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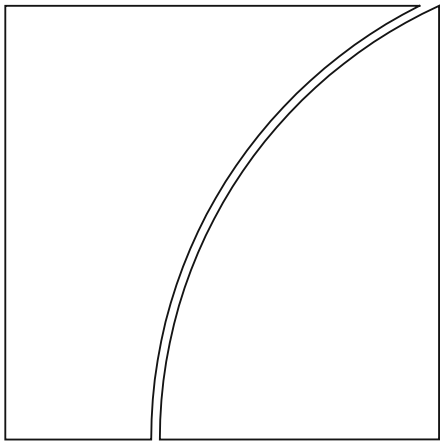

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Spread the Word: International Spillovers from Central Bank Communication

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Monetary and Economic Department

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Keywords: communication, monetary policy, international policy transmission

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Spread the Word: International Spillovers from Central Bank Communication*

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November 2019

Abstract

We construct a novel text dataset to measure the sentiment component of communications for 23 central banks over the 2002-2017 period. Our analysis yields three results. First, comovement in sentiment across central banks is not reducible to trade or financial flow exposures. Second, sentiment shocks generate cross-country spillovers in sentiment, policy rates, and macroeconomic variables; and the Fed appears to be a uniquely influential generator of such spillovers, even among prominent central banks. And third, geographic distance is a robust and economically significant determinant of comovement in central bank sentiment, while shared language and colonial ties have weaker predictive power. (*JEL* E52, E58, F42)

Keywords: communication, monetary policy, international policy transmission.

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1 Introduction

Central bank communication has grown in frequency and scope since the 1990s Woodford (2005); Bernanke (2013), and has become an increasingly important policy tool during the prolonged period of low global interest rates. The existing literature has established that central bank communication affects domestic interest rates and macroeconomic variables Bernanke et al. (2004); Gürkaynak et al. (2005); Schmeling and Wagner (2019); Cieslak and Schrimpf (2019) and is particularly effective during periods of unconventional policy, such as forward guidance Hansen and McMahon (2015). It remains unclear, however, whether these effects spill over to foreign central bank communication, policy rates, and macroeconomic variables. Given the literature on monetary policy spillovers, which finds effects for both conventional[1] and unconventional monetary policy,[2] it seems plausible that communication could also have an impact outside of the domestic economy. Indeed, recent policy debates about monetary policy and communication have centered around this question.[3]

This paper contributes to the literature by making the first attempt to measure international spillovers from central bank communication across a large set of central banks. In doing so, we pose the following research questions. First, is there evidence of international spillovers from central bank communication? If so, do communication spillovers exhibit a different pattern than economic exposures, such as trade and financial flows? Second, do communication spillovers matter for critical macroeconomic and policy variables? And third, do non-economic factors, such as language, geographic distance and high-level international central bank meetings contribute to the observed comovement in central bank communication?

We study central bank communication using the sentiment content of central bankers' speeches. This involves extracting a latent component of communication from speeches that captures "positivity" with the approach introduced in Loughran and McDonald (2011). We do

[1]This line of research dates back to Mundell (1963) and Fleming (1962) who studied the impact of exchange rate regimes on capital mobility. Canova (2005) and Maćkowiak (2007) identify the effects of U.S. monetary shocks on Latin American and East Asian countries, while di Giovanni and Shambaugh (2008) look at the effect of foreign interest rates on output growth in other countries. Dedola et al. (2017) offer a study extended to high income countries with a focus on the financial dimension. Rey (2015) relates spillovers in emerging markets to the global financial cycle governed by monetary conditions in the center.

[2]See, e.g., Eichengreen and Gupta (2015), who analyze the impact of the Federal Reserve's tapering talk on emerging markets; Neely (2014), who demonstrates the impact of unconventional monetary policy in the U.S on international bond yields and exchange rate; and Berge and Cao (2014), who show how it affects asset price responses. Morais et al. (2019) document how the corporate loan supply and risk-taking in Mexico is affected by foreign monetary policy shocks. For a study on the spillovers from unconventional policy measures in the Eurozone, see Fratzscher et al. (2016).

[3]Policymakers in emerging markets aired concerns that their economies were being negatively affected by loose U.S. monetary conditions, which initially generated a surge of capital inflows and exchange rate appreciations Chen et al. (2014). These were later reversed in the so-called "taper tantrum" Neely (2014).

this for speeches given by 23 central banks over the period between 2002 and 2017.[4] While announcements are typically used for high frequency analysis of central bank communication, speeches provide a more stable measure of low frequency sentiment because they are more numerous and longer.[5] Speeches also have the advantage of being available for more countries, which is vitally important for a complete analysis of international spillovers. Furthermore, using a measure of communication that permits the inclusion of more countries enables us to perform the first cross-country analysis of comovement in central bank communication. Consequently, we are able to uncover non-economic linkages in central bank communication that may have implications for policy, complementing the existing literature on central bank decision making Malmendier et al. (2017); Sibert (2006).

We first determine how communication is transmitted by mapping out relations in sentiment between central banks. We do this by generating directed sentiment networks using the technique introduced in Billio et al. (2012). A comparison of the sentiment network to the equivalent networks for trade and financial flows reveals two non-trivial differences. First, in some cases, the direction of communication flows differs from trade and financial flows, which suggests that comovement in communication across countries is unlikely to be driven entirely by economic forces. Second, we find that outgoing communication sentiment links are not necessarily a function of the prominence of the central bank. As expected, the Federal Reserve (Fed) has a strong impact on sentiment at other central banks; however, the Bank of Japan (BoJ) and the European Central Bank (ECB) are primarily influenced by other central banks, even though Japan and the Eurozone generate trade and financial flow exposures for many countries in the network. Taken together, this evidence suggests that it is possible for a central bank to generate spillovers through its influence over another central bank's communication, even if it does not directly affect bilateral trade or financial flows.

We next consider whether spillovers from central bank communication affect foreign macroeconomic variables and policy rates. To do this, we measure the impact of a shock to sentiment at one country's central bank on domestic and foreign sentiment, policy variables, and macroeconomic variables. We do this by running quarterly sign-restricted vector autoregressions (VARs) with the rejection method introduced in Rubio-Ramirez et al. (2010) for a subset of central banks with the highest number of speeches and independent monetary policy. This approach

[4]The speeches are obtained from the Bank for International Settlements (BIS) website: `https://www.bis.org/cbspeeches/`.

[5]While individual speeches are noisy, they are also available at a higher frequency than announcements for most central banks. Speeches also typically contain thousands of words; whereas announcements only contain a few hundred. Since dictionary-based methods rely on the repetition of words and phrases, the average sentiment score in many documents with many words will typically contain less noise than a single document with fewer words. In fact, we show that this is the case for the Fed. Andersson et al. (2006) also provide a similar observation about speeches.

allows us to avoid placing restrictions on the response of foreign variables. We find that a positive, structural shock to Fed sentiment tends to generate immediate spillovers to foreign sentiment and lagged spillovers to foreign policy rates and unemployment. In contrast, we do not find that shocks to ECB or BoJ sentiment generate substantial international spillovers, but we do find that the Bank of England (BoE) generates spillovers for the ECB and the Eurozone.

Having established the disconnect between cross-country economic exposures and central bank sentiment, we further examine whether non-economic factors explain comovement in sentiment for the full set of 23 central banks. We do this by regressing the bilateral correlation in quarterly central bank communication sentiment on a dummy for shared language, a dummy for colonial ties, a measure of geographic distance between central banks, and a broad set of controls, including comovement in real GDP growth and in inflation, bilateral trade flows, bilateral financial flows, country fixed effects, and a shared continent dummy. Our findings suggest that shared language and colonial ties generate economically significant, but not robust, increases in central bank sentiment comovement. Furthermore, geographic distance between central banks emerges as a uniquely robust and economically significant predictor of central bank sentiment comovement. In the specification with the most extensive set of controls and fixed effects, distance remains significant at the 1% level. The economic significance of geographical distance is substantial, and implies that an 8,000km increase in distance (i.e. Beijing to London) is associated with a 42% reduction in sentiment correlation for the median pair of central banks.[6] The results are robust to dropping influential central banks, such as the Fed, and including a dummy for shared continent. They are also robust to expanding the sample from 23 to 55 central banks to include more emerging market economies.

In addition to distance, we also study the impact of attendance at the BIS Global Economy Meeting (GEM). The BIS GEM is focused narrowly on discussions about macroeconomic developments, which suggests that central banks who attend could gain insights into each others' assessments of economic fundamentals and policy inclinations. This could lead to convergence toward a common description of the underlying state of the global economy and, consequently, convergence in sentiment. In fact, we find that countries that are members or observers of the BIS GEM tend to experience greater sentiment comovement. This suggests that increased frequency of communication among central banks can translate into increased alignment in sentiment.

Overall, our results suggest that central bank communication generates international spillovers

[6]This result complements the finding in the international business cycle literature that regional comovement has increased Mumtaz et al. (2011); Kose et al. (2012). We find that geographic distance remains an important determinant of communication comovement, even after controlling for business cycle comovement and an indicator for whether a country-pair shares a continent.

for sentiment, policy, and macroeconomic variables. The largest and most durable spillovers appear to be generated by the Fed, while the ECB primarily internalizes sentiment generated elsewhere. This suggests that domestic central bank sentiment can be influenced by foreign central bank sentiment and that comovement in sentiment across central banks is not reducible to trade and financial flow exposure. Thus, foreign central bank sentiment can have direct implications for domestic policy and macroeconomic variables, as well as indirect implications via domestic central bank sentiment. Moreover, if central bank communication is not primarily influenced by the countries to which that central bank is most exposed economically, but systematically affected by non-economic factors, then communication may be misaligned, yielding suboptimal policy.

Our paper is closely related to Hansen and McMahon (2015), who use topic modeling to isolate different dimensions of central bank communication. In contrast to Hansen and McMahon (2015), we use dictionary-based methods, which measure sentiment and allow for the inclusion of a large number of central banks and speeches. One downside of our approach is that it does not distinguish between a central bank's assessment of the state of the economy and its use of forward guidance, as is done in Hansen and McMahon (2015). We do, however, show that a simple dictionary-based measure can reveal a central bank's latent sentiment position and predict its future policy rate decisions. Based on our findings, it is reasonable to infer that this measure does not entirely overlap with forward guidance information or with the quantitative forecast of the central bank. Consequently, we treat sentiment as a mixture of the central bank's private information on the economy and "implicit" forward guidance with the former tending to dominate in our sample period. Miranda-Agrippino and Ricco (2018) contains a discussion on the ample empirical evidence that there are information asymmetries between financial markets and central banks.

Beyond this, we also contribute to the literature on monetary policy spillovers Canova (2005); Maćkowiak (2007); di Giovanni and Shambaugh (2008); Dedola et al. (2017) by analyzing communication spillovers. Existing work has measured the impact of central bank communication spillovers on exchange rates (e.g. Fratzscher (2006), Fratzscher (2008), and Burkhard et al. (2010)). Related work also documents that central bank communication appears to predict policy decisions Apel and Grimaldi (2014), movements in interest rates Schmeling and Wagner (2019), and equity prices Cieslak and Schrimpf (2019). Further evidence has shown that central bank communication is often used to prepare markets and typically has the strongest effect in advance of decisions Ehrmann and Fratzscher (2007b). Moreover, the effects from communication appear to have persisted during the zero lower bound (ZLB) period, but were primarily concentrated in long term yields Carvalho et al. (2016).

Our paper also relates to the work on central bank press conferences, where the impact of communication is measured in a short window around the monetary policy announcement (e.g. Schmeling and Wagner (2019) and Ehrmann and Talmi (2017)).[7] In contrast, we focus on the low-frequency component of central bank communication and its relationship with domestic and foreign macroeconomic variables, such as unemployment, output, inflation, and interest rates. Earlier literature, including Brainard (1967) and, more recently, Woodford (2005) and Stein and Sunderam (2018) model the phenomenon of gradualism for central banks with various motivations. They show that central banks may prefer to release private information gradually to avoid spooking financial markets. Focusing on speeches allows us to capture this component of communication. It also allows us to measure central bank sentiment beyond the carefully planned and highly anticipated announcements, and to characterize how communication at one central bank affects communication at others.

Finally, on a conceptual level, our paper is also related to the literature on sentiment and business cycle fluctuations Angeletos and La'O (2013) and on gross capital flows at the country level Benhima and Cordonier (2017). Central banks are key players in the economy, which gives them a naturally important role in the coordination of market participant beliefs Morris and Shin (2002). In our paper, we identify the component of sentiment that is affected by foreign central banks. Moreover, we document its cross-country transmission, as well as its effect on domestic macroeconomic variables.

The paper is organized as follows: Section 2 describes the data and Section 3 presents the sentiment score measurement. Section 4 describes the network analysis, the sign-restricted VARs, and the cross-sectional sentiment regressions. Finally, Section 5 concludes.

2 Data

We first compiled a database of international central bankers' speeches. We did this by scraping the Bank for International Settlements' (BIS) speech archive for the 2002-2017 period, collecting both speech text and metadata for all documents. This yielded a total of 12,024 English-translated speeches. We then selected the 23 central banks who gave at least 100 speeches over the 2002-2017 period and restricted our sample to speeches from these institutions, yielding 7,554 speeches.[8] Figure I provides a list of speech counts for the five central banks that we

[7] Similar to speeches, the transcripts of press conference are typically sufficiently large to allow for the reliable measurement of sentiment. However, unlike speeches, they have the advantage of being narrowly-focused on policy-relevant content and are available with precise time stamps.

[8] Since each central bank typically has multiple institutional identifiers (e.g. the Fed may be referred as Federal Reserve or the FOMC), we attempted to associate a unique institution with each speech. We did this by identifying the longest substring that is contained in all references to the central bank, and then checked each institution name for a match.

examined in greater detail in the empirical exercise.[9] For a robustness, exercise we also collected all policy announcements from the Federal Open Market Committee (FOMC) and European Central Bank (ECB). In Section 6.1 of the Appendix, we provide more information about the text data and how it is processed into a format suitable for use in regressions.

We also collected data on real GDP growth, inflation, trade flows, and financial flows for all 23 countries in the networks we construct. All real GDP growth and CPI inflation data came from the OECD, Eurostat, or the Atlanta Fed.[10] Unemployment, policy rate, stock returns, exchange rate, and imports data was also collected from the OECD or ECB. Bilateral trade flows come from the World Integrated Trade Solution (WITS) database and bilateral private financial flows were reconstructed from the BIS's Locational Banking Database. Additionally, for the United States, the United Kingdom, the Eurozone, Sweden, and Japan–the countries we examine in greater detail in the VAR exercise–we also collected data on unemployment, the policy rate, stock returns, the exchange rate, and imports. We used the X-13 approach to deseasonalize when seasonally-adjusted series were not available.

For the cross-sectional regression exercise, we collected additional data on geographic distance, language, and colonial ties. We used great circle distances in thousands of kilometers to measure the distance between country capitals. For the shared language variable, we required central banks in a pair to have at least one matching official language. For colonial ties, we required at least one country to have been a colony of another or to have gained independence from the other. We used the ICOW Colonial History Database Hensel (2014) to construct this variable. Finally, we also collected data on the BIS Global Economy Meeting (GEM) attendance and on Financial Stability Forum (FSF) and Financial Stability Board (FSB) membership. We use these measures in a robustness exercise where we also expand the sample to include 55 central banks.

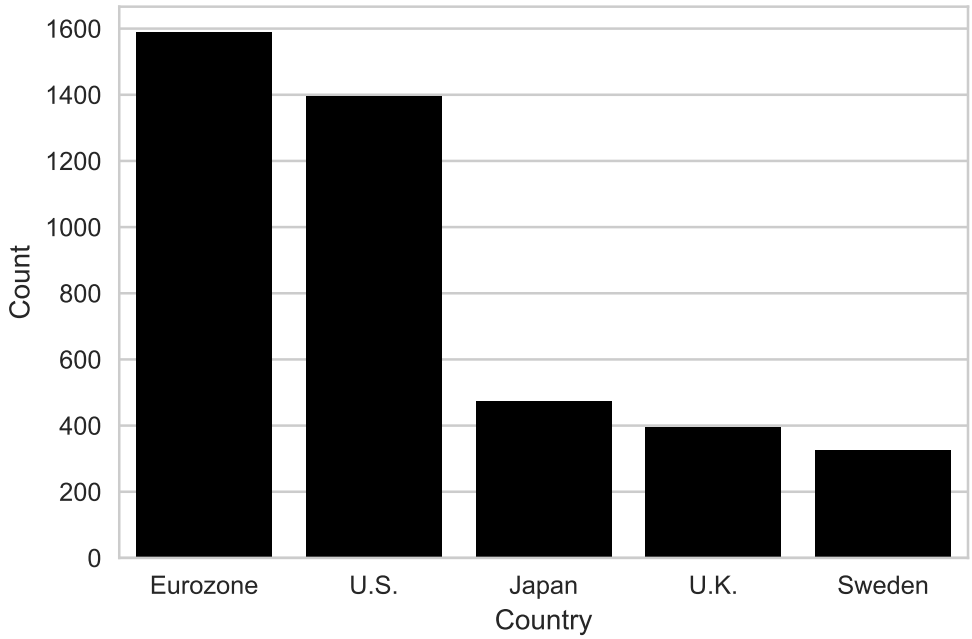
3 Central Bank Communication Sentiment

We clean and process the central bank speech data and the FOMC announcement data as described in Section 6.1 of the Appendix. Thereafter we proceed with the automated text analysis as described below.

[9] We selected these 5 most frequent communicators, subject to two constraints: 1) they must have control over their own monetary policy; and 2) they must have complete data for all macroeconomic and policy variables needed for the quarterly VARs.

[10] We used the Atlanta Fed's series for quarterly Chinese GDP because it covers our entire sample period.

Figure I: Speech Counts by Institution



Notes: This figure lists speech counts for the central banks associated with the following monetary unions and countries: the ECB (Eurozone), the Fed (U.S.), the BoJ (Japan), the BoE (U.K.), and the Riksbank (Sweden). All speeches were collected from the BIS's English language archive over the 2002-2017 period.

3.1 Measuring Sentiment

To measure sentiment, we adopt the most commonly-used, dictionary-based method for economic and financial documents, which was constructed by Loughran and McDonald (2011).[11] This method consists of a dictionary of words, which are classified as either positive or negative. The positivity, P, and negativity, N, are measured as follows:

$$P = \frac{\text{\# of Positive Words}}{\text{\# of Total Words}} \qquad N = \frac{\text{\# of Negative Words}}{\text{\# of Total Words}}. \tag{1}$$

For each document we define a net positivity score as $P_N = P - N$.

This dictionary-based method allows to us extract the sentiment component of each text, which indicates the extent to which a central bank official was positive or negative in his or her assessment of the economy. It also captures indications of potential paths for forward guidance. If, for instance, a monetary policy committee remains divided, speeches may give hints about

[11] Apel and Grimaldi (2014) and Carvalho et al. (2016) have found that similar indices contain predictive content about future policy decisions and interest rates. Following a methodology similar to Loughran and McDonald, Correa et al. (2017) develop a dictionary tailored to the financial stability context to study financial stability reports.

individual committee member positions.

Figure II shows plots of normalized speech sentiment for the Fed and ECB over the 2002-2017 period. The line in each plot is the rolling net sentiment mean of the 40 most recent speeches. The measured sentiment appears to capture factors related to the economic assessment and policy outlook well. Note that Fed sentiment deteriorated earlier than ECB sentiment and prior to the financial crisis in 2007. Later, there is a noticeable uptick in Fed sentiment in 2012, a few years before the Federal Open Market Committee (FOMC) published its "Policy Normalization Principles and Plans" FOMC (2014), which preceded the eventual increase in the Fed funds rate in December of 2015. The upward trend in Fed sentiment lasted till 2014 and experienced only a temporary dip during the taper tantrum in 2013. While Fed sentiment stabilized at a pre-crisis level after 2013, the ECB sentiment remained muted throughout, as additional crises afflicted the Eurozone.

Table I shows cross-country correlations for real GDP growth and central bank speech sentiment for the U.S., U.K., Eurozone, Japan, and Sweden. We select these four countries and one monetary union because they communicate most frequently among the subset of central banks and have complete data on macroeconomic variables. One clear pattern that emerges is that real linkages, captured by real GDP growth, are not sufficient to explain comovement in cross-country central bank sentiment. Thus, it is unlikely that comovement in sentiment across countries is simply a reflection of comovement in business cycles across countries.

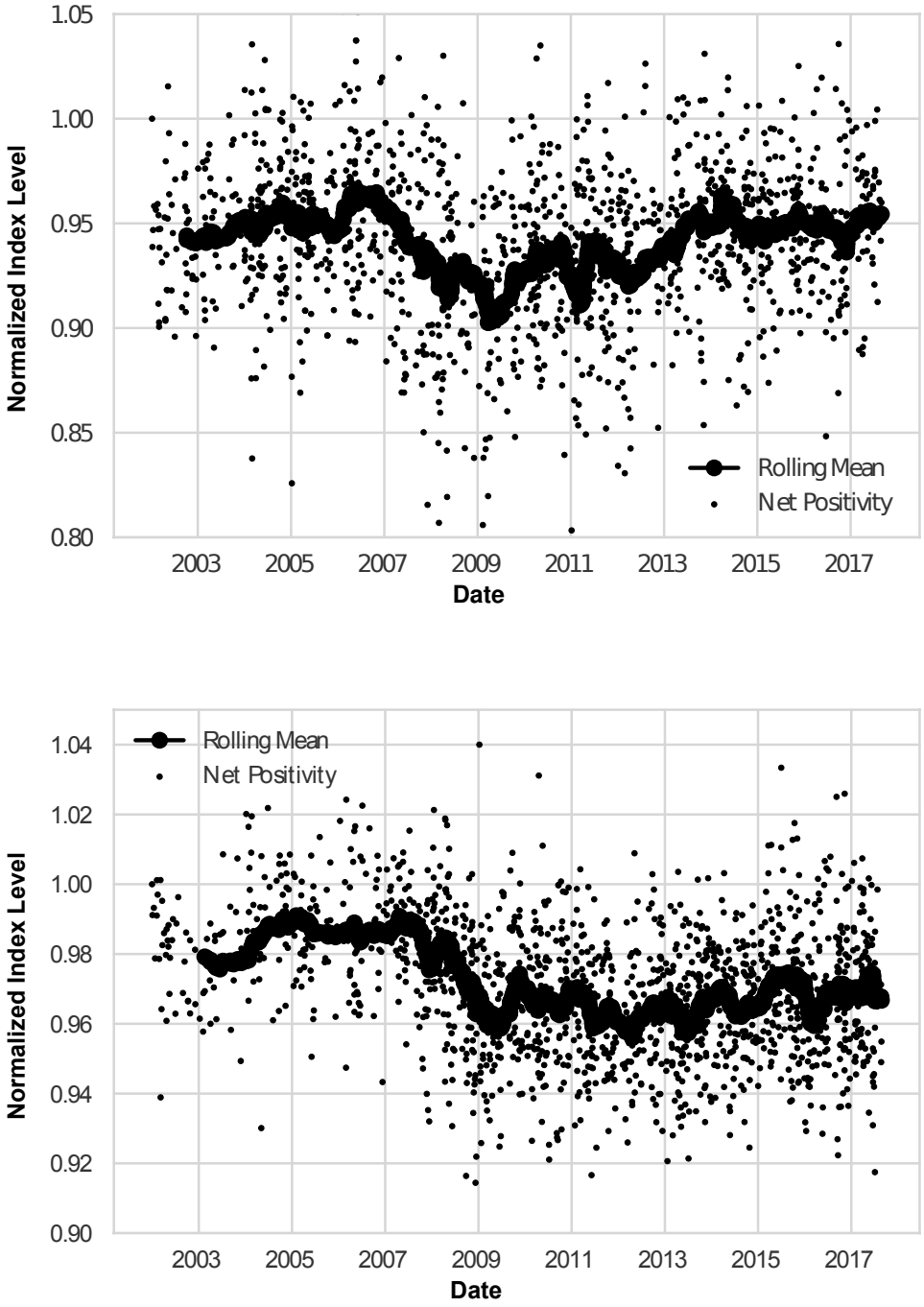
Table I: Cross-Country Correlations: Sentiment and Output

	Eurozone	U.S.	Japan	U.K.	Sweden
Real GDP Growth					
Eurozone	1.00	0.61	0.63	0.79	0.72
U.S.	-	1.00	0.43	0.62	0.61
Japan	-	-	1.00	0.53	0.51
U.K	-	-	-	1.00	0.58
Sweden	-	-	-	-	1.00
Central Bank Speech Sentiment					
Eurozone	1.00	0.38	0.37	0.38	0.34
U.S.	-	1.00	0.49	0.47	0.54
Japan	-	-	1.00	0.21	0.45
U.K	-	-	-	1.00	0.37
Sweden	-	-	-	-	1.00

Notes: This table provides cross-country correlations from our selection of five central banks. Cross-correlations are computed on quarterly sentiment data.

If, for instance, we look at the relationship between the U.S., the U.K., and the Eurozone,

Figure II: Rolling Speech Sentiment for the Fed (top) and ECB (bottom).



Notes: The plots above show the normalized net sentiment scores associated with Fed (top) and ECB (bottom) speeches. The line shows the rolling net sentiment mean of the 40 most recent speeches. Sentiment scores are computed using a dictionary-based approach documented in Loughran and McDonald (2011).

we can see that U.K. real GDP growth comoves most strongly with real GDP growth in the Eurozone; however, comovement in U.K. speech sentiment is strongest with U.S. speech sentiment. Similarly, real GDP growth in Japan comoves most strongly with the Eurozone, but sentiment comoves more strongly with the U.S. than with the Eurozone.

This basic, descriptive finding is non-trivial. It suggests that certain central banks may be attuned to the communication of certain other central banks in a way that is not justified by business cycle comovement. Since the literature has demonstrated that central bank communication affects policy-making and macroeconomic variables, this could be sufficient to generate international spillovers, even if there were no direct transmission of shocks from foreign sentiment to domestic variables. Historical relationships, geographic distance, or linguistic ties might cause central banks to overweight responses to the wrong country's shocks.[12] Such biases could lead to suboptimal policy-making and hamper monetary policy transmission. A similar situation may arise if financial linkages cause central banks to overweight responses by more than is warranted by economic ties.[13] We explore these hypotheses in greater detail in a cross-sectional regression.

The quarterly plots of net sentiment in Figure III further reinforce this relationship across central banks. Both Sweden and the United Kingdom appear to be more closely aligned with Fed sentiment than with the ECB, despite having stronger economic ties with the Eurozone. This result is in line with the Federal Reserve's uniquely influential role for global financial markets (Bruno and Song, 2015; Brusa et al., 2019).

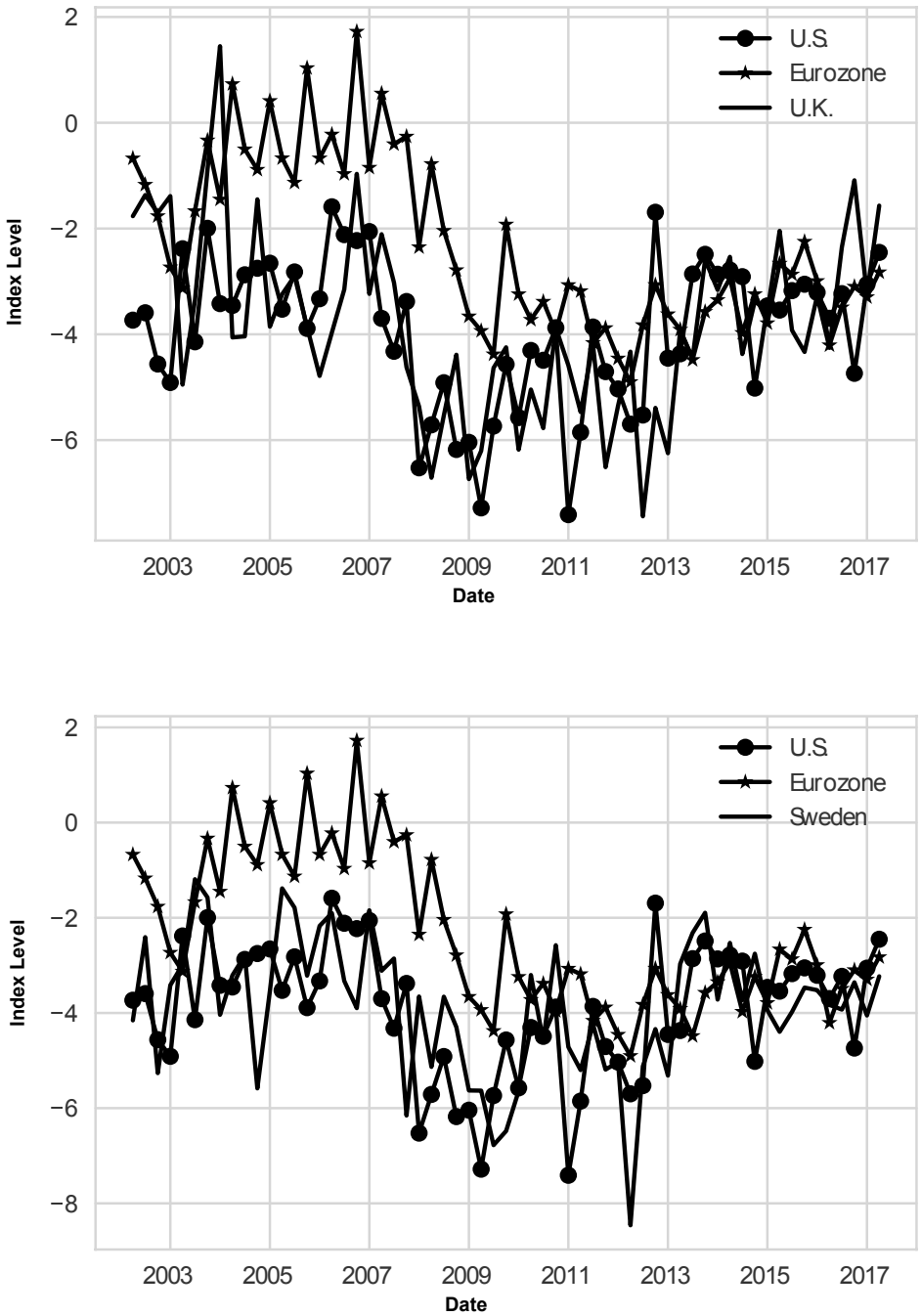
3.2 Alternative sentiment measures

In this section, we discuss alternative approaches that could be used to construct a quarterly measure of central bank speech sentiment. Moreover, we verify that the content of Fed speeches covers policy relevant topics and that speech sentiment strongly comoves with the sentiment of FOMC announcements. We further demonstrate that the ECB speeches cover similar topics and generate a similiar sentiment measure as ECB announcements. The previously described quarterly measure of central bank sentiment is constructed by averaging over scores for individual speeches. There are, of course, alternative approaches that could be used to construct a quarterly measure of sentiment; and, in principle, these approaches could yield a more informative series. Empirically, however, we will show that such alternatives do not appear to provide any meaningful gain over the mean sentiment and typically introduce substantial drawbacks. We will consider three such alternative measures in this section. The first uses the median

[12] See David (1994) and Eichengreen (1985) for a historical exploration.

[13] International capital flows are considerably more volatile than output, especially for emerging markets (see Federico et al. (2013) for descriptive statistics on gross capital inflow and domestic output volatility).

Figure III: Quarterly Speech Sentiment for the U.S., U.K., Eurozone, and Sweden

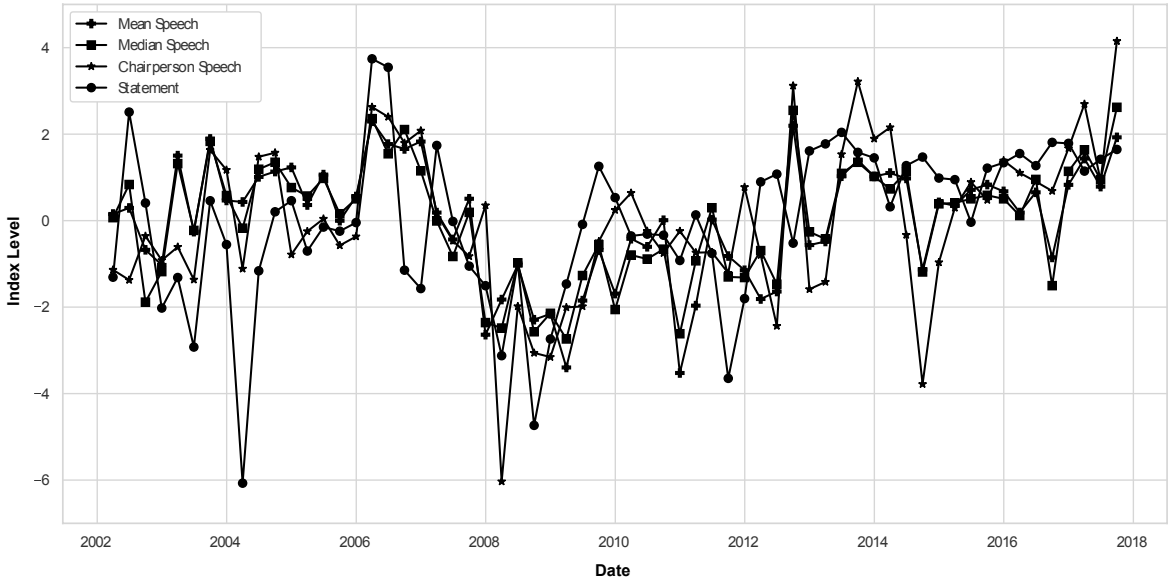


Notes: The plots above show quarterly speech sentiment for the U.S., U.K., Eurozone, and Sweden. Quarterly sentiment is computed as the mean speech sentiment of all speeches given by a central bank official within the quarter.

speech sentiment. The second exclusively uses the chairperson's speech sentiment. And the third measure uses announcements, rather than speeches.

We will first consider using the median speech sentiment, which should be less sensitive to outliers and could potentially provide a more stable measure of low frequency sentiment. To discern whether this is the case, we construct a median sentiment series for each central bank. We find that the weakest correlation between mean and median sentiment series is 0.95. Figure IV also shows that the mean and median sentiment series for the Fed are visually indistinguishable. The next alternative measure only keeps speeches given by the chairperson. One might assume that such speeches are more informative, since the chairperson typically has more power, is more influential, and is more likely to be covered by the media.[14] The mean speech series and the chairperson series have nearly identical trends, but the chairperson series is substantially more volatile, as is shown in Figure IV. This also suggests that placing fixed weights on sentiment of speakers from the same central bank is unlikely to be useful, since any such scheme will simply yield a linear combination of two series that are already highly similar.

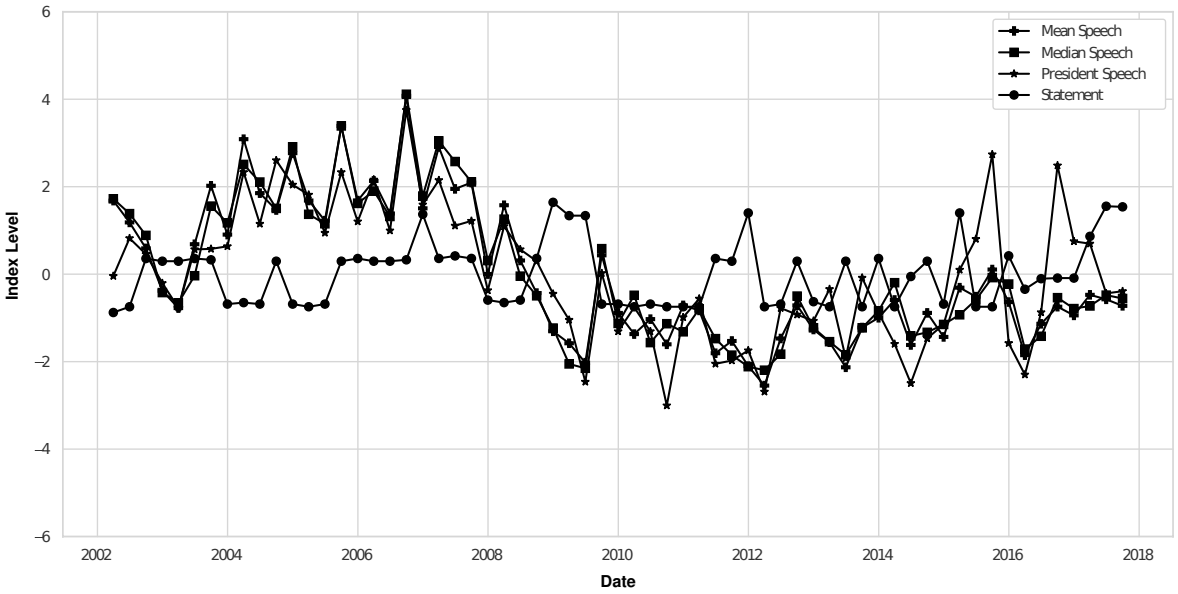
Figure IV: Alternative Sentiment Series for Fed Speeches and Announcements



Notes: This plot depicts our baseline series, mean sentiment, and three alternative sentiment series. The first alternative uses the median, rather than the mean. The second alternative uses the chairperson's speeches only. The third alternative computes sentiment using FOMC announcements, rather than speeches.

[14] A drawback to this approach is that it reduces the sample size and ignores the sentiment positions of all other officers. In fact, we find that the reduction in sample size appears to overwhelm any gains from increased relevance.

Figure V: Alternative Sentiment Series for ECB Speeches and Announcements



Notes: This plot depicts our baseline series, mean sentiment, and three alternative sentiment series. The first alternative uses the median, rather than the mean. The second alternative uses the president's speeches only. The third alternative computes sentiment using ECB announcements, rather than speeches.

In addition to modifying how speech sentiment is processed and included, we also consider using FOMC statements, rather than speeches. Speeches are arguably noisy, since they can contain content that is unrelated to monetary policy. Statements exclusively contain policy relevant material and, thus, should be less noisy in principle. We collected announcements– that is, the FOMC's statements about its policy decisions. Over the 2002-2017 period, 156 such statements were issued and 1395 speeches were given. Comparing announcements and speeches allows us to rule out the possibility that speech sentiment is noisy or unrelated to policy. Empirically, however, this is not as simple as it appears. First, announcements are a problematic choice for sentiment extraction because they are quite short. Many standard dictionaries will only identify a handful of relevant terms. To the contrary, speeches will typically contain hundreds of instances of relevant terms. Announcements are also given less frequently, which means that they only yield 1-2 sentiment samples per quarter. As we show in a case study for the Fed, the sentiment series for announcements and speeches is similar, but announcement sentiment contains more uninformative noise, as can be seen in Figure IV. While announcements are certainly more informative for other text analysis exercises, they appear to be an inferior

choice for low frequency sentiment analysis.[15] Note that we find the same results for the ECB in Figure V.

Finally, we perform a comparison of the topic content of announcements and speeches to determine whether speeches contain too much content that is not relevant for policy. It is certainly true that some speeches address topics that are not narrowly focused on monetary policy. Thus, we might expect that the sentiment content from such speeches could introduce noise into our measure. First, we use a Latent Dirichlet Allocation (LDA) to extract topics from both Fed speeches and FOMC announcements over the 2002-2017 period.[16] Depending on the model settings, we find a 60-70% overlap in the topic content of speeches and FOMC announcements. The remaining 30-40% topics cover other central bank concerns, including financial stability. We also find similar, but slightly weaker results for the ECB: approximately 50% of the topics overlap between speeches and statements. Importantly, any topics in speeches that are unrelated to core areas of central bank policy interest will only add noise to the sentiment measure. As the trend in announcements coincides with the trend in speech sentiment, this noise is unlikely to be cause for concern. Rather, it suggests that our empirical evidence may understate the relevance of sentiment spillovers. Our second exercise, shown in Figures VIII and IX in the Appendix, provides a simple visual comparison of announcements and speeches for both the FOMC and ECB using word clouds, which indicate the relative frequencies of term use through font size. Notice that differences in term use across clouds is mostly driven by the choice of language. In both cases, common terms are typically highly policy relevant, notably the monetary policy and financial stability as the largest clusters. In the ECB's case, the difference between announcements and speeches is primarily driven by the detailed discussion of specific policy instruments in announcements. This contrasts with the high-level policy information conveyed in speeches.

3.3 Interpreting Sentiment

To structure our discussion on the interpretation of sentiment, we follow the literature (see, e.g., Blinder et al. (2008) for an overview) and assume, for simplicity, that central banks conduct monetary policy using a Taylor-type interest rate rule, as shown in equation (2), where i_t is the nominal interest rate, x_t is a vector of economic variables, F_t is the rule's (possibly) time-varying functional form, and ϵ_t is a deviation:

[15] Other forms of central bank communication, such as minutes and press conference opening statements, are longer than announcements and could provide an alternative to speeches for measuring central bank sentiment reliably.

[16] We use a term-document matrix with 500 features and extract 100 features from both speeches and announcements.

$$i_t = F_t(x_t) + \epsilon_t. \tag{2}$$

Such a central bank may wish to communicate its views on the state of the economy, x_t, or its intent to deviate from the rule, ϵ_t, including through the use of forward guidance. Alternatively, it might wish to communicate that it is changing how it responds to economic inputs–that is, how it modifies the functional form of F_t. New board members, for instance, might place different weights on the components of x_t. This could also happen if a central bank decided to adopt an explicit inflation target.

One general problem we encounter when analyzing the effects of central bank communication is identification. The most common approach for dealing with this issue is to focus on a narrow window around each monetary policy statement. While this approach is sensible for measuring forward guidance shocks, it may be less reliable for subtler forms of communication. If, for instance, a central bank wanted to communicate that it had changed the way it interprets some underlying economic trend, a speech might be a better channel to disseminate this information. This is particularly true in the case where no policy decision has yet been reached. For instance, a member of the central bank's board might use a speech to argue that high inflation is temporary and, thus, does not warrant an interest rate response. The financial market's reaction to such a speech might not be measurable until the next inflation data release. Furthermore, a speech might reveal a board member's optimism, which could ultimately have an impact on policy in the future, but would not be detectible in policy statements initially. Indeed, as we and others Andersson et al. (2006) have shown, speeches appear to capture the low frequency component of communication better than statements and announcements.

We make a first attempt at describing the economic content of speech sentiment by computing its principal components. We do this using the sentiment series from the 23 central banks that each gave a large number of speeches during the 2002-2017 period. Note that the countries (and monetary unions) included in this exercise, along with their central banks and two-letter country codes are given in Table IV. Figure X in the Appendix plots the variance share explained by each of the first 10 principal components. Note that the first principal component explains 28% of the total variance; however, this declines rapidly, with the second principal component explaining only 12%. The first five principal components explain just over 50% of the variance and the first ten are needed to account for 75%. This suggests that the sentiment content of central bank speeches are not simply reducible to Fed, ECB, or BoE sentiment.

Figure XI in the Appendix plots the first, second, and third principal components, along with their correlations with central bank sentiment for each of the 23 central banks. Note that the first principal component appears to capture the underlying sentiment that drives central

bank policy. This component declines prior to the Great Recession, remains flat until 2013, begins to rise in response to the unwinding of asset purchase programs, and then rises again as central banks consider increasing rates for the first time. The first principal component also appears to be positively correlated with all countries considered, except China, whose monetary policy was less affected by the Great Recession. In contrast to the first principal component, the second appears to be more closely associated with financial and macroeconomic variables, and begins to recover rapidly after the Great Recession.

4 Empirical Section

In this section, we provide an empirical analysis of central bank communication spillovers, focusing specifically on network structure and impulse response functions. Additionally, we examine what social and economic factors have predictive power for international sentiment comovements. Our analysis proceeds in three steps. First, we characterize the macroeconomic and sentiment linkages between countries and central banks in a descriptive exercise. In particular, we compare directed networks in the style of Billio et al. (2012) for sentiment with directed networks for trade and financial flows. Next, we use sign-restricted vector autoregressions (VARs) to explore the impact of sentiment shocks on domestic policy and macroeconomic variables, as well as spillovers to foreign countries and central banks. Finally, we perform a set of cross-sectional regressions to determine whether a shared language, colonial ties, geographic distance, or group membership explains comovement in sentiment across central banks.

4.1 Directed Networks: Trade and Financial Flows

We construct two types of directed networks in this paper. The first type, which we cover in this subsection, captures the direction of the trade and financial flows. The second type, which is based on the concept of Granger causality, is covered in the following subsection. Since bilateral trade and financial flows involve both countries and are, thus, directionally ambiguous, we instead use a measure that captures the importance of such flows for the first type of networks: whether a country is a top five partner for trade or finance with another country.

The trade network is constructed using data on bilateral import and export flows from the World Integrated Trade Solution (WITS) database and is depicted in Figure XII in the Appendix. Edges in the network connect pairs of nodes where at least one country (node) is a top five import or export partner of the other. For the direction of the relationship, we use the concept described in the previous paragraph. If, for instance, China is one of the five countries from which Australia receives the most imports or one of the five countries to which

Australia sends the most exports, then an edge will connect Australia to China in the network. Furthermore, an arrow will point from China to Australia, since this relationship is important for Australia, but not necessarily China. If Australia is also one of the top five destinations for China's exports or is one of top five sources of imports in China, then an additional edge will connect the two, but with an arrow pointing at China.

The financial flows network is constructed using information on bilateral financial claims from the BIS's Locational Banking Statistics (LBS) database and depicted in Figure XIII in the Appendix. Similar to the trade network, the financial flows network has an edge between each pair of countries for which at least one country is a top five provider or receiver of cross-border funding flows. We also use a concept of direction that is similar to what we used in the trade networks: if Canada is a top five source or destination of funds for Mexico, then the arrow will point from Canada to Mexico. Furthermore, if Mexico is a top five source or destination of funds for Canada, then a separate edge will connect the two with an arrow that points from Mexico to Canada.

The purpose of constructing directed trade and financial flow networks is to provide a comparison for sentiment networks. In the following section, we will introduce sentiment networks, which will use a different concept of directionality, since sentiment is defined separately for each central bank. We will also compare the trade and financial flows networks with the sentiment networks. This will allow us to demonstrate that the sentiment network is not explained by trade or financial flow exposure.

4.2 Directed Networks: Sentiment

In the previous section, we constructed quarterly measures of net sentiment for 23 central banks. We will now use these time series to construct directed networks for these countries. Importantly, we treated the ECB and ESCB member central banks separately in our analysis.[17] Specifically, we follow Billio et al. (2012), who constructed linear Granger causality networks with inter-relationships that take the following form:

$$R^i_{t+1} = a^i R^i_t + b^{ij} R^j_t + e^i_{t+1} \tag{3}$$

$$R^j_{t+1} = a^j R^j_t + b^{ji} R^i_t + e^j_{t+1}. \tag{4}$$

Here, entities are indexed by i and j. Furthermore, it is assumed that entity j Granger-causes

[17] We acknowledge that ESCB banks coordinate and have strong ties. Moreover, there could be a strategic component of the national banks' communication (Tillmann and Walter, 2019); however, we leave this question to future research.

entity i when b^{ij} is significantly different from zero; and entity i Granger-causes entity j when b^{ji} is significantly different from zero. We then modify the process to deal with potential non-stationarity in the series using the following approach, which is outlined in Toda and Yamamoto (1995) and consists of four steps:

1. Compute m=max$\{m_i, m_j\}$, where m_j is the order of integration of R_t^j.
2. Recover the maximum lag length, p, for model variables using the Akaike Information Criterion (AIC).
3. Take the specification determined in step 2 and add m lags to each variable.
4. Apply a Wald test for Granger non-causality on the first p coefficients for the foreign entity in each equation.

The adjusted model equations are as follows:

$$R_{t+1}^i = a_0^i + \sum_{s=0}^{p+m} a_s^i R_{t-1-s}^i + \sum_{s=0}^{p+m} b^{ij} R_{t-1-s}^j + e_{t+1}^i \tag{5}$$

$$R_{t+1}^j = a_0^j + \sum_{s=0}^{p+m} a_s^j R_{t-1-s}^j + \sum_{s=0}^{p+m} b^{ji} R_{t-1-s}^i + e_{t+1}^j. \tag{6}$$

If the test rejects the null of Granger non-causality in step 4, we claim that there is evidence for Granger causality. We perform the same test for each country pair. In each case, we run separate pairwise VARs and perform Granger causality tests for net central bank speech sentiment. It is necessary to point out that the Granger causality is based on the statistical test, and it does not imply identified causality.

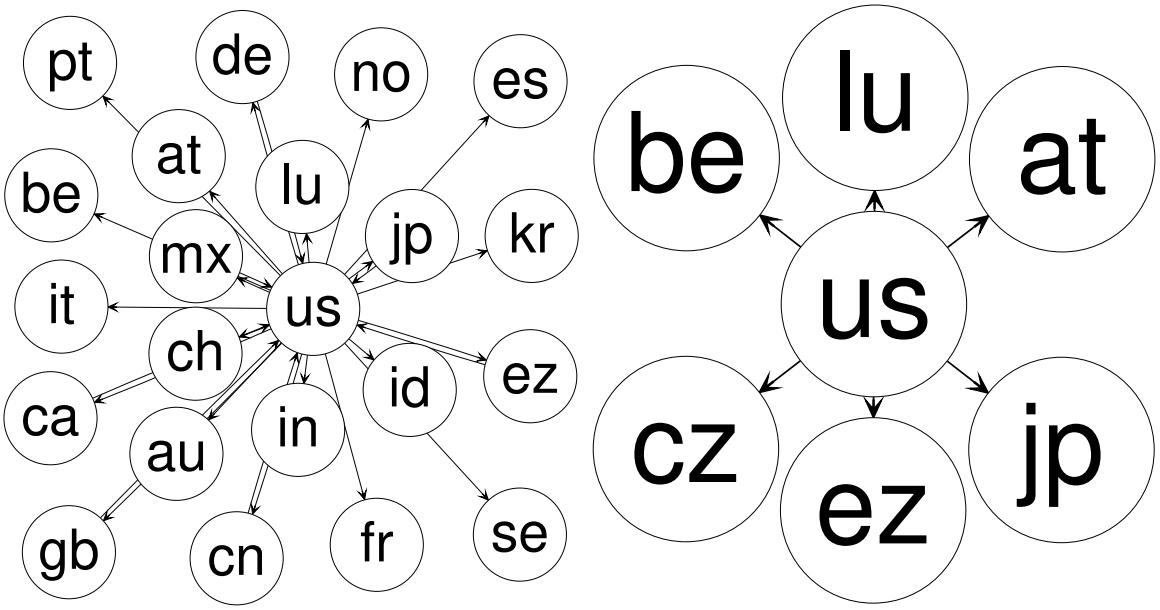
We next construct a network diagram for net central bank sentiment. Each country pair with at least one Granger causality link in either direction is connected by an edge. If the Granger causal connection runs from country j to country i, then the arrow on the edge connecting j and i will point to i.

Figure XIV in the Appendix shows the sentiment network across central banks. This network should not be interpreted as reflecting actual casual effects between pairs of central banks. Rather, it is a descriptive exercise that facilitates the identification of a possible spillover direction based on the time lead-lag relationship and provides a direction for each edge in the graph. Importantly, there are stark differences between the network structure for trade and financial flows, and central bank speech sentiment. The most obvious difference is the direction of relationships. We can also see that some of the largest network nodes have many incoming

and outgoing connections. In the rest of this section, we will examine the trade and sentiment subnetworks for the largest nodes, including their incoming and outgoing connections. We will skip a detailed analysis of the financial flows network due to its similarity to the trade network.

We will start with the subnetworks for the United States, which are depicted in Figure VI. The network on the left shows the linkages in trade between all countries and the United States. As we might expect, the U.S. is a top source of imports and destination of exports for many countries. It also has inbound links from large economies, such as the Eurozone, China, the United Kingdom, Japan, Germany, and Canada. With respect to sentiment transmission, the U.S. has a smaller network, but affects large central banks, such as the ECB and BoJ. Furthermore, it does not have inbound links, which suggests it is a generator, rather than receiver, of central bank sentiment. Overall, this largely conforms to what we might expect for a large economy.

Figure VI: Trade and Sentiment Networks: United States

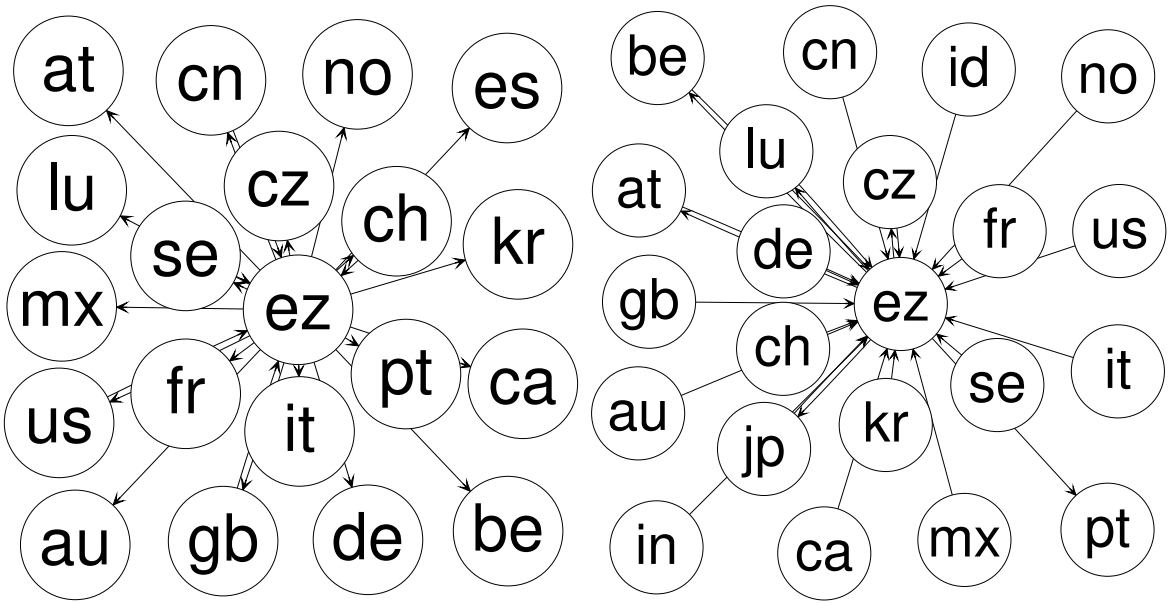


Notes: The subnetwork on the left depicts trade flows for the United States. The subnetwork on the right shows central bank sentiment for the United States.

We next consider the Eurozone subnetwork, which is shown in Figure VII. Note that we treat speeches given by national central banks in the Eurozone separately from the ECB. Here, we find a stark difference between the trade and sentiment networks. While most Eurozone trade links are outbound, virtually all sentiment links are inbound. This could be related to the ECB's institutional mandate as the representative of all Eurozone countries.

Overall, there are substantial differences between the United States and the Eurozone in

Figure VII: Trade and Sentiment Networks: Eurozone



Notes: The subnetwork on the left depicts trade flows for the Eurozone. The subnetwork on the right shows central bank sentiment for the Eurozone.

the subnetwork graphs. While both are important trading and financial partners for many countries, the Fed is primarily a generator of central bank sentiment while the ECB takes in sentiment from other central banks. As Figure XIV in the appendix shows, certain other large central banks, such as the Bank of Japan, also tend to primarily take in sentiment, rather than influencing the sentiment of other central banks.

As stated earlier, the network construction exercise should be interpreted as a descriptive exercise. The purpose of using Granger causality networks is to generate directions for the edges. For this reason, we revisit the idea of spillovers in a sign-restricted VAR exercise with an extended vector of variables to tease out international spillover effects.

4.3 Sign-Restricted VARs

With the basic network structure of sentiment transmission across central banks in place, we next quantify the impact shocks to central bank communication have on domestic and foreign macro and policy variables. We do this by performing quarterly sign-restricted VARs with the rejection method described in Rubio-Ramirez et al. (2010). This approach allows for partial identification of impulse responses functions (IRFs) for a single structural shock. In each case, we examine the impact of a shock to net domestic speech sentiment on domestic or foreign variables. Note that we do not make claims about the impacts of shocks to other variables

on sentiment, since we do not identify such shocks. Additionally, we focus specifically on the five central banks with the highest number of speeches, among those with complete data and independent monetary policy: the Fed, the ECB, the BoE, the BoJ, and the Riksbank.

We perform two sets of quarterly VARs. The first captures the domestic impact of sentiment shocks with an expanded set of macroeconomic variables. For each central bank, we perform a sign-restricted VAR with quarterly measures of central bank speech sentiment, the policy rate, unemployment, stock returns, the real exchange rate, and imports.[18] The second set of quarterly VARs also has six variables: domestic and foreign central bank sentiment, domestic and foreign central bank policy rates, and domestic and foreign unemployment.[19] We make the following sign restrictions on all VARs in this subsection: a positive structural shock to domestic central bank sentiment has a 1) non-negative effect in the first period on domestic central bank sentiment, the domestic policy rate, domestic stock returns, the exchange rate, and imports; and 2) a non-positive effect in the first period on unemployment.

Our choice of sign restrictions is based on the conceptual framework discussed in Section 3.3 and aligns closely with the concept of a central bank information shock, as measured in Gertler and Karadi (2015) and Nakamura and Steinsson (2018). Jarociński and Karadi (2018) and Gürkaynak et al. (2005) point out that such shocks contain two types of information: signals about monetary policy and information about the central bank's assessment of the economy. In our case, a positive structural shock to domestic central bank sentiment has a direct and non-negative effect on the domestic policy rate if the change in sentiment signals future policy. If the shock instead stems from a positive assessment of the underlying state of the economy, then a non-negative effect on the domestic policy rate follows from the Taylor rule in equation (2). In both cases, we arrive at the postulated sign restriction.

We next consider the sign restriction on unemployment. If a positive structural shock to central bank sentiment contains information about the future state of the economy, then we would expect it to have a non-positive effect on unemployment on impact.[20] To the contrary, if an increase in sentiment signals an increase in the future policy rate, we would instead expect the change in unemployment to be non-negative on impact. We will focus on positive information shocks that contain information about the central bank's assessment of the economy. For this

[18] We have also tried alternative specifications that included real GDP growth and inflation. We generally find that the impact of a sentiment shock on real GDP growth is weaker than the impact on unemployment. Additionally, the impact on inflation is minimal for the period we consider, other than for developing countries with high and volatile inflation rates.

[19] Note that for the second set of VARs, we drop stock returns, the real exchange rate, and imports.

[20] Moreover, central bank communication can serve as a coordination device or focal point for the beliefs of market participants about the macroeconomic fundamentals or the interpretation thereof (Amato et al., 2002). It is not, however, possible to talk up the economy indefinitely irrespective of the data. In addition, factors such as the central bank's credibility play an important role in its ability to favorably affect the beliefs of economic actors.

reason, we will apply a non-positive sign restriction on unemployment. Moreover, we expect the initial positive assessment to have similar effects on impact on stock returns, the real exchange rate, and imports, justifying the imposed sign restrictions.

Note that we do not make any assumptions about the effect on foreign country or foreign central bank variables. Rather, we exclusively make assumptions about the effect on impact for domestic variables that are in line with the existing literature on central bank communication and are justified through theory. Additionally, our results are qualitatively robust to adjustments on the sign restriction for domestic unemployment. In particular, we find similar results if we instead assume that the impact comes with a single-quarter delay. Finally, consistent with the literature, all IRFs shown use 68% confidence intervals.

We will start by examining the results for the domestic VARs. The first half of Table II provides a summary of the impulse responses from five single-country VARs that include sentiment, the policy rate, unemployment, stock returns, the exchange rate, and imports. All entries that contain an '–' correspond to IRFs with no statistically significant result. Other entries correspond to IRFs with significance in at least one period. For instance, +1 indicates that the maximum effect was positive and occurred on the first quarter. Note that the impact of a positive sentiment shock on sentiment is largest and positive in the first period for all single-country VARs. Similarly, the maximum impacts on channels that are critical for international transmission–such as stock returns, the real exchange rate, and imports–typically arrive within the first quarter.[21] The impact on the policy rate arrives later, generating a positive and significant effect after 2-4 additional quarters. Similarly, the impact on unemployment is negative and appears 1-3 quarters after impact of a positive sentiment shock. Finally, in the bottom half of Table II, we consider a robustness exercise in which we swap the policy rate with the 2-year bond yield. With the exception of a few idiosyncratic differences, we find similar results.

Next, we consider whether central bank communication generates international spillovers. The results of 20 quarterly VARs with both domestic and foreign variables are summarized in Table III. All results shown are for spillovers from the "domestic" to "foreign" country (or monetary union). The first entity listed receives the shock to domestic central bank speech sentiment. Again, all results with a sign (+/-) and a period of maximum impact were statistically significant in at least that period.

Our results indicate that Fed communication has the most expansive impact of all central banks considered, generating spillovers to sentiment, the policy rate, and unemployment in the

[21] We have also tested a specification without the sign restriction placed on the exchange rate, since the direction of the effect will arguably differ across countries. We still find that the maximum impact tends to materialize in the first period, but the sign differs across countries.

Table II: VAR Summary: Domestic Impact

	Sentiment	Policy Rate	2-Year Rate	Unemployment	Stock Returns	Exchange Rate	Imports
Eurozone	+1	+5	N/A	-4	+1	+1	+1
U.S.	+1	+4	N/A	-4	+1	+1	+1
Japan	+1	+3	N/A	-2	+1	+1	+1
U.K.	+1	+4	N/A	-4	+1	+1	+1
Sweden	+1	+3	N/A	-4	+1	+1	+1
Eurozone	+1	N/A	+3	-4	+1	+1	+2
U.S.	+1	N/A	+3	-4	+1	+1	+2
Japan	+1	N/A	+4	-3	+1	+1	+1
U.K.	+1	N/A	+3	-3	+1	+3	+1
Sweden	+1	N/A	+3	-4	+1	+1	+1

Notes: This table provides a summary of the single-country VAR IRFs for the Eurozone, U.S., Japan, U.K., and Sweden. Each VAR in the top half of the table contains sentiment, the policy rate, unemployment, stock returns, the real broad effective exchange rate, and imports of goods and services. In the bottom half of the table, we swap the policy rate for the 2-year bond yield. In each case, we examine the response to a domestic sentiment shock. We indicate the sign of the maximum impact and the quarter in which it arrived. For example, +1 indicates that the maximum effect was positive and occurred on impact. Finally, '–' indicates that there was no statistically significant effect.

Eurozone and the U.K., and spillovers to sentiment and the policy rate in Sweden. Furthermore, consistent with the weaker network structure results, none of the central banks considered appear to affect U.S. sentiment, the policy rate, or unemployment.

The ECB, which communicates more frequently than any other central bank, affects sentiment, the policy rate, and unemployment in Sweden, but does not affect any of the other central banks. The BoJ does not appear to have an impact on communication directly, but does influence policy rates at other central banks. Finally, the BoE appears to have a substantial impact on the ECB and Eurozone and a weaker impact on Sweden. The Riksbank appears to have a weak effect on the ECB policy rate with a delay and sentiment at the BoE.

We next examine relationships between the most frequent communicators within a selected group of central banks: the Fed, the BoE, and the ECB. We will start with the ECB and BoE. Note that all IRFs are shown in the Appendix. Figure XV shows the impact of a positive structural shock to BoE sentiment on domestic and foreign (ECB and Eurozone) policy and macroeconomic variables. Here, we find that the impact on domestic sentiment lasts 4 quarters, but has a longer impact on the BoE's policy rate and domestic unemployment. We also see symmetric effects on ECB sentiment, the ECB's policy rate, and Eurozone unemployment. These effects, however, arrive with a substantial delay for the ECB policy rate and Eurozone unemployment.

Table III: VAR Summary: Cross-Country Spillovers

	Sentiment	Policy Rate	Unemployment
Eurozone			
Eurozone → U.S.	–	–	–
Eurozone → U.K.	–	–	–
Eurozone → Japan	–	–	–
Eurozone → Sweden	+1	+5	-4
U.S.			
U.S.→ Eurozone	+1	+5	-5
U.S. → Japan	–	–	–
U.S. → U.K.	+2	+3	-6
U.S. → Sweden	+2	+5	–
Japan			
Japan → Eurozone	–	+5	–
Japan → U.S.	–	–	–
Japan → U.K.	–	+2	–
Japan → Sweden	–	+2	–
U.K.			
U.K. → Eurozone	+2	+7	-6
U.K. → U.S.	–	–	–
U.K. → Japan	–	–	–
U.K. → Sweden	–	+2	–
Sweden			
Sweden → Eurozone	–	+5	–
Sweden → U.S.	–	–	–
Sweden → Japan	–	–	–
Sweden → U.K.	+2	–	–

Notes: This table provides a summary of spillover effects from two-country VAR IRFs for the Eurozone, U.S., Japan, U.K., and Sweden. Each VAR contains foreign and domestic sentiment, policy rates, and unemployment. In each case, we examine the response to a domestic sentiment shock, where the "domestic" country is listed first. We indicate the sign of the maximum impact and the quarter in which it arrived. For example, +1 indicates that the maximum effect was positive and occurred on impact. Finally, note that '–' alone indicates that there were no significant results.

Importantly, as shown in Figure XVI, the impact of a structural shock to ECB sentiment on ECB, Eurozone, BoE, and U.K. variables is not symmetric. The shock to ECB sentiment has only a small, one-quarter impact on domestic macroeconomic variables and policy variables. Additionally, there are no spillovers from ECB sentiment shocks to the U.K. or to BoE sentiment or policy.

Next, we consider the impact of Fed sentiment on the U.S. and on the Eurozone in Figure XVII, and the impact of ECB sentiment on the Eurozone and the U.S. in Figure XVIII. Here,

we find that a positive shock to Fed sentiment has stronger and more persistent effects on future Fed sentiment, the target policy rate, and unemployment. We also find larger and more persistent effects on ECB sentiment and policy, as well as Eurozone unemployment.

Again, we do not find spillovers from a positive shock to ECB sentiment to the Fed or to U.S. unemployment. Along with the network analysis, this suggests that the ECB primarily takes in sentiment from large foreign central banks, rather than influencing it. While this may appear counterintuitive, it is likely consistent with its mandate as an institution that represents many countries within the Eurozone. Moreover, a status quo bias due to the European Central Bank's institutional setup with a heterogeneous decision committee may Riboni (2008) contribute to our finding.

We also examine spillovers between the Fed and the BoE in Figures XIX and XX. Figure XIX suggests that there are weak spillovers from Fed sentiment to BoE policy rates and U.K. unemployment. And Figure XX suggests that these spillovers do not flow in the opposite direction from the BoE to the Fed.

Finally, we perform two robustness tests. In the first test, we replace the policy rate with 10-year government bond yields. In the second test, we truncate the sample to exclusively examine the effective lower bound (ELB) period. We perform this exercise for just the Fed and ECB. In both cases, we find that the results are qualitatively similar to the baseline results–namely, the Fed generates sentiment spillovers to the Eurozone and ECB, but not vice versa. The only substantive difference is that the spillover from Fed sentiment to Eurozone unemployment is not statistically significant when we restrict ourselves to the ELB period and use the same sign restrictions; however, if we allow for the non-positive impact on unemployment to occur in either the first or second period, then we achieve statistical significance. Note that we have omitted the impulse response function plots, since they are similar to the original results. All robustness results are available upon request.

Overall, we find evidence for international spillovers from sentiment to sentiment, sentiment to policy rates, and sentiment to unemployment. These effects are typically only in one direction; and the Fed appears to generate particularly large and durable spillover effects. The prominence of the Fed in affecting central bank sentiment is rather intuitive, and there are a few channels that may explain this result. One possible explanation is that the U.S. economy has been a strong growth driver for the world economy. This could explain why other central banks are highly influenced by the Fed's speech sentiment. Alternatively, it could reflect the role of the U.S. dollar as reserve currency and the Fed's key role in setting the risk free interest rate in the integrated global financial market. Investors across the world pay close attention to Fed communication, and other central banks react accordingly. Another explanation is that this

finding could be the result of the Fed being in a unique position to interpret global business cycle shocks or to affect global sentiment (see, e.g., Brusa et al. (2019)). In our sample, the Federal Reserve System delivers a large number of speeches, which could potentially update market participants on the Fed view of the economy. It is, however, challenging to test these channels separately.

4.4 Cross-Sectional Regressions

We have now demonstrated that a shock to central bank sentiment affects domestic macroeconomic variables, and may spill over to foreign central bank sentiment, policy rates, and macroeconomic variables. We also showed that sentiment cannot be reduced to exposure to trade and financial flows. In fact, in some extreme cases, countries that have a broad reach with respect to trade and financial flows are receivers, rather than generators, of central bank sentiment. We next consider what explains strong comovement in sentiment between pairs of central banks. In particular, we estimate equation (7):

$$\rho_{i,j} = \beta_0 + \beta_1 D_{i,j} + \beta_2 L_{i,j} + \beta_3 C_{i,j} + \beta_4 X_{i,j} + \gamma_{i,j} + \zeta_{i,j} + e_{i,j}. \tag{7}$$

Note that i and j in the equation above index countries i and j. The dependent variable, $\rho_{i,j}$, is the cross-country correlation in central bank sentiment. Our variables of interest are $D_{i,j}$, $L_{i,j}$, and $C_{i,j}$, where $D_{i,j}$ is the distance in thousands of kilometers between a pair of central banks;[22] $L_{i,j}$ is an binary variable that is equal to 1 if the pair of countries share a common language; and $C_{i,j}$ indicates whether one country was a colony of or gained independence from the other. The vector, $X_{i,j}$, is a set of control variables. And finally, $\gamma_{i,j}$ are country fixed effects and $\zeta_{i,j}$ is a binary variable that indicates whether a pair of central banks is located on the same continent.[23]

Our results are given in Table V in the Appendix. Column 1 shows the results for distance, $D_{i,j}$, with no controls included. Column 2 adds shared language, $L_{i,j}$, and colonial ties, $C_{i,j}$. Columns 3-5 add controls, $X_{i,j}$, sequentially: 1) the pairwise correlation in real GDP growth; 2) the pairwise correlation in inflation; 3) a measure of the importance of the bilateral trade relationship;[24] and 4) a measure of the importance of the financial flow relationship.[25] Column

[22] We compute this as the great circle distance between a pair of countries' capital cities.

[23] Note that country fixed effects will pick up all unchanging attributes of a country over our sample period, such as its location within the euro area and its exchange rate regime. They will not, however, pick up unchanging attributes of country pairs.

[24] For a pair of countries, A and B, we compute the bilateral trade share of total trade for A with B and for B with A. We then compute the maximum of the two values. This indicates how important the relationship is for the member of the pair for which the relationship is most important.

[25] For a pair of countries, A and B, we compute the bilateral private financial claims as a share of all claims for A with B and for B with A. We then compute the maximum of the two values. This indicates how important

6 includes a control for the natural logarithm of the number of speeches given by the pair. Column 7 adds country fixed effects, $\gamma_{i,j}$, which indicate whether either country i or j is country k. Column 8 includes a dummy, $\zeta_{i,j}$, for whether the two central banks are located on the same continent. Columns 9 and 10 drop China and the U.S., respectively. All columns use heteroskedasticity-robust standard errors and are robust to using errors clustered by shared continent.

Not surprisingly, comovement in real GDP and comovement in inflation are positively associated with the correlation of central bank sentiment. Among the economic controls, they have the most predictive power for sentiment comovement; however, they become insignificant after including country fixed effects. The only exception is cross-country comovement in inflation, which has a significant, positive association after excluding China. Moreover, columns 1-6 indicate that all three variables of interest–distance, shared language, and colonial ties–have at least a weak impact on the correlation in sentiment across central banks. The coefficient on shared language implies that two central banks with a common language have, on average, a 0.0735 higher correlation in sentiment. This is a 24% increase for the median pair of central banks. Similarly, if one central bank in a pair is located in a country that was a colony of the other or gained independence from the other, this is associated with a 0.1295 increase in sentiment correlation. This amounts to a 40% increase in correlation for the median pair of central banks. Importantly, however, shared language is not robust to the inclusion of inflation and other economic controls. To the contrary, colonial ties are robust to the inclusion of all economic and non-economic controls, but not country fixed effects.

We next consider the impact of distance, which is our most robust finding. It remains significant at the 1% level in all specifications, even when economic control variables, country fixed effects, and shared continent dummies are included.[26] It also remains significant if the U.S. or China is dropped, and does not appear to be sensitive to method used to construct standard errors. Moreover, it remains significant even in specifications where the correlation in real GDP growth does not. Our preferred specification in column 6 suggests that a 1,000 kilometer (km) increase in distance between a pair of central banks is associated with a 0.0175 reduction in central bank sentiment correlation. Thus, an 8,000km increase in distance (e.g. from London to Beijing) is associated with a 0.13 decrease in central bank sentiment correlation. This is a 42% reduction for the median central bank pair.

Finally, in Table VI, we perform a set of robustness tests. First, we expand the sample from

the relationship is for the member of the pair for which the relationship is most important.

[26] We have also tested the significance of distance in a rolling regression, where each correlation in the regression is computed over 3-year, overlapping windows. We find that the impact of distance remains negative, significant, and quantitatively similar over the entire sample period.

23 to 55 central banks, including many emerging market economies for which we lacked high quality data.[27] We find that the impact of distance on sentiment comovement declines, but remains significant at the 1% level. If we add controls for BIS Global Economy Meeting (GEM) attendance (columns 2 and 4) and Financial Stability Board (FSB) membership (column 3), distance remains significant at the 1% level and its magnitude remains largely unchanged.[28] We find that being either a member or observer of the BIS GEMs is associated with a 0.059 increase in sentiment correlation, which complements the work in Imisiker and Tas (2019). We find no increase for FSB membership; however, this may be because the content of FSB discussions is less likely to appear in central bank speeches. A plausible explanation for this finding is that the BIS GEM is rich in economic discussion focusing on macroeconomic and financial developments, while FSB discussions have a more technical nature and are primarily about the coordination of financial regulation, supervision and financial policy.

Our findings are robust and have potentially important implications for policy. Namely, they suggest that distance is an important factor in the alignment of central bank communication. Even when country, language, colonial ties, continent, and real GDP and inflation comovement are controlled for, distance stands alone as a uniquely statistically and economically significant predictor of comovement in central bank sentiment. Our findings also indicate that group membership is associated with an increase in sentiment comovement, which suggests a potential mechanism for distance: it could pick up increased frequency of communication and participation in regional groups. If central bank communication is influenced more by distance than by exposure to common shocks, then it might be possible to reap policy gains by adjusting communication to correct for this bias.

4.5 Discussion

Speech sentiment appears to contain central bank interpretations of macroeconomic and financial data and is predictive of central bank policy, as we have shown in the previous sections. One possible explanation for this is that central bankers have access to private information that could potentially influence the way they interpret incoming news about macroeconomic variables. Their access to information relating to undisclosed financial stress-testing data is one clear example (Correa et al., 2017); however, they also have privileged conversations with

[27] In the cases where only annual data was available, we imputed quarterly values using a cubic spline. For time series that were not complete over the 2002-2017 period, we computed the correlations over the period for which the data was available. Finally, for central banks that gave less than one speech per quarter, we used the latest available speech to compute the sentiment score.

[28] The BIS variable is equal to 1 if a country was either a member or observer since 2003. The FSB dummy variable is equal to 1 if a country has participate in FSB meetings since at least 2009. Prior to April 2009 the meetings were held by the FSF.

political and private market representatives that might yield non-public information that is unavailable to other forecasters. Another factor that gives importance to central bank communication is the role of speeches and announcements in coordinating market participants' beliefs about macroeconomic fundamentals, as well as their interpretations of relevant macroeconomic information (Amato et al., 2002; Morris and Shin, 2002; Svensson, 2006). In other words, the reach of central bank communication and the role of central banks as key players in the economy gives them the ability to establish reference points for the beliefs of market participants and for other central banks. A stark example of this is when central banks strive to underpin market confidence, as was the case, for instance, with ECB president Mario Draghi's "whatever it takes" speech. More generally, central banks may influence the overall sentiment in the economy and, thereby, business cycle fluctuations (Angeletos and La'O, 2013).

Our results suggest that central bank communication contains systematic spillover patterns that are not explained by economic or financial ties. While we can only point to potential drivers and explanations, the spillover patterns we identify may be informative for policymakers when deciding how to allocate their attention. Overweighting Fed sentiment relative to bilateral economic and financial linkages may be optimal because the U.S. dollar plays a dominant role in financial markets and world trade (Bruno and Song, 2015; Miranda-Agrippino and Rey, 2019). The Feds access to privileged information may also align it more closely with the global business cycle. However, overweighting sentiment due to geographical location, shared language, or colonial ties may instead be the result of a suboptimal bias in attention.

There are several potential explanations for why a central bank might choose to overweight the communication of other central banks in a way that appears to be suboptimal. First, geographic, linguistic, and cultural closeness may simply make it easier to focus attention on closer peers. They may also increase the likelihood that central bankers attend the same conferences and develop similar views, sometimes based on shared experiences.[29] Moreover, culture may color the way in which policy makers assess the economic outlook and risks. The potential role played by personal interactions at conferences or meetings is also highlighted by the positive association in the comovement of central bank speech sentiment among BIS GEM attendees.

Another clear implication of our results is that the Fed plays a uniquely influential role in generating sentiment spillovers, even relative to other prominent central banks. As mentioned previously, this is consistent with the existing literature on monetary policy spillovers, such as recent studies of the U.S. dollar dominance in global financial markets and in trade (Bruno and Song, 2015; Miranda-Agrippino and Rey, 2019). Brusa et al. (2019) also find that FOMC announcements have a unique impact on global equity markets. In contrast, announcements

[29]See Malmendier et al. (2017) for the role of inflation experiences.

by other central banks, including the ECB, exhibit only local effects on market uncertainty. Beyond the dominant role of the Federal Reserve, the ECB does, however, play a significant role with regard to interest rate spillovers (Kearns et al., 2018), which contrasts with mild interest rate spillovers from the Bank of England and Bank of Japan. Our findings suggest that ECB speeches do not play such a significant role when it comes to the comovement of central bank speech sentiment. A potential explanation could lie in the difference in communication strategies adopted by central banks (Ehrmann and Fratzscher, 2007a). Such considerations appear to be particularly important when it comes to the ECB's institutional setting and its role in taking in sentiment from national central banks; however, we leave a more thorough exploration of this question to future research.

5 Conclusion

We assemble a novel dataset using English-translated central bank speeches from the BIS's archive. We then conduct a sentiment analysis of the speeches given by 23 of the central banks over the 2002-2017 period by applying the dictionary introduced in Loughran and McDonald (2011). Using the net positivity measure, we establish several results. First, we show that the central bank speech sentiment network is not reducible to exposure to trade, financial flows, or business cycle comovement. Second, we use sign-restricted VARs to demonstrate that there are substantial international spillovers in sentiment, policy rates, and macroeconomic variables between important nodes in the central bank communication network. And third, we find in a cross-sectional regression that having either a shared language or colonial ties tends to generate positive comovement in central bank speech sentiment. Furthermore, we find that geographic distance between central banks is a uniquely statistically and economically significant predictor of comovement in central bank sentiment, even in the presence of controls and fixed effects.

Our results suggest that there are regular patterns in central bank communication that are not explained by economic and financial linkages, which complements existing work on biases in central bank communication and decision making. While there may be circumstances under which it is optimal to overweight the communication of a particular central bank relative to its bilateral economic and financial linkages, we think that central bankers could benefit from knowledge of the existence of such patterns in communication. Being aware of this allows a central bank to consider whether its communication is unjustifiably influenced by the frequencies with which it communicates with different central banks. Furthermore, if a central bank deems the overweighting of another central bank's communication undesirable from the perspective of their mandate, they could make an effort to correct for it by increasing engagement with central banks who face common shocks, rather than those who are nearby geographically or who are

easy to communicate with as a consequence of linguistic and cultural ties.

Beyond our findings, this paper also contributes to the literature by introducing a novel and comprehensive dataset of sentiment scores for international central bank communication. While our work describes international spillovers from communication, future research might make use of our data to study international policy cooperation. Furthermore, we do not separate the different dimensions of the central bank communication, either with respect to monetary policy or financial stability. This leaves room for future research to tease out the impacts of different components of central bank speeches with alternative dictionaries for monetary policy or financial stability. Finally, while we focus on the low frequency dimension of central bank speeches, a different research project might instead consider a narrow-window approach to analyze the market response to prominent central bankers' speeches.

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6 Appendix

6.1 Description of the Textual Data

Since our dataset consists of unstructured text contained in central bank speeches, as well as FOMC and ECB announcements, we first applied standard cleaning routines to prepare the text for use in regressions. We used the following procedure to format each text:

1. Convert the document from pdf to txt format.

2. Clean the document to remove all punctuation, special characters, and numbers.

3. Remove stopwords, such as articles and prepositions.

We then tokenized each document into a list of words. Finally, we applied dictionary-based methods to identify all instances of positive and negative words. We used the positive and negative counts to construct a measure of net positivity, which we use in our regression exercises.

6.2 Additional Figures and Tables

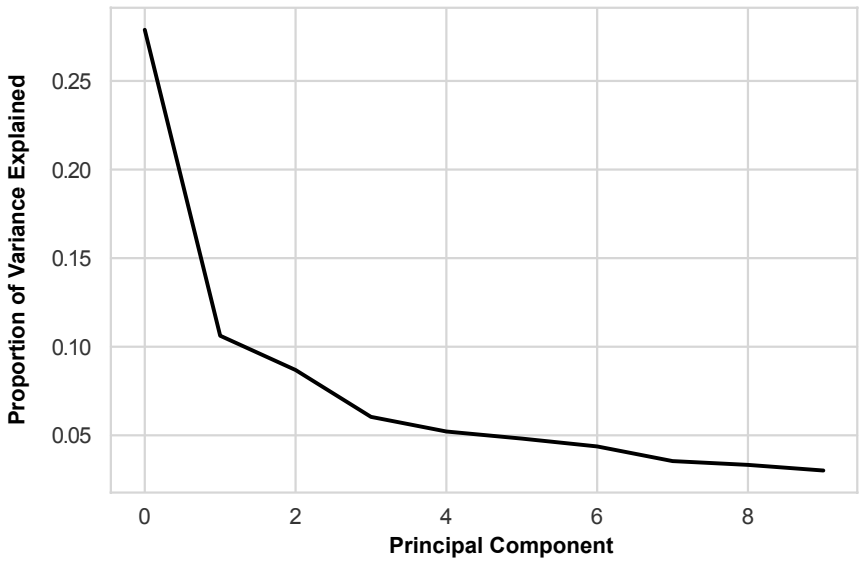
Figure VIII: Word Clouds: Fed Speeches and Announcements

Notes: This figure shows word clouds for Fed announcements (left) and speeches (right). A larger font indicates that a term is used with a higher frequency in its respective text corpus.

Figure IX: Word Clouds: ECB Speeches and Announcements

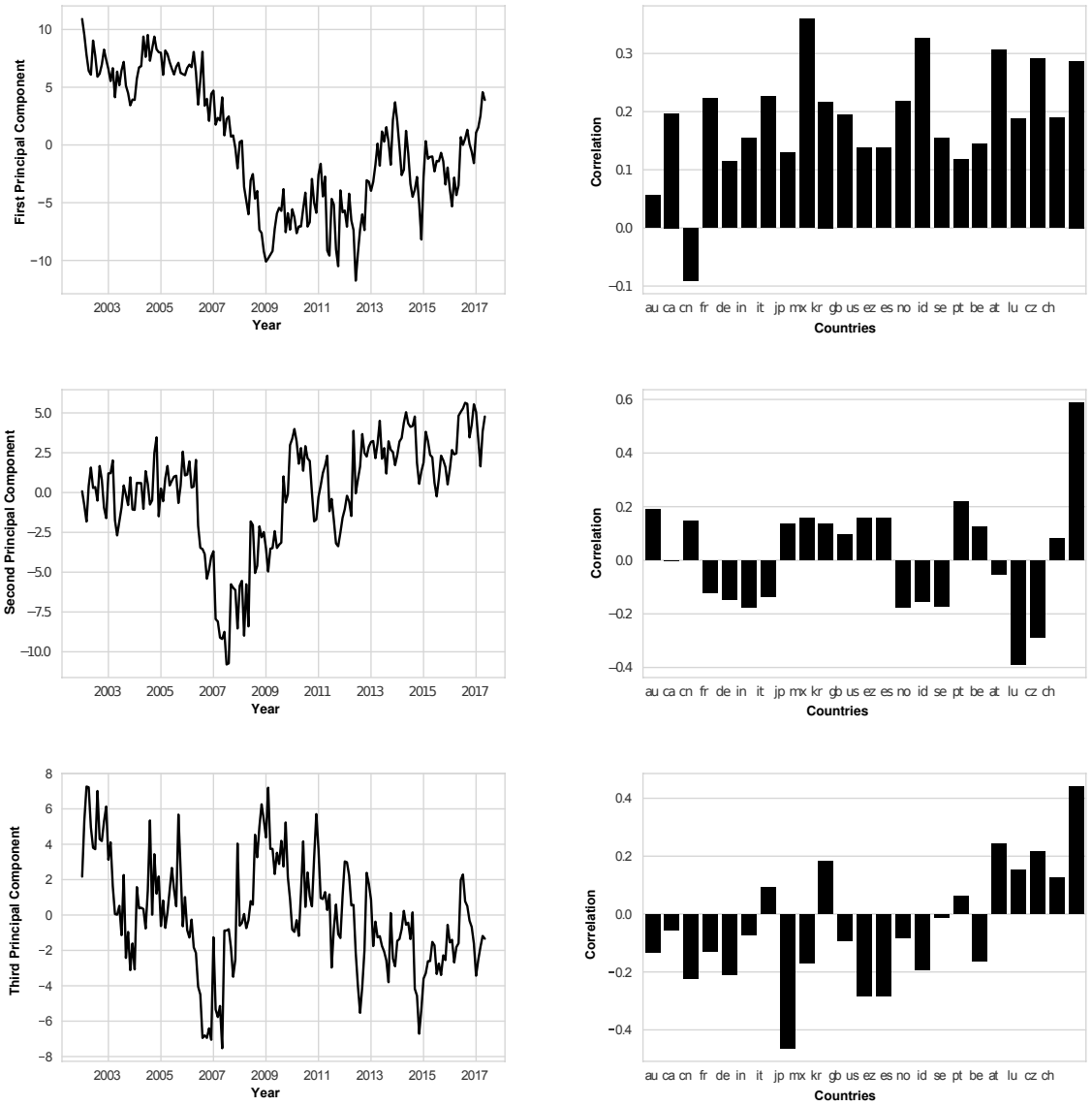
Notes: This figure shows word clouds for ECB announcements (left) and speeches (right). A larger font indicates that a term is used with a higher frequency in its respective text corpus.

Figure X: Explained Variance Ratio for Principal Components



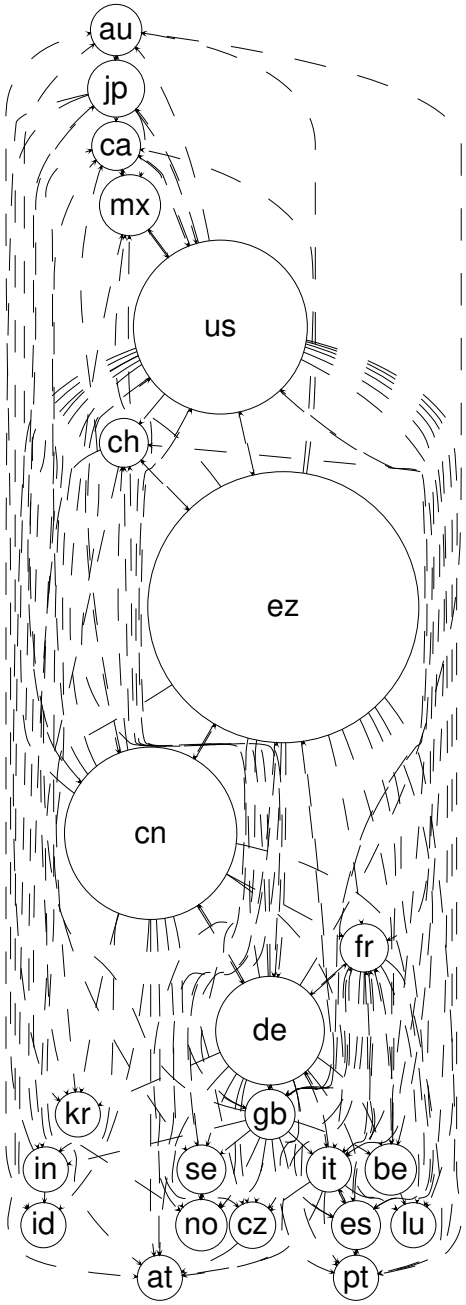
Notes: The plot above shows the share of variance explained for each of the first 10 principal components. Note that the first principal component, which is indexed by 0, explains over 25% of the variation in the data. We performed principal components on the net sentiment series for 23 countries over the 2002-2017 period.

Figure XI: First, Second, and Third Principal Component and Correlations



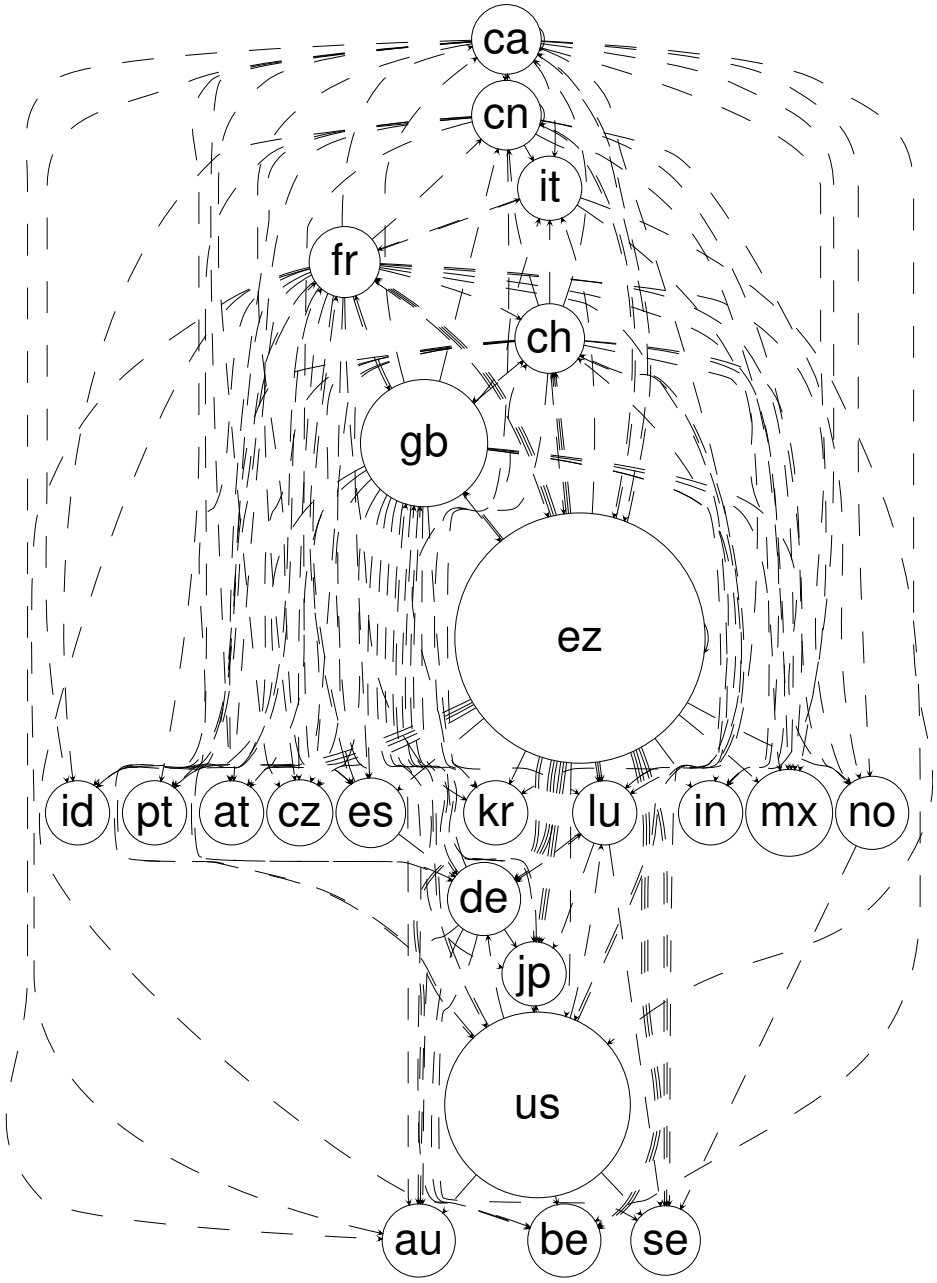
Notes: The top panel shows the time series of the first principal component (left) and correlations between the first principal component and country series (right). In the mid and bottom panels we do the same for the second and third principle component, respectively. All analysis is done for 23 countries over the 2002-2017 sample period.

Figure XII: Directed Network: Trade



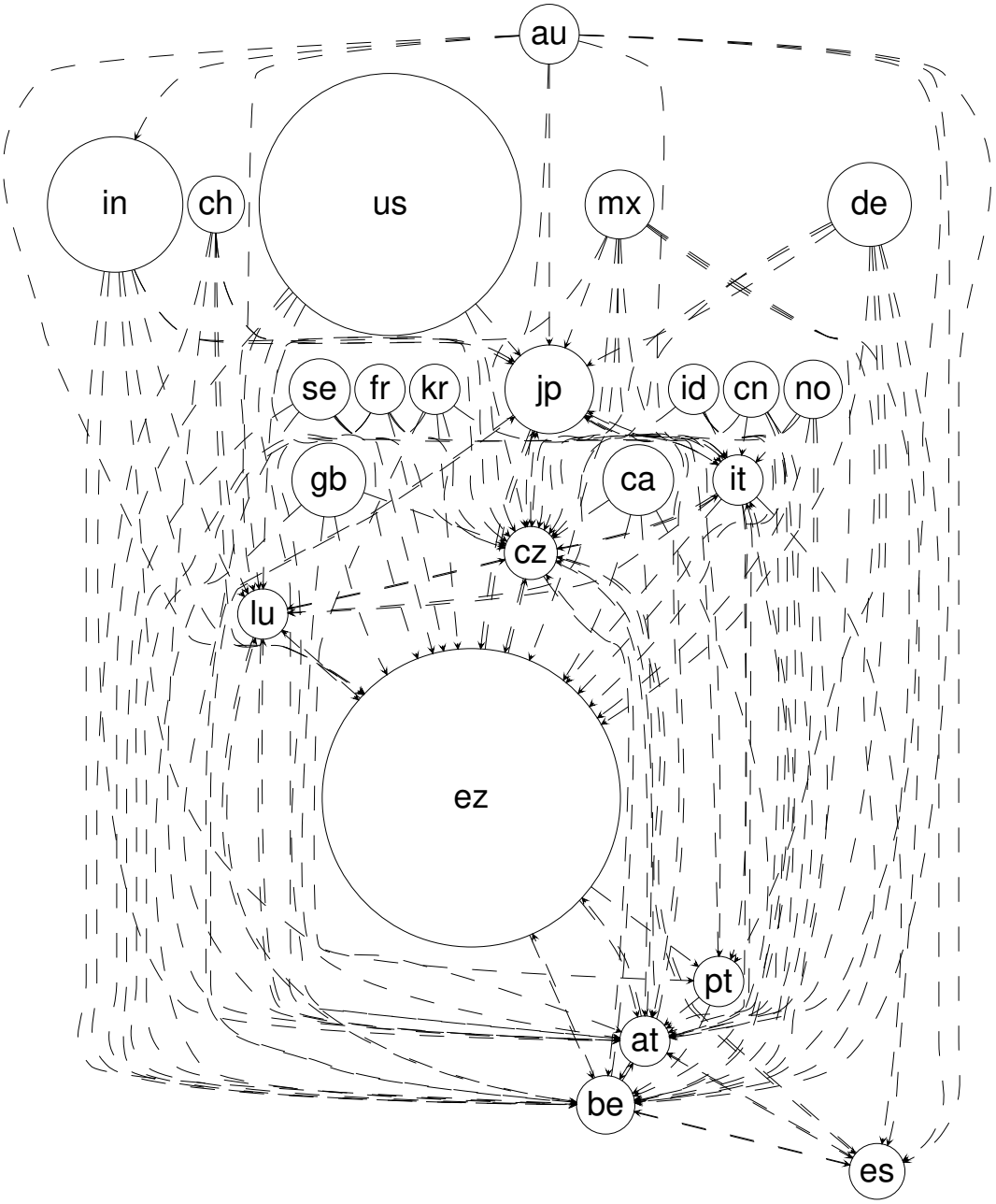
Notes: The network diagram above shows a directed network of trade flows. Edges indicate that at least one country is a top five import or export partner of the other. Arrows point to the country for which the trade relationship is important. An arrow pointing from Germany to Luxembourg indicates that Germany is a top five import or export partner of Luxembourg. Note that the size of each node is proportional to total trade.

Figure XIII: Directed Network: Financial Flows



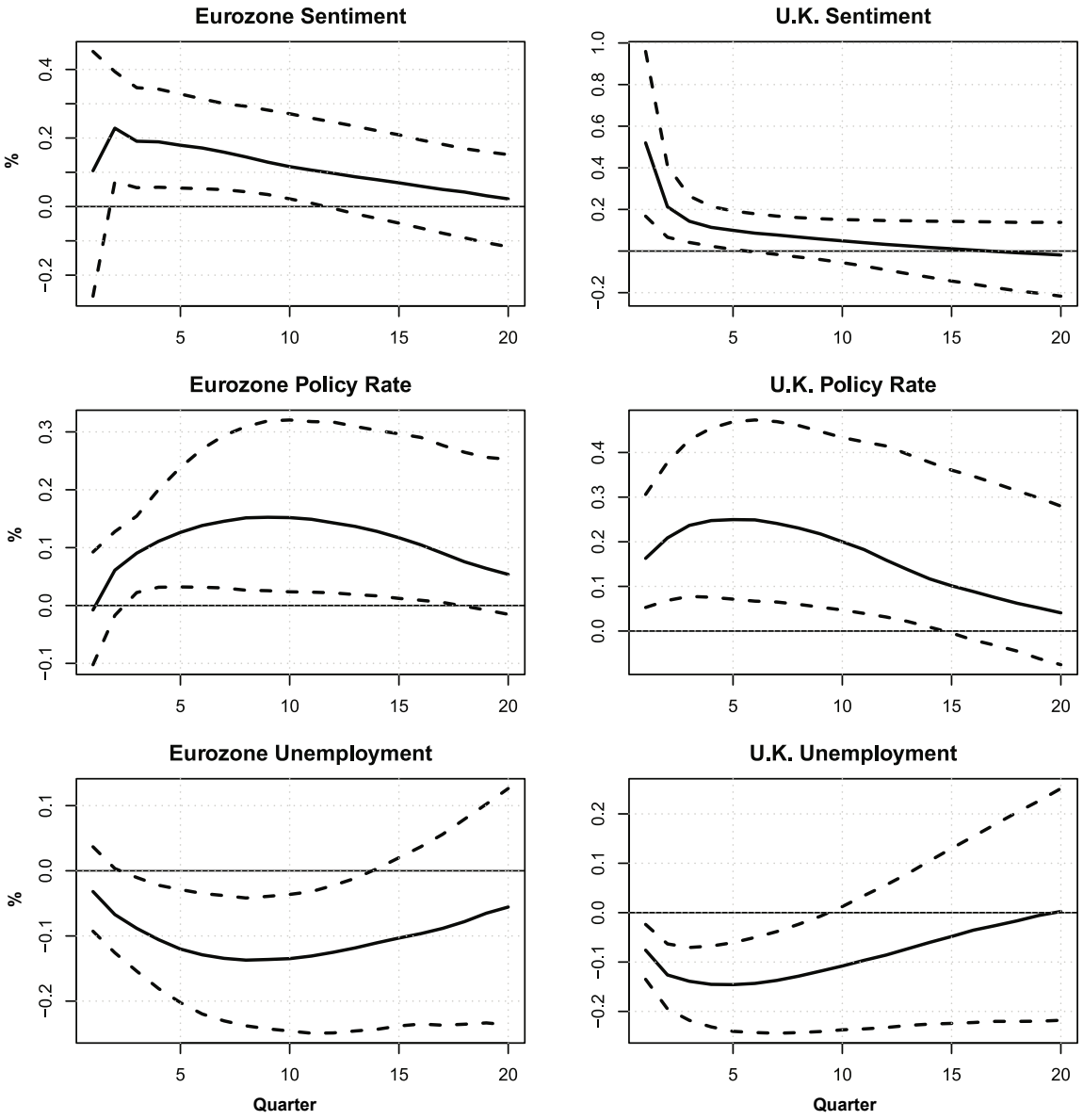
Notes: The network diagram above shows a directed network of private financial flows. Edges indicate that at least one country is a top source or destination of funds from the other. Arrows point to the country for which the flow is important. An arrow pointing from Switzerland to Italy indicates that Switzerland is either a top five provider of funds to Italy or a top five destination of funds for Italy. Note that size of each node is proportional to gross financial flows.

Figure XIV: Directed Network: Central Bank Sentiment



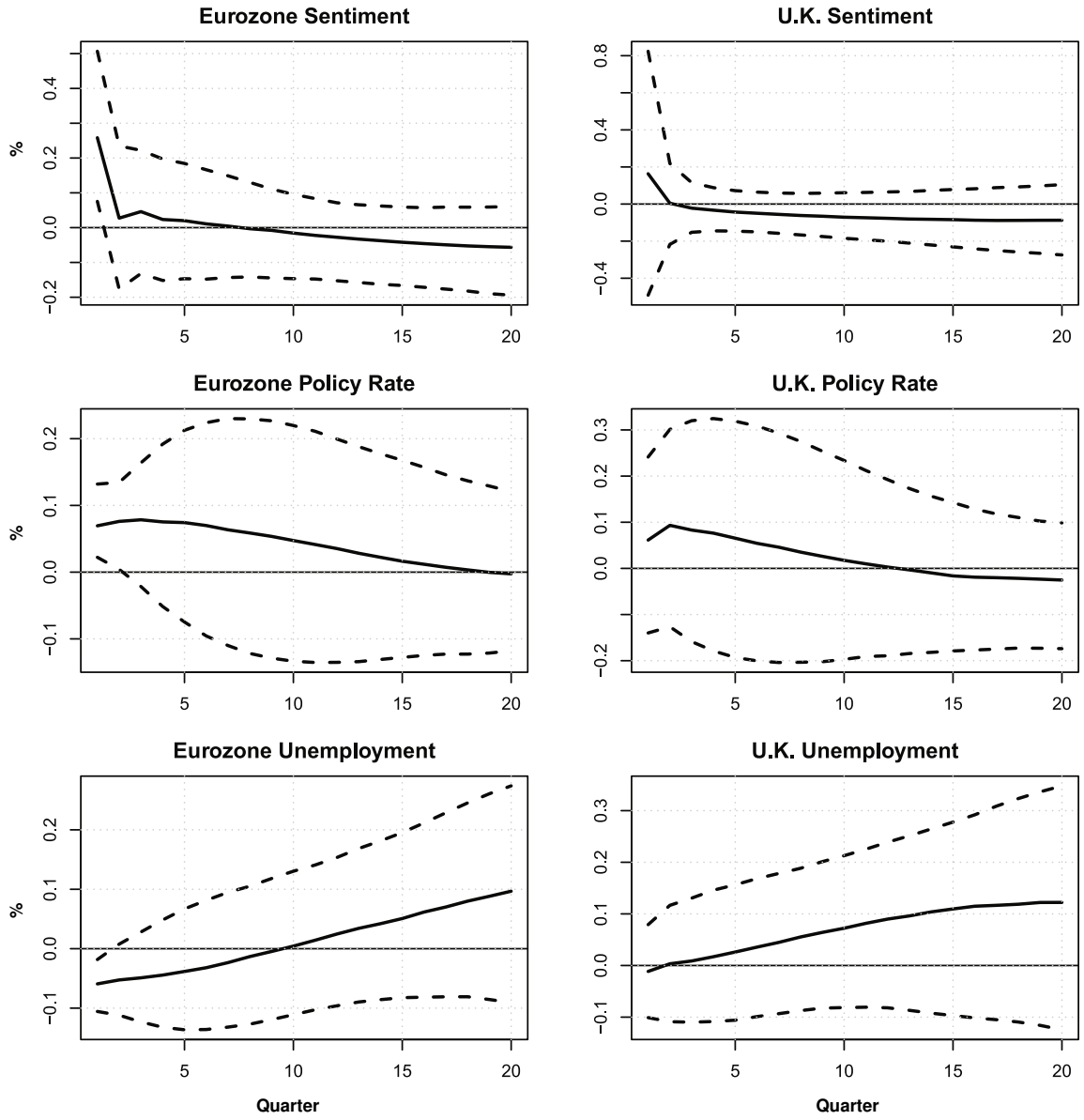
Notes: The network diagram above shows Granger causal connections in sentiment between each pair of countries in our dataset. Edges indicate the presence of at least one Granger causal connection between two nodes. Arrows indicate the direction of causality. Node size is proportional to the total number of speeches given by officials at the central bank over the 2002-2017 period.

Figure XV: Impact of Positive Shock to BoE Speech Sentiment on U.K. and Eurozone



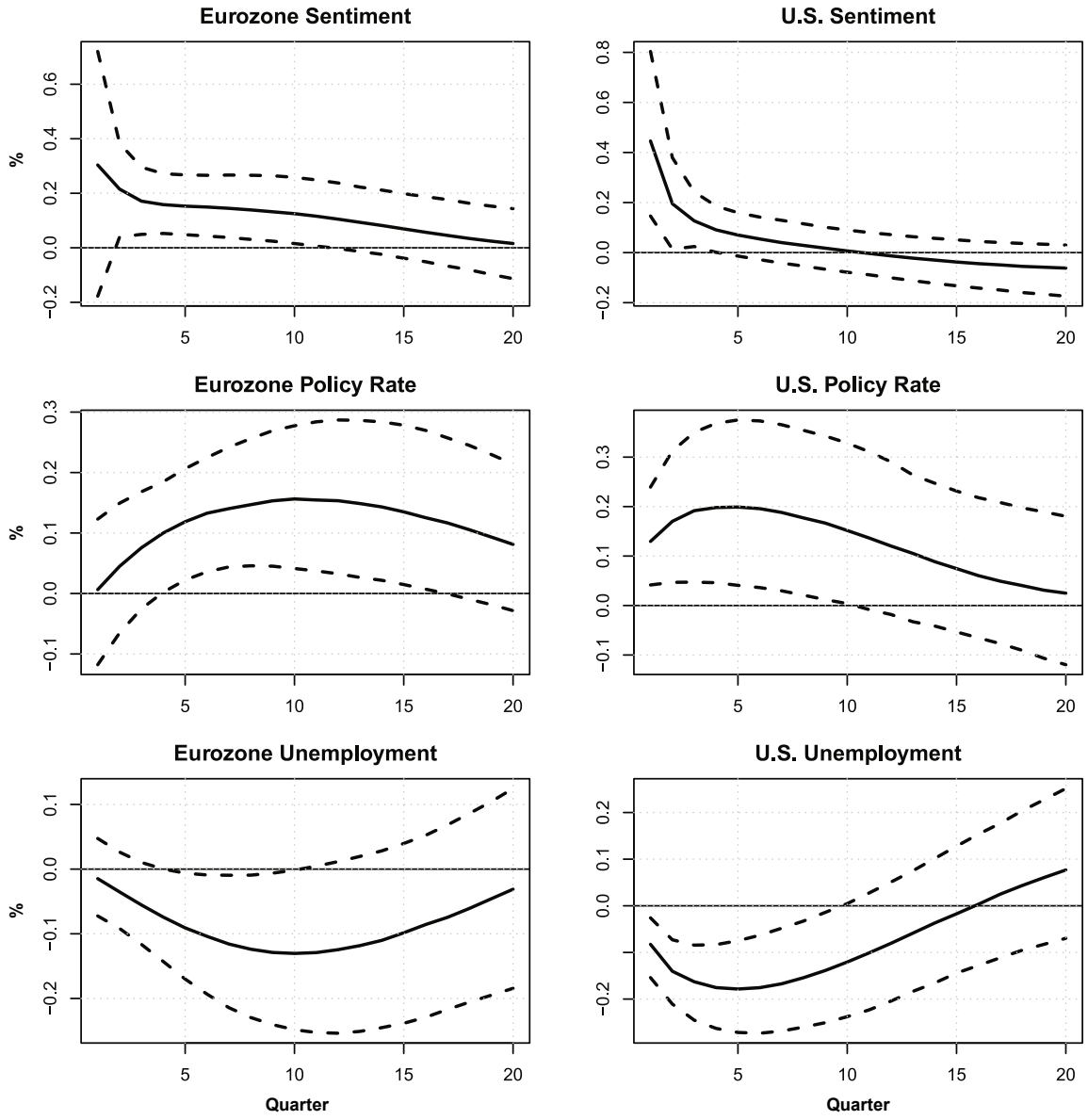
Notes: The plots above show IRFs from a positive structural shock to Bank of England speech sentiment. We computed the IRFs using the using the rejection method introduced by Rubio-Ramirez et al. (2010). For identification, we exclusively make assumptions about first period impacts on domestic variables.

Figure XVI: Impact of Positive Shock to ECB Speech Sentiment on Eurozone and U.K.



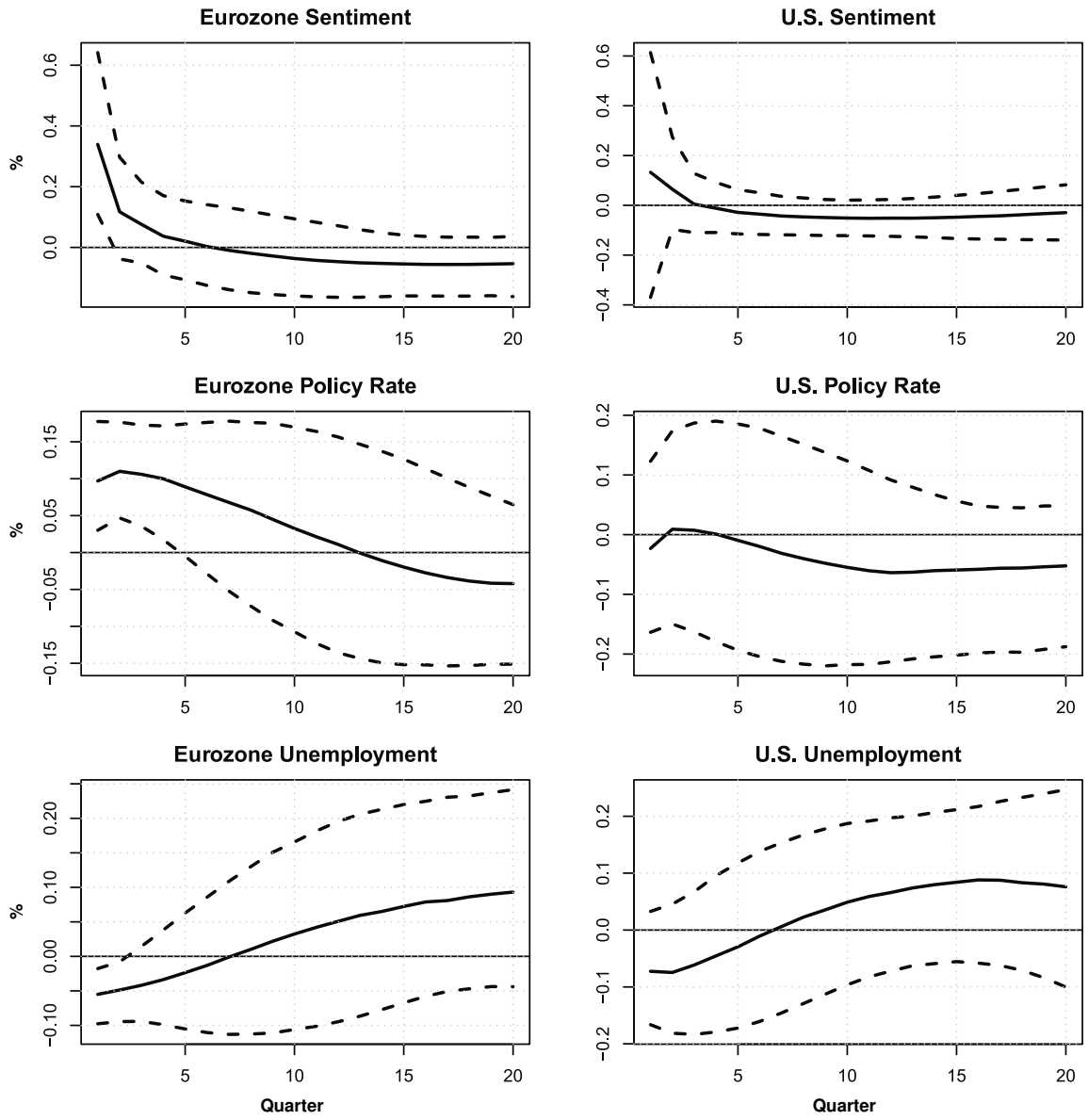
Notes: The plots above show IRFs from a positive structural shock to European Central Bank speech sentiment. We computed the IRFs using the using the rejection method introduced by Rubio-Ramirez et al. (2010). For identification, we exclusively make assumptions about first period impacts on domestic variables.

Figure XVII: Impact of Positive Shock to Fed Speech Sentiment on U.S. and Eurozone



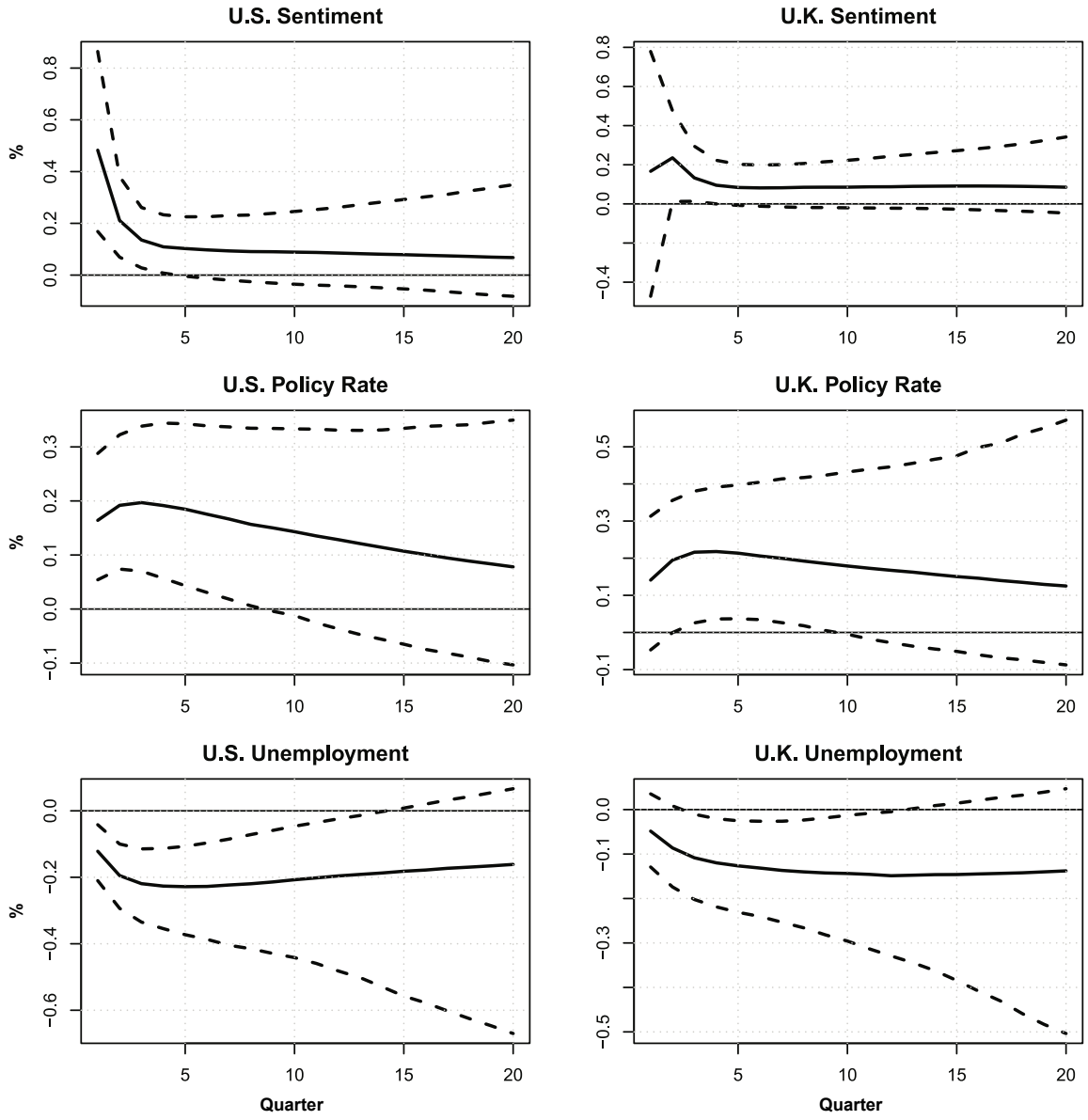
Notes: The plots above show IRFs from a positive structural shock to Federal Reserve speech sentiment. We computed the IRFs using the using the rejection method introduced by Rubio-Ramirez et al. (2010). For identification, we exclusively make assumptions about first period impacts on domestic variables.

Figure XVIII: Impact of Positive Shock to ECB Speech Sentiment on Eurozone and U.S.



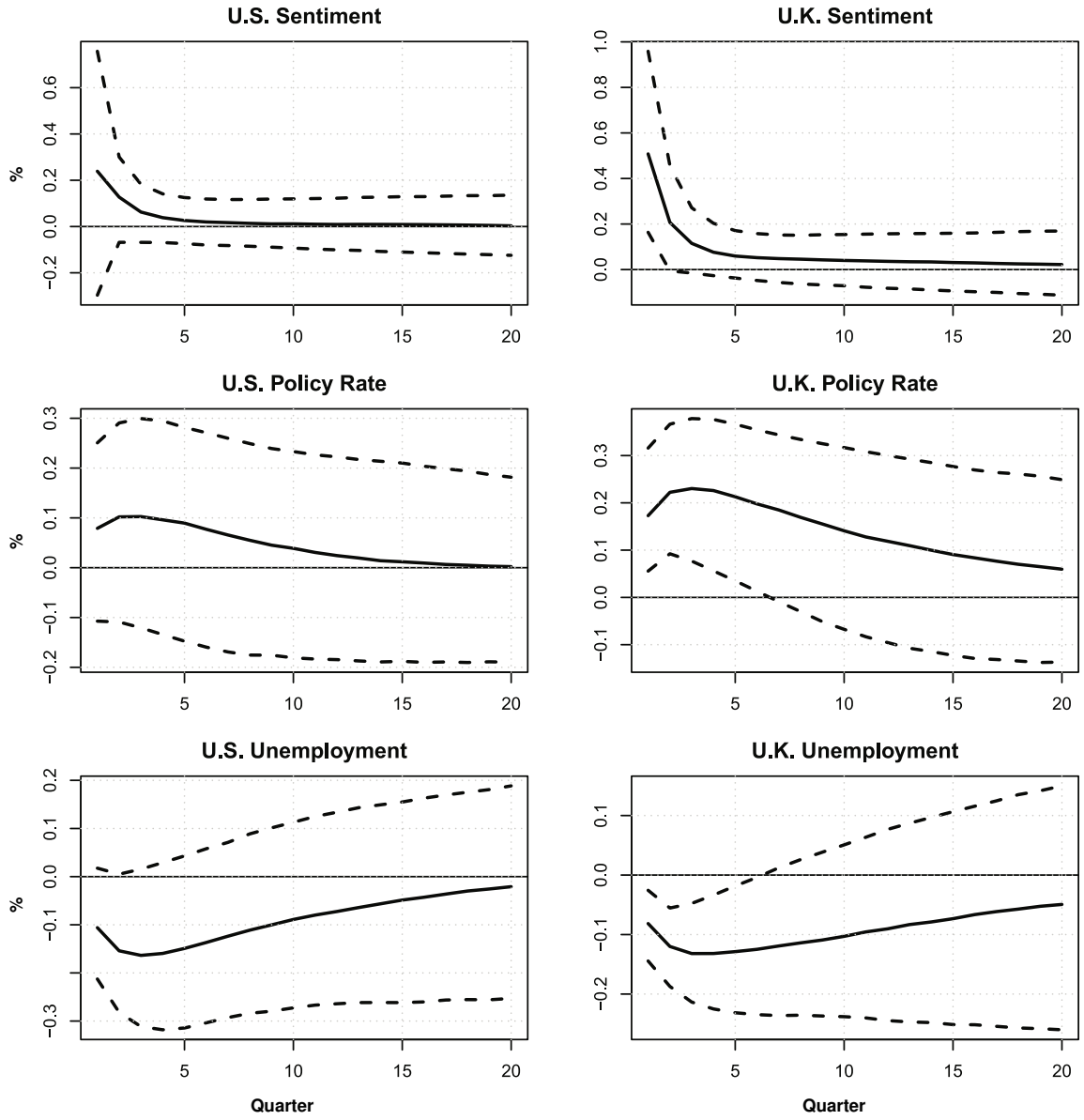
Notes: The plots above show IRFs from a positive structural shock to European Central Bank speech sentiment. We computed the IRFs using the using the rejection method introduced by Rubio-Ramirez et al. (2010). For identification, we exclusively make assumptions about first period impacts on domestic variables.

Figure XIX: Impact of Positive Shock to Fed Speech Sentiment on U.S. and U.K.



Notes: The plots above show IRFs from a positive structural shock to Federal Reserve speech sentiment. We computed the IRFs using the using the rejection method introduced by Rubio-Ramirez et al. (2010). For identification, we exclusively make assumptions about first period impacts on domestic variables.

Figure XX: Impact of Positive Shock to BoE Speech Sentiment on U.K. and U.S.



Notes: The plots above show IRFs from a positive structural shock to Bank of England speech sentiment. We computed the IRFs using the using the rejection method introduced by Rubio-Ramirez et al. (2010). For identification, we exclusively make assumptions about first period impacts on domestic variables.

Table IV: Country Abbreviations

Country	Central Bank	Abbreviation
Australia	Reserve Bank of Australia	AU
Austria	National Bank of Austria	AT
Belgium	National Bank of Belgium	BE
Canada	Bank of Canada	CA
China	People's Bank of China	CN
Czech Republic	Czech National Bank	CZ
Eurozone	European Central Bank	EZ
France	Bank of France	FR
Germany	Deutsche Bundesbank	DE
India	Reserve Bank of India	IN
Italy	Bank of Italy	IT
Japan	Bank of Japan	JP
Luxembourg	Central Bank of Luxembourg	LU
Mexico	Bank of Mexico	MX
Norway	Norges Bank	NO
Portugal	Bank of Portugal	PT
South Korea	Bank of Korea	KR
Spain	Bank of Spain	ES
Sweden	Sveriges Riksbank	SE
Switzerland	Swiss National Bank	CH
United Kingdom	Bank of England	GB
United States	Federal Reserve System	US

Notes: The table above contains the country and central bank associated with each of the two-letter abbreviations in the plots and network diagrams.

Table V: Impact of Distance, Shared Language, and Colonial-Ties on Central Bank Sentiment Correlation

	(1) (OLS)	(2) (OLS)	(3) (OLS)	(4) (OLS)	(5) (OLS)	(6) (OLS)	(7) (OLS)	(8) (OLS)	(9) (OLS)	(10) (OLS)
Distance	-0.0115***	-0.0112***	-0.0086***	-0.0064**	-0.0082***	-0.0084***	-0.0131***	-0.0150***	-0.0135***	-0.0164***
	(0.0026)	(0.0026)	(0.0028)	(0.0030)	(0.0030)	(0.0032)	(0.0032)	(0.0048)	(0.0049)	(0.0052)
Language		0.0730**	0.0592*	0.0124	0.0333	0.0342	-0.0180	-0.0178	-0.0140	-0.0392
		(0.0332)	(0.0325)	(0.0352)	(0.0378)	(0.0375)	(0.0358)	(0.0361)	(0.0354)	(0.0406)
Colonial Ties		0.0896*	0.0988**	0.1335**	0.1306**	0.1295**	0.0490	0.0475	0.0266	0.0832
		(0.0537)	(0.0500)	(0.0608)	(0.0617)	(0.0614)	(0.0586)	(0.0609)	(0.0605)	(0.0659)
Real GDP Correlation			0.1916***	0.1464**	0.1464**	0.1447**	-0.0140	-0.0230	0.0624	-0.0754
			(0.0615)	(0.0589)	(0.0582)	(0.0572)	(0.0838)	(0.0839)	(0.0835)	(0.0854)
Inflation Correlation				0.2098***	0.2196***	0.2182***	0.0943	0.0999	0.1289**	0.0977
				(0.0632)	(0.0650)	(0.0641)	(0.0648)	(0.0644)	(0.0622)	(0.0663)
Trade Flows					-0.0029	-0.0030	0.0006	0.0009	0.0004	0.0003
					(0.0022)	(0.0023)	(0.0014)	(0.0014)	(0.0013)	(0.0029)
Private Financial Flows					-0.0416	-0.0427	-0.0033	-0.0017	0.0355	-0.0052
					(0.0299)	(0.0306)	(0.0263)	(0.0264)	(0.0243)	(0.0302)
Log(Speeches)						0.0042	-0.0087	-0.0119	-0.0407*	-0.0313
						(0.0178)	(0.0251)	(0.0251)	(0.0244)	(0.0368)
Country FE	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Shared Continent FE	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES
No China	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO
No U.S.	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES
Adj. R-squared	0.058	0.072	0.112	0.152	0.166	0.163	0.567	0.566	0.382	0.595
N	231	231	231	231	231	231	231	231	210	210

Notes: Each regression uses our baseline sample of 22 central banks. The dependent variable is the bilateral correlation in quarterly central bank sentiment over the 2002-2017 period. "Distance" is the great circle distance in thousands of kilometers between the capital cities of each country pair. "Colonial Ties" is a dummy variable equal to 1 if either country in the pair was a colony of the other or gained independence from it. "Real GDP Correlation" is the correlation in real GDP growth per capita between members of the country pair. "Inflation Correlation" is the correlation in inflation between members of the country pair. "Private Financial Flows" is the maximum share of bilateral private financial claims to total financial claims for a trading partner pair. We construct this variable using bilateral private financial flows from the BIS's Locational Banking Statistics. "Trade Flows" is the maximum share of bilateral trade to total trade for a trading partner pair. Finally, "Log(Speeches)" is the natural logarithm of the sum of the speech counts for the central banks in the pair. The reported standard errors are heteroskedasticity robust; however, the results are robust to geographic clustering. The following countries and monetary unions are included in each regression: Australia, Austria, Belgium, Canada, China, Czech Republic, Eurozone, France, Germany, India, Italy, Japan, Luxembourg, Mexico, Norway, Portugal, South Korea, Spain, Sweden, Switzerland, United Kingdom, United States. *** indicates significance at 1%, ** indicates significance at 5%, and * indicates significance at 10%.

Table VI: Robustness Tests: Sample Expansion, BIS GEM Membership, FSB Membership

	(1) (OLS)	(2) (OLS)	(3) (OLS)	(4) (OLS)
Distance	-0.0052***	-0.0051***	-0.0052***	-0.0051***
	(0.0015)	(0.0015)	(0.0015)	(0.0015)
BIS		0.0588***		0.0596***
		(0.0194)		(0.0194)
FSB			-0.0163	-0.0211
			(0.0187)	(0.0186)
All Controls	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Shared Continent	YES	YES	YES	YES
Adj. R-squared	0.36	0.36	0.36	0.36
N	1484	1484	1484	1484

Notes: Each regression uses an expanded sample of 55 central banks. The dependent variable is the bilateral correlation in quarterly central bank sentiment. We restrict the sample to the 2003-2017 period, where BIS GEM membership was stable. "Distance" is the great circle distance in thousands of kilometers between the capital cities of each country pair. "BIS" is a dummy variable that indicates whether a central bank was either a member or observer at the BIS Global Economy Meeting (GEM). "FSB" is a dummy variable that indicates whether a country or central bank has attended Financial Stability Forum (FSF) and Financial Stability Board (FSB) meetings since at least 2009. The "All Controls" row indicates whether colonial ties, language, real GDP correlation, trade, financial flows, and log number of speeches controls have been included. The following countries and monetary unions are included in each regression: Albania, Argentina, Australia, Austria, Bahrain, Barbados, Belgium, Canada, China, Czech Republic, Denmark, Eurozone, Fiji, Finland, France, Germany, Ghana, Greece, Hong Kong, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Kenya, Luxembourg, Macedonia, Malaysia, Malta, Mauritius, Mexico, Namibia, New Guinea, Norway, Pakistan, Philippines, Portugal, Romania, Russia, Serbia, Singapore, South Africa, South Korea, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Trinidad, Uganda, United Kingdom, United States, and Zambia. The reported standard errors are heteroskedasticity robust. *** indicates significance at 1%, ** indicates significance at 5%, and * indicates significance at 10%.

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