, restricting fixed effects be the same for high- and low-leverage firms.

3.6 Rationalizing real spillover heterogeneity

The remaining puzzle. The stronger spillovers in non-floaters arise from firms with high leverage that respond more strongly in non-floaters than in floaters. Exchange rate fluctuations contribute to this because they amplify the financing channel for high-leverage firms in non-floaters but not in floaters. Rational firms anticipate the consequences of their leverage and USD debt. This section presents a simple conceptual framework of firms' currency choice in borrowing. It explains why firms are willing to accept the increased exposure to monetary policy, and how this decision depends on the exchange rate regime.

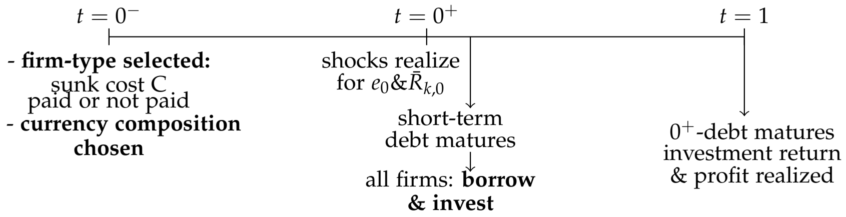
Implications of empirical findings for model choice. My empirical approach blends out macroeconomic factors that affect all firms equally. I also currently do not assess the consequences of the firm-level effects for macroeconomic aggregates and how they feedback to a government's decision to peg. Therefore, I will focus on partial equilbrium. Furthermore, I will consider currency choice without hedging of the exchange rate risk because my estimates imply that firms in non-floaters do experience adverse balance sheet effects due to home currency depreciations. Lastly, I will abstract from the interaction of the currency choice in borrowing and the choice to engage in international trade (and currency choice therein) because the adverse effects of home depreciation are strongest for non-exporters (in non-floaters).

3.6.1 Setup

A small open economy is populated with a continuum of risk-neutral firms. Firm p's optimization problem is to decide how much to borrow and the currency de-

[20] Relative to crawls or bands, "hard" pegs are naturally associated with smaller and less frequent exchange rate fluctuations (Appendix Table C.18) but they can still be substantial. Therefore, and for continuity in my analysis, I include pegs in my baseline analysis.

nomination of debt, US Dollar or Euro (home currency). This borrowing finances investment X_p in a linear technology A_pX_p and a cash outflow related to debt rollover. Figure 3.1 illustrates the timing. Each firm starts at $t = 0^-$ with cash



Notes: Illustration of timing assumptions. Bold letters indicate endogenous firm choices.

Figure 3.1: *Model timeline*

holdings E_p and pre-existing debt $Q_{p,\text{-}1}$. A fraction γ of pre-existing debt is maturing at $t = 0^+$, the complement $1 - \gamma$ matures at $t = 1$. Pre-existing debt consists either only of Euro-denominated debt or a combination of Euro and Dollar debt, depending on firm type (more below). Each firm thus faces a flow-of-funds identity

$$\underbrace{X_p + \gamma Q_{p,\text{-}1} R_{\text{-}1,w}}_{\text{cash outflows at } t=0^+} = \underbrace{E_p}_{\text{cash}} + \underbrace{Q_{€,p} + Q_{\$,p} e_0}_{\text{borrowing in period } t=0^+}. \tag{3.7}$$

e_0 is the exchange rate expressed as Euros per 1 US Dollar. The fractions γ and $1 - \gamma$ of pre-existing debt may be interpreted as "short-term" and "long-term" debt respectively. An alternative interpretation is that the firms inherit debts with the same original maturity –but different remaining maturity– from earlier generations.

Debt contracting. Only a fraction ϕ of future income can be pledged to investors, implying a borrowing constraint in the spirit of Kiyotaki and Moore (1997). Using the flow-of-funds identity, the constraint is

$$Q_{\$,p} R_{\$p} e_1 + Q_{€,p} R_{€p} \leq \phi A_p (Q_{\$,p} e_0 + Q_{€,p}) + \xi_p, \tag{3.8}$$

where $\xi_p = \phi A_p (E_p - \gamma Q_{p,\text{-}1} R_{p,\text{-}1}) - (1 - \gamma) Q_{p,\text{-}1} R^2_{p,\text{-}1}$ is a convenient compound-parameter, summarizing how the exogenous firm-specific parameters, financial friction ϕ and maturity structure γ combine to the firm's exogenous "starting capital."

Issuing foreign currency debt. My approach to endogenize the currency composition of debt follows closely Maggiori et al. (2018). To issue debt denominated in US Dollar, the firm has to pay a fixed, sunk cost C. C captures long-term costs, e.g. legal work for prospectuses or building up an investor base. Interest rates are currency- and firm-specific, linearly increasing in the amount debt $Q_{p,k}$ in currency

$k \in \{€, \$\}$

$$R_{k,p} = \bar{R}_{k,t} + \frac{\Gamma_k}{E_p} Q_{p,k} \tag{3.9}$$

$\bar{R}_{k,t}$ represents a benchmark rate for corporate bonds in currency k, like the country's government bond yields. The levels of benchmark interest rates, $\bar{R}_{\$,t}$ and $\bar{R}_{€,t}$ are log-normally distributed. The time-0 exchange rate e_0 loads on the US-rate shock. I impose that a *risk-adjusted* form of the uncovered interest rate parity holds in expectations, $E(\bar{R}_{\$,t}\frac{e_1}{e_0}) = E(\bar{R}_{€,t})$. See Appendix C.5.1.1 for details.

I assume $\Gamma_€ > \Gamma_\$ > 0$ which signifies a benefit of issuing in US Dollars, relative to in Euros, even if the UIP holds.[21]

Optimization problem. Firm p maximizes its profit $\pi_{p,t=1}$

$$\max_{\{Q_{p,€}, Q_{p,\$}\}} \quad E_{t=0^-}\Big(A_p X_p - R_{€,p} Q_{€,p} - R_{\$,p} Q_{\$,p} e_1 - (1-\gamma) Q_{p,\text{-}1} R^2_{p,\text{-}1} - C\ \mathbb{1}_{Q_{p,\$}>0}\Big),$$

subject to the borrowing constraint, flow-of-funds, and debt demand curves. In this simple frame, firm p's uncertainty about $\pi_{p,t=1}$ is coming exclusively from the shocks to benchmark rates $\bar{R}_{\$,t}$ and $\bar{R}_{€,t}$.

Solution. The firm problem can be solved by first characterising the optimal choices of the two types of firms. One type will borrow only in home currency. The other type will borrow in both currencies. Each firm then selects its type by comparing expected profits under both types. Firms learn their productivity, size and starting capital at $t = 0^-$, so the only source of uncertainty are the levels of the benchmark rates and exchange rate.[22] Appendix C.5.2 provides details.

3.6.2 Equilibrium outcomes

Two firm types arise endogenously. The first type, home currency firms, borrow only in their home currency Euro (henceforth HC firms). The second type, multi-currency firms, borrow in both Euro and US Dollars (MC firms). Before exploring the firm type selection, I will revisit my identification approach through the model's lens.

[21] Maggiori et al. (2018) microfound this assumption with the argument that the response of interest rates to changes in the supply of debt are weaker for currencies' which attract a large pool of wealth from investors ("deep markets"). An alternative motivation for the positive slope could be risk-considerations by investors. The empirical literature on currency choices also highlights hedging of operational cash flows (Allayannis et al., 2003,Graham and Harvey, 2001,Géczy et al., 1997). McBrady and Schill (2007) finds evidence of financial return motives by public sector issuers.

[22] For each type, the borrowing constraint may bind or not bind not. When evaluating profit expectations, each firm takes into account the probability that it may become constrained.

3.6.2.1 Exogenous and endogenous sources of heterogeneity

Heterogeneous effects due to maturing debt. Consider the example of a surprise increase in $\bar{R}_{€}$ at $t = 0^+$. For both firm types, the higher interest rate will be associated with lower investment. Importantly, the model shows that the reduction in investment will be larger, the more maturing debt the firm has. This is illustrated in Figure 3.2a. Appendix C.5.3.2 discusses analytical expressions.

Interest rate increases reduce the present value (PV) of both assets and outstanding debt. For firms without maturing debt ($\gamma = 0$), the fall in PVs of assets and "old" debt perfectly offset each other, leaving net worth unchanged. Instead, if $\gamma > 0$, the maturing debt is replaced with new debt. Since the interest rate paid on new debt will reflect the rate change, the present value of the total debt (remaining old+new) will fall by less than under $\gamma = 0$. Therefore its net worth will fall by more. If the firm's borrowing constraint binds, the net worth reduction translates to lower feasible borrowings and lower investment.[23] This net worth channel holds qualitatively for both home- and multi-currency firms and home and US monetary shocks.

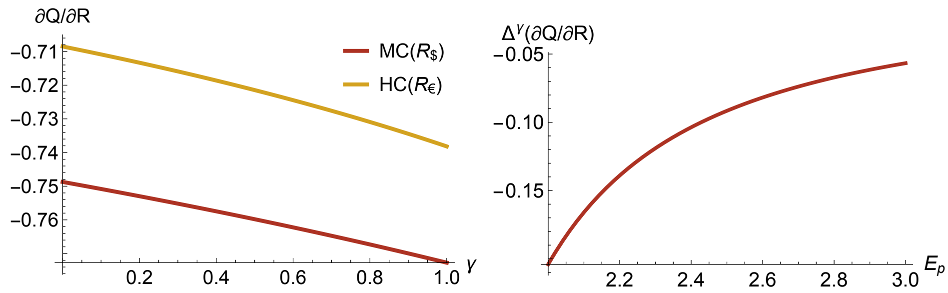
In the model, MC firms face an additional cash flow reduction because the Dollar strength ensuing US monetary tightening raises the repayment value of maturing debt in home currency terms. In reality, similar cash flow affects can arise for both firms due to higher interest expenses on the newly issued debt, or any gap between the amounts of maturing debt and new issuance.

To map the model concretely to the data, firms that have debt maturing shortly after the FOMC can be thought of as having $\gamma > 0$, and firms without maturing debt as $\gamma = 0$. The exact *timing of debt maturity* (before/after an FOMC) is arguably exogenous because the average original maturity of corporate bonds is around 4-8 years, an horizon at which firms cannot anticipate the precise timing of the FOMC, let alone the interest rate decision taken. This is the central identification argument used in this paper. Firms with debt maturing shortly after an FOMC announcement will be more exposed to it than firms that do not.

Maturing effect by firm characteristics. Figure 3.2b plots Δ^{γ}, the differential response of a firm with maturing debt relative to without, against initial cash E_p. Δ^{γ} is the model-analog to the coefficient on the maturing×shock interaction in the empirics. As E_p increases, leverage endogenously decreases. This makes net worth losses conditional on maturing debt smaller, and hence the jump in responsiveness due to maturing debt gets smaller. The way Δ^{γ} changes over the range of E_p is

[23]Generally speaking, the maturity structure of a firm as well as the amount of rollover risk taken, are endogenous choices. However, γ can be thought of as indicating the maturity of debt issued at earlier time but with same original maturity as the remaining old debt stock. The different interpretation of γ does not change the predicted heterogeneity in effects due to γ, but it is crucial for empirical identification.

(a) *by share of maturing debt* **(b)** *maturing vs not-maturing gap by E_p*



Notes: Subfigure 3.2a plots the partial derivatives $\partial\widehat{Q}_{p,hc,€}/\partial\bar{R}_€$ and $\partial\widehat{Q}_{p,mc}/\partial\bar{R}_\$$ against γ, the share of pre-existing debt maturing at $t = 0^+$. Subfigure 3.2b plots the difference in partial derivatives $\Delta^{\gamma}_{p,mc} = (\partial\widehat{Q}_{p,mc}/\partial\bar{R}_\$)|_{\gamma=1} - (\partial\widehat{Q}_{p,mc}/\partial\bar{R}_\$)|_{\gamma=0}$, (the within-firm maturing effect) for a spectrum of MC firms differing by initial cash E_p. Derivatives are scaled such that the y-axis represents changes in borrowing in response to a 1% increase in the gross interest rates.

Figure 3.2: *Comparative statics on borrowing response to monetary shock*

analog to estimating the coefficient on different subsamples, i.e. leverage-groups.[24]

Endogenous determinants of heterogeneity. The endogenous selection into firm-types generates a spectrum of heterogenous responses, which is explained not only by the different exposures of the firm types but also by the drivers of the selection. In other words, MC firms respond more strongly to US monetary policy than HC firms, not only because they have outstanding US Dollar debt but also because they are "fundamentally different." A counterfactual MC firm without US Dollar debt would still react differently than a HC firm because it is more productive/larger.

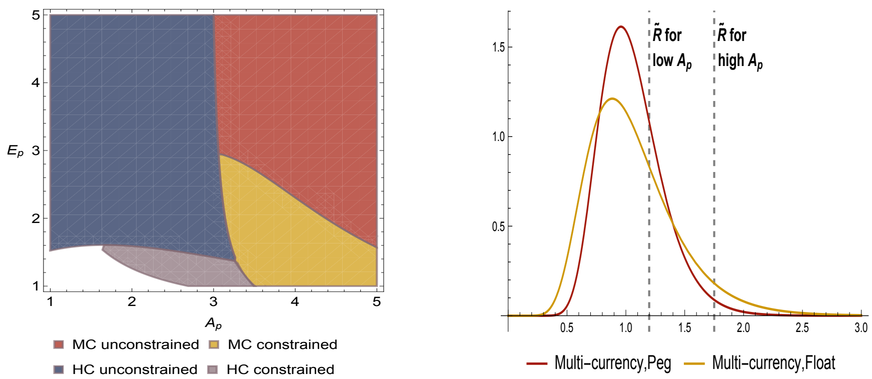
3.6.2.2 Firm-type selection and exchange rate regime

Firm-type selection. The endogenous selection into firm-types is governed by two channels. The *fixed cost channel* implies that large and cash rich firms are more likely to tap the US Dollar debt market because they can afford the fixed costs more easily. Instead, the *resiliency channel* represents the trade-off faced by the firms between lower funding costs and exposure to more shocks. More productive, or cash rich, firms can cope better with the increased exposure to shocks and therefore more likely to become a multi-currency firm.

Figure 3.3 illustrates these channels. Subfigure 3.3a illustrates the *fixed cost channel*. I switch off uncertainty about interest rates and plot the regions of each firm-type in the parameter space for initial cash and productivity. (Appendix C.5.4.1 contains derivations.) Multi currency firms are those with highest initial

[24]In the model, I define leverage as Q_p/ξ_p, i.e. borrowing amount over initial net worth. It is an endogenous variable that is decreasing in E_p and increasing in A_p.

(a) *Firm-types in parameter space* **(b)** *Density & threshold of borrowing rate*



Notes: Subfigure 3.3a plots regions in parameter space (E_p, A_p) associated with different firm types. Other parameters are fixed, stochastic variables kept at expected values. Subfigure 3.3b plots the distribution of the multicurrency benchmark rate under floating and pegged exchange rate regime (see main text for details). Vertical bars are threshold benchmark rates above which the borrowing constraint would become binding.

Figure 3.3: *Firm characteristics, uncertainty and firm-types*

cash endowments or highest productivity, or both, illustrating the standard fixed cost channel of firm type selection. Large and cash rich firms are more likely borrow in US Dollars because they can pay more easily for the fixed costs.

Subfigure 3.3b illustrates the *resiliency channel*. The key interaction of firm characteristics with uncertainty concerns whether the borrowing constraint is binding or not.[25] I solve the condition under which the borrowing constraint binds, $\widehat{Q}^c_{p,\cdot} < \widehat{Q}^u_{p,\cdot}$, for threshold benchmark rates $\widetilde{R}_{p,k}$. If the realized benchmark rate is above the threshold, $\bar{R}_{k,t} > \widetilde{R}_{p,k}$, firm p will be constrained. The threshold rates $\widetilde{R}_{k,p}$ depend on firm characteristics. The more productive the firm, the deeper is the threshold in the tail of the distribution (e.g. right-hand vertical bar in 3.3b), meaning it can sustain higher rate realizations before becoming constrained. This is the "resiliency channel" of firm-type selection. More productive firms are better able to deal with the increased exposure to shocks resulting from US Dollar borrowing and thus more likely to do so.

Role of exchange rate regimes. Subfigure 3.3b also illustrates how the exchange rate regime choice may affect the resiliency channel. It plots the distribution of the multi-currency benchmark rate under a floating and a managed exchange rate regime.[26] The multi-currency benchmark rate's variance is smaller under the

[25]In this setup, when considering mean-preserving shifts in uncertainty, the probability that the constraint is binding is a sufficient statistic for the impact of uncertainty on expected proftability and hence the firm-type selection. Appendix C.5.2 provides more discussion.

[26]See the Appendix for details on the distribution (C.5.2.4) and on parameters related to exchange rate policy (C.5.1.2). In this simple model with two stochastic shocks (one for each currency's benchmark rate), I define a managed exchange rate regime as one where the exchange rate loads only weakly on the interest rate shock (which reduces the variance of the exchange rate). Consistent with the Trilemma trade-off and evidence thereof, the managed exchange rate regime is also characterised

pegged exchange rate regime, reducing the probability of becoming constrained relative to the floating regime. This reduction in uncertainty benefits relatively more the firms with low productivity (left-hand vertical bar) than those with high productivity (right-hand vertical bar). Exchange rate management thus dampens the resiliency channel, predicting that the size/productivity gap between HC and MC firms should shrink.

Two remarks are at order. First, since the effects of exchange rate management on the resiliency channel vary across the spectrum of firms, it would be interesting for future work to derive the aggregate effect based on countries' firm productivity/size distributions. Second, to isolate the effects of changing uncertainty, the comparison of exchange rate regimes in 3.3b considers mean-preserving uncertainty changes. Appendix C.5.1.2 suggests that potential shifts in first moments of borrowing costs would further raise the attractiveness of US Dollar borrowing under exchange rate management.[27]

Role of capital account regimes. Capital controls may be interpreted as impacting the size of the fixed cost C to issue foreign currency debt. The reason is that, under stringent capital controls, firms have to construct complex legal frameworks or resort to tax havens to borrow from foreigners. Coppola et al. (2020) provide related empirical evidence. In this sense, tighter capital controls are predicted to be associated with larger size/productivity gaps between HC and MC firms.

3.6.3 Validating model implications

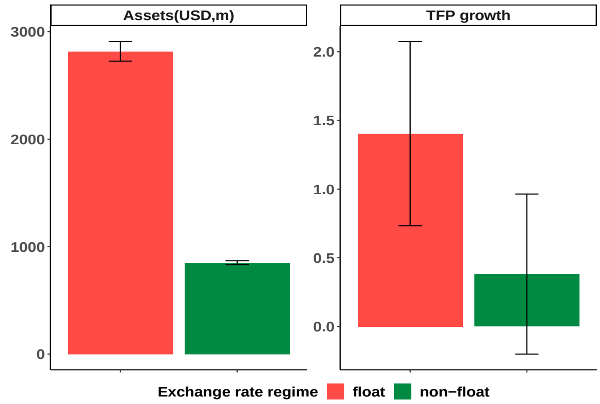
The model rationalizes my finding of stronger spillovers in non-floaters by showing that limited exchange rate variability allows ex-ante weaker firms to borrow in foreign currency, which leads to higher financial vulnerability to monetary spillovers.

In the model, regardless of the exchange rate regime, firms borrowing in foreign currency are on average larger and/or more productive than firms borrowing only in home currency. This size/producivity gap between home- and multi-currency firms are decreasing with a) the fixed costs required to borrow in foreign currency and b) with the expected exchange rate variability.

To provide a first, crude empirical validation of these model implications, I compare average firm characteristics between firm-types. Figure 3.4 plots the difference between firms with and without USD debt in terms of average total assets and productivity growth. I estimate the latter following the procedure in

by a stronger loading of the Euro benchmark rate on the USD benchmark rate shock, raising its variance and enhancing further the relative attractiveness of USD borrowing.

[27] There is a lack of systematic evidence on how the pricing of risky assets differs across exchange rate regimes (especially when disregarding currency crises). This seems an interesting avenue for future work although challenging due to the endogeneity of exchange rate regime choices.



Notes: Figure plots differences in average firm characteristics by exchange rate regime. E.g. the left-most bar is defined as total assets of average multi-currency firm minus total assets of average home-currency firm, based on firms in floating exchange rate regimes.

Figure 3.4: *Home currency vs multi currency gaps by exchange rate regime*

Wooldridge (2009). The fact that all bars have positive values illustrates that, as predicted by the model, firms that borrow in US Dollars are on average larger and more productive than their home-currency counterparts.

The size gap also holds when measuring it in terms of log-differences,[28] which echos the empirical findings in Maggiori et al. (2018). Figure 3.4 also shows that the gaps between HC and MC firms are smaller in countries with non-floating exchange rates, confirming the predictions by the model. Especially the firm size gap is highly statistically significant. At present, these results are obtained on the sample of firms with quarterly data. In future work, the same analysis can be done using annual data which would allow for a considerably larger number of firms to be included.[29]

Implications for aggregate responsiveness to foreign MP. The findings in this section suggest that exchange rate and capital account policies alter an economy's aggregate responsiveness to foreign monetary policy also by changing firms incentives to borrow in foreign currency. In the model, and as confirmed in the data, lower exchange rate variability allows smaller and less productive firms to borrow in foreign currency increasing the *amount* of exposure in the economy. Thus, exchange rate policy alters aggregate responsiveness to foreign monetary policy not only at the intensive margin but also at the extensive margin. Finally, these

[28] This relationship persists in unreported regressions with country fixed effects.

[29] One should also account for cross-country differences in the firm size distributions in terms of higher moments (e.g. skewness). Measuring the MC gap as log-difference helps somewhat but a more rigorous examination seems promising (though outside the scope of this paper). Another concern could be that countries with pegged exchange rates are also often less developed. In the model, financial development might be captured with the level of financial frictions ϕ, suggesting that lower development might be associated with *larger* MC gaps. From this perspective, my basic estimates of the *difference* in MC gaps across regimes might be biased downwards.

findings appear also important for financial stability, which is here not discussed to stay within the scope of this paper but seems promising for future work.

3.7 Policy implications: Revisiting the Trilemma

The battle lines in the Trilemma debate depend crucially on the definition of monetary policy independence. A narrow definition could be called *narrow instrument independence* and is the ability of a central bank to steer short-term nominal interest rates freely according to domestic monetary policy objectives. A broader definition, *wide monetary independence*, focuses on the central bank's ability to achieve its monetary policy objectives.[30]

Considerable evidence has accumulated that confirms the Trilemma in the narrow sense (Shambaugh, 2004; Obstfeld et al., 2005 and others). At the same time, research on the global financial cycle (Rey, 2013 and others) suggest that domestic financial conditions are so strongly influenced by foreign factors that *wide monetary independence* fails even in floaters. The departure from the Trilemma advocated in Rey (2013) concerns the lack of *wide* monetary independence *in floaters*.

My evidence informs about monetary independence in the wide sense because I capture the real effects of spillovers, i.e. the spillover consequences for variables that are the local central bank's (intermediate) targets. They confirm the Trilemma, in the sense that non-floaters experience stronger interference in their target variables than floaters do. Importantly, they also explain how this is consistent with pervasive financial globalization.

First, while I have emphasised the fact that non-floaters react more strongly, it is important to stress that spillovers are indeed significant also for floaters. Second, my evidence sheds light on how global finance shapes monetary spillovers differently in non-floaters than in floaters. I find that the firm-financing channel works through both local currency and foreign currency debt, capturing two forms of financial globalization. First, arbitrage activity in integrated markets imply that local interest rates are subject to foreign factors. Second, domestic firms which borrow internationally, in foreign currency, establish a direct exposure to foreign interest rates and exchange rates that would exist even if local financing conditions are totally disconnected from foreign factors. The second view, the

[30] In their original articles, Fleming (1962) and Mundell (1963) do not discuss the influence of foreign shocks or foreign monetary policy on domestic monetary policy. They compare the effectiveness of domestic monetary policy under floating and fixed exchange rates, assuming an open capital account. The role of capital flows in the arguments, then and now, illustrates well how economic models have evolved. In Fleming (1962), stronger reaction of capital flows to the interest rate *enhances* the effectiveness in domestic monetary policy (since it leads to larger deprecations boosting the trade balance). Instead, nowadays, capital flows and their response to interest rates are thought to obstruct it by putting pressure on local balance sheets and asset prices.

internationalization of corporate finance, offers one explanation for the puzzling lack of wide monetary independence in floaters. It also helps to explain why non-floaters experience even stronger spillovers. My findings suggest that exchange rate pegs reduce monetary independence not only by hijacking the monetary instrument but by allowing weaker firms to borrow in foreign currency, which compromises monetary independence in the wide sense.

These issues might get intensified in the future, both in floaters and non-floaters, due to the increasing use of tax heavens (Coppola et al., 2020; Zucman, 2014) allowing companies to avoid capital controls. A pessimistic, and misleading, conclusion might therefore be that the Dilemma morphs into "no choice at all," in the sense that there will always be foreign financial shocks interfering with domestic monetary policy regardless of regime choice. To the contrary, my findings imply that, while some global influence is inevitable, regime choices do matter significantly in determining the strength of spillovers.

Finally, the Trilemma has become even more difficult since financial stability objectives have been added explicitly to central bank mandates (Obstfeld et al., 2010; Aizenman, 2013; Aizenman, 2019). My findings about the role of high leverage firms, and weaker firms borrowing in foreign currency, suggest that, at least in this respect, financial stability and monetary objectives might be aligned. Financial stability policies aimed at curbing foreign currency leverage will also help insulating monetary policy from foreign factors.

3.8 Conclusion

Macroeconomic phenomena are the result of microeconomic decisions. In this spirit, this paper analyzed firm-level data at global scale to shed new light on one of the oldest issues in international macro and finance, the Mundell-Fleming Trilemma.

My findings are as follows. Reductions in business investment following US monetary tightening are largest in countries with pegged or managed exchange rates but also significant in floaters. The stronger spillovers in non-floaters are driven by firms with higher leverage. Home currency depreciations ensuing surprise Fed tightening contribute to the heterogeneity because they amplify spillovers for non-floaters and dampen them for floaters. The higher vulnerability of high-leverage firms in non-floaters can be explained through the endogenous increase in foreign currency borrowing associated with exchange rate management.

Since Fleming (1962) and Mundell (1963) first stipulated the Trilemma, vast globalization has steered a debate whether it still holds. Substantial evidence shows that the global capital flows and asset price cycles transmit financial conditions forcefully, leading some to conclude that only complete isolation would ensure monetary independence.

I interpret my findings as reconciling the traditional Trilemma argument with the recent evidence on strength and pervasiveness of the global financial cycle. On the one hand, my estimates are in line with the traditional Trilemma argument: Limited exchange rate flexibility is associated with stronger spillovers and exchange rate fluctuations cushion the blow for floaters. On the other hand, I find that also floaters experience significant spillovers. Importantly, the stronger spillovers in non-floaters are driven especially by high-leverage firms.

So financial spillovers are ubiquitous and powerful, consistent with the global financial cycle literature. The endogenous reponse by firms to exchange rate management implies that financial spillovers are more powerful in non-floaters, validating the prediction of the traditional Trilemma. The Trilemma thus manifests itself not only through hijacking domestic monetary policy but also through foreign currency borrowing and associated financial vulnerabilities.

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Appendix A

A.1 Data Appendix

A.1.1 Parsing content of speeches

Year	Top word 1	Top word 2	Top word 3	Top word 4	Top word 5
1996	losses	problems	failures	question	problem
1997	problems	unemployment	late	challenge	question
1998	crisis	problems	problem	crises	unemployment
1999	problem	crisis	problems	unemployment	challenge
2000	unemployment	crisis	problems	challenge	question
2001	slowdown	question	late	problem	problems
2002	critical	unemployment	problems	recession	loss
2003	problems	late	losses	unemployment	problem
2004	late	volatility	concerns	problems	unemployment
2005	concerns	late	concern	problems	question
2006	concerns	late	losses	problems	stress
2007	problems	crises	crisis	losses	concerns
2008	problems	foreclosures	crisis	turmoil	losses
2009	crisis	losses	problems	failure	problem
2010	crisis	unemployment	losses	problems	recession
2011	crisis	unemployment	recession	stress	problems
2012	unemployment	crisis	recession	losses	problems
2013	crisis	unemployment	stress	recession	losses
2014	crisis	unemployment	stress	recession	question
2015	crisis	recession	stress	unemployment	force
2016	crisis	stress	unemployment	questions	recession
2017	crisis	stress	unemployment	force	tightening

Notes: The table shows for every year the words from the Loughran-McDonald "negative words"-dictionary that were found most often in the speeches.

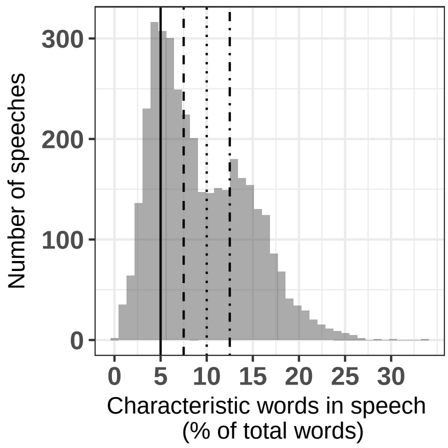
Table A.1: *10 negative words in the LMcD dictionary found most often in speeches by year*

variable	Mean	SD	Min	Max
τ	96.34	1.64	89.18	99.90
Total words	1658.25	703.56	208.00	4497.00
Negative words	61.95	40.25	1.00	271.00

Notes: This table shows summary statistics for the speech tone (τ), number of total words, and number of negative words in the speeches used in the analysis.

Table A.2: *Summary statistics of speech tone*

I have also verified that the speech tone measure is driven by a diverse set of words, to avoid that few particular words are driving the tone variation. To do so, I have computed the normalized Herfindahl-Hirschman index across matched words (for brevity unreported). A value of 100 percent would indicate that only a single word drives the index. The index hovered around 1 to 2 percent over the sample, implying that the tone is driven by a diverse set of words.



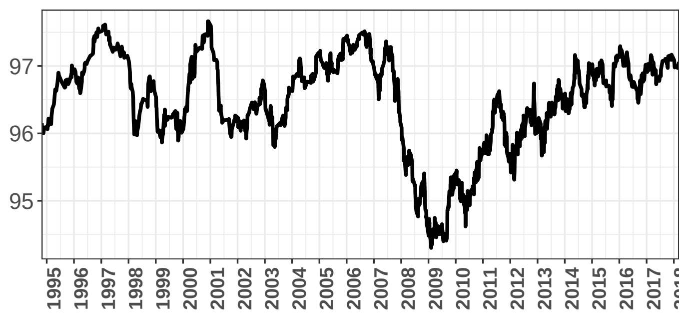
Notes: The figure plots the number of speeches (vertical axis) for the share of characteristic words as % of total words in these speeches. The vertical bars show the thresholds (5%,7.5%, 10% and 12.5%) used to decide whether a speech should be labelled as monetary policy relevant. The most representative words of the monetary policy topic are as identified by $\omega_{p,c}$ are listed in Table A.4 in the Appendix.

Figure A.1: *Identifying speeches relevant to monetary policy*

		'Mexp'	All	%
	total	240	3470	6.92
Weeks before FOMC	1-4	182	2479	7.34
	5-8	58	991	5.85
Speaker type	President	172	2174	7.91
	Governor	68	1296	5.25

Notes: Column "Mexp" reports counts of speeches including phrases about "market expectations," as defined in Table 1.5. Based on sample of scheduled FOMC meetings.

Table A.3: *Number of speeches by sub-sample*



Notes: The figure plots the moving average over the last 25 speeches of speech tone.

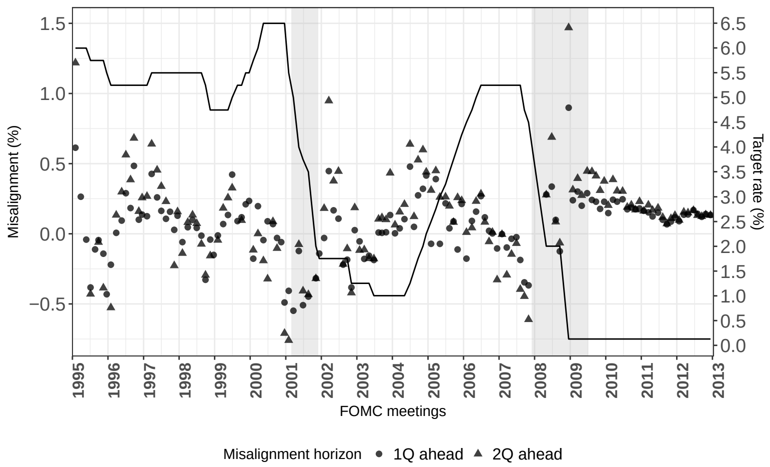
Figure A.2: *Speech tone τ*

word	ω	word	ω	word	ω
inflation	0.1255	gradual	0.0141	firm	0.0096
outlook	0.0675	community	0.0139	maximum_employment	0.0095
labor_market	0.0595	economic_activity	0.0137	improvement_labor	0.0094
funds_rate	0.0548	**supervision**	0.0137	forecast	0.0094
unemployment_rate	0.0465	rate	0.0136	weakness	0.0093
recovery	0.0462	conditions	0.0135	**internal**	0.0093
fomc	0.0448	favorable	0.0135	nominal	0.0093
unemployment	0.0440	utilization	0.0135	disinflationary	0.0093
monetary_policy	0.0433	cra	0.0133	slow	0.0093
spending	0.0381	organizations	0.0133	market_discipline	0.0093
banks	0.0373	annual_rate	0.0132	core	0.0093
longer_run	0.0348	policy	0.0132	standards	0.0092
basel	0.0340	pickup	0.0131	upward_pressure	0.0092
risk_management	0.0293	real_gdp	0.0131	elevated	0.0092
fiscal	0.0288	tightening	0.0130	personal_consumption	0.0091
energy_prices	0.0279	organization	0.0127	long_run	0.0091
nairu	0.0276	low	0.0127	communities	0.0091
price_stability	0.0267	expected	0.0127	treasury_securities	0.0091
slack	0.0263	committee	0.0126	readings	0.0091
supervisors	0.0262	long_term	0.0125	subdued	0.0091
inflation_expectations	0.0259	commodity_prices	0.0124	inventories	0.0090
interest_rates	0.0258	management	0.0122	restraining	0.0089
pace	0.0257	developments	0.0121	movements	0.0089
prices	0.0245	near_term	0.0121	commodities	0.0089
banking	0.0241	gradually	0.0120	loan	0.0089
aggregate_demand	0.0239	oil_prices	0.0120	restraint	0.0089
longer_term	0.0237	rates	0.0119	**regulations**	0.0089
regulatory	0.0235	purchases	0.0119	coming_quarters	0.0088
productivity_growth	0.0231	**systems**	0.0116	sustainable	0.0088
resource_utilization	0.0226	recession	0.0115	oil	0.0088
employment	0.0226	slowdown	0.0115	year	0.0088
supervisory	0.0222	housing	0.0113	target	0.0088
activities	0.0217	equipment	0.0110	per_month	0.0088
productivity	0.0216	asset_purchases	0.0109	wage	0.0087
demand	0.0212	outlays	0.0108	cbo	0.0087
labor_force	0.0209	accommodative	0.0108	continued	0.0086
accommodation	0.0207	moderate	0.0108	**industry**	0.0086
growth	0.0206	prospects	0.0106	boost	0.0086
community_banks	0.0206	percent	0.0105	next_year	0.0085
institutions	0.0202	services	0.0105	transitory	0.0085
consumer_spending	0.0202	stance_monetary	0.0104	anticipated	0.0085
bank	0.0191	**capital_requirements**	0.0104	agencies	0.0084
full_employment	0.0183	unit_labor	0.0104	sales	0.0084
output	0.0183	derivatives	0.0103	stimulus	0.0084
energy	0.0177	import_prices	0.0103	rising	0.0084
increases	0.0176	quarters	0.0103	slower	0.0083
decline	0.0175	rebound	0.0102	solid	0.0082
regulation	0.0170	remains	0.0102	highly_accommodative	0.0082
budget	0.0169	expenditures	0.0102	recent_months	0.0082
neutral	0.0163	equipment_software	0.0102	phillips_curve	0.0082
banking_organizations	0.0161	indicators	0.0101	remained	0.0082
trend	0.0159	**bankers**	0.0101	residential_construction	0.0082
rise	0.0155	weak	0.0101	price	0.0081
compliance	0.0154	last_year	0.0101	effects	0.0081
federal	0.0154	risk	0.0101	likely	0.0081
forecasters	0.0153	taylor_rule	0.0100	manufacturing	0.0080
unemployed	0.0152	expansion	0.0100	job	0.0080
cyclical	0.0151	slowed	0.0100	disclosure	0.0080
hiring	0.0150	production	0.0099	new_jersey	0.0080
headwinds	0.0148	labor	0.0099	capital	0.0079
regulators	0.0148	price_index	0.0099	persistent	0.0079
drag	0.0147	effect	0.0098	appears	0.0079
percentage_point	0.0147	well_anchored	0.0098	projections	0.0079
slowing	0.0146	pce	0.0098	first_half	0.0078
second_half	0.0145	economy	0.0097	household	0.0078
practices	0.0145	institution	0.0097	net_exports	0.0077
gains	0.0142	dual_mandate	0.0096		

Notes: The table lists the 200 phrases most characteristic of the “monetary policy” topic as identified by $\omega_{p,c}$ defined in Eq. 1.6 following Gentzkow and Shaprio (2010). A higher value in ω means the word is more characteristic. The values are values of ω multiplied by 100 for illustration and sorted in decreasing order from left to right. Two-part phrases separated by an underscore are bigrams formed on the basis of how often these words occur together and are treated as a single word when $\omega_{p,c}$ is computed. **Bold** phrases were disregarded in classifying speeches, in order to reduce the risk of misclassifying speeches that talk purely on banking regulation and supervision.

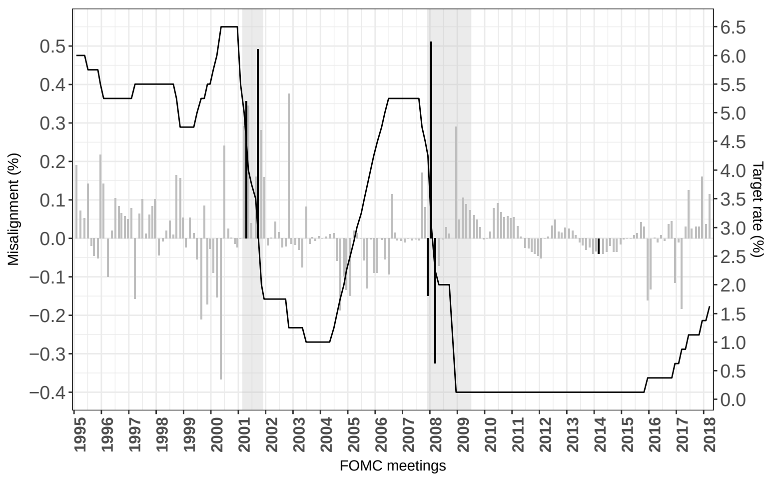
Table A.4: *Words characteristic of “monetary policy relevant topic”*

A.1.2 Measure of misaligned expectations, details



Notes: Each dot/triangle represents average misalignment (left-hand axis) between the Greenbook release and corresponding FOMC, derived from the Greenbook projections. The right-hand axis plots the Fed funds target rate. When the Fed announces a range for its target, the arithmetic average of that range is used. Gray shades indicate NBER recessions.

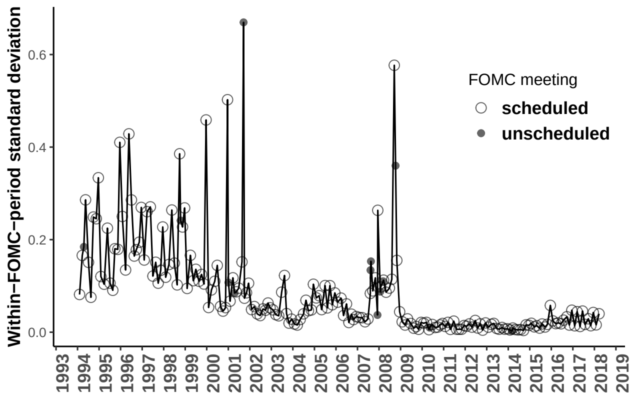
Figure A.3: *Time series of misalignment for upcoming quarters (Greenbook)*



Notes: Each bar represents average misalignment (left-hand axis) in the fourth week before a FOMC meeting. The misalignment was derived assuming perfect foresight of the central bankers. The right-hand axis plots the Fed funds target rate. When the Fed announces a range for its target, the arithmetic average of that range is used. Gray shades indicate NBER recessions. Black bars are unscheduled FOMC meetings which will be excluded in the regressions.

Figure A.4: *Time series of misalignment for upcoming decision (perfect foresight)*

End-of-month volatility and aggregate excess reserves. Two complications with my measurements of $E_t^{\text{Market}}(r_{t_{fomc}})$ arise from the fact that the effective Fed funds rate (EFFR), r_t does not perfectly match the "target rate," formally $r_t = r_t^{tar} + \epsilon_t$. In a frictionless and risk-neutral world, it would hold $\sum_t \epsilon_t = 0$. The relevance and implications of risk premia were discussed in Section 1.2.2 and are omitted here as a source of ϵ_t. The first source of non-zero ϵ_t are end-of-month/settlement-period effects, which normally affects the *average* EFFR only by very few basis points. However, when very high volatility materializes (mostly relevant for before 2000) and the FOMC takes place at the end of the month (large $\frac{d}{D-d}$), it can bias $E_t^{\text{Market}}(r_{t^{fomc}})$. To avoid such bias, I replace $\bar{r}_{t<d}$ with $\bar{r}_{t<d}^{tar}$ for the sample before 2002 at end-of-month FOMC meetings. I choose 2002 because it marks the end of a downward trend in the standard deviation of daily values of the EFFR, see Figure A.5. An alternative break point could be 2000 but I prefer 2002 because it excludes the few extreme outliers in the standard deviation between 2000-2002.



Notes: Standard deviation of daily effective fed funds rate computed over FOMC periods.

Figure A.5: *Standard deviation of daily effective fed funds rate by FOMC period*

The second source of ϵ_t are more persistent shifts in the position of the average EFFR relative to target. This is most important in the post-crisis period. First because the FOMC started to announe a target range instead of a target rate and second because of the build-up of large aggregate excess reserve holdings in the banking system. During this period, the EFFR deviated systematically from the mid point of the range. Examining the forecast errors implied by the futures suggests that markets are indeed able to predict these deviations correctly (unreported). I adjust the measure of the target rate and of misalignment (defined below) to account for the fact that the market correctly anticipates them. I do this by using, for the post-crisis period, the realized average effective fed funds rate instead of the future target rate for the misalignment measure under perfect foresight. Table A.15 shows that the main findings do not change with this adjustment.

Contract months. If the next FOMC meeting is in the current month, we use the expected rate $E_t^{\text{Market}}(r_{t^{fomc}})$ as implied by the generic current month contract ($FF1_t$). If it is in the month following the current month, we use the generic second month contract ($FF2_t$). Let t^{fomc} be the date of the next FOMC meeting at any date

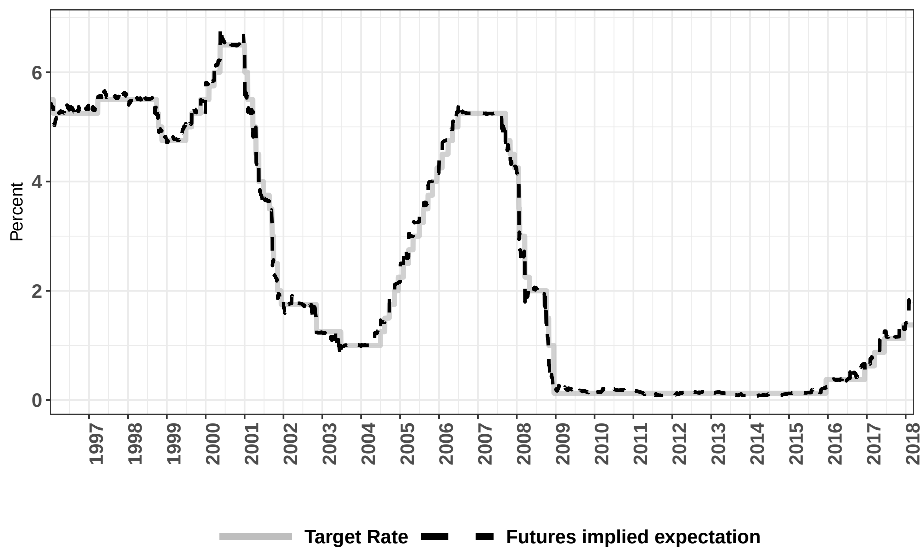
t. Let $m(t)$ be the function that returns the number of the calendar month of date t. The contracts used to derive $E_t^{\text{Market}}(r_{t^{fomc}})$ are then

$$\text{Contract used} = \begin{cases} FF1_t, & \text{if } m(t^{fomc}) = m(t) \\ FF2_t, & \text{if } m(t^{fomc}) = m(t) + 1 \\ FF3_t, & \text{if } m(t^{fomc}) = m(t) + 2. \end{cases} \tag{A.1}$$

Instrument	Bloomberg Ticker	Reference period
30 Day Federal Funds Futures (from CBOT)	ff1 Comdty	Current calendar month
30 Day Federal Funds Futures (from CBOT)	ff2 Comdty	Next calendar month
30 Day Federal Funds Futures (from CBOT)	ff3 Comdty	After next calendar month
OIS based on FOMC announcement dates	USSOFED1 Curncy	Next FOMC
OIS based on FOMC announcement dates	USSOFED2 Curncy	After next FOMC

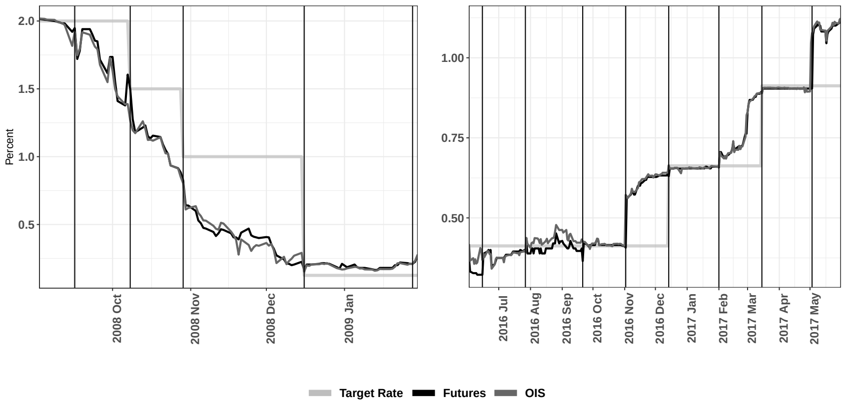
Notes: The table lists the Bloomberg tickers of the time series used to construct the measures of market expectations in this analysis.

Table A.5: *Sources of asset price data*



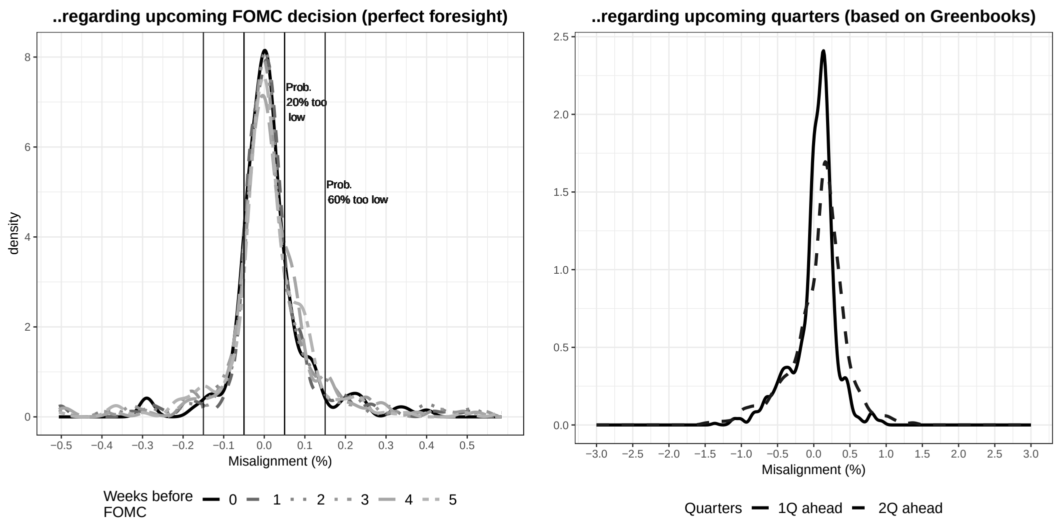
Notes: The figure plots the market's expectations concerning the interest rate after the next FOMC decision $E_t^{\text{Market}}(r_{t^{fomc}}^{tar})$, as defined in Equation 1.2, along with the actual Fed funds target rate $r_{t^{fomc}}^{tar}$.

Figure A.6: *Futures based interest rate expectations and Fed target rate*



Notes: The figure plots interest expectations based on Fed funds futures and OIS swaps. Vertical bars mark dates of FOMC meetings.

Figure A.7: *Comparison of OIS and Futures based interest rate expectations*



Notes: The figure shows kernel estimates of the empirical density functions of misalignment measures.

Figure A.8: *Empirical distribution of misalignment*

A.1.3 Measuring macroeconomic news

Table A.6 provides the Bloomberg ticker and basic summary statistics for the data used to construct the surprise indices covering the categories *employment, inflation, output and macro-sentiment*. Variables are first standardized with telescopic averages and standard deviations. To summarize all variables within a given category, the equally weighted average of these standardised variables is computed. Let $surp_t^C$ be the surprise index for category C at day t, we have

$$surp_t^C = \sum_j^N \frac{1}{N} \hat{x}_{t,j,C}, \tag{A.2}$$

where N is the number of surprise variables in category C and $\hat{x}_{t,j,C}$ is the standardised data surprise for variable j on day t.

event	category	ticker	Obs	Start	End	Mean(X)	$\sigma(X)$	Mean($\hat{x}$)	$\sigma(\hat{x})$
Initial Jobless Claims	employment	INJCJC Index	1084	1997	2018	-46.13	17521.28	-0.02	0.98
Change in Nonfarm Payrolls	employment	NFP TCH Index	255	1997	2018	-13180.39	82430.83	0.00	0.80
Change in Manufact. Payrolls	employment	USMMMNCH Index	233	1999	2018	-5394.12	21663.72	0.25	0.74
Unemployment Rate	employment	USURTOT Index	254	1997	2018	0.03	0.14	0.01	0.99
Avg Weekly Hours Production	employment	USWHTOT Index	130	1999	2010	-0.02	0.10	-0.04	0.92
ADP Employment Change	employment	ADP CHNG Index	141	2006	2018	5943.26	52689.90	0.15	0.79
Average Weekly Hours All Employees	employment	AWH TOTL Index	99	2010	2018	-0.01	0.08	-0.17	0.99
Change in Private Payrolls	employment	NFP PCH Index	97	2010	2018	-5443.30	58715.76	0.02	0.84
Change in Household Employment	employment	USEMNCHG Index	16	2013	2016	-36.69	267.28	-0.04	0.94
CPI MoM	inflation	CPI CHNG Index	259	1996	2018	-0.01	0.12	0.05	1.04
CPI Ex Food and Energy YoY	inflation	CPI XYOY Index	175	2003	2018	-0.01	0.09	0.01	0.90
CPI YoY	inflation	CPI YOY Index	176	2003	2018	0.00	0.15	-0.06	0.83
CPI Ex Food and Energy MoM	inflation	CPUPXCHG Index	257	1997	2018	-0.01	0.09	0.03	1.02
CPI Index NSA	inflation	CPURNSA Index	164	1998	2018	4.07	25.89	-0.27	0.28
Employment Cost Index	inflation	ECI SA% Index	85	1997	2018	-0.01	0.17	-0.02	0.90
GDP Price Deflator	inflation	GDP DCHG Index	85	1998	2005	-0.07	0.74	0.21	0.39
ISM Prices Paid	inflation	NAPMPRIC Index	215	2000	2018	0.36	5.11	0.06	0.91
PCE Core YoY	inflation	PCE CYOY Index	164	2004	2018	0.00	0.08	-0.02	0.87
PCE Deflator YoY	inflation	PCE DEFY Index	163	2004	2018	-0.01	0.13	-0.06	0.71
PPI MoM	inflation	PPI CHNG Index	193	1997	2014	0.02	0.46	0.09	1.14
PPI Ex Food and Energy YoY	inflation	PPI XYOY Index	115	2003	2014	0.00	0.24	0.06	0.84
PPI YoY	inflation	PPI YOY Index	119	2002	2014	0.05	0.51	-0.15	0.92
PPI Ex Food and Energy MoM	inflation	PXFECHNG Index	205	1996	2014	0.00	0.25	0.09	1.06
CPI Core Index SA	inflation	CPUPAXFE Index	64	2010	2018	-0.01	0.20	0.13	0.89
GDP Price Index	inflation	GDP PIQQ Index	156	2005	2018	-0.03	0.37	0.02	0.92
Core PCE QoQ	inflation	GDPCPCEC Index	141	2006	2018	0.01	0.13	0.06	0.85
PCE Core MoM	inflation	PCE CMOM Index	155	2005	2018	-0.01	0.06	-0.06	0.84
PCE Deflator MoM	inflation	PCE DEFM Index	74	2012	2018	-0.02	0.06	0.09	0.92
PPI Final Demand MoM	inflation	FDIDFDMO Index	53	2014	2018	-0.01	0.26	0.00	0.83
PPI Ex Food, Energy, Trade MoM	inflation	FDIDSGUM Index	41	2014	2018	0.00	0.19	0.28	0.89
PPI Final Demand YoY	inflation	FDIUFDYO Index	52	2014	2018	-0.02	0.26	0.06	0.92
PPI Ex Food, Energy, Trade YoY	inflation	FDIUSGUY Index	16	2014	2017	-0.07	0.17	0.41	0.81
ABC Consumer Confidence	macro_sent	ACNFCOMF Index	131	2004	2011	-0.64	2.76	-0.03	0.88
Bloomberg Consumer Comfort	macro_sent	COMFCOMF Index	167	2004	2012	-0.54	2.54	-0.01	0.83
Conf. Board Consumer Confidence	macro_sent	CONCCONF Index	254	1997	2018	0.27	4.94	-0.03	1.02
Avg Hourly Earning MOM Prod	other	USHETOT% Index	140	1998	2010	0.00	0.13	0.12	0.91
Avg Hourly Earning YOY Prod	other	USHEYOY Index	47	2003	2010	0.04	0.17	-0.13	0.90
Average Hourly Earnings MoM	other	AHE MOM% Index	99	2010	2018	-0.05	0.15	0.07	0.90
Average Hourly Earnings YoY	other	AHE YOY% Index	99	2010	2018	-0.03	0.18	-0.04	0.96
GDP Annualized QoQ	output	GDP CQOQ Index	253	1997	2018	0.02	0.48	-0.15	0.89
Leading Index	output	LEI CHNG Index	253	1996	2018	0.02	0.17	0.03	1.15
ISM Non-Manufacturing	output	NAPMNMAN Index	109	1999	2008	0.43	3.37	-0.04	0.99
ISM Manufacturing	output	NAPMPMI Index	258	1996	2018	0.14	1.86	0.03	0.97
Retail Sales Advance MoM	output	RSTAMOM Index	205	2001	2018	-0.01	0.58	-0.07	0.63
Retail Sales Ex Auto MoM	output	RSTAXMOM Index	205	2001	2018	-0.03	0.44	-0.01	0.86
Advance Retail Sales	output	RTSDCHNG Index	54	1996	2001	-0.01	0.34	0.23	1.02
Retail Sales Less Autos	output	RTSDXCHG Index	47	1997	2001	0.01	0.29	0.34	1.29
ISM Non-Manf. Composite	output	NAPMNMI Index	124	2008	2018	0.12	1.93	0.08	0.80
Retail Sales Ex Auto and Gas	output	RSTAXAG% Index	107	2009	2018	-0.06	0.32	-0.14	0.87
ISM New Orders	output	NAPMNEWO Index	3	2016	2017	1.57	1.55	-0.76	0.08

Notes: List of data releases included in the macro surprise indices. Data is from Bloomberg's ECOS function. X is the surprise variable defined as actual minus the median forecast from the Bloomberg survey. σ_X is the standard deviation. $\hat{x}$ is the standardised surprise variable. Standardisation is done with telescopic means and standard deviations to avoid forward-looking biases. The category column follows the classification in Beber et al. (2015).

Table A.6: *Data underlying macro surprise indeces*

A.1.4 Forward-looking Taylor Rules

For few occasions where the interest rate projections underlying Greenbook forecasts are not available, I estimate forward-looking Taylor rules to construct interest rate projections from the inflation and output forecasts.

	Dependent variable:				
	i_t	Orphanides	$F^{GB}(i_t)$	$F^{GB}(i_{t+1})$	$F^{GB}(i_{t+2})$
	(1)	(2)	(3)	(4)	(5)
θ_π	0.426***	0.520***	0.364***	0.627***	0.792***
	(0.045)	(0.130)	(0.046)	(0.072)	(0.092)
$\theta_{\Delta y}$	0.300***	0.510***	0.251***	0.444***	0.520***
	(0.043)	(0.170)	(0.041)	(0.059)	(0.066)
θ_y	0.245***	0.100***	0.229***	0.352***	0.420***
	(0.021)	(0.030)	(0.023)	(0.028)	(0.036)
θ_i	0.778***	0.810***	0.795***	0.678***	0.615***
	(0.027)	(0.060)	(0.030)	(0.038)	(0.045)
θ_0	−0.130	−0.340	−0.049	−0.144	−0.232*
	(0.088)	(0.320)	(0.086)	(0.116)	(0.133)
Observations	160	-	144	158	157
R^2	0.978	-	0.980	0.959	0.948
Adjusted R^2	0.977	-	0.979	0.958	0.947

Notes: *p<0.1; **p<0.05; ***p<0.01. OLS estimates of $x_t = \theta_0 + \theta_i x_{t-1} + \theta_\pi \pi^a_{t+3} + \theta_{\Delta y} \Delta^a y_{t+3} + \theta_y y_{t-1}$, where x is the realized average Fed funds rate (i_t), the Greenbook forecast for the current ($F^{GB}(i_t)$), next ($F^{GB}(i_{t+1})$) or after next ($F^{GB}(i_{t+2})$) quarter. The equation follows Orphanides (2003) and column 2 shows the estimates by Orphanides, based on the sample period 1982Q3 to 1997Q4. The first column is on the largest sample from 1987Q2 to 2007Q4.

Table A.7: *Taylor rule estimates*

Median forecasts from the Summary of Economic Projections (SEP) are likely not a viable alternative to the Taylor rule implied interest rate projections. The SEP was first released in October 2007, but only from 2012 onwards it includes a table with forecasts for the Fed funds rate. Between 2007 and 2012, the SEP includes a section where individual members comment on whether their forecast for the target rate is aligned with the Greenbook projections, converting this into a FOMC median forecast would entail many degrees of freedom as the format and content of the comments differ a lot.

	Dependent variable:		
	FFR0	FFR1	FFR2
	(1)	(2)	(3)
$\widehat{FFR0}$	1.007***		
	(0.012)		
$\widehat{FFR1}$		1.010***	
		(0.016)	
$\widehat{FFR2}$			1.011***
			(0.019)
Constant	−0.060	−0.079	−0.085
	(0.060)	(0.082)	(0.091)
Observations	150	164	163
R^2	0.977	0.955	0.945
Adjusted R^2	0.977	0.955	0.944

Notes: *p<0.1; **p<0.05; ***p<0.01. The table shows regressions of Greenbook interest rate projections on the Taylor Rule implied interest rate forecasts based on inflation and output gap forecasts.

Table A.8: *Comparison of Greenbook interest rate projections and rates implied by Taylor Rule using Greenbook forecasts*

A.2 Further analysis and robustness tests

(a) *Presidents*

	Dependent variable: τ_{jt}			
$misal_{t-1}$	-0.164^{***}	-0.210^{***}	-0.244^{***}	-0.240^{***}
	(0.049)	(0.059)	(0.053)	(0.064)
Speaker FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Subset	MP5	MP7.5	MP10	MP12.5
Observations	938	762	589	449
R^2	0.231	0.254	0.239	0.263

(b) *Governors*

	Dependent variable: τ_{jt}			
$misal_{t-1}$	-0.066	-0.098^{*}	-0.157^{**}	-0.289^{***}
	(0.047)	(0.053)	(0.063)	(0.089)
Speaker FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Subset	MP5	MP7.5	MP10	MP12.5
Observations	765	483	289	194
R^2	0.113	0.111	0.116	0.217

Notes: *p<0.1; **p<0.05; ***p<0.01. OLS estimates of equation: $\tau_{j,t} = a + \alpha_j + \beta \text{misal}_{t-1} + \theta \text{misal}_{t-1} \times \text{Status}_{jt} + \phi \text{Status}_{jt} + \gamma X_{t-1} + \epsilon_{j,t}$ for subsets on speeches based on monetary policy relevance measure defined in the main text. "Presidents" ("Governors") denotes the sample of speeches by Fed presidents (Fed Board Governors). Standard errors are HC White-Hubert. misal_{t-1} is lagged 5-day rolling average misalignment, standardized by its standard deviation. Status_{jt} is a dummy equal to one if the speaker is a voting FOMC member (in the Fed presidents sample) or equal to one if the speaker is the chair/vice chair (in the Board of Governors sample). Controls are data surprises for 51 macroeconomic variables at $t-1$ (see Appendix A.1.3) and dummies for the Asian, Russian, Dotcom and 2008 financial crisis. Sample includes speeches within 5 weeks of the upcoming FOMC. ZLB period is excluded.

Table A.9: *Effects of misalignment assuming perfect foresight, by speech-relevance*

(a) *Presidents*

	Dependent variable: τ_{jt}			
	1Q ahead	1Q ahead	2Q ahead	2Q ahead
$misal_{t-1}$	−0.199	−0.012	−0.210**	−0.028
	(0.122)	(0.161)	(0.103)	(0.136)
$misal_{t-1} \times Voting_{jt}$		−0.467**		−0.452**
		(0.201)		(0.179)
MPshock	1.990	1.046	2.288	1.621
	(3.710)	(3.611)	(3.744)	(3.583)
Obs	205	205	200	200
R^2	0.387	0.395	0.394	0.402

(b) *Governors*

	Dependent variable: τ_{jt}			
	1Q ahead	1Q ahead	2Q ahead	2Q ahead
$misal_{t-1}$	−0.189	0.173	−0.169	0.174
	(0.182)	(0.198)	(0.162)	(0.203)
$misal_{t-1} \times Chairs_{jt}$		−1.121***		−0.845**
		(0.324)		(0.328)
MPshock	9.261**	10.008**	8.995**	9.711**
	(4.036)	(4.248)	(3.941)	(4.111)
Obs	102	102	100	100
R^2	0.309	0.359	0.306	0.346

Notes: *p<0.1; **p<0.05; ***p<0.01. Speech sentiment τ_{jt} on day t is regressed on the misalignment based on Greenbook projections between 1996 and 2012. "Presidents" ("Governors") denotes the sample of speeches by Fed presidents (Fed Board Governors). Standard errors are HC White-Hubert. Misalignment compares market expectations measured at date t with the projections from the most recent Greenbook. $Voting_{jt}$ ($Chairs_{jt}$) is a dummy equal to one if the speaker is a voting president (chair/vice chair of Fed Board). For each Greenbook, speeches up to 3 weeks after it was released to the FOMC are included. Periods between unscheduled and subsequent scheduled FOMC meetings are excluded. Controls are rolling 5-day averages of data surprises at $t-1$ (see A.1.3) and real-time estimates of previous quarters CPI inflation and real GDP growth obtained from the Greenbooks. Based on the subsets of speeches "MP10" with at least 10% of all words are "monetary policy relevant words."

Table A.10: *Effects of misalignment based on Greenbook projections, controlling for monetary shocks at last meeting*

	Dependent variable: τ_{jt}			
	Presidents		*Governors*	
$misal_{t-1}$	-0.288^{***}	-0.452^{***}	-0.286^{***}	-0.308^{***}
	(0.083)	(0.110)	(0.081)	(0.098)
$misal_{t-1} \times$ week3	0.170	0.428^{**}	0.342	0.032
	(0.150)	(0.174)	(0.292)	(0.337)
$misal_{t-1} \times$ week4	0.071	0.281^{**}	0.199	-0.012
	(0.102)	(0.143)	(0.151)	(0.241)
$misal_{t-1} \times$ week5	-0.048	0.176	0.390^{*}	0.040
	(0.150)	(0.177)	(0.200)	(0.228)
Speeches	MP10	MP12.5	MP10	MP12.5
Speaker FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	589	449	289	193
R^2	0.248	0.281	0.134	0.225

Notes: *p<0.1; **p<0.05; ***p<0.01. OLS estimates of equation: $\tau_{jt} = \alpha_j + \beta \text{misal}_{t-1} + \sum_{week=3}^{5} \gamma^{week} \times \text{misal}_{t-1} + \gamma X_{t-1} + e_{jt}$. Misalignment is standardized by its standard devation. "Presidents" ("Governors") denotes the sample of speeches by Fed presidents (Fed Board Governors). Standard errors are HC White-Hubert. Controls are data surprises for 51 macroeconomic variables at $t-1$ (see A.1.3) and dummies for the Asian, Russian, Dotcom and 2008 financial crisis. Based on the subsets of speeches "MP10" ("MP12.5"), at least 10% (12.5%) of all words are "monetary policy relevant words", and within 5 weeks of the upcoming FOMC. ZLB period is excluded.

Table A.11: *Effects of misalignment assuming perfect foresight, by week*

(a) *Presidents*

	Dependent variable: τ_{jt}		
$misal_{t-1}$	-0.170^{***}	-0.189^{*}	-0.164^{**}
	(0.061)	(0.110)	(0.067)
$misal_{t-1} \times Voting_{jt}$	-0.250^{**}	-0.174^{*}	-0.273^{**}
	(0.111)	(0.103)	(0.129)
Excl GFC	N	N	Y
FOMC FE	N	Y	N
Observations	589	589	559
R^2	0.247	0.578	0.197

(b) *Governors*

	Dependent variable: τ_{jt}		
$misal_{t-1}$	-0.055	-0.325	-0.073
	(0.078)	(0.416)	(0.079)
$misal_{t-1} \times Chairs_{jt}$	-0.273^{**}	-0.265^{*}	-0.305^{**}
	(0.121)	(0.156)	(0.150)
Excl GFC	N	N	Y
FOMC FE	N	Y	N
Observations	289	289	274
R^2	0.122	0.608	0.111

Notes: *p<0.1; **p<0.05; ***p<0.01. OLS estimates of equation: $\tau_{j,t} = a + \alpha_j + \beta \text{misal}_{t-1} + \gamma X_{t-1} + \epsilon_{j,t}$, where (j,t) indexes speaker and day of speech. misal_{t-1} is lagged 5-day rolling average misalignment, standardized by its standard deviation. "Presidents" ("Governors") denotes the sample of speeches by Fed presidents (Fed Board Governors). Standard errors are HC White-Hubert. Controls are data surprises for 51 macroeconomic variables at $t-1$ (see Appendix A.1.3) and dummies for the Asian, Russian, Dotcom and 2008 financial crisis. Sample includes speeches of the subset "MP10" (least 10% of all words are "monetary policy relevant words"), and within 5 weeks of the upcoming FOMC. ZLB period is excluded.

Table A.12: *FOMC period fixed effects and the global financial crisis*

(a) *Presidents*

	Dependent variable: τ_{jt}		
	Adj. L&McD	Original L&McD	Apel & Grimaldi
$misal_{t-1}$	-0.244^{***}	-0.262^{***}	-6.157^{**}
	(0.053)	(0.052)	(2.408)
Speaker FE	Y	Y	Y
Controls	Y	Y	Y
Observations	589	589	589
R^2	0.239	0.257	0.106

(b) *Governors*

	Dependent variable: τ_{jt}		
	Adj. L&McD	Original L&McD	Apel & Grimaldi
$misal_{t-1}$	-0.157^{**}	-0.139^{**}	-10.269^{***}
	(0.063)	(0.059)	(3.803)
Speaker FE	Y	Y	Y
Controls	Y	Y	Y
Observations	289	289	289
R^2	0.116	0.115	0.119

Notes: *p<0.1; **p<0.05; ***p<0.01. OLS estimates of equation: $\tau_{j,t} = a + \alpha_j + \beta \text{misal}_{t-1} + \theta \text{misal}_{t-1} \times \text{Status}_{j,t} + \phi \text{Status}_{j,t} + \gamma X_{t-1} + \epsilon_{j,t}$ for subsets on speeches based on monetary policy relevance measure defined in the main text. "Presidents" ("Governors") denotes the sample of speeches by Fed presidents (Fed Board Governors). Standard errors are HC White-Hubert. misal_{t-1} is lagged 5-day rolling average misalignment, standardized by its standard deviation. $\text{Status}_{j,t}$ is a dummy equal to one if the speaker is a voting FOMC member (in the Fed presidents sample), or equal to one if the speaker is the chair/vicec hair (in the Board of Governors sample). Controls are data surprises for 51 macroeconomic variables at $t-1$ (see Appendix A.1.3) and dummies for the Asian, Russian, Dotcom and 2008 financial crisis. Sample includes speeches within 5 weeks of the upcoming FOMC. ZLB period is excluded.

Table A.13: *Different speech tone measures*

	Dependent variable: Prob(Speech with "Mexp")$_{jt}$			
	Presidents		*Governors*	
$abs(misal)_{t-1}$	0.89	0.78*	−0.05	0.26
	(0.60)	(0.46)	(0.38)	(0.30)
$abs(misal)_{t-1} \times Status_{jt}$	1.05***	1.16***	1.44***	0.92**
	(0.40)	(0.32)	(0.43)	(0.40)
Model	Logit	Relogit	Logit	Relogit
Obs	4490	4490	3700	3700

Notes: *p<0.1; **p<0.05; ***p<0.01. Relogit uses a rare-events logistic regression estimator that corrects for the potential small sample bias stemming fron a rare-event outcome variable. Estimates of equation $Prob(Topic = \text{"Mexp"})_{jt} = \phi\big[\beta \text{ abs}(misal)_{t-1} + \theta \text{ abs}(misal)_{t-1} \times Status_{jt} + Status_{jt} + \phi \text{ abs}(misal)_{t-2} + X_{jt-1}\big]$ where (j, t) indexes speaker and week. "Presidents" ("Governors") denotes the sample of speeches by Fed presidents (Fed Board Governors), both including weeks 5 to 2 before each FOMC. $Topic_{jt}$ = "Mexp" indicates whether a speech mentions market expectations. $abs(misal_{t-1})$ is the absolute value of misalignment. X_{t-1} is a vector of controls (see main text). Status$_{jt}$ is a dummy equal to one if the speaker is a voting FOMC member (in the Fed presidents sample) or equal to one if the speaker is chair/vice chair (in the Board of Governors sample).

Table A.14: *Effect of misalignment on occurrence of market expectations topic*

	Dependent variable: τ_{jt}					
	Presidents			*Governors*		
$misal_{t-1}$	-0.176^{***}	-0.170^{***}	-0.146^{**}	-0.054	-0.043	-0.037
	(0.065)	(0.065)	(0.062)	(0.037)	(0.036)	(0.037)
$misal_{t-1} \times Status_{jt}$	-0.243^{**}	-0.242^{**}	-0.169^{*}	-0.250^{***}	-0.256^{***}	-0.200^{***}
	(0.116)	(0.114)	(0.093)	(0.061)	(0.070)	(0.066)
Incl ZLB	N	N	Y	N	N	Y
Controls	N	Y	Y	N	Y	Y
Speaker FE	Y	Y	Y	Y	Y	Y
Obs	589	589	789	289	289	336
R^2	0.238	0.241	0.214	0.101	0.119	0.114

Notes: *p<0.1; **p<0.05; ***p<0.01. OLS estimates of equation: $\tau_{j,t} = a + \alpha_j + \beta \text{misal}_{t-1} + \theta \text{misal}_{t-1} \times \text{Status}_{j,t} + \phi \text{Status}_{j,t} + \gamma X_{t-1} + \epsilon_{j,t}$. "Presidents" ("Governors") denotes the sample of speeches by Fed presidents (Fed Board Governors). "Incl ZLB" indicates whether zero lower bound period was included. Standard errors are clustered at the speaker-level. misal_{t-1} is misalignment about the future effective Fed funds rate (EFFR), not future target rate as in baseline. EFFR-misalignment is used to account for QE-related structural shifts of the EFFR within the target rate corridor. $\text{Status}_{j,t}$ is a dummy equal to one if the speaker is a voting FOMC member (in the Fed presidents sample), or equal to one if the speaker is the chair/vice chair (in the Board of Governors sample). Controls are data surprises for 51 macroeconomic variables at $t-1$ (see A.1.3) and dummies for the Asian, Russian, Dotcom and 2008 financial crisis. Sample includes speeches of the subset "MP10" (at least 10% of all words are "monetary policy relevant"), and within 5 weeks of the upcoming FOMC.

Table A.15: *Effects of misalignment (about EFFR) and ZLB*

A.3 Model Appendix

A.3.1 Deriving the optimal forecast function

Since all variables involved are zero mean, I can omit the constant. Optimal coefficients are given by

$$(a_1, a_2) = \underset{a_1,a_2}{\arg\min}\, E\Big[\big(i_t^* - (a_1 \Delta i_t + a_2 s_t)\big)^2\Big] \tag{A.3}$$

Differentiating with respect to (a_1, a_2) gives the usual orthogonality conditions

$$\begin{aligned} E\Big[\big(i_t^* - (a_1 \Delta i_t + a_2 s_t)\big)\Delta i_t\Big] &= 0 \\ E\Big[\big(i_t^* - (a_1 \Delta i_t + a_2 s_t)\big)s_t\Big] &= 0 \end{aligned} ,$$

which can be rewritten in matrix form as

$$\begin{bmatrix} Cov(i_t^*, \Delta i_t) \\ Cov(i_t^*, s_t) \end{bmatrix} = \begin{bmatrix} Var(\Delta i_t) & Cov(s_t, \Delta i_t) \\ Cov(s_t, \Delta i_t) & Var(s_t) \end{bmatrix} \times \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}.$$

Inverting the variance-covariance matrix and multiplying from the left gives the coefficients:

$$\begin{aligned} a_1 &= \frac{Var(s_t)Cov(i_t^*, \Delta i_t) - Cov(\Delta i_t, s_t)Cov(s_t, i_t^*)}{Var(s_t)Var(\Delta i_t) - Cov(s_t, \Delta i_t)^2} \\ a_2 &= \frac{Var(\Delta i_t)Cov(i_t^*, s_t) - Cov(\Delta i_t, s_t)Cov(\Delta i_t, i_t^*)}{Var(s_t)Var(\Delta i_t) - Cov(s_t, \Delta i_t)^2}. \end{aligned}$$

A.3.2 Deriving the loss function

Due to the random walk property of the Fed target, the $t = 2$ infinite-horizon forward rate i_2^∞ equals the expectation $i_2^\infty = E_2(i_2^* | \Delta i_1, s_2) = \widehat{e}_{1,t=2}$. Thus the change in the forward rate in period 2 is

$$\begin{aligned} \Delta i_2^\infty &= \widehat{e}_{1,t=2} - \widehat{e}_{1,t=1} \\ &= (\alpha_1 - \chi)\Delta i_1 + \alpha_2 s_2 \\ (\Delta i_2^\infty)^2 &= (\alpha_1 - \chi)^2 (\Delta i_1)^2 + 2(\alpha_1 - \chi)\alpha_2 \Delta i_1 s_2 + \alpha_2^2 s_2^2. \end{aligned}$$

The other loss term in period 2, $(i_2^* - i_2)^2$, is obtained by plugging in the respective definitions. We have

$$\begin{aligned}(i_2^* - i_2)^2 &= \Big(i_0 + e_1 - (i_0 + \beta s_2 + u_2)\Big)^2 \\ &= \Big(e_1 - (\beta s_2 + u_2)\Big)^2 \\ &= \sigma_e^2 - 2e_1(\beta s_2 + u_2) + \beta^2 s_2^2 + \sigma_u^2\end{aligned}$$

In period 3, the market will be able to fully infer e_1 because the central bank is known to set the nominal interest rate exactly at target. The change in the forward rate will be

$$\begin{aligned}\Delta i_3^\infty &= e_1 - \widehat{e}_{1,t=2} \\ (\Delta i_3^\infty)^2 &= (e_1 - \widehat{e}_{1,t=2})^2 \\ &= \sigma_e^2 - 2e_1(\alpha_1 \Delta i_1 + \alpha_2 s_2) + (\alpha_1 \Delta i_1 + \alpha_2 s_2)^2.\end{aligned}$$

As the central bank sets the interest rate to target, we have $(i_3^* - i_3)^2 = 0$.

A.3.3 Remarks on central bank's loss function

A noteworthy feature of this setup lies with the interpretation of the central bank's aversion to bond market volatility. Due to the random-walk assumption on the Fed target rate, the infinite-horizon forward rate equals always the market's estimate of the former. In Stein and Sunderam, the measure used as volatility is the squared change in the infinite-horizon forward rate. This term can be rewritten in terms of the expectational error with respect to the true target rate:

$$\begin{aligned}\Delta i_1^\infty &= \widetilde{e}_{1,1} - \widetilde{e}_{1,0} \\ &= -\big[\underbrace{e_1 - \widetilde{e}_{1,1}}_{FE_1} - \underbrace{(e_1 - \widetilde{e}_{1,0})}_{FE_0}\big] \\ \Delta i_2^\infty &= \underbrace{e_1 - \widetilde{e}_{1,1}}_{FE_1}.\end{aligned}$$

The important implication is that while in period 2 the central bank cares about the *level of expectational error*, in period 1 the central bank cares only about the *change* in the expectational error. If one would instead assume that every period new information about the target rate arrives, we would have $(\Delta i_1^\infty)^2 = (\Delta FE_1 - \Delta e_1)^2$.

A.3.4 Proof of proposition 1

With Equations 1.26, it's immediately clear that if $\theta = 0$, $k = 1$. Also, $v_1 = \beta$ and $v_2 = 0$. Thus,

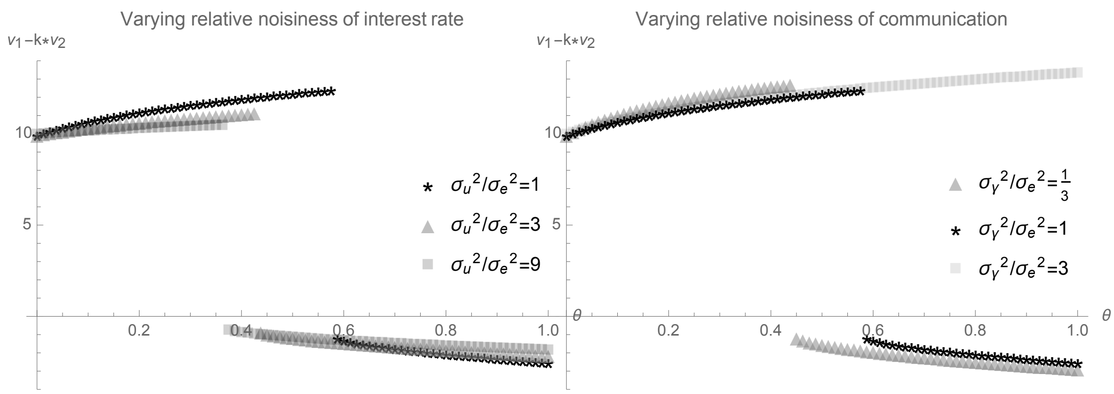
$$\alpha_1 = \frac{\sigma_e^2 \sigma_\gamma^2}{\sigma_u^2(\sigma_\gamma^2 + \sigma_e^2\beta^2) + \sigma_e^2\sigma_\gamma^2}$$
$$\alpha_2 = \frac{\sigma_e^2 \sigma_u^2 \beta}{\sigma_u^2(\sigma_\gamma^2 + \sigma_e^2\beta^2) + \sigma_e^2\sigma_\gamma^2}.$$

It follows immediately the content of Proposition A.3.4: If $\theta = 0$ and $\beta > 0$, $k = 1$ and $\alpha_1, \alpha_2 > 0$. From Equation 1.24, $\alpha_1 > 0$ requires $\sigma_e^2, \sigma_\gamma^2 > 0$. For α_2, the expression above trivally suggests that iff $\beta, \sigma_u^2 > 0$, $\alpha_2 > 0$.

A.3.5 Further illustrations

Deriving threshold $\bar{\theta}$. Here, I identify the threshold $\bar{\theta}$ numerically.

(a) **(b)**



Notes: The figure plots the equilibrium value of $v_1 - k * v_2$ as a function of θ. A.9a varies the ratio of the variance of interest rate noise σ_u^2 to the variance of the private information σ_e^2. A.9b varies the ratio of the variance of the communication noise σ_σ^2 to the variance of the private information σ_e^2.

Figure A.9: *Analysis of threshold $\bar{\theta}$*

The main feature of the multiplicity is the emergence of $\alpha_2 < 0$. To find $\bar{\theta}$, I solve the model for different values of θ, starting at $\theta = 0$ and going to $\theta = 1$ with a stepsize of 0.0125. By Equation 1.25, we must have $v_1 - k * v_2 > 0$ for $\alpha_2 < 0$. I therefore use it as a sufficient statistic for equilibrium uniqueness. Figure A.9 shows the results. Indeed, $v_1 - k * v_2$ is positive and monotonically increasing in θ until a discontinuity emerges: $v_1 - k * v_2$ suddenly jumps to negative values. This is the numerical solution for the critical threshold value $\bar{\theta}$.

Figure A.9a illustrates that $\bar{\theta}$ is decreasing in the variance of the interest rate noise relative to the variance of the private information. As explained in the main text, the intuition is that as the relative variance of the interest rate noise term increases, the margin of error for the market's estimate in period 1 increases. This leaves more room for speculation and hence makes multiple equilibria possible for lower degrees of aversion to bond market volatility. The opposite holds for the variance of the noise term in the signal s (Fig. A.9b) As the noisiness of communication increases, agents put less weight on it and therefore the interpretation becomes less important.

Figure A.16 compares the outcomes in the two types of equilibria (see discussion in main text).

(a) *unique equilibrium with* $\theta = 0.2$

	Private info (i^*)	Interest rate	Guess of i^* (end of per)	Signal	Loss $(i^* - i)^2$	$Loss((\Delta i^{\infty})^2)$
Period 1	0.750	0.697	0.347	-	0.003	0.024
Period 2	0.750	0.710	0.662	7.104	0.002	0.020
Period 3	0.750	0.750	0.750	-	0.000	0.002
Total	-	-	-	-	0.004	0.045

(b) *bad equilibrium with* $\theta = 0.6$

	Private info (i^*)	Interest rate	Guess of i^* (end of per)	Signal	Loss$(i^* - i)^2$	$Loss((\Delta i^{\infty})^2)$
Period 1	0.750	0.708	0.353	-	0.002	0.075
Period 2	0.750	-0.051	0.367	-0.507	0.641	0.001
Period 3	0.750	0.750	0.750	-	0.000	0.088
Total	-	-	-	-	0.643	0.163

Notes: The trajectory of key variables is reported for $\theta = 0.2$ and $\theta = 0.6$. For illustration the private information was set to $e_1 = 0.75$ and $u_1 = 0$. As stated below, I set $i_0 = 0$ and hence $i_1^* = i_2^* = i_3^* = e_1$ for simplicity and without loss of generality. $Loss(i * -i)^2$ and $Loss((\Delta i^{\infty})^2)$ show the central bank's loss due to the wedge between the actual short rate and the target rate and the loss due to bond market volatility respectively. The baseline calibration was used $\sigma_u^2, \sigma_\gamma^2, \sigma_e^2 = 1$ and $\beta = 0.1$.

Table A.16: *Equilibrium outcomes*

A.4 Narrative analysis

This Appendix provides a brief narrative analysis of FOMC transcripts and minutes to showcase how FOMC members are comparing their own and market expectations, consistent with the observed misalignment measure. Important parts are highlighted in **bold** letters.

Positive misalignment ahead of the tightening cycles in 1999 and 2004.

- Transcript from the FOMC meeting on 12th August 2003:
  - Kohn: "In that regard, the **implied upturn in Eurodollar rates next spring is at odds with the flat path in the staff forecast** and I suspect from the tenor our last meeting with many of our own forecasts as

well. The market seems to be anticipating some combination of a more vigorous bounceback in demand and greater inflation pressure than is built into these forecasts."

- Ferguson: "Nobody can understand fully why **market expectations for monetary policy have shifted so dramatically toward a future tightening** by the FOMC. It may be due to the more positive tone in the recent economic information, as Governor Kohn has suggested, but it may also be that communication challenges will create a bit of a problem for us going forward."
- Bernanke: "This time around is different, or should be. Inflation is not a threat. Therefore, the FOMC does not need to take away the punch bowl so early in the party, so by rights interest rates should remain subdued despite the pickup in growth. **Judging by federal funds futures and other indicators, however, the markets have largely missed this point and have bid up interest rates well beyond where they ought to be in some sense**, to the detriment of the recovery. **To the extent that we can sharpen our message that economic growth no longer implies an immediate and automatic policy tightening, we should make every effort to do so.**"

The statements made in 1999 are less straightforwardly interpreted in terms of "misalignment" but there are still clear references to market expectations and comparisons to the FOMC views.

- Minutes from the FOMC meeting on 30th March 1999:
  - The FOMC members agreed that the next policy move was likely to be a tightening:
    * "many of the members commented that the **risks to their forecasts were tilted toward the eventual emergence of somewhat greater inflation pressures**."
    * "While many believed that the next policy move likely would be in the direction of some tightening, such an outcome was not a foregone conclusion, and in any event the timing of the next policy action was highly uncertain."
  - But "it was **clear that forecasts in recent years typically had overstated the rise in inflation**"
  - And therefore "the members agreed that were they to announce a shift to a tightening bias, it would likely have in current circumstances a

relatively pronounced and undesired effect on financial markets. In particular, **the markets might well build in higher odds of a policy tightening move at the May or June meetings than currently was consistent with the members' thinking**."

- Transcript from FOMC Meeting in May 1999:
  - Ferguson: "As others have indicated, the markets have already priced in some of this policy tightening, so we need not be concerned about an outsized reaction on their part, although there may be some as Don Kohn has indicated. "
  - Poole: "I anticipate a tightening trend. [...] I think we need to have some idea of how much that is going to be. [...] **it is possible that the markets will move long-term interest rates higher than we might consider justified**. I think we are now at about the outer time limit of being able to make a credible case that we are simply undoing some of the policy easing from last fall. The more distant in time that becomes, the less credible it will be to appeal to that as a way of **providing some cap on market expectations of where this tightening process might take us**."

Negative misalignment during 2007. For most part of the year 2007, market expectations have been more dovish than the Fed's own expectations. However, there were considerable dynamics within the year. According to the transcripts, misalignment narrowed by June 2007 before it widened again, consistent with observed misalignment.

- Transcript from FOMC in March 2007:
  - Dudley: "Nevertheless, the potential **gap between market expectations and the Committee's interest rate expectations may pose a bit of a conundrum for the Committee**. If the Committee were to shift the bias of its statement in the direction of neutral, market expectations with respect to easing would undoubtedly be pulled forward and might become more pronounced."
- Transcript from FOMC meeting in June 2007:
  - Moskow: "The change in fed funds futures brings market expectations into better alignment with what I think will be the appropriate path for monetary policy."

  - Reinhart: "**For all this year you have been hinting that prevailing market expectations for the fed funds rate were too low. Now that market participants have adjusted in your desired direction**, you might not want to surprise them."

- Transcript from FOMC in October 2007:

  - Kohn: "The **expectations now built into markets imply too much easing** over the next eighteen months, more than I think we're likely to have to do."

Appendix B

	Observations	Mean	Std. Dev.	Min	Max
Number of speeches	1,735	0.504	0.814	0.000	4.000
Tone of speeches	586	96.093	1.337	90.810	99.457
Regional unemployment	1,735	5.745	1.763	2.725	11.481
Absolute unemployment gap	1,735	0.650	0.542	0.002	2.746
Regional inflation	1,735	2.406	1.314	-4.366	6.275
Absolute inflation gap	1,735	0.673	0.635	0.000	4.495
Regional return on assets	1,735	1.185	0.556	-3.330	2.780
Absolute return on assets gap	1,735	0.258	0.299	0.000	3.230

Notes: The table reports summary statistics of the variables employed in the econometric analysis.

Table B.1: *Summary statistics*

District	MSA	MSA-states	Series ID	Source
Boston	Boston-Cambridge-Newton	MA-NH	CUURA103SA0	fred
New York	New York-Newark-Jersey City	NY-NJ-PA	CUURA101SA0	fred
Philadelphia	Philadelphia-Camden-Wilmington	PA-NJ-DE-MD	CUURA102SA0	fred
Cleveland	Cleveland-Akron	OH	CUURA210SA0	fred
Richmond	Washington-Baltimore (pre 2008)	DC-VA-MD-WV	CUURA311SA0	fred
Richmond	Washington-Arlington-Alexandria	DC-VA-MD-WV	CUURS35ASA0	bls
Atlanta	Atlanta-Sandy Springs-Roswell	GA	CUURA319SA0	fred
Chicago	Chicago-Naperville-Elgin	IL-IN-WI	CUURA207SA0	fred
St. Louis	St Louis	MO-IL	CUURA209SA0	fred
Minneapolis	Minneapolis-St.Paul-Bloomington	MN	CUURS24ASA0	bls
Kansas City	Denver-Aurora-Lakewood	CO	CUURS48BSA0	bls
Dallas	Dallas-Fort Worth-Arlington	TX	CUURA316SA0	fred
Dallas	Houston-The Woodlands-Sugar Land	TX	CUURA318SA0	fred
San Francisco	Los Angeles-Riverside-Orange County	CA	CUURA421SA0	fred
San Francisco	San Francisco-Oakland-Hayward	CA	CUURA422SA0	fred

Notes: The table shows lists the data sources used to compile CPI inflation for individual districts of the Federal Reserve System.

Table B.2: *Population weights of states within Fed districts*

District	State	Weight	District	State	Weight
Boston	Connecticut	0.199	St Louis	Illinois	0.113
	Maine	0.099		Missouri	0.278
	Massachusetts	0.486		Arkansas	0.188
	New Hampshire	0.090		Indiana	0.068
	Rhode Island	0.081		Kentucky	0.164
	Vermont	0.045		Mississippi	0.080
New York	Connecticut	0.034		Tennessee	0.108
	New Jersey	0.220	Minneapolis	Michigan	0.042
	New York	0.745		Minnesota	0.578
Philadelphia	Delaware	0.058		North Dakota	0.084
	New Jersey	0.209		South Dakota	0.092
	Pennsylvania	0.733		Wisconsin	0.099
Cleveland	Ohio	0.673		Montana	0.105
	Kentucky	0.101	Kansas	Kansas	0.183
	Pennsylvania	0.214		Missouri	0.120
	West Virginia	0.011		Colorado	0.243
Richmond	Virginia	0.265		New Mexico	0.071
	West Virginia	0.070		Wyoming	0.034
	Dc	0.026		Oklahoma	0.232
	Maryland	0.205		Nebraska	0.117
	North Carolina	0.284	Dallas	Louisiana	0.050
	South Carolina	0.149		Texas	0.920
Atlanta	Georgia	0.203		New Mexico	0.030
	Tennessee	0.111	San Francisco	California	0.637
	Alabama	0.127		Hawaii	0.024
	Florida	0.406		Nevada	0.026
	Louisiana	0.103		Arizona	0.078
	Mississippi	0.049		Idaho	0.022
Chicago	Illinois	0.327		Oregon	0.061
	Indiana	0.153		Washington	0.104
	Iowa	0.091		Utah	0.037
	Wisconsin	0.135		Alaska	0.012
	Michigan	0.293			

Notes: The table shows the weights of each state within a Fed district based on population weights based on material published by the Federal Reserve Board (access link here).

Table B.3: *Population weights of states within Fed districts*

	(1) Without voting	(2) Benchmark	(3) 5% threshold	(4) 10% threshold	(5) Reuters coverage	(6) No Reuters coverage	(7) Conditional on speaking	(8) Control for # of others' speeches	(9) Probit model	(10) Add inflation and RoA	(11) Until 2018	(12) Tone of beige book proxies for economy	(13) Pre-beige book release	(14) Post-beige book release
Absolute UE gap (β_u^N)	-0.084	-0.065	-0.066	-0.068	-0.036	-0.031	-0.075	-0.072	0.065	-0.065	-0.062	-0.047	-0.078	0.026
	(0.041)**	(0.043)	(0.042)	(0.035)**	(0.036)	(0.028)	(0.067)	(0.041)*	(0.057)	(0.041)	(0.043)	(0.027)*	(0.044)*	(0.018)
Absolute UE gap × voting (γ^N)	–	-0.062	-0.088	-0.051	-0.063	-0.005	0.008	-0.071	0.086	-0.054	-0.057	-0.037	-0.059	-0.034
		(0.037)*	(0.032)***	(0.033)	(0.036)*	(0.017)	(0.059)	(0.042)*	(0.034)**	(0.037)	(0.033)*	(0.022)*	(0.030)**	(0.023)
Voting (β_v^N)	–	0.007	0.029	0.007	0.007	-0.001	-0.098	0.010	-0.031	0.030	-0.007	0.042	0.019	0.009
		(0.027)	(0.025)	(0.020)	(0.025)	(0.015)	(0.044)**	(0.035)	(0.032)	(0.042)	(0.025)	(0.026)	(0.029)	(0.016)
Speeches by other members	–	–	–	–	–	–	–	-0.018	–	–	–	–	–	–
								(0.003)***						
Abs. Infl gap (non-voting)	–	–	–	–	–	–	–	–	–	-0.023	–	–	–	–
										(0.026)				
Abs. Infl gap × voting	–	–	–	–	–	–	–	–	–	-0.033	–	–	–	–
										(0.033)				
Abs. RoA gap (non-voting)	–	–	–	–	–	–	–	–	–	0.022	–	–	–	–
										(0.054)				
Abs. RoA gap × voting	–	–	–	–	–	–	–	–	–	-0.009	–	–	–	–
										(0.064)				
Meeting FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Speaker FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,735	1,735	1,735	1,735	1,735	1,735	586	1,735	1,570	1,735	2,084	1,735	1,735	1,735

Notes: The table shows marginal effects for the effect of regional macroeconomic conditions and voting status on the number of speeches given by FOMC members in the rotation scheme, based on an ordered probit model following Eq. 2.2, for the outcome of zero speeches. Information in the columns follows the format of Table 2.3. Numbers in brackets are standard errors. ***/**/* denote statistical significance at the 1%/5%/10% level.

Table B.4: *Determinants of the number of speeches given, marginal effects*

	First intervention			All interventions		
	(1)	(2)	(3)	(4)	(5)	(6)
Absolute UE gap (β_u^W)	0.058	–	0.064	0.024	–	0.023
	(0.143)		(0.144)	(0.044)		(0.044)
Absolute UE gap × voting (γ_{uv}^W)	-0.095	–	-0.107	0.018	–	0.020
	(0.138)		(0.147)	(0.034)		(0.036)
Number of speeches (β_N^W)	–	-0.065	-0.068	–	0.010	0.009
		(0.051)	(0.048)		(0.010)	(0.010)
Number of speeches × voting (γ_{Nv}^W)	–	0.070	0.079	–	-0.011	-0.014
		(0.061)	(0.060)		(0.015)	(0.016)
Voting status (β_v^W)	-0.052	-0.146***	-0.082	0.011	0.027	0.016
	(0.089)	(0.046)	(0.089)	(0.023)	(0.023)	(0.025)
Absolute UE gap, voting ($\beta_u^W + \gamma_{uv}^W$)	-0.037		-0.044	0.042		0.043
	(0.125)		(0.133)	(0.031)		(0.029)
Number of speeches, voting ($\beta_N^W + \gamma_{Nv}^W$)		0.004	0.012		-0.001	-0.004
		(0.056)	(0.060)		(0.011)	(0.012)
Period FE	Yes	Yes	Yes	Yes	Yes	Yes
President FE	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.335	0.335	0.336	0.849	0.849	0.849
Observations	1,714	1,714	1,714	1,714	1,714	1,714

Notes: The table shows coefficient estimates for the effect of regional macroeconomic conditions, the number of speeches and voting status on the tone of interventions at the FOMC meeting, following the OLS regression: $W_{i,t} = \mu_i + \mu_t + \beta_u^W |u_{d_i t} - u_{\text{US},t}| + \beta_v^W v_{d_i t} + \gamma_{uv}^W v_{d_i t} |u_{d_i t} - u_{\text{US},t}| + \beta_N^W N_{i,t} + \gamma_{Nv}^W N_{i,t} v_{d_i t} + \epsilon_{it}$. The left panel relates to the tone of the first intervention at the FOMC meeting, the right panel to the tone of all interventions together. Standard errors are in brackets. Coefficients in bold are statistically significantly different from the top row coefficients at least at the 10% level. ***/**/* denote statistical significance at the 1%/5%/10% level.

Table B.5: *Determinants of the length of meeting interventions*

Appendix C

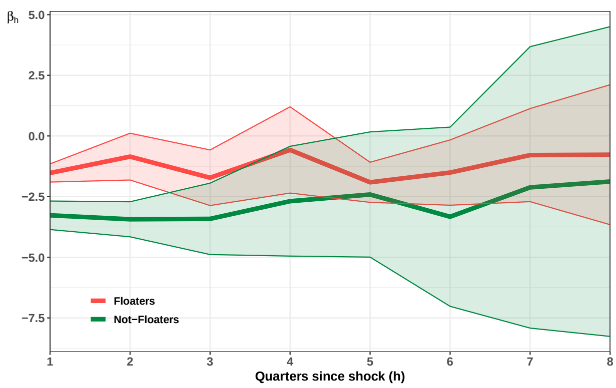
C.1 Robustness tests

C.1.1 Robustness: Macro heterogeneity

	Dep-var: $\Delta k_{p,t}$			
	(1)	(2)	(3)	(4)
$\text{mp}^{\$}_{W} \times \text{Mat}^{\$}_{p,Z}$	-1.268^{**}	-0.659^{**}	-1.695^{**}	-1.270^{**}
	(0.621)	(0.272)	(0.814)	(0.484)
$\text{mp}^{\$}_{W} \times \text{Mat}^{\$}_{p,Z} \times \mathbb{1}^{\text{nflt}}_{c,t}$	-1.754^{***}	-3.178^{**}	-3.124^{**}	-2.755^{*}
	(0.610)	(1.550)	(1.276)	(1.435)
Maturing timing (Z)	F2($t-1$)−F1(t)	F1($t-1$)−F1(t)	F2($t-1$)+2w	F2($t-1$)+2w−F1(t)+2w
MP shock from (W)	F2($t-1$)	F1($t-1$)+F2($t-1$)	F2($t-1$)	F2($t-1$)+F1(t)
Obs	208,479	208,631	208,479	208,479
Adjusted R^2	0.182	0.176	0.180	0.180

Notes: "Maturing timing (Z)" indicates the timing over which maturing debt is captured. "MP shock from (W)" indicates the corresponding monetary shocks. F1($t-1$) refers to the first FOMC in previous quarter, F1(t) to first FOMC in current quarter. F2($t-1$)+2w captures the two weeks following the second FOMC in previous quarter. If two shocks are used (e.g. F2($t-1$)+F1(t)) the shocks are effectively weighted. $\Delta k_{p,c,t}$ is the log change in net PPE, normalized by its standard deviation. Includes triple interaction with openess index $\text{KO}_{c,t}$ (Chinn and Ito, 2006), estimates thus conditional on financial openness. All specs include firm-, fiscal-quarter-, and country×date FE; and firm-, and interaction controls. Standard errors two-way clustered by country and date. Quarterly firm data from 2003 to 2016, crises excluded.

Table C.1: *Different maturing-timing assumptions*



Notes: Local projection estimates á la Jordà (2005) of the specification

$$k_{p,c,t+h} - k_{p,c,t} = \beta^h \, \text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} + \gamma_1 X_{p,t-1} + \gamma_2 \, \text{mp}^{\$}_{t-1} \times X_{p,t-1} + \vec{a}_{p,t} + \epsilon_{p,t,h},$$

for horizons $h \in [0, 8]$. k is in log of net PPE. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarocinski,Karadi 2018). $\text{Mat}^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD debt maturing after the last FOMC in previous quarter. $\vec{a}_{p,t}$ denotes firm-, fiscal-quarter-, and country×date FE. Quarterly firm data from 2003 to 2016, crises excluded.

Figure C.1: *Dynamics of maturing×shock-interaction coefficient*

	Dep-var: $\Delta k_{p,t}$				
	(1)	(2)	(3)	(4)	(5)
$\text{Mat}^{\$}_{p,t-1}$	0.006	−0.018	0.041	−0.005	−0.004
	(0.043)	(0.028)	(0.044)	(0.021)	(0.032)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$	-1.782^{***}	-1.304^{***}	-2.889^{***}	-1.954^{***}	-2.441^{***}
	(0.537)	(0.399)	(0.280)	(0.637)	(0.731)
Group	All	Float	Non-Float	Developed	Developing
Obs	208,479	71,774	136,561	90,848	117,425
Adjusted R^2	0.182	0.141	0.156	0.115	0.161

Notes: $\Delta k_{p,c,t}$ is the log change in net PPE, normalized by its country-specific standard deviation. $\text{Mat}^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). Includes triple interaction with openess index $\text{KO}_{c,t}$ (Chinn and Ito, 2006), estimates thus conditional on financial openness. All specs include firm-, fiscal-quarter-, and country×date FE; and firm-, and interaction controls. Firm controls (at previous quarter) are real sales growth, cash flow, log assets, leverage, cash/TA, variable-rate debt/TA, USD-debt-dummy. Int-controls are interactions of $\text{mp}^{\$}_{t-1}$ with the latter five controls. Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises excluded.

Table C.2: *Spillover estimates by sub-sample, $\Delta k_{p,t}$ normalized by country-specific SD*

	Dep-var: $\Delta k_{p,t}$			
	(1)	(2)	(3)	(4)
$\text{Mat}^{\$}_{p,t-1}$	0.006	−0.018	−0.002	−0.016
	(0.043)	(0.028)	(0.051)	(0.083)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$	-1.782^{***}	-1.304^{***}	-3.021^{***}	-3.151^{***}
	(0.537)	(0.399)	(0.768)	(1.062)
Group	All	Float	Managed	Peg
Observations	208,479	71,774	66,437	69,826
Adjusted R^2	0.182	0.141	0.121	0.215

Notes: $\Delta k_{p,c,t}$ is the log change in net PPE, normalized by its country-specific standard deviation. $\text{Mat}^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). Includes triple interaction with openess index $\text{KO}_{c,t}$ (Chinn and Ito, 2006), so that estimates of maturing interactions are conditional on financial openness. All specs include firm-, fiscal-quarter-, and country×date FE; and firm-, and interaction controls. Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises excluded.

Table C.3: *Granular classification of exchange rate regime*

	Dep-var: $\Delta k_{p,t}$					
	(1)	(2)	(3)	(4)	(5)	(6)
$\text{MP}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$	-1.258^{**}	-1.250^{**}	-1.272^{**}	-1.268^{**}	-1.273^{**}	-1.425^{***}
	(0.596)	(0.594)	(0.625)	(0.621)	(0.554)	(0.511)
$\text{MP}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$	-1.818^{***}	-1.790^{***}	-1.774^{***}	-1.754^{***}	-1.613^{**}	-1.392^{**}
	(0.564)	(0.571)	(0.625)	(0.610)	(0.651)	(0.626)
Int-controls	None	+TA	+Cash	+Lev	+STdebt	+TobinQ
Obs	208,479	208,479	208,479	208,479	206,005	179,268
Adjusted R^2	0.182	0.182	0.182	0.182	0.184	0.202

Notes: Interaction controls are added 1-by-1 as indicated in row Int-controls. Cash and short-term debt (STdebt) are ratios over total assets. Int-controls means triple interactions of $\text{mp}^{\$}_{t-1}$ with firm controls and ER-regime-dummy. $\text{Mat}^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). Includes triple interaction with openess index $\text{KO}_{c,t}$ (Chinn and Ito, 2006), estimates of maturing interactions are thus conditional on financial openness. All specifications include firm-, fiscal-quarter-, and country×date FE. Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises excluded.

Table C.4: *Floaters vs Not-Floaters-differences by controls*

excluded	$mp^{\$} \times Mat^{\$}$		$mp^{\$} \times Mat^{\$} \times \mathbb{1}^{nflt}$		excluded	$mp^{\$} \times Mat^{\$}$		$mp^{\$} \times Mat^{\$} \times \mathbb{1}^{nflt}$	
IRL	-1.32^{**}	(0.59)	-1.70^{***}	(0.60)	PER	-1.23^{*}	(0.63)	-1.26^{**}	(0.55)
FRA	-1.30^{**}	(0.62)	-1.72^{**}	(0.67)	LKA	-1.27^{**}	(0.58)	-1.78^{***}	(0.65)
CYP	-1.11^{**}	(0.58)	-1.94^{**}	(0.80)	CHL	-1.28^{*}	(0.63)	-1.88^{***}	(0.64)
ESP	-1.15^{**}	(0.47)	-1.92^{***}	(0.64)	SWE	-1.31^{**}	(0.63)	-1.71^{**}	(0.64)
GRC	-1.28^{**}	(0.63)	-1.74^{**}	(0.64)	TUR	-1.30^{**}	(0.57)	-1.58^{***}	(0.53)
GBR	-1.38^{**}	(0.61)	-1.67^{***}	(0.57)	MEX	-1.27^{**}	(0.62)	-1.98^{**}	(0.95)
LUX	-1.30^{**}	(0.62)	-1.73^{**}	(0.70)	POL	-1.14^{*}	(0.64)	-2.19^{**}	(0.89)
NLD	-1.27^{*}	(0.64)	-1.74^{**}	(0.71)	DEU	-1.37^{**}	(0.55)	-1.67^{***}	(0.53)
DNK	-1.27^{*}	(0.63)	-1.75^{**}	(0.64)	IND	-1.32^{**}	(0.63)	-1.89^{***}	(0.67)
CHE	-1.52^{**}	(0.72)	-1.54^{**}	(0.65)	ISR	-1.19^{**}	(0.58)	-2.03^{***}	(0.43)
ARG	-1.27^{*}	(0.63)	-1.76^{**}	(0.66)	BRA	-1.43^{***}	(0.50)	-1.26^{***}	(0.33)
ITA	-1.24^{*}	(0.63)	-1.78^{**}	(0.68)	IDN	-1.25^{*}	(0.64)	-1.90^{***}	(0.65)
HRV	-1.28^{*}	(0.66)	-1.71^{***}	(0.62)	SGP	-1.29^{**}	(0.53)	-1.87^{***}	(0.68)
NOR	-1.55^{**}	(0.61)	-1.52^{***}	(0.48)	KOR	-1.28^{**}	(0.62)	-1.99^{***}	(0.60)
HKG	-1.29^{**}	(0.63)	-1.81^{**}	(0.74)	THA	-1.25^{*}	(0.63)	-1.73^{**}	(0.66)
PHL	-1.28^{*}	(0.63)	-1.68^{**}	(0.67)	MYS	-1.27^{**}	(0.62)	-1.70^{**}	(0.76)
FIN	-1.28^{**}	(0.62)	-1.74^{***}	(0.61)	JPN	-1.15^{**}	(0.57)	-1.91^{**}	(0.93)
VNM	-1.27^{*}	(0.63)	-1.76^{**}	(0.66)	CHN	-1.17^{*}	(0.62)	-1.61^{**}	(0.63)

Notes: Estimates of Eq.: $\Delta k_{p,c,t} = \beta^R \text{ mp}^{US}_{t-1} \times \text{ Mat}^{\$}_{p,t-1} + \gamma^R \text{ mp}^{US}_{t-1} \times \text{ Mat}^{\$}_{p,t-1} \times \mathbb{1}^{nflt}_{c,t} + \vec{a}_{p,t} + \epsilon_{p,t}$, Columns "excluded" indicate the country that was dropped from the sample. $\mathbb{1}^{nflt}_{c,t}$ equals 1 if country c has a de-facto non-floating exchange rate (from Ilzetzki et al., 2019). $\text{Mat}^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). Includes triple interaction with openess index $KO_{c,t}$ (Chinn and Ito, 2006), so that estimates of maturing interactions are conditional on financial openness. All specs include firm-, fiscal-quarter-, and country×date FE; and firm-, and interaction controls. Firm controls (at previous quarter) are real sales growth, cash flow, log assets, leverage, cash/TA, variable-rate debt/TA, USD-debt-dummy. Int-controls are interactions of $\text{mp}^{\$}_{t-1}$ with the latter five controls. Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises excluded.

Table C.5: *Float vs Non-Float gap (γ^R) in subsamples excluding one country at a time*

C.1.2 Robustness: Macro x firm heterogeneity

	Dep-var: $\Delta k_{p,t}$							
Sorting variable:	Net lev$(t-2)$		Net lev $(t-1$,w/i regime)		Book lev $(t-1)$		Net lev $(t-1)$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$	-1.661^{**}	-0.832^{**}	-1.757^{**}	-0.902^{*}	-2.641^{***}	-0.548	-0.503	-1.679^{**}
	(0.770)	(0.331)	(0.726)	(0.444)	(0.549)	(0.377)	(1.164)	(0.673)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$	-2.349^{***}	-0.751	-2.065^{***}	-0.994	-2.031^{***}	-1.623	-3.663^{***}	0.642
	(0.634)	(1.085)	(0.606)	(1.244)	(0.401)	(1.368)	(1.242)	(1.459)
Firm group (R)	High Lev	Low Lev	High Lev	Low Lev	High Lev	Low Lev	High Lev	Low Lev
Firm types	All	All	All	All	All	All	Exporter	Exporter
Obs	102,450	103,546	103,100	102,896	102,371	103,625	56,924	56,783
Adjusted R^2	0.169	0.220	0.169	0.219	0.181	0.203	0.165	0.200

Notes: The table reports estimates of β^R and γ^R, split the sample into high and low leverage groups using different measures of leverage. Eq.: $\Delta k_{p,c,t} = \beta^R \text{ mp}^{\$}_{t-1} \times \text{ Mat}^{\$}_{p,t-1} + \gamma^R \text{ mp}^{\$}_{t-1} \times \text{ Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t} + \vec{a}_{p,t} + \epsilon_{p,t}$, Net lev is debt minus cash over assets, the baseline. $t-2$ indicates that I sorted on the second lag. For Net lev $(t-1$,w/i regime), I classify firms based on the median of net leverage computed within the group of firms in floaters and non-floaters, rather than the grand-median (baseline). Book lev is debt over assets. In Columns 7 and 8, I compare, within the group of exporters, high vs low net leverage. $\mathbb{1}^{\text{nflt}}_{c,t}$ equals 1 if country c has a de-facto Non-floating exchange rate (from Ilzetzki et al., 2019). $\text{Mat}^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). Includes triple interaction of $\text{mp}^{\$}_{t-1}, \text{Mat}^{\$}_{p,t-1}$ with openess index $\text{KO}_{c,t}$ (Chinn and Ito, 2006), thus estimates of maturing interactions are conditional on financial openness. All specs include firm-, fiscal-quarter-, and country×date FE; and firm-, and interaction controls. Interaction controls are triple interactions of $\text{mp}^{\$}_{t-1}$ with firm controls and $\mathbb{1}^{\text{nflt}}_{c,t}$. Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises excluded.

Table C.6: *Leverage sub-samples, different leverage measures for sorting*

	Dep-var: $\Delta k_{p,t}$			
	(1)	(2)	(3)	(4)
$mp^{\$}_{t-1} \times Mat^{\$}_{p,t-1}$	-2.198^{**}	-1.544^{**}	-1.413^{*}	-2.436^{***}
	(0.832)	(0.626)	(0.717)	(0.677)
$mp^{\$}_{t-1} \times Mat^{\$}_{p,t-1} \times \mathbb{1}^{nflt}_{c,t}$	-1.561^{**}	-0.946	-1.310	0.817
	(0.650)	(0.989)	(0.968)	(1.039)
$mp^{ER}_{t-1} \times Mat^{\$}_{p,t-1}$	0.028	0.056	0.046	0.083^{*}
	(0.056)	(0.044)	(0.061)	(0.042)
$mp^{ER}_{t-1} \times Mat^{\$}_{p,t-1} \times \mathbb{1}^{nflt}_{c,t}$	-0.136^{**}	-0.088	-0.108	-0.173^{**}
	(0.059)	(0.076)	(0.078)	(0.071)
Firm group (R)	High Lev	Low Lev	Export	Non-Export
Obs	70,245	65,932	80,801	57,410
Adjusted R^2	0.158	0.162	0.150	0.139

Notes: $mp^{ER}_{t-1} \times Mat^{\$}_{p,t-1}$, the home currency depreciation after FOMCs interacted with the maturing dummy. $\mathbb{1}^{nflt}_{c,t}$ equals 1 if country c has a de-facto managed exchange rate (from Ilzetzki et al., 2019); hard pegs are excluded from the sample. $Mat^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. $mp^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). Includes triple interaction of $mp^{\$}_{t-1}, Mat^{\$}_{p,t-1}$ with openess index $KO_{c,t}$ (Chinn and Ito, 2006), thus estimates of maturing interactions are conditional on financial openness. All specs include firm-, fiscal-quarter-, and country×date FE; and firm-, and interaction controls. Interaction controls are triple interactions of $mp^{\$}_{t-1}$ with firm controls and $\mathbb{1}^{nflt}_{c,t}$. Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises excluded.

Table C.7: *Exporter/Leverage sub-samples controlling for ER, excl. hard pegs*

	Dep-var: $\Delta k_{p,t}$			
	(1)	(2)	(3)	(4)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \text{KO}_{c,t}$	1.304^{**}	1.102^{*}	1.958^{***}	1.844^{*}
	(0.628)	(0.623)	(0.684)	(1.024)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$	-1.900^{**}	-2.153^{*}	-2.734^{**}	-3.307^{***}
	(0.816)	(1.230)	(1.039)	(1.204)
$\text{mp}^{ER}_{c,t-1} \times \text{Mat}^{\$}_{p,t-1}$		0.041		0.113^{**}
		(0.063)		(0.049)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$	-2.710^{***}	-1.566^{*}	-1.029	-0.115
	(0.787)	(0.826)	(0.987)	(1.045)
$\text{mp}^{ER}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$		-0.150^{**}		-0.108
		(0.055)		(0.080)
$\text{mp}^{ER}_{c,t-1} \times \text{Mat}^{\$}_{p,t-1} \times \text{FinDev}_{c,t}$		0.035		0.011
		(0.062)		(0.021)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \text{FinDev}_{c,t}$	-0.112	-0.283	-1.068^{*}	-1.380^{**}
	(0.715)	(0.727)	(0.579)	(0.556)
Firm group (R)	High Lev	High Lev	Low Lev	Low Lev
Obs	104,063	104,063	101,933	101,933
Adjusted R^2	0.170	0.170	0.219	0.219

Notes: $\text{FinDev}_{c,t}$ is IMF yearly financial development index (higher values=less developed). $\text{KO}_{c,t}$ measures capital openness (Chinn and Ito, 2006;higher values=less open). $\mathbb{1}^{\text{nflt}}_{c,t}$ equals 1 if country c has a de-facto Non-floating exchange rate (from Ilzetzki et al., 2019). $\text{Mat}^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). All specs include firm-, fiscal-quarter-, and country×date FE; and firm-, and interaction controls. Interaction controls are triple interactions of $\text{mp}^{\$}_{t-1}$ with firm controls and $\mathbb{1}^{\text{nflt}}_{c,t}$. Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises excluded.

Table C.8: *Leverage sub-samples, controlling for exchange rate and financial development*

	Dep-var: $\Delta k_{p,c,t}$		
	(1)	(2)	(3)
$mp^{\$}_{t-1} \times Mat^{\$}_{p,t-1}$	-1.268^{**}	-1.012^{**}	-1.754^{**}
	(0.621)	(0.414)	(0.826)
$mp^{\$}_{t-1} \times Mat^{\$}_{p,t-1} \times KO_{c,t}$	0.993^{***}	1.109^{***}	1.645^{**}
	(0.259)	(0.397)	(0.648)
$mp^{\$}_{t-1} \times Mat^{\$}_{p,t-1} \times \mathbb{1}^{nflt}_{c,t}$	-1.754^{***}	-0.135	-0.025
	(0.610)	(0.642)	(0.533)
$mp^{\$}_{t-1} \times Mat^{\$}_{p,t-1} \times \mathbb{1}^{high\text{-}lev}_{p,t-1}$		-0.358	-0.477
		(0.728)	(0.759)
$mp^{\$}_{t-1} \times Mat^{\$}_{p,t-1} \times \mathbb{1}^{high\text{-}lev}_{p,t-1} \times \mathbb{1}^{nflt}_{c,t}$		-2.898^{**}	-2.344^{**}
		(1.392)	(1.116)
$mp^{\$}_{t-1} \times Mat^{\$}_{p,t-1} \times FinDev_{c,t}$			-0.924
			(0.758)
Obs	208,479	208,470	208,470
Adjusted R^2	0.182	0.182	0.182

Notes: $\mathbb{1}^{high\text{-}lev}_{p,t-1}$ equals 1 if firm p's net leverage is above the median. $\mathbb{1}^{nflt}_{c,t}$ equals 1 if country c has a de-facto Non-floating exchange rate (from Ilzetzki et al., 2019). $FinDev_{c,t}$ is IMF yearly financial development index (higher values=less developed). $KO_{c,t}$ measures capital openness (Chinn and Ito, 2006;higher values=less open). $Mat^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. $mp^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). All specs include firm-, fiscal-quarter-, and country×date FE; and firm-, and interaction controls. Interaction controls are triple interactions of $mp^{\$}_{t-1}$ with firm controls and $\mathbb{1}^{nflt}_{c,t}$. Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises excluded.

Table C.9: *Leverage-interaction, exchange rate regime and fin. development*

	Dep-var: $\Delta k_{p,c,t}$				
	(1)	(2)	(3)	(4)	(5)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$	-1.268^{**}	-1.012^{**}	-0.954^{**}	-1.355^{*}	-0.470
	(0.621)	(0.414)	(0.458)	(0.689)	(0.856)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$	-1.754^{***}	-0.135	-0.075	0.021	0.856
	(0.610)	(0.642)	(0.723)	(0.879)	(2.215)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{high-lev}}_{p,t-1}$		-0.358	1.011	-0.254	-0.761
		(0.728)	(1.039)	(0.870)	(0.851)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{high-lev}}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$		-2.898^{**}	-4.061^{**}	-3.054^{**}	-3.557^{**}
		(1.392)	(1.715)	(1.456)	(1.725)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times Z_{p,t-1}$			-2.535^{*}	0.500	-0.855
			(1.280)	(1.599)	(1.432)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times Z_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$			1.526	-1.194	-1.380
			(1.848)	(2.770)	(2.495)
New control ($Z_{p,t-1}$)	-	-	ST debt	Bond debt	Cash
Obs	208,479	208,470	207,577	207,577	207,577
Adjusted R^2	0.182	0.182	0.183	0.183	0.184

Notes: This table reports the effect of the leverage-regime interaction controlling for other firm balance sheet features. $Z_{p,t-1}$ equals 1 if firm p's share of short-term debt, bond debt or cash over assets is greater its grand median. $\text{Mat}^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). $\mathbb{1}^{\text{nflt}}_{c,t}$ equals 1 if country c has a de-facto Non-floating exchange rate (from Ilzetzki et al., 2019). Includes triple interaction of $\text{mp}^{\$}_{t-1}, \text{Mat}^{\$}_{p,t-1}$ with openess index $\text{KO}_{c,t}$ (Chinn and Ito, 2006), thus estimates of maturing interactions are conditional on financial openness. All specs include firm-, fiscal-quarter-, and country×date FE; and firm-, and interaction controls. Interaction controls are triple interactions of $\text{mp}^{\$}_{t-1}$ with firm controls and $\mathbb{1}^{\text{nflt}}_{c,t}$. Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises excluded.

Table C.10: *Controlling for shares of short-term debt, bond debt, cash holdings*

	Dep-var: $\Delta k_{p,c,t}$			
	(1)	(2)	(3)	(4)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$	-1.592^{***}	-1.124^{*}	-0.781	-1.210^{*}
	(0.489)	(0.589)	(0.669)	(0.649)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$		-1.505^{**}	-0.237	-0.713
		(0.688)	(0.946)	(1.026)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{high-lev}}_{p,t-1}$			-0.715	
			(0.764)	
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{high-lev}}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$			-2.473^{**}	
			(1.045)	
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{high-USD-lev}}_{p,t-1}$				0.373
				(1.540)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{high-USD-lev}}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$				-3.781^{*}
				(1.877)
Leverage measure	-	-	overall	USD
Obs	111,736	111,736	111,736	111,736
Adjusted R^2	0.171	0.171	0.172	0.171

Notes: The table contrasts estimates based on overall leverage (basline, column 3) with those based on USD-leverage (USD-debt over assets, column 4). $\mathbb{1}^{\text{high-lev}}_{p,t-1}$ and $\mathbb{1}^{\text{high-USD-lev}}_{p,t-1}$ equal 1 if the respective leverage measure is above the median. Based on subsample of firms with USD-debt outstanding. $\text{Mat}^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). $\mathbb{1}^{\text{nflt}}_{c,t}$ equals 1 if country c has a de-facto Non-floating exchange rate (from Ilzetzki et al., 2019). Includes triple interaction of $\text{mp}^{\$}_{t-1}, \text{Mat}^{\$}_{p,t-1}$ with openess index $\text{KO}_{c,t}$ (Chinn and Ito, 2006), thus estimates of maturing interactions are conditional on financial openness. All specs include firm-, fiscal-quarter-, and country×date FE; and firm-, and interaction controls. Interaction controls are triple interactions of $\text{mp}^{\$}_{t-1}$ with firm controls and $\mathbb{1}^{\text{nflt}}_{c,t}$. Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises excluded.

Table C.11: *Leverage and ER regime interactions: Dollar leverage*

C.1.3 Robustness: Other

	Dep-var: $\Delta k_{p,t}$		
	(1)	(2)	(3)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1}$	-1.777^{***}	-1.481^{***}	-1.590^{**}
	(0.324)	(0.376)	(0.769)
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{>2010}_{t}$		-1.706	
		(1.276)	
$\text{mp}^{\$}_{t-1} \times \text{Mat}^{\$}_{p,t-1} \times \mathbb{1}^{\text{mp}>0}_{t}$			0.117
			(1.725)
Obs	208,479	208,479	208,479
Adjusted R^2	0.181	0.181	0.181

Notes: $\mathbb{1}^{\text{mp}>0}_{t}$ equals 1 if the sign of monetary shock is positive and $\mathbb{1}^{>2010}_{t}$ equals 1 for the sample after 2010. $\text{Mat}^{\$}_{p,t-1}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in previous quarter. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). All specs include firm-, fiscal-quarter-, and country×date FE; and firm-, and interaction controls. Firm controls (at previous quarter) are real sales growth, cash flow, log assets, leverage, cash/TA, variable-rate debt/TA, USD-debt-dummy. Int-controls are interactions of $\text{mp}^{\$}_{t-1}$ with the latter five controls. Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises excluded.

Table C.12: *Testing for effect asymmetry and sample period*

	Dep-var: $\text{Mat}^{\$}_{p,t}$
$\Delta\text{sales}_{p,t-1}$	-0.00000
	(0.00002)
$\log \text{TA}_{p,t-1}$	-0.00100
	(0.00100)
$\text{CF}_{p,t-1}$	-0.00004
	(0.00010)
$\text{Cash/TA}_{p,t-1}$	-0.00003
	(0.00004)
$\text{Lev}_{p,t-1}$	0.00004
	(0.00003)
Country×date FE	Y
Firm FE	Y
Obs	208,479
Adjusted R^2	0.097

Notes: Standard errors two-way clustered by firm and date. Estimates of a linear probability model, regressing the maturing-dummy $\text{Mat}^{\$}_{p,t}$ on firm characteristics measured at preceding quarter. Firm characteristics are (in this order) real growth in sales, log of total assets, cash flow over assets, cash over assets, and book leverage. Further controls for a dummy that equals 1 if firm p has USD-debt (mechanically linked to $\text{Mat}^{\$}_{p,t}$; omitted for brevity). All specs include firm-, country×date and fiscal-quarter-FE. $\text{Mat}^{\$}_{p,t}$ is a dummy equal to 1 if firm p had USD-debt maturing after the last FOMC in current quarter.

Table C.13: *Effect of firm characteristics on main maturing variable*

C.2 Additional analysis

C.2.1 Further discussion of results

Economic magnitude of effects. Interpreting the economic size of my estimates of the maturing debt effect requires careful attention.

An important reference point are the estimates reported in Ottonello and Winberry (2018) because they provide an estimate of the *level* of the effect of US monetary policy shocks on US investment, as opposed to estimates of firm heterogeneity. The estimates reported in Ottonello and Winberry (2018) imply that the average US firm cuts investment by around -4% on impact following a 1 pp. contractionary shock. I estimate that firms with USD debt reduce their investment by -5% relative to firms without USD debt. Firms with maturing USD debt, reduce their investment by -12% relative to all other firms. The maturing effect (on average across non-US firms) is thus around 2-3 times larger than the difference between firms with and without USD debt, and around 3 times larger than the average reaction of US firm. This is large but reasonable, for two key reasons

1. the maturing effect captures also exchange rate effects, which provide an amplification mechanism that is absent for US firms

2. my estimates isolate a bond-financing spillover channel. Other monetary spillover channels might influence investment in the opposite direction. For instance, the estimates based on country-level aggregate data reported in Ilzetzki and Jin (2013) imply that the overall effect of US monetary tightening on economic activity could be positive (which could be explained with Fed information effects).

Another reference point are the estimates of firm heterogeneity in investment responses provided in Jeenas (2018). Jeenas (2018) estimates that firms with a leverage that is 1-standard deviation higher than the average firm experience -6.6% lower cumulative growth in physical capital over three years.

Focus on large, public firms. Given my data sources, my analysis focuses on large, publicly traded firms. The lack of consistent quarterly accounting data for private companies does not allow me to analyze private firms, which make up a substantial part of many economies. Equally, my identification approach based on maturing debt means that I require detailed information on the firms' debt maturity structure, which I do not have for small private firms. Despite this limitation, the finding that few large firms drive a significant share of aggregate fluctuations (Gabaix, 2011) strongly supports the importance of my results.

Unconventional monetary policy. Empirical papers generally find that the Fed's forward guidance and quantitative easing measures have had significant impact on international asset prices (Chen et al., 2012; Neely, 2015; Bowman et al., 2015; Rogers et al., 2018) and portfolio flows (Fratzscher et al., 2018). Duca et al. (2016) shows that the Fed's large scale asset purchases programmes (LSAP) were associated with increases in gross corporate bond issuance, particularly in Advanced economies.

It is less clear whether and how international transmission differs between unconventional and conventional US monetary policy regimes. Examining yields on USD-denominated sovereign bonds in Emerging and Advanced economies, Gilchrist et al. (2019) concludes that international transmission of US monetary policy is broadly similar between conventional and unconventional regimes. Instead, examining local currency sovereign bond yields, Albagli et al. (2019) finds that US monetary spillovers have strengthened significantly after 2008.

In the context of unconventional monetary policy, the literature typically takes into account the multi-dimensionality of monetary surprises, i.e. news relevant for specific parts of the yield curve (e.g. Swanson, 2020). Three separate measures of monetary surprises are derived for the level of future short-term interest rates (the traditional *level/target* shock), the path of future short-rates (*path* shock) and the long-end of the yield curve (*term premium/LSAP* shock). All three types have been shown to affect foreign long-term bond yields (Kearns et al., 2020) and Dollar exchange rates (Rogers et al., 2018).

To test whether my estimates of the real effects are different for unconventional policies, I estimate the effect of the maturing×shock variables for the subsets of FOMC announcements related to LSAPs and forward guidance.[1]

First, I use my baseline monetary shock measures from Jarociński and Karadi (2020) based on 3-month future contracts. To facilitate comparison, I rescale the coefficients such that the standard deviation of the shocks is the same across samples (the unit of coefficient is still 1 percentage point). Table C.14 confirms that the Fed's unconventional policy had significant real effects (columns 2 and 3) but also that the main effect is robust to excluding them (column 1). Columns 4 and 5 show that the investment responses to LSAP announcements are driven by non-floaters. Instead, the responses to forward guidance announcements are also significant for floaters (similar to the baseline). This seems consistent with Albagli et al. (2019) who find that spillovers to long-term rates in Emerging markets arise through the responses in term premia whereas in Advanced economies through future short-rates.[2]

[1] I obtain dates of major unconventional policy announcements from https://www.newyorkfed.org/markets/programs-archive/large-scale-asset-purchases and https://www.federalreserve.gov/monetarypolicy/timeline-forward-guidance-about-the-federal-funds-rate.htm. I end up with 17 dates for LSAPs and 18 for forward guidance (with 4 coinciding), ranging from initial announcement over extension/slowdowns/modifications to normalization. For continuity in the analysis, I ignore announcements outside the regular FOMC schedule which means I also disregard the announcement of the Fed's first round of QE in November 2008. These simplifications mean that my estimates for unconventional policy likely represent the lower bound.

[2] Albagli et al. (2019) uses the two-day change over the FOMC annoucement day in the 2-year US Treasury yield as monetary policy shock measure, which captures news about both the level and path of future short-rates.

	Dep-var: $\Delta k_{p,c,t}$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\text{mp}^{\$,X}_{t-1} \times \text{Mat}^{\$,Z}_{p,t-1}$	-1.023^{***}	-2.940^{***}	-2.595^{***}	-0.146	-1.435^{**}	0.176	-2.090^{***}
	(0.358)	(0.789)	(0.582)	(1.362)	(0.639)	(1.311)	(0.675)
$\text{mp}^{\$,X}_{t-1} \times \text{Mat}^{\$,Z}_{p,t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$				-3.983^{***}	-1.786^{***}	-4.776^{***}	-1.434^{*}
				(0.782)	(0.393)	(1.721)	(0.828)
FOMCs (Z)	excl QE/FWG	QE	FWG	QE	FWG	QE	FWG
Shock type (X)	baseline	baseline	baseline	baseline	baseline	path	path
Obs	208,479	208,479	208,479	208,479	208,479	208,479	208,479
Adjusted R^2	0.181	0.180	0.180	0.180	0.180	0.180	0.180

Notes: "Shock type" indicates the monetary policy shock measure: baseline is the high-frequency response in Fed futures (3-month contracts). path is the principle component of high frequency response in Fed futures/Eurodollars with up to 1 year horizon from Steinsson et al. (2018). FOMCs indicates the set of announcements used in defining the maturing variable, e.g. FWG refers to FOMCs with forward guidance announcements. Includes triple interaction with openess index $\text{KO}_{c,t}$ (Chinn and Ito, 2006), estimates thus conditional on financial openness. All specs include firm-, fiscal-quarter-, and country×date FE; and firm-, and interaction controls (following preceding tables).

Table C.14: *Investment responses to unconventional monetary policy*

Second, I use the path shock from Steinsson et al. (2018).[3] The results (columns 6 and 7) are qualitatively similar to the baseline shock[4] and broadly consistent with the findings in Miranda-Agrippino and Rey (2020) using a similar path shock. Using the long-end/LSAP shock, Miranda-Agrippino and Rey (2020) find that the international effects of US monetary easing were the opposite of the traditional findings, i.e. associated with a sell-off in risky assets and Dollar appreciation. I currently do not have the long-end shocks available but it will be interesting to explore in future work.

The findings remain largely unchanged when controlling also for the complement (orthogonal) set of FOMCs (omitted for brevity).

C.2.2 Analysis of bond-level data

Number of bonds over the FOMC cycle. Figure C.2 shows that corporate bond maturity is approximately uniformly distributed across the FOMC cycle. Two consecutive scheduled FOMC meetings are usually between 6 and 7 weeks apart. Under the uniform distribution hypothesis, each week should contain between 1/7 and 1/6 of the total number of issuances/maturing observations in a given FOMC

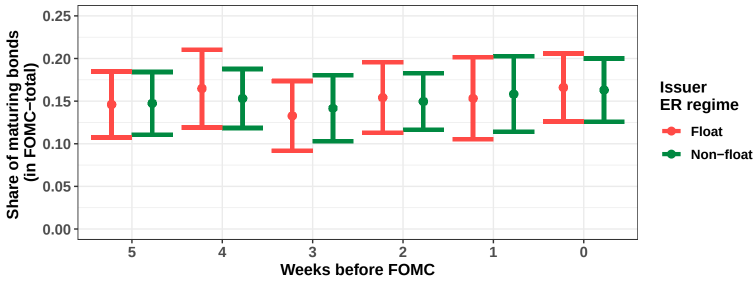
[3] Steinsson et al. (2018) obtain their path shock as first principle component of high-frequency changes in Fed future and Eurodollar prices for contracts up to 1-year ahead. Their sample ends in March 2014, after which I classify all announcements as conventional.

[4] To assess the quantitative differences across shock types carefully, the coefficients should be rescaled to imply the same change in a target variable like the 10-year UST yield.

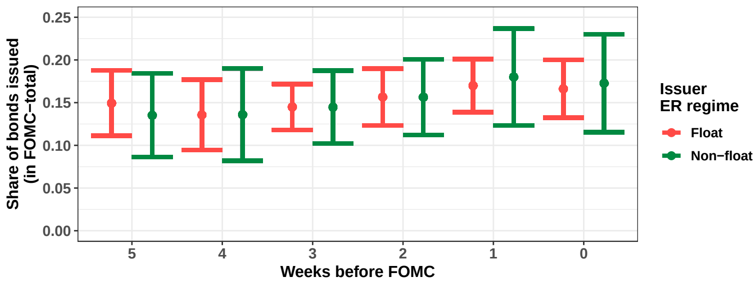
period.[5]

Maturity-Issuance link. Are the maturing bonds actually rolled over, i.e. replaced

(a) *Maturing bonds*



(b) *Bond issuances*



Notes: The figures plot the share of bonds maturing/issued by weeks before the FOMC, relative to the total in the FOMC period. Dots represent the average shares. The error bars represent one standard deviation ranges (of the shares across FOMCs). Weeks are measured as 7-day intervals before the FOMC announcement day, e.g. Week 0 covers the 7 days leading up to the announcement day. Sample includes corporate bonds by non-US, non-financial issuers covering the period between 2003 and 2017 and excluding periods preceding or following unscheduled FOMC meetings.

Figure C.2: *Bond-level data over the FOMC cycle*

with a new bond? Table C.15 in Appendix C.2.2 suggests that there is a significant link between the maturity of one bond and the issuance of a new one.[6] For this purpose, I assemble a balanced week-firm panel and estimate a probit regression that explains the probability that firm p issues a bond in week w with a dummy indicating whether it has a bond maturing in the same week. For the sub-sample of USD denominated bonds, the average marginal effect implies that having a bond maturing raises the probability of new bond issuance by around 10 percentage points. This 10 percentage point increase is economically substantial since the unconditional probability of bond issuance in any week is very low at the firm-level (firms issue at most few times a year). In unreported results, I do not find any evidence that the monetary policy shocks are associated with a switch between issuance currencies.

[5]A formal test should account for variations in the length of FOMC periods, holidays/weekends.

[6]The related corporate finance literature highlights the importance of credit risk premia in exacerbating rollover exposure. He and Xiong (2012) provide a theoretical model, Nagler (2020) provides evidence on the US and Valenzuela (2016) on international corporate bonds. Choi et al. (2018) explain why firms take on rollover risk with costly issuances.

Sample	Currency	AME	SE	p
Floater	home	0.021	0.003	0.000
Floater	US Dollar	0.103	0.007	0.000
Not-Floater	home	0.074	0.004	0.000
Not-Floater	US Dollar	0.096	0.007	0.000

Notes: Table reports average marginal effects (AME) of probit regression. AME indicate the change in probability, expressed in decimals, that firm p issues a bond in week w given that it has a bond maturing in the same week. Estimated on a balanced firm $\times$ week panel, and separately for bonds denominated in p's home currency or in US Dollars.

Table C.15: *Predict bond issuance with bond maturity by currency and ER regime*

C.2.3 Trade effects

Table C.16 reports estimates of the effect of exchange rate fluctuations on sales growth for non-exporters *relative* to exporters, controlling for country$\times$date$\times$sector fixed effects. The estimates suggest that non-exporters' sales growth is generally less correlated with US GDP forecasts.

For floaters, home currency depreciations are associated with stronger sales growth for non-exporters, relative to exporters. This effect could point to that non-exporters benefit from expenditure switching towards locally produced goods (sold relatively more by non-exporters). This is supported by the fact that depreciation-sales correlation is weaker for countries with a low share of imports invoiced in USD.

However, the issue requires further analysis and my analysis should be considered only a first attempt for two reasons. First, I control for country$\times$date$\times$sic1-fixed effects. While it ensures that my results are not driven by depreciation-induced increases in *country/sector-level* prices (and hence nominal sales volumes), I cannot rule out that the result is driven by different price dynamics at the firm-level. Second, the empirical trade literature displays ambiguous messages regarding the speed of adjustment of international trade after aggregate shocks. Traditionally, trade is viewed to respond only with a lag, which is confirmed in shipment-level data. In contrast, in recent experience, e.g. the Great Recession, trade adjustment was very fast. (see Alessandria et al., 2020 for a recent literature review)

	Dep-var: $\Delta\text{sale}_{p,c,t}$		
$\mathbb{1}_p^{\text{non-export}} \times F_{t-1}(\text{rgdp}_{t+2}^{\text{US}})$	-0.058^{*}	-0.093^{**}	-0.017
	(0.030)	(0.045)	(0.012)
$\mathbb{1}_p^{\text{non-export}} \times \Delta\text{ER}_{c,t}$	0.559	1.215^{**}	-0.328
	(0.373)	(0.519)	(0.241)
$\mathbb{1}_p^{\text{non-export}} \times \Delta\text{ER}_{c,t} \times \text{low-\$invoice}_{c,t}^{\text{Imports}}$	-0.630^{*}	-0.906	0.064
	(0.347)	(0.553)	(0.397)
Group	All	Float	Not-Float
Country×date×sic1 FE	Y	Y	Y
Obs	121,149	66,475	54,674
Adjusted R^2	0.202	0.283	0.157

Notes: $\Delta\text{sale}_{p,c,t}$ is the quarterly percentage change in sales, normalized by its grand standard deviation. $\mathbb{1}_p^{\text{non-export}}$ equals 1 if firm p does not report international sales. $\Delta\text{ER}_{c,t}$ is the quarterly change in country c exchange rate in pp (positive value=Dollar strength). In "country×date×sic1", "sic1" refers to 1-digit SIC sector codes. $\text{low-\$invoice}_c^{\text{Imports}}$ equals 1 if country c share of USD invoicing of imports is below median (yearly). $F_t(\text{rgdp}^{\text{US}})$ is the two-quarter ahead SPF forecast of US real GDP growth. All specs include firm-, fiscal-quarter-FE; and firm-, and interaction controls. Firm controls are lag of dependent variable, cash flow, total assets, book leverage (at previous quarter). Int-controls are interactions of $\Delta\text{ER}_{c,t}$ with the firm controls. Unreported interaction terms are omitted for brevity. Invoicing currency shares are from Gopinath (2015) and Ito and Kawai (2016). Standard errors two-way clustered by firm and date. Quarterly firm data from 2003 to 2016, crises excluded.

Table C.16: *Effect of exchange rate on sales growth, non-exporters vs exporters*

C.2.4 Further summary statistics

	Assets(USD,m)				Debt/TA(%)			
	Not-Float		Float		Not-Float		Float	
	Not-Exp	Exporter	Not-Exp	Exporter	Not-Exp	Exporter	Not-Exp	Exporter
Mean	577.14	823.91	789.93	2495.9	28.23	27.09	27.01	24.68
p25	52.13	99.09	36.91	151.8	13.80	12.88	12.29	11.30
p50	163.44	261.70	149.77	567.8	26.98	26.12	25.15	23.00
p75	512.24	817.81	565.11	2305.2	40.95	39.60	39.99	35.80
SD	1119.06	1594.78	2086.22	4965.9	17.57	17.02	17.60	16.37

Notes: Not-Exp stands for Not-exporter. Exporter status measured as non-zero international sales. Ratios expressed in percentage points. TA is book value of total assets. Debt is book value of debt. Quarterly firm data from 2003 to 2016, crises (author's update of Reinhart and Rogoff, 2009) excluded.

Table C.17: *Summary statistics by exporter status and exchange rate regime*

	$\Delta\text{spot}_{c,t}$			$\text{mp}^{\text{ER}}_{c,t-1}$			$\Delta y^{2y}_{c,t}$			$\text{mp}^{\text{loc}}_{c,t-1}$		
	Float	Managed	Peg	Float	Managed	Peg	Float	Managed	Peg	Float	Managed	Peg
Mean	0.26	0.28	−0.19	−0.06	−0.07	−0.02	−0.01	−0.02	0.06	0.00	0.00	0.00
p25	−3.16	−2.42	−1.08	−0.52	−0.30	−0.05	−0.05	−0.23	−0.16	−0.01	−0.01	−0.02
p50	−0.13	−0.23	−0.21	0.05	−0.06	0.00	−0.01	−0.02	0.11	0.00	0.00	0.00
p75	3.51	2.36	0.02	0.42	0.20	0.03	0.05	0.19	0.30	0.01	0.02	0.02
SD	4.74	4.68	1.57	0.86	0.56	0.10	0.23	0.55	0.48	0.02	0.06	0.06

Notes: All variables in percentage points. For average magnitude of exchange rate fluctuations compare standard deviation and interquartile ranges. $\Delta y^{2y}_{c,t}$ and $\Delta\text{spot}_{c,t}$ are quarterly changes. Variables "mp" are two-day changes over the FOMC announcement days. Sample period from 2003 to 2016.

Table C.18: *Summary statistics of asset prices by exchange rate regime*

C.3 Data details

This Appendix contains a detailed description of the data and its construction process.

C.3.1 Country classifications

Table C.19 shows the classifications and sample period for each country in my sample.

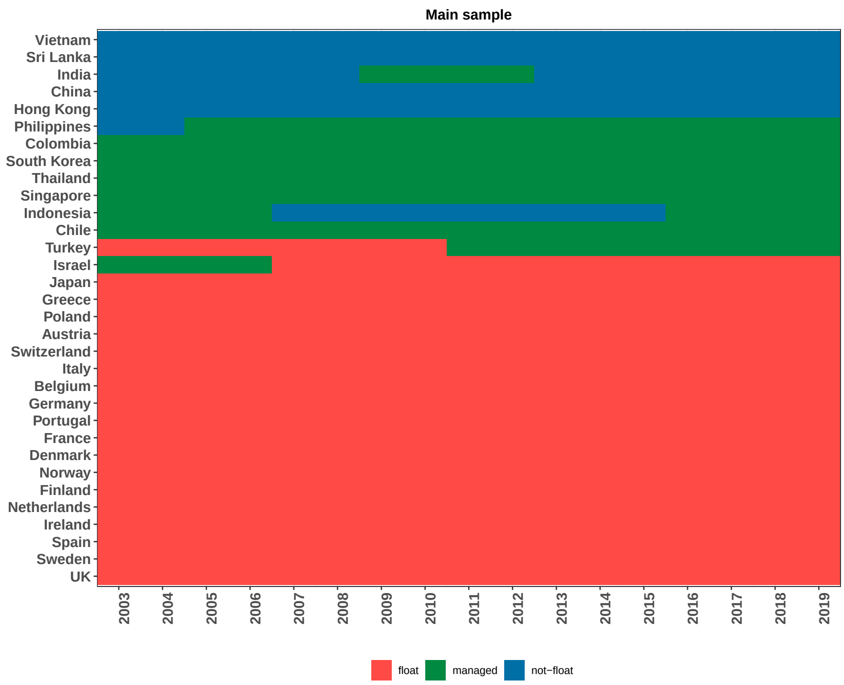
country	Dev-Status (WB)	ER-regime	Start	End	country	Dev-Status (WB)	ER-regime	Start	End
Argentina	UM	nflt	2006	2015	Luxembourg	H	flt	2003	2016
Brazil	UM	mgdd	2003	2016	Malaysia	UM	mgdd	2003	2016
Chile	H	mgdd	2003	2016	Mexico	UM	mgdd	2003	2016
China	UM	nflt	2003	2016	Netherlands	H	flt	2003	2016
Croatia	H	flt	2005	2016	Norway	H	flt	2003	2016
Cyprus	H	flt	2005	2016	Peru	UM	nflt	2003	2016
Denmark	H	flt	2003	2016	Philippines	LM	mgdd	2003	2016
Finland	H	flt	2003	2016	Poland	H	flt	2003	2016
France	H	flt	2003	2016	Singapore	H	mgdd	2003	2016
Germany	H	flt	2003	2016	South Korea	H	mgdd	2003	2016
Greece	H	flt	2003	2016	Spain	H	flt	2003	2016
Hong Kong	H	nflt	2003	2016	Sri Lanka	LM	nflt	2009	2016
India	LM	nflt	2003	2016	Sweden	H	flt	2003	2016
Indonesia	LM	mgdd	2003	2016	Switzerland	H	flt	2003	2016
Ireland	H	flt	2003	2016	Thailand	UM	mgdd	2003	2016
Israel	H	flt	2003	2016	Turkey	UM	mgdd	2003	2016
Italy	H	flt	2003	2016	United Kingdom	H	flt	2003	2016
Japan	H	flt	2003	2016	Vietnam	LM	nflt	2005	2016

Notes: List of countries in sample, with classifications in last year of sample. "Dev-Status" shows the development status according to the Worldbank. UM = Upper middle income, H = high, LM = lower middle. "ER-regime" gives the exchange rate regime label, based on Ilzetzki et al. (2019). "flt"=floating ER, "nflt"=non-floating, and "mgdd"=managed. Start and End give the year of first and last observations.

Table C.19: *Country sample list with classifications*

Exchange rate regime. I classify countries as floating, managed, or pegged exchange rate regimes against the US Dollar based on the quarterly version of the scheme by Ilzetzki et al. (2019). Countries like Denmark or Bulgaria, who peg their exchange rates to the Euro, are classified as "floating" because the currency they are pegging to is floating against the dollar. Specifically, my regime labels correspond to the group numbers from the "coarse" classification as follows (abbreviated description by Ilzetzki et al. (2019) in brackets). The floating group consists of group 4 ("freely floating"). "Not floating" is group 1 ("de facto peg") and 2 ("crawling peg" with narrow band). "Managed" group is group 3 ("crawling peg" with wide band, "moving band", or "managed floating").[7] Figure C.3 shows the evolution of regime classifications over time.

Capital controls and development. For capital account policies, I use the index provided in Chinn and Ito (2006). For financial development, I use the IMF's financial development index, available here. Further, I follow the Worldbank scheme based on PPP-adjusted GDP per capita to group countries into Developed and Developing Economies.



Notes: Three groups of countries according to the exchange rate flexibility against the US dollar. Original classification taken from Ilzetzki et al. (2019).

Figure C.3: *Regime classification used in empirical analysis*

C.3.2 Data construction

Firm-level accounting data. The quarterly firm-level accounting data is obtained from four sources. From Compustat Global and Worldscope, I obtain standard

[7] Fratzscher et al. (2019) provide evidence on the efficacy of FX interventions to implement exchange rate policies using a unique data set for 33 countries. Melvin et al. (2009) analyze empirically the implementation of crawling pegs.

variables such as investment, total assets etc. From Capital IQ, I obtain detailed information about the firms' debt structure, in particular the currency denomination of debt and approximate maturity dates. I capture international trade activity at the firm-level using the annual Geographic Segment dataset in Worldscope, or Annual Orbis data if the former is not available. For each firm, I construct two dummy variables indicating whether it has reported sales abroad and sales to the United States respectively.

I do not use Orbis and Amadeus to increase coverage of private companies because the frequency of observation is predominantely annual for these datasets.

Final sample. Firms are only included if there are at least 15 quarters of complete observations. Firms in my sample are the subset of the Compustat and Worldscope universes, which I could match with the bond and Capital IQ data. When a firm is covered by both sources, the source with the least missing observations is selected. Each firm has at least one quarter with maturing debt (denominated in US Dollars or other currencies).

I exclude all firms in the finance (SIC $6000 - 7000$) and public sectors (SIC $\geq$ 9000). I also exclude utility companies (2-digit SIC code 49). Most firms are publicly traded, given the coverage of Worldscope and Compustat.

Category	Key variables	Obs-level	Data source
Firm fundamentals	Total assets, Capital expenditures, Cash flows, Q	Firm-Qtrs	Compustat Global/ Worldscope
Firm debt structure	Debts by debt type, currency, maturity date (balance sheet data)	Firm-Qtrs	Capital IQ
	Debt maturing in quarter (by currency, bond/bank)	Firm-Qtrs	Capital IQ
	Bonds maturing in quarter (by currency, issuance data)	bond	SDC, Mergent, Dealogic
Firm trade activity	Dummy flagging exporters	Firm	Worldscope and Orbis
Exchange rates, bond yields	Exchange rate against USD, 2- and 10-year nominal bond yields. Quarterly changes and (1 or 2-day) changes over FOMC dates.	Country-Day	Global Financial Data & Eikon
US monetary policy	High-frequency shocks (Fed Funds Futures)	FOMCs	Jarociński and Karadi (2020)
Exchange rate regime	Classification of regime (floating, pegged, managed) and anchor currency.	Country-Year	Ilzetzki, Reinhart, and Rogoff (2019)
Trade data	Direction of trade	Country-Year	IMF website
	Invoicing currencies	Country-Year	Gopinath (2015), Ito and Kawai (2016), author's own calculation

Notes: Table lists key variables and data sources as used in analysis.

Table C.20: *Summary of data sources*

Country-level inflation and deflators. I obtain GDP price deflators from the IMF's international financial statistics. If this is not available, I use the CPI index.

Country-level sovereign and corporte bond yields and exchange rates. For each country in my sample, I obtain daily observations of 2-year or 10-year nominal government bond yields and the US Dollar exchange rate from Global Financial Data. The corporate bond yield indeces for most countries are from Standard & Poors and track the yields and returns of domestic, local currency corporate bonds. I then compute two key time series for each country's bond yields and exchange rate. First, one day changes over the FOMC announcement day and, second, quarterly time series.

Invoicing currency data. The invoicing data I use is a combination of two sources. First, data presented in Gopinath (2015) downloaded from Gita Gopinath's website (link). Second, Hiro Ito kindly shared with me the data presented in Ito and Kawai (2016).

Data cleaning. I clean the data with the following operations (this in order):

- exclude firm-quarters
  - flagged as being affected by Mergers & Acquisitions
  - with total assets greater than 500 billion US Dollars
  - with negative total assets
  - with quarterly growth in PPE beyond the 0.5% percentiles
  - with absolute value of quarterly percentage growth in real sales greater than 100%
- winsorize accounting variables at the 2% level (by country)

My main findings are robust to winsorizing only at 1% level. My baseline choice is 2% because cross-country (country group) comparisons are important for my analysis but data quality varies by country. Therefore it seems prudent to clean somewhat more strongly and to do so by country.

For my daily country-level asset price data, I disregard observations when

- the 1-day percentage change in the spot exchange rate over the FOMC announcement day exceeds 10%
- the 1-day change in nominal interest rates over the FOMC announcement day exceeds 5 percentage points

I then winsorize these variables at the 1% level.

C.3.3 Bond data details

I merge the accounting data with information on bonds issued by these firms. The bond-level data is the union of three sources: Mergent Fixed Income Securities Database (FISD), SDC Platinum New Issues and Dealogic. I merge these datasets at the bond-level using CUSIP or ISIN bond identifiers. Bond information includes dates of issuance and maturity, issuance amount, coupon, yield to maturity and currency denomination.

The final data set covers around half a million bond issuances. I can match around 60% of these bonds successfully to firms in Compustat (Global and North America) and Worldscope. Around 55% of the matched bond issuances are issued by financial companies, which are not included in my sample. I then also delete all bonds issued by US firms, callable bonds and bonds at variable rates.

Firm-quarter aggregates. I then aggregate the bond-level information to quarter-firm level. For each firm and quarter, I record the total sum of face values of bonds maturing in that quarter. The Mergent database provides *historic snapshots* of the amounts outstanding of each bond at a given reporting date, allowing to account for early redemptions etc. SDC and Dealogic do not provide this information and I therefore exclude all callable bonds and use the face value at issuance to compute the amount due at maturity date. The exact maturity dates allow me to keep track of the time of maturity relative to the FOMC meetings within a given quarter.

Bond-firm map. Creating a map between the security identifiers and the firm-level data is challenging because both Compustat and Worldscope contain only the most recent security identifier of each firm (if at all). I address this challenge by creating a *historic* firm-bond mapping using information contained in the FactSet Ownership database, allowing me to link active and inactive CUSIP and ISIN identifiers contained in the historic portfolio holding statistics to the permanent firm identifiers of this database.

C.4 Asset price reactions

This Appendix provides direct evidence on the effect of US monetary policy shocks on sovereign bond yields, corporate bond yields, and exchange rates. In C.4.1, I report results based on the bond-level corporate bond issuance data. In C.4.2, I examine daily country-level data for the countries in my sample. In C.4.3, I examine FOMC-level data, regressing US treasury yields, aggregate corporate bond indices and the Dollar factor on the monetary policy shocks. In C.4.4, I provide a brief overview of the empirical literature on international asset price reaction to US monetary shocks.

C.4.1 Corporate bond issuance yields

Spillovers on yields of USD-denominated corporate bonds. Due to data constraints, I have to assume in the 2SLS exercise that the reaction of financing conditions is the same for all firms within a given country. I further have to focus on the yields of local currency bonds because long time series on yields of USD-denominated corporate bonds are sparse even at the country-level.

	Dep-var: $y_{b,p,t}$			
	(1)	(2)	(3)	(4)
$\text{mp}^{\$}_{\text{fomc}(t)} \times \mathbb{1}^{\text{after}}_{b,t}$	1.334**	1.289*	1.401**	1.190*
	(0.563)	(0.685)	(0.671)	(0.635)
$\text{mp}^{\$}_{\text{fomc}(t)} \times \mathbb{1}^{\text{after}}_{b,t} \times \mathbb{1}^{\text{nflt}}_{p}$		1.130	0.582	0.490
		(2.674)	(2.759)	(2.764)
$\text{mp}^{\$}_{\text{fomc}(t)} \times \mathbb{1}^{\text{after}}_{b,t} \times \mathbb{1}^{\text{HY}}_{b}$				0.965
				(1.571)
Rating FE	N	N	Y	Y
Bond controls	N	Y	Y	Y
Obs	15,961	14,805	14,206	14,206
Adjusted R^2	0.724	0.726	0.769	0.769

Notes: Estimates of Eq.: $y_{b,p,t} = \tilde{\theta}\ \text{MP}^{\$}_{\text{fomc}(t)} \times \mathbb{1}^{\text{after}}_{b,t} + \mathbb{1}^{\text{after}}_{b,t} + \vec{\alpha}_{p,\text{fomc}(t)} + \epsilon_{b,p,t}$,
Standard errors clustered by FOMC-period. All specifications include issuer and FOMC-period fixed effects ($\vec{\alpha}_{p,\text{fomc}(t)}$). Sample of issuances of USD-denominated corporate bonds by non-US, non-financial firms within 2 weeks of closest FOMC. $\mathbb{1}^{\text{after}}_{b}$ equals 1 if bond b was issued after the FOMC closest to the date of issuance. $\mathbb{1}^{\text{nflt}}_{p}$ equals 1 if issuer p is headquarted in non-floater country. $\mathbb{1}^{\text{HY}}_{b}$ equals 1 if bond b has a high yield rating. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). Other controls are: time to maturity in years and size of bonds (log of amount). Estimates of coefficients for $\mathbb{1}^{\text{after}}_{b,t}$ and $\mathbb{1}^{\text{after}}_{b,t} \times \mathbb{1}^{\text{nflt}}_{p}$, omitted for brevity, are always close to zero and insignificant.

Table C.21: *Issuance yields and monetary shocks, before and after FOMC*

To alleviate concerns arising from these assumptions, I estimate the relationship between the monetary shocks and corporate bond yields at time of issuance from my bond issuance data set. Specifically, I match each bond b with the FOMC date $\text{fomc}(t)$ that is closest to the issuance date t. I then define a dummy $\mathbb{1}^{\text{after}}_{b,t}$ that equals 1 if the bond was issued *after* the closest FOMC date, and 0 if it was issued before. In my baseline specification, shown in top of Table C.21, I regress the yield on the monetary shock, interacted with the after-FOMC-dummy.[8] I also include

[8] I thank Yannick Timmer for providing me with the idea for such specification.

issuer and FOMC fixed effects. Note that the magnitude of estimates cannot be readily compared with the first stage of the 2SLS.

Table C.21 shows that the yields of USD-denominated corporate bonds react significantly to the US monetary shocks. The coefficient on the non-floater interaction is estimated to be positive but insignificant, which is the case for a wide-range of unreported specifications and subsamples. The statistical insignificance is due to persistently large standard errors. Columns 2 and 3 report specifications with rating fixed effects and a triple interaction with a dummy flagging high-yield bonds. The coefficient on the non-floating interaction shrinks, suggesting that at least part of the non-floating dummy captures effects also associated with credit ratings.

For the purpose of this study, my evidence based on USD-denominated bonds further cements the view that differential asset price reaction cannot fully explain the heterogeneity in reduced form estimates. Even taking the estimates at face value, they imply that yields react more strongly in non-floaters by a factor of 1.4 to 1.9 (consistent with literature). Since my reduced-form estimates differ by a factor of 2.4 to 3, the stronger asset price response would still not be enough to explain it away.

C.4.2 Country×FOMC panel regressions

I construct a country×FOMC-date panel and estimate the equation

$$Y_{c,t} = \alpha_c + \theta^Y \mathrm{MP}_t^{\$} \times \mathbb{1}_{c,t}^{\mathrm{nflt}} + \mathbb{1}_{c,t}^{\mathrm{nflt}} + e_{c,t}, \tag{C.1}$$

where the dependent variable $Y_{c,t} \in \{\Delta y_{c,t}^{\mathrm{crdt}}, \Delta y_{c,t}^{2y}, \Delta y_{c,t}^{10y}, \Delta \mathrm{ER}_{c,t}\}$ is the two-day change over the FOMC announcement t in country c's domestic corporate bond yield, 2-year (10-year) nominal government bond yield or bilateral exchange rate against the USD. $\mathbb{1}_{c,t}^{\mathrm{nflt}}$ equals one if the country does not have a floating exchange rate against the US Dollar.

	Dependent variable:			
	$\Delta y^{2y}_{c,t}$	$\Delta y^{10y}_{c,t}$	$\Delta y^{\text{crdt}}_{c,t}$	$\Delta \text{ER}_{c,t}$
	(1)	(2)	(3)	(4)
$\text{mp}^{\$}_{t}$	0.398***	0.936***	1.159***	12.429***
	(0.033)	(0.103)	(0.066)	(0.866)
$\text{mp}^{\$}_{t-1} \times \mathbb{1}^{\text{nflt}}_{c,t}$	0.376*	−0.010	0.460**	−8.283***
	(0.211)	(0.347)	(0.216)	(1.537)
$\text{mp}^{\$}_{t-1} \times \text{KO}_{c,t}$	−0.051	0.079	−0.248**	−0.638
	(0.222)	(0.257)	(0.104)	(0.689)
Obs	3,678	3,492	3,678	3,678
Adjusted R^2	0.038	0.028	0.088	0.122

Notes: Standard errors clustered at country-level. Country fixed effects included. $\Delta y^{2y}_{c,t}, \Delta y^{10y}_{c,t}, \Delta y^{\text{crdt}}_{c,t}, \Delta \text{ER}_{c,t}$ are the two-day changes over FOMC announcement day t in two- and ten-year government bond yield, domestic corporate bond yield and bilateral exchange rate, respectively. $\text{mp}^{\$}_{t-1}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). $\text{KO}_{c,t}$ measures capital openness (Chinn, Ito 2006;higher values=less open). $\mathbb{1}^{\text{nflt}}_{c,t}$ equals 1 if country c has a de-facto not-floating exchange rate (from Ilzetzki et al 2017). Sample excludes unscheduled FOMCs and crises.

Table C.22: *Asset price reponses to US monetary shocks, country×FOMC-panel*

C.4.3 Time series of FOMCs

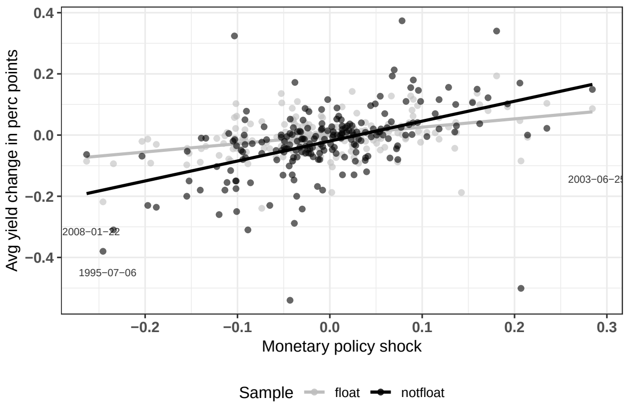
US Treasury yield curve and US monetary shocks. In Table C.23, I show that the US monetary policy shocks continue to move the US yield curve significantly during the ZLB.

	Maturities (m)										
Sample	1y	2y	3y	5y	7y	10y	Obs	R^2(1y)	R^2(2y)	SD(1y)	SD(2y)
1994-2016	0.593***	0.561***	0.498***	0.377***	0.277***	0.17*	194	0.33	0.21	0.06	0.07
	(0.062)	(0.079)	(0.090)	(0.100)	(0.101)	(0.096)					
1994-2007	0.584***	0.514***	0.433***	0.313***	0.22**	0.127	119	0.31	0.19	0.06	0.07
	(0.081)	(0.098)	(0.103)	(0.101)	(0.096)	(0.088)					
2003-2016	0.659***	0.697***	0.655***	0.510***	0.38**	0.251	118	0.27	0.20	0.06	0.07
	(0.101)	(0.130)	(0.150)	(0.172)	(0.177)	(0.168)					
2009-2015	1.227***	2.254***	2.596***	2.48**	2.14*	1.672	57	0.26	0.27	0.03	0.06
	(0.279)	(0.504)	(0.727)	(1.013)	(1.115)	(1.094)					

Notes: Each cell reports an estimate of Φ from a separate estimate of Equation: $\Delta y_t^m = \Phi \text{ mp}_t^{\$} + \epsilon_t$, where Δy_t^m is the change of the nominal zero-coupon US Treasury yield with maturity m over the FOMC announcement day t. SD(m) is the standard deviation of Δy_t^m. R2(m) is the R-squared from the regression with Δy_t^m as dependent variable. $\text{mp}_t^{\$}$ is the high-frequency response of fed futures from same meeting (from Jarociński and Karadi, 2020). The nominal UST yield curve data is from Gürkaynak et al. (2007a).

Table C.23: *Nominal UST yield curve and fed funds future shocks*

Sovereign yield averages for country groups. Figure C.4 provides a scatter plot to illustrate the main finding in a simple and robust way: When the Fed tightens, foreign government bond yields rise along with US rates. This effect is stronger for countries whose exchange rate is managed or pegged against the US Dollar.



Notes: US monetary policy shocks (x-Axis) are plotted against two-day changes in local government bond yields over the corresponding FOMC meeting, averaged across country groups with floating (float) and non-floating (notfloat) exchange rates against the US Dollar. The US monetary shock is measured as the two-day change in the 2y nominal UST yield, as in Hanson and Stein (2015).

Figure C.4: *Changes in local-2y yields (group-averages) and US monetary shocks*

Aggregate corporate bond indeces. Table C.24 provides benchmark results on the reaction of corporate bond yields to US monetary policy shocks using aggregate bond indeces by Bank of America & Merill Lynch and ICE Bank of America. I regress daily changes in yields or returns, measured over the FOMC announcement day, on the monetary policy shock.

	Dep-var: Δy_t^{inx}							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$MP_t^{\$}$	0.451^{***}	0.389^{***}	0.286^{**}	0.214^{***}	0.290^{***}	0.245^{**}	0.442^{**}	0.282^{***}
	(0.082)	(0.084)	(0.132)	(0.068)	(0.083)	(0.099)	(0.187)	(0.086)
Bond index (inx)	US.AAA	US.BBB	EM.HY	EM.IG	Asia.EME	Lat.EME	EUR.HY	NFC.EME
Observations	160	160	144	144	144	144	152	144
R^2	0.160	0.119	0.032	0.065	0.079	0.041	0.036	0.070
Adjusted R^2	0.155	0.114	0.025	0.059	0.072	0.034	0.029	0.064

Notes: Changes in corporate bond yield indices regressed on US monetary shocks.

Table C.24: *Reaction in corporate bond yields (aggregate indices)*

	Dep-var: R_t^{inx}			
	(1)	(2)	(3)	(4)
$MP_t^{\$}$	-2.113^{***}	-1.957^{***}	-0.913^{***}	-1.216^{*}
	(0.597)	(0.569)	(0.304)	(0.663)
Bond index (inx)	US.AAA	US.BBB	EM.ALL	EM.HY.USD
Observations	144	144	144	144
R^2	0.081	0.077	0.060	0.023
Adjusted R^2	0.075	0.070	0.053	0.016

Notes: Corporate bond returns regressed on US monetary shocks.

Table C.25: *Reaction in corporate bond returns (aggregate indices) to US monetary shocks*

Exchange rate reaction: Robustness check with Dollar factor. I compute the dollar factor for different subsets of countries. Specifically, I define the dollar factor for all countries with exchange rate regime type R as the arithmetic average of changes in the bilateral exchange rates $\Delta e_{c,t}$, that is $DOL_{t,R} = \frac{1}{N}\sum_{c\in R}^{N} \Delta e_{c,t}$. I define $e_{c,t}$ as foreign currency units per US Dollar such that $\Delta e_{c,t} > 0$ and $DOL_t > 0$ signify Dollar appreciation. The changes are computed as one, or two-day changes over the FOMC announcements.

I estimate the following equation for the full sample ("Full") and each regime type $R \in \{\text{Full}, \text{float}, \text{managed}, \text{peg}\}$ separately

$$DOL_{t,R} = \alpha + \theta^e \, MP_t^{\$} + e_t, \qquad (C.2)$$

where $MP_t^{\$}$ is the high-frequency response of fed futures to FOMC announcements (from Jarocinski,Karadi 2018). Figure C.5 illustrates the main result for the group of countries with floating exchange rate against the dollar: A surprise tightening of US monetary policy is, on average, associated with a significant strengthening of the US dollar, and this relationship seems to have strengthened post crisis.

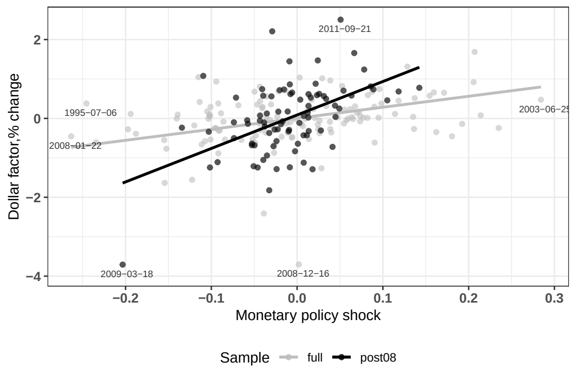


Figure C.5: *Value of dollar against basket (Dollar factor) and US monetary shocks*

Table C.26 reports OLS estimates of Equation C.2 for the different regimes.

	Dep-var: $DOL_{t,R}$			
$R =$	Full	Float	Managed	Peg
	(1)	(2)	(3)	(4)
$MP_t^{\$}$	1.236***	3.075***	1.354***	0.215
	(0.294)	(0.716)	(0.444)	(0.139)
Obs	191	191	191	191
Adjusted R^2	0.105	0.120	0.044	0.015

Notes: $MP_t^{\$}$ is the two-day change of the 2y-nominal US Treasury over the FOMC announcement day, in percentage points. Unscheduled FOMC meetings and the Global Financial Crisis are excluded.

Table C.26: *Dollar and US monetary shock by FX regime*

Table C.27 then focuses on the sample of countries with floating exchange rate against the Dollar ("Float") and reports estimates for different sample periods.[9]

[9]The regimes R were defined in Section C.3.

	Dep-var: $DOL_{t,float}$			
	(1)	(2)	(3)	(4)
$MP_t^{\$}$	2.793***	3.075***	1.676***	4.895***
	(0.610)	(0.716)	(0.463)	(1.481)
Sample	Full	ex08	pre08	post08
Obs	214	191	109	80
Adjusted R^2	0.098	0.120	0.103	0.192

Notes: $MP_t^{\$}$ is the two-day change of the 2y-nominal US Treasury over the FOMC announcement day, in percentage points. Unscheduled FOMC meetings and the Global Financial Crisis are excluded.

Table C.27: *Dollar and US monetary shock by period, floaters only, 2day chg*

C.4.4 Previous literature

Timmer (2018) shows that US monetary tightening is associated with higher yields abroad using local currency corporate bond indeces. The link is stronger for Emerging market economies and non-floaters, but the difference is statistically significant only for the former. Gilchrist et al. (2019) find that yields of USD-denominated foreign sovereign bonds increase after US monetary tigthening. Yield increases of bonds with speculative ratings are larger than those of investment grade bonds by a factor of 1.4 to 2.4. Albagli et al. (2019) find that the reaction of local government bond yields to US monetary shocks is larger in EMEs than in AEs only in the post-2008 sample. Yields of EME bonds with 2 and 10 year maturity react more strongly by a factor of 1.6 and 1.3 respectively. Bowman et al. (2015) find that, within EMEs, countries with higher financial vulnerability experience stronger passthrough of US monetary shocks to sovereign yields by a factor of 2. Managed exchange rates are only associated with higher passthrough of US risk-free rates, not US corporate bond high-yield bonds.

Table C.28 summarizes several empirical studies that have studied close relatives of θ across country groups.

Study	Asset class	Groups compared (Y,X)	θ^Y/θ^X
Gilchrist et al (2019)	USD sov. bonds	(Speculative-,IG)	1.4-2.4
Albagli et al (2019)	LC sov. bonds, 2y	(EME,AE)	1.6
	LC sov. bonds, 10y	(EME,AE)	1.3
Bowman (2015)	LC sov. bonds (EME)	(high, low vulnerab.)	2
Bluedorn et al(2015)	short-term rate	(Peg,Non-Peg)	4.06
Timmer (2018)	LC corp. bonds	(Peg,Non-peg)	0.56

Notes: Table summarizes empirical studies providing evidence related to the relative sensitivity of financing conditions $\theta^{\text{nflt}}/\theta^{\text{flt}}$.

Table C.28: *Findings of previous literature related to θ*

C.5 Model Appendix

C.5.1 Stochastic properties

C.5.1.1 Baseline

The levels of benchmark interest rates, $\bar{R}_{\$,t}$ and $\bar{R}_{€,t}$, and the time-0 exchange rate e_0 are log-normally distributed, following the processes

$$\log(\bar{R}_{\$,t}) = \log(\hat{R}_{\$}) + \sigma_{US} Z_t^{US} \tag{C.3}$$

$$\log(\bar{R}_{€,t}) = \log(\hat{R}_{€}) + \beta_{€}\sigma_{US} Z_t^{US} + \sigma_{€} Z_t^{€} \tag{C.4}$$

$$\log(e_0) = \log(\hat{e}_0) - \beta_{\$}\sigma_{US} Z_t^{US}, \tag{C.5}$$

where $\log(\cdot)$ is the natural log and $Z_t^{US} \sim N(0,1)$ and $Z_t^{€} \sim N(0,1)$ are independent standard-normal random variables.[10] These stochastic properties imply the following Normal distributions of the logs of variables

$$\log(\bar{R}_{\$,t}) \sim N\big(\log(\hat{R}_{\$}), \sigma_{US}^2\big)$$
$$\log(\bar{R}_{€,t}) \sim N\big(\log(\hat{R}_{€}), \beta_{€}^2\sigma_{US}^2 + \sigma_{€}^2\big)$$
$$\log(\frac{e_1}{e_0}) \sim N\big(\log(\frac{e_1}{\hat{e}_0}), \beta_{\$}^2\sigma_{US}^2\big).$$

[10]Equation C.5 could equivalently be formulated in terms of the log-change in the exchange rate as $\log(\frac{e_1}{e_0}) = \log(e_1) - \log(\hat{e}_0) + \beta_{\$}\sigma_{US} Z_t^{US}$. Concerning the distribution of $\frac{e_1}{e_0}$ and e_0, multiplying the random variable $\frac{e_1}{e_0}$ with the constant $\frac{1}{e_1}$ yields $\frac{1}{e_0} \sim \text{LogNorm}\Big(\log(\frac{e_1}{\hat{e}_0}) + \log(\frac{1}{e_1}), \widehat{\sigma}_e^2\Big) = \text{LogNorm}\Big(\log(\frac{1}{\hat{e}_0}), \widehat{\sigma}_e^2\Big)$ Using the reciprocal property of the log-normal distribution and substituting the definition of $\hat{e}_0$, I thus arrive at $e_0 \sim \text{LogNorm}\Big(\bar{e}_0, \widehat{\sigma}_e^2\Big)$.

The distribution of $\log(\bar{R}_{€,t})$ is derived as the sum of two (correlated) normal variables, and the distribution of $\bar{R}_{€,t}$ (not the log) as the product of two log-normal variables. The mean m_y and standard deviation σ_y of the log-normal distribution of variable Y, whose natural log is normally distributed with $\log(Y) = X \sim N(m_x, \sigma_x^2)$, are given by $m_y = \exp(m_x + \frac{1}{2}\sigma_x^2)$ and $\sigma_y^2 = \exp(2m_x + \sigma_x^2)(\exp(\sigma_x^2) - 1)$. To simplify expressions, I define the means of the log-normal variables as follows: $\hat{R}_\$ = \bar{R}_\$ \exp(-\frac{1}{2}\sigma_{US}^2)$, $\hat{e}_0 = \bar{e}_0 e^{\frac{1}{2}\beta_\$^2\sigma_{US}^2}$, and $\hat{R}_€ = \bar{R}_€ \exp(-\frac{1}{2}(\beta_€^2\sigma_{US}^2 + \sigma_€^2))$. See Appendix C.5.1.2 for a discussion without rescaling. I then use these definitions and the formula to go from the parameters of the normal distribution to the means and standard deviation of the log-normal variables:[11]

$$\frac{e_1}{e_0} \sim \text{LogNorm}(\frac{e_1}{\bar{e}_0}, \widehat{\sigma}_e^2)$$
$$\bar{R}_{\$,t} \sim \text{LogNorm}(\bar{R}_\$, \widehat{\sigma}_\$^2)$$
$$\bar{R}_{€,t} \sim \text{LogNorm}(\bar{R}_€, \widehat{\sigma}_€^2),$$

where

$$\widehat{\sigma}_\$^2 = \exp\left[2(\log(\hat{R}_\$)) + \frac{1}{2}\sigma_{US}^2\right]\left[\exp(\frac{1}{2}\sigma_{US}^2) - 1\right]$$
$$\widehat{\sigma}_e^2 = \exp\left[2(\log(\frac{e_1}{\hat{e}_0})) + \frac{1}{2}\beta_\$^2\sigma_{US}^2\right]\left[\exp(\beta_\$^2\sigma_{US}^2) - 1\right]$$
$$\widehat{\sigma}_€^2 = \exp\left[2\ln(\hat{R}_€) + (\beta_€^2\sigma_{US}^2 + \sigma_€^2))\right]\left[\exp((\beta_€^2\sigma_{US}^2 + \sigma_€^2)) - 1\right].$$

For the distribution of $\bar{R}_{\$,t}\frac{e_1}{e_0}$, note that

$$\bar{R}_{\$,t}\frac{e_1}{e_0} = \exp\Big(\log(\bar{R}_{\$,t})\Big)\exp\Big(\log(\frac{e_1}{e_0})\Big)$$
$$= \exp\Big(\log(\hat{R}_\$\frac{e_1}{\hat{e}_0}) + (1+\beta_\$)\sigma_{US}Z_\$\Big),$$

which implies

$$\log(\bar{R}_{\$,t}\frac{e_1}{e_0}) \sim N\Big(\log(\hat{R}_\$\frac{e_1}{\hat{e}_0}), (1+\beta_\$)^2\sigma_{US}^2\Big).$$

Applying the formula above then yields $E(\bar{R}_{t,\$}\frac{e_1}{e_0}) = \bar{R}_\$\frac{e_1}{\bar{e}_0}e^{\beta_\$\sigma_{US}^2}$.

C.5.1.2 First moments and UIP without rescaling of means

For the main part of the analysis, the rescaling of the means of stochastic processes in Appendix C.5.1.1 is covenient and inconsequential. However, since it obscures how changes in the exchange rate regime might impact the first moments, I report them here without rescaling. No rescaling implies the definitions $\hat{R}_€ = \bar{R}_€$, and

[11] In slight deviation from notational convention, I report here the expected value and variance of the log-normal distribution not the associated normal distribution.

$\hat{R}_{\$} = \bar{R}_{\$}$, and $\hat{e}_0 = \bar{e}_0$. Based on the distributional assumptions in Equations C.3 to C.5, the first moments are then

$$E(\bar{R}_{€,t}) = \bar{R}_{€} \exp\left(\frac{1}{2}(\beta_{€}^2 \sigma_{US}^2 + \sigma_{€}^2)\right)$$
$$E(\bar{R}_{\$,t}\frac{e_1}{e_0}) = \bar{R}_{\$}\frac{e_1}{\bar{e}_0} \exp\left(\frac{1}{2}(1+\beta_{\$})^2 \sigma_{US}^2\right).$$

In both equations, the left-hand exponential terms can be thought of as "risk premia" compensating for fluctuations due to the shocks.[12]

As discussed in the main text, a simple way to think about a managed exchange rate regime is as low $\beta_{\$}$ and high $\beta_{€}$ (so after US shocks, the exchange rate reacts weakly but therefore home interest rates strongly). Compared to a free float (high $\beta_{\$}$, low $\beta_{€}$), home currency bond premia will be higher (because the loading on US shocks is higher) and the premium on exchange rate adjusted USD borrowing costs will be lower. For the risk-adjusted UIP to continue to hold when shifting from free float to managed exchange rate regime ($\beta_{€} \uparrow$,$\beta_{\$} \downarrow$), risk-free rates ($\bar{R}_k$ etc) need to adjust. Importantly, the properties of the log-normal distribution imply that adjustments in $\bar{R}_k$, to leave the first moment unchanged, do not fully offset the effect of changes in β on the variances. Such "mean-preserving" regime change then still affects firm decisions via the probability of being constrained (as discussed in the main text).

Extensions should account for asymmetry in exchange rate changes implied by some regimes (e.g. "depreciations are welcome, appreciations not"), and for exchange-rate specific shocks.

C.5.2 Solution details

C.5.2.1 Problem setup & solution strategy

Firm p maximizes its profit $\pi_{p,t=1}$

$$\max_{\{Q_{p,€},Q_{p,\$}\}} \quad E_{t=0^-}\Big(A_p X_p - R_{€,p}Q_{€,p} - R_{\$,p}Q_{\$,p}e_1 - (1-\gamma)Q_{p,\text{-}1}R^2_{p,\text{-}1} - C\ \mathbb{1}_{Q_{p,\$}>0}\Big), \tag{C.6}$$
$$\text{s.t. } Q_{\$,p}R_{\$p}e_1 + Q_{€,p}R_{€p} \leq \phi A_p(Q_{\$,p}e_0 + Q_{€,p}) + \xi_p$$
$$X_p + \gamma Q_{p,\text{-}1}R_{p,\text{-}1} = E_p + Q_{€,p} + Q_{\$,p}e_0$$
$$R_{k,p} = \bar{R}_{k,t} + \Gamma_k / E_p Q_{p,k}, \text{ for } k \in \{€, \$\}.$$

Auxiliary assumptions. To focus on economically interesting outcomes, I maintain the following assumptions 1) $A_p - \frac{e_1}{e_0}\bar{R}_{\$} = A_p - \bar{R}_{€} > 0 \ \ \forall\ p$ ensures positive investment by all firms. To ensure non-negative investment if starting capital

[12] Changes in the variance matter to the risk-neutral firms because the shocks are log-normally distributed, and I solve the model in levels not in logs.

is negative, a lower bound $\underline{\xi} < \xi_p$ is derived below. 2) $\Gamma_€, \Gamma_\$ > 0$ ensure that investment will be finite. 3) $\Gamma_€ > \Gamma_\$$ signifies benefits from issuing in US Dollar even in absence of UIP deviations.

Problem reformulation. The optimization problem can be simplified by substituting in the flow-of-funds identity and defining aggregate borrowing $Q_{w,p} = Q_{€,p} + Q_{\$,p}e_0$ expressed in Euros and a weighted average multi-currency interest rate $R_{w,p} = w_{\$,p}R_{\$,p}e_1 + w_{€,p}R_{€,p}$. (Definitions of multi-currency variables are based on $Q_{\$,p}R_{\$,p}e_1 + Q_{€,p}R_{€,p} = w_{\$,p}Q_{w,p}R_{\$,p}e_1 + w_{€,p}Q_{w,p}R_{€,p} = Q_{w,p}\underbrace{(w_{\$,p}R_{\$,p}e_1 + w_{€,p}R_{€,p})}_{R_{w,p}}$.)

Solution. Problem C.6 can be solved by first characterising the optimal choices of the two types of firms that will arise: Home currency (HC) and multi currency firms (MC). Each firm type has two varieties. For the first variety, the borrowing constraint is not binding ("unconstrained firms"). For the second, it is binding ("constrained firms"). Since firms learn their productivity, size and starting capital at $t = 0^-$, the only source of uncertainty are the levels of the benchmark rates.

C.5.2.2 Currency choice

Multi-currency firms: optimal currency choice. To find the optimal currency composition, firm p minimizes borrowing costs C_p as expected at $t = 0^-$

$$\min_{w_{\$p}, w_{€p}} E_{0^-}\left(R_{\$p}\frac{e_1}{e_0}w_{\$p} + R_{€p}w_{€p}\right) \tag{C.7}$$

subject to $w_{\$p} + w_{€p} = 1$, and the debt demand curves defined in Equation 3.9. Evaluating the expectations and plugging in the constraint, total borrowing costs become[13]

$$\begin{aligned} E(C_p) =& E\Big(\frac{e_1}{e_0}(\bar{R}_{\$,t} + \frac{\Gamma_\$}{E_p}w_{\$p})\Big)w_{\$p} + E\Big([R_{,t€} + \frac{\Gamma_€}{E_p}(1-w_{\$p})](1-w_{\$p})\Big) \\ &= (\bar{R}_\$\frac{e_1}{\bar{e}_0}\exp(\beta_\$\sigma^2_{US}))w_{\$p} + \frac{e_1}{\bar{e}_0}\frac{\Gamma_\$}{E_p}w^2_{\$p} + (\bar{R}_€ + \frac{\Gamma_€}{E_p}(1-w_{\$p}))(1-w_{\$p}). \end{aligned}$$

The first order condition yields the optimal currency shares

$$\widehat{w}_{0^-,\$,p} = \frac{\Gamma_€}{\Gamma_\$\frac{e_1}{\bar{e}_0} + \Gamma_€} \qquad \widehat{w}_{0^-,€,p} = \frac{\Gamma_\$\frac{e_1}{\bar{e}_0}}{\Gamma_\$\frac{e_1}{\bar{e}_0} + \Gamma_€}, \tag{C.8}$$

[13] It is helpful to explain the units in the currency shares. They are $w_{\$p} = \frac{Q_{\$p}\bar{e}_0}{Q_{\$p}\bar{e}_0 + Q_{€p}}$ and $w_{€p} = \frac{Q_{€p}}{Q_{\$p}\bar{e}_0 + Q_{€p}}$. Note that if the *share* of Dollar debt increases by δ, while keeping total debt fixed, the *amount* of Dollar debt issued increases by $\frac{\delta}{\bar{e}_0}$. Plugging in the demand curves and $w_{\$p} + w_{€p} = 1$, we have $C_p = \frac{e_1}{e_0}(\bar{R}_\$ + \Gamma_\$\frac{w_{\$p}}{\bar{e}_0})w_{\$p} + [\bar{R}_€ + \Gamma_€(1-w_{\$p})](1-w_{\$p})$. The expected interest rate expenses for Dollar debt in Euro terms are $R_{\$p}e_1$, but given the definition of the curreny shares (in terms of total borrowing in Euros), the Dollar-share needs to be normalized by $1/\bar{e}_0$.

where I have used the assumption that the risk-adjusted UIP holds.[14]

As in Maggiori et al. (2018), if the demand curve for €-denominated debt gets steeper ($\Gamma_{€} \uparrow$), all else equal, firm p issues a higher proportion of its debt in US Dollar. As the expected Euro depreciation rate increases ($\frac{e_1}{\bar{e}_0} \uparrow$), the repayment value of Dollar debt rises in Euro terms. This makes Dollar debt less attractive and leads to a higher proportion of debt issued in home currency. As stated before, the curreny shares in pre-existing debt, $\widehat{w}_{\$,p,\text{-}1}$ and $\widehat{w}_{€,p,\text{-}1}$ are exogenous. However, I impose that they take the same values as the endogenous currency shares of the newly issued debt in Equation C.8. The idea is that, if firm p has become a MC firm in the current period, persistent firm characteristics would have made it a MC firm already in earlier generations.

C.5.2.3 Deriving optimal borrowing amounts

I now derive the optimal borrowings of firm p as home- and multi-currency firm. The firm solves for its optimal borrowings twice. The first time at $t = 0^-$, it evaluates its expectations and derives its optimal expected borrowing amounts to assess its profit prospects as each type. (Since fixed cost C is a sunk cost, firms do not switch type after $t = 0^-$.) The second time at $t = 0^+$, it uses the realized value of $\bar{R}_{t,k}$.

The home-currency firm simply uses the debt-demand curve for the Euro. For the problem faced by multi-currency firms, the optimal currency shares can be used to define a multi-currency demand curve R_{wp} as

$$R_{w,p} = \bar{R}_{w,t} + \frac{\Gamma_w}{E_p} Q_w \tag{C.9}$$

with $\Gamma_w = \frac{\Gamma_{\$} \frac{e_1}{\bar{e}_0} \Gamma_{€}}{\Gamma_{\$} \frac{e_1}{\bar{e}_0} + \Gamma_{€}}$ and $\bar{R}_{w,t} = \widehat{w}_{\$,p} \bar{R}_{\$,t} e_1 + \widehat{w}_{€,p} \bar{R}_{€,t}$. $Q_{w,p} = Q_{€,p} + Q_{\$,p} e_0$ is the total amount of debt issued by firm p.

Optimal unconstrained borrowing. If the borrowing constraint is not binding, optimal borrowing is pinned down by the first order condition for Problem C.6. The unconstrained optimal borrowing amounts are

$$\widehat{Q}^u_{hc,p,€} = E_p \frac{A_p - \bar{R}_{€}}{2\Gamma_{€}} \qquad \widehat{Q}^u_{mc,p} = E_p \frac{A_p - \bar{R}_w}{2\Gamma_w} \tag{C.10}$$

Constrained borrowing. If the borrowing constraint imposed by the lenders is

[14]Without assuming the risk-adjusted term, the optimal Euro-weight is $\widehat{w}_{\$p} = \frac{\Gamma_{€} + \frac{E_p}{2}\left(\bar{R}_{€} - (\frac{e_1}{\bar{e}_0}\bar{R}_{\$} + e_1 \beta^{\$} \sigma^2_{US})\right)}{\frac{e_1}{\bar{e}_0}\Gamma_{\$} + \Gamma_{€}}$. $\widehat{w}_{\$p}$ shows that 1) if the covariation between the Dollar interest rate and the exchange rate rises, the weight on Dollar debt falls 2) as in the previous analyses, differences in the levels of interest rates shift the weight as expected 3) covariation between US and Euro interest rates would add further terms.

binding, Equation 3.8 holds with equality. Plugging in the flow-of-funds identity and the debt demand curve yields

$$\widehat{Q}^{c}_{hc,p} = E_p \frac{\phi A_p - \bar{R}_{€} + [(\phi A_p - \bar{R}_{€})^2 + \frac{4\Gamma_{€}\xi_p}{E_p}]^{\frac{1}{2}}}{2\Gamma_{€}} \tag{C.11}$$

$$\widehat{Q}^{c}_{mc,p} = E_p \frac{\phi A_p - \bar{R}_{w} + [(\phi A_p - \bar{R}_{w})^2 + \frac{4\Gamma_{w}\xi_p}{E_p}]^{\frac{1}{2}}}{2\Gamma_{w}}. \tag{C.12}$$

For both types of firms, it holds that

$$\widehat{Q}^{c}_{\cdot,p|\xi>0} > \widehat{Q}^{c}_{\cdot,p|\xi=0} > \widehat{Q}^{c}_{\cdot,p|\xi<0}.$$

If $\xi_p > 0$, the firm starts with positive starting capital and therefore, pledgeable income is depleted only at higher levels of borrowing relative to a firm with $\xi \leq 0$. For derivation details, see Appendix C.5.4.2.

C.5.2.4 Selection into firm types

Two conditions pin down which firms become home- or multi-currency firms and for which the borrowing constraint is binding:

1. $\widehat{Q}^{c}_{hc,p,€} < \widehat{Q}^{u}_{hc,p,€}$ and $\widehat{Q}^{c}_{mc,p} < \widehat{Q}^{u}_{mc,p}$.
2. $E_{0^-}(\pi_{mc,p}) > E_{0^-}(\pi_{hc,p})$

The first two conditions represent the definition of being constrained. A firm is constrained if, in the absence of the borrowing constraint, it would increase its borrowing. As explained earlier, at $t = 0^-$ firm p is uncertain whether it will be constrained or unconstrained due to the stochasticity of the interest rates.

Probability of being constrained. To derive the probability that firm p is constrained or unconstrained as a given firm type, I solve the first two conditions. I solve the two inequalities for firm-specific threshold benchmark interest rates, $\widetilde{R}_{\$}$ and $\widetilde{R}_{€}$. For derivations, see C.5.4.1. If the benchmark interest rate realizes above the threshold, the firm is constrained. It holds that

$$\bar{R}_{w,t} \dot{\sim} \text{LogNormal}(\widetilde{\mu}_w, \widetilde{\sigma}^2_w), \text{ with cdf } F_w(\cdot)$$
$$\bar{R}_{€,t} \sim \text{LogNormal}(\bar{R}_{€}, \widehat{\sigma}^2_{€}), \text{ with cdf } F_{€}(\cdot)$$

$\bar{R}_{w,t}$ follows an approximate log-normal distribution whose analytical distribution is not known but can be approximated well based on the parameters of its two summands.[15] Appendix C.5.4.3 shows the analytical distribution with normal distributions.

[15]The common approach is to sample from the two terms of the sum, $\widehat{w}_{\$}\bar{R}_{\$,t}e_1$ and $\widehat{w}_{€}\bar{R}_{€,t}$, and then estimate on the sum the parameters of the approximated shifted Log-normal distribution. See

Fixing the level of benchmark rates at their expected values, Section C.5.4.1 presents derivations for threshold levels of initial capital $\bar{\xi}_p$ or benchmark rates $\widetilde{R}$. By switching off the uncertainty about rates, this allows to understand the role of firm characteristics in driving firm selection.

Expected profits. The firm uses $F_w(\cdot)$ and $F_€(\cdot)$ to compute the expected profits as each firm type

$$E_{0^-}(\pi^{mc}_{p,t=1}) = F_w(\widetilde{R}_{w,p})E_{0^-}\left[\pi^u_{mc}(\widehat{Q}^u_{mc,p}, \widehat{R}^u_{mc,p})\right] + (1 - F_w(\widetilde{R}_{w,p}))E_{0^-}\left[\pi^c_{mc}(\widehat{Q}^c_{mc,p}, \widehat{R}^c_{mc,p})\right] \tag{C.13}$$

$$E_{0^-}(\pi^{hc}_{p,t=1}) = F_€(\widetilde{R}_{€,p})E_{0^-}\left[\pi^u_{hc}(\widehat{Q}^u_{hc,p}, \widehat{R}^u_{hc,p})\right] + (1 - F_€(\widetilde{R}_{€,p}))E_{0^-}\left[\pi^c_{hc}(\widehat{Q}^c_{hc,p}, \widehat{R}^c_{hc,p})\right]. \tag{C.14}$$

Each firm then selects its firm-type according to the rule[16]

$$\text{type of } p = \begin{cases} \text{multi-currency if} & E_{0^-}(\pi^{mc}_{p,t=1}) \geq E_{0^-}(\pi^{hc}_{p,t=1}) \\ \text{home-currency if} & \text{otherwise.} \end{cases} \tag{C.15}$$

Equation C.15 pins down the regions in the parameter space associated with different firm-types. Investment $\widehat{X}_p$ is then determined simply by substituting the derived optimal borrowing amounts into the flow-of-funds identity

$$\widehat{X}_{p,0^+}(\bar{R}_\$, \bar{R}_€, e_0) = E_p - \gamma Q_{p,\text{-}1} R_{p,\text{-}1} + \widehat{Q}_p\left[\bar{R}_€, \bar{R}_\$, e_0(\bar{R}_\$)\right]. \tag{C.16}$$

C.5.3 Predictions details

C.5.3.1 Total derivative: Exchange rate response to interest rates

In the data, as well as in the model, $\bar{R}_{\$,t}$, $\bar{R}_{€,t}$ and e_t are correlated. Shocks to the US interest rate affect the exchange rate and foreign interest rates. In Equation C.16, that is emphasised through the notation $e_0(\bar{R}_\$)$. Before analysing partial derivatives, it is therefore helpful to consider the total derivative of investment with respect to $\bar{R}_{\$,t}$, which is

$$\frac{d\widehat{X}_p}{d\bar{R}_\$} = \begin{cases} \frac{\partial \widehat{X}_p}{\partial \bar{R}_€}\frac{\partial \bar{R}_€}{\partial \bar{R}_\$} & \text{if } p \text{ is a home-curreny firm} \\ \frac{\partial \widehat{X}_p}{\partial \bar{R}_\$} + \frac{\partial \widehat{X}_p}{\partial e_0}\frac{\partial e_0}{\partial \bar{R}_\$} + \frac{\partial \widehat{X}_p}{\partial \bar{R}_€}\frac{\partial \bar{R}_€}{\partial \bar{R}_\$} & \text{if } p \text{ is a multi-curreny firm.} \end{cases} \tag{C.17}$$

If the partials $\frac{\partial e_0}{\partial \bar{R}_\$}$ and $\frac{\partial \bar{R}_€}{\partial \bar{R}_\$}$ are non-zero, it is clear that also home-currency firms will be effected by US monetary policy shocks through the reaction of local benchmark rates. Similarly, the exposure of multi-currency firms to US monetary policy does not stem only from changes in the US benchmark rate but also from associated

Fenton (1960) or more recently Lo (2012). The firms in my model follow this procedure and are thus able to fully understand the stochasticity of $\bar{R}_{w,t}$.

[16] I made the assumption that the "roll-over problem" does not drive the decision to become a multi-currency firm. The firm does not anticipate systematically different costs of rolling over pre-existing debt as multi-currency firm or home-currency firm.

responses in local currency rates and the exchange rate. The strength and direction of the responses of local rates and exchange rates are parametrized in the model with $\beta_{€}$ and $\beta_{\$}$ respectively.

C.5.3.2 Analytical expressions for partial derivatives

In the main text, I illustrated graphically the investment responses to a change in the US benchmark rate. Here I present analytical derivatives and distinguish between a cash flow and net worth channel.

$$\frac{\partial \widehat{X}^c_{p,mc}}{\partial \bar{R}_\$} = \underbrace{-\frac{E_p e_1 \widehat{w}_{\$,0^-}}{2\Gamma_w}}_{\text{direct "FOC effect"}} \underbrace{-\left(2\phi A_p e_1 \widehat{w}_{\$,0^-} + 2\bar{R}_\$ (e_1 \widehat{w}_{\$,0^-})^2\right)\left[\frac{E_p}{2\Gamma_w}[(\phi A_p - \bar{R}_w)^2 + \frac{4\Gamma_w \xi_p}{E_p}]^{-\frac{1}{2}}\right]}_{\text{net worth effects}} < 0. \tag{C.18}$$

Equation C.18 shows that the response of investment to an interest rate change can be split into two components. The first one reflects the first order condition and is the same for constrained and unconstrained firms. Firms increase their borrowing until the marginal borrowing costs reach the marginal productivity. Increases in the benchmark rates squeeze the initial margin, and therefore reduce the space to raise borrowing. The second term is specific to constrained firms and reflects how borrowing responds to changes in pledgeable income induced by the rate change.

Finally, Equation C.19 shows the investment response to an exchange rate change. In addition to the net worth effect, investment is also reduced by the increased cash outflow for repayment of US Dollar debt that a Euro depreciation triggers.

$$\begin{aligned}\frac{\partial \widehat{X}^c_{p,mc}}{\partial e_0} &= \underbrace{-\gamma \widehat{w}_{\$,0^-} Q_{\text{-}1,p} R_{\text{-}1,p}}_{\text{cash flow effect}} + \underbrace{\frac{\partial \widehat{Q}_{p,mc}}{\partial \xi_p}\frac{\partial \xi_p}{\partial e_0}}_{\text{net worth effects}} \\ &= -\gamma \widehat{w}_{\$,0^-} Q_{\text{-}1,p} R_{\text{-}1,p} + \underbrace{\frac{1}{E_p}\left[(\phi A_p - \bar{R}_w)^2 + \frac{4\Gamma_w \xi_p}{E_p}\right]^{-\frac{1}{2}}}_{\frac{\partial \widehat{Q}_{p,mc}}{\partial \xi_p} > 0} \times \underbrace{-(\phi A_p \gamma \widehat{w}_{\$,\text{-}1} Q_{\text{-}1,})}_{\frac{\partial \xi_p}{\partial e_0} < 0}\end{aligned} \tag{C.19}$$

The partial derivatives in Equations C.19 and C.18 can be plugged into the total derivative in Equation C.17, to derive the overall investment reponse to a monetary shock, allowing exchange rate responses to the monetary shock.

Cross-partial w.r.t. share of maturing debt. Equation C.20 confirms that the investment reponse to benchmark rate shocks strengthens as γ increases (Figure 3.2a).

$$\frac{\partial \widehat{X}^{c}_{p,mc}}{\partial \bar{R}_{\$}\partial \gamma} = \frac{\partial}{\partial \xi_p}\Big(\frac{\partial \widehat{X}_{p,mc}}{\partial \bar{R}_{\$}}\Big) \times \frac{\partial \xi_p}{\partial \gamma} \tag{C.20}$$

$$= \underbrace{-(\phi A_p - R_{\text{-}1,p})Q_{\text{-}1,p}R_{\text{-}1,p}}_{\frac{\partial \xi_p}{\partial \gamma}<0} \underbrace{\left(\left[2\phi A_p \widehat{w}_{\$,0} - e_1 + 2\bar{R}_{\$}(\widehat{w}_{\$,0} - e_1)^2\right]\left[(\phi A_p - \bar{R}_w)^2 \frac{4\Gamma_w \xi_p}{E_p}\right]^{-\frac{2}{3}}\right)}_{=\frac{\partial}{\partial \xi_p}\left(\frac{\partial \widehat{X}_{p,mc}}{\partial \bar{R}_{\$}}\right)>0} < 0$$

C.5.4 Derivations details

C.5.4.1 Selection into firm-types

The following presents the derivations for the regions of the parameter space for each firm type when the uncertainty is switched off ("fixed cost channel").

Deriving borrowing amounts for types and varities. In a first step, I derive the borrowing amounts firm p expects as each firm-type variety (constrained vs unconstrained). I compute the constrained amounts by setting the pledge income equal to zero. (see the following section C.5.4.2) Conditions under which the borrowing constraint will be binding, can be characterized by solving $\widehat{Q}^{c}_{mc,p,w} < \widehat{Q}^{u}_{mc,p,w}$. If $\xi = 0$, this condition is simply $A_p < \frac{\bar{R}_{€}}{2(\phi - \frac{1}{2})} \equiv \tilde{A}$ or solving for $\bar{R}$, $\widetilde{R}_{€} \equiv \bar{R}_{€} > A_p 2(\phi - \frac{1}{2})$ and $\widetilde{R}_w \equiv \bar{R}_w > A_p 2(\phi - \frac{1}{2})$. For $\xi_p \neq 0$, it is

$$\widehat{Q}^{u}_{mc,p,w} > \widehat{Q}^{c}_{mc,p,w} \iff A_p(1-\phi) > [(\phi A_p - \bar{R}_w)^2 + \frac{4\Gamma_w \xi_p}{E_p}]^{\frac{1}{2}}.$$

Assuming that both sides of the inequality are greater than zero,[17] it is

$$\begin{aligned} A_p^2(1-\phi)^2 >& (\phi A_p - \bar{R}_w)^2 + \frac{4\Gamma_w \xi_p}{E_p} \\ \iff \xi_p <& E_p \frac{A_p^2(1-2\phi) + 2\phi A_p \bar{R}_w - \bar{R}_w^2}{4\Gamma_w} \equiv \bar{\bar{\xi}}_{mc,p}. \end{aligned} \tag{C.21}$$

Condition C.21 highlights that, if firms start with positive or negative pledgeable income, the conditions under which the borrowing constraint becomes binding is different for multi-currency and home-currency-only firms. This can be seen, inter alia, through the presence of Γ_w in the condition. To explain the economics of this, consider the case $\xi_p > 0$. The pace at which borrowing costs rise, which is the slope of demand curve for debt, determines how fast the initial pledgeable income is driven to zero once the marginal pledgeable revenue is less than the marginal cost of borrowing.

[17] This requires imposing a lower bound for initial pledgeable income $\xi_p > -E_p \frac{(\phi A_p - \bar{R}_w)^2}{4\Gamma_w}$.

For home-currency only firms, it is

$$\widehat{Q}^{c}_{hc,p,€} < \widehat{Q}^{u}_{hc,p,€} \iff \xi_p < E_p \frac{A_p^2(1-2\phi) + 2\phi A_p \bar{R}_€ - \bar{R}_€^2}{4\Gamma_€} \equiv \bar{\bar{\xi}}_{hc,p}. \tag{C.22}$$

Comparing profits between firm-type varieties. Each firm selects the firm-type variety that yields the highest (expected) profit. The minimum profit of a multi-currency firm conditional on ξ_p is the one associated with constrained borrowing. Instead the maximum profit reaped by a home-currency firm is the one associated with its unconstrained optimal borrowing $\widehat{Q}^{u}_{hc,p}$. I can therefore focus on the comparison of constrained multi-currency firms vs unconstrained home-currency firms. Thresholds are given by $E_{0^-}(\pi^c_{mc,p,t=1}) > E_{0^-}(\pi^u_{hc,p,€,t=1})$.

C.5.4.2 Maximum feasible borrowing under binding constraint

For the multi-currency firm, expected pledgeable income is

$$E(PI_{mc,p}) = E(\phi A_p Q_{mc,p} - R_{w,p} Q_{mc,p} + \xi_p)$$

The maximum permissable borrowing is reached when the pledgeable income equals zero:

$$(\phi A_p - \bar{R}_w) Q_{mc,p} - \frac{\Gamma_w}{E_p} Q^2_{mc,p} + \mu_{\xi_p} = 0 \tag{C.23}$$

If exogenous net starting capital is zero $\mu_{\xi_p} = 0$, $\widehat{Q}^{c}_{mc,p} = E_p \frac{\phi A_p - \bar{R}_w}{\Gamma_w}$. If $\mu_{\xi_p} \neq 0$, we have

$$\widehat{Q}^{c}_{mc,p} = E_p \frac{\phi A_p - \bar{R}_w \pm \sqrt{(\phi A_p - \bar{R}_w)^2 + \frac{4\Gamma_w \mu_{\xi_p}}{E_p}}}{2\Gamma_w}. \tag{C.24}$$

At issuance level $Q = E_p \frac{\phi A_p - \bar{R}_w}{2\Gamma_w}$, the partial derivative of pledgeable income wrt to borrowing switches sign from positive to negative. In economic terms, if $\xi_p > 0$, pledgeable income is boosted, and the maximum feasible borrowing will exceed $\widehat{Q}^{c,\xi=0}_{mc,p} = E_p \frac{\phi A_p - \bar{R}_w}{\Gamma_w}$. If $\xi_p < 0$, firm p enters the model with negative pledgeable income, hence maximum feasible borrowing declines relative to the case with $\xi_p = 0$. Considering the negative root in expression C.24 would imply that $\widehat{Q}^{c,\xi>0}_{mc,p} < \widehat{Q}^{c,\xi=0}_{mc,p}$ which is economically not permissable. Therefore I focus on the positive root in C.24. Derivations for the home-currency firm are completely analogous.

C.5.4.3 Distribution of $\bar{R}_{w,t}$ with normal distributions

Recall the definition

$$\bar{R}_{w,t} = \widehat{w}_{\$}\bar{R}_{\$,t}e_1 + \widehat{w}_{€}\bar{R}_{€,t} = \underbrace{\widehat{w}_{\$}\bar{R}_{\$}e_1 + \widehat{w}_{€}\bar{R}_{€}}_{=a} + \underbrace{(\widehat{w}_{\$}e_1 + \beta_{€})}_{b}\epsilon_t^{US} + \underbrace{\widehat{w}_{€}}_{c}\epsilon_t^{€}.$$

Define $\bar{R}_{w,t} = X + Y$ with $X \sim N(a, b^2\sigma_{US}^2)$ and $Y \sim N(0, c^2\sigma_{€}^2)$. The characteristic function of $X + Y$ is

$$\begin{aligned} \varphi_{X+Y}(t) =& \varphi_X(t)\varphi_Y(t) \\ =& exp(it \cdot a - \frac{t^2(b^2\sigma_{US}^2 + \widehat{w}_{€}^2\sigma_{€}^2)}{2}), \end{aligned}$$

which is the characteristic function of distribution $N(\widehat{w}_{\$}\bar{R}_{\$}e_1 + \widehat{w}_{€}\bar{R}_{€}, (\widehat{w}_{\$}e_1 + \beta_{€})^2\sigma_{US}^2 + \widehat{w}_{€}\sigma_{€}^2)$. It follows that

$$\bar{R}_{w,t} \sim N(\widehat{w}_{\$}\bar{R}_{\$}e_1 + \widehat{w}_{€}\bar{R}_{€}, (\widehat{w}_{\$}e_1 + \beta_{€})^2\sigma_{US}^2 + \widehat{w}_{€}^2\sigma_{€}^2).$$