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International Monetary Policy Spillovers: Evidence from a TVP-VAR

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Abstract

In this study, we examine the transmission of international monetary policy shocks across developed economies based on a time-varying parameter vector autoregressive (TVP-VAR) methodology. Using daily data on shadow short rates over the period of January 2, 1995 to September 22, 2017, we find the following empirical regularities. International monetary policy shocks is an important source of domestic monetary policy fluctuations. Moreover, the magnitude of international monetary policy spillovers behaves heterogeneously overtime, with peaks reached during the “Great Recession”. In addition, the dominant transmitters of international monetary policy shocks are the Euro Area and the US, while Japan and the UK are the dominant receivers of international monetary policy shocks. Interestingly enough, international monetary policy shocks originating from the US are the largest during the zero lower bound and the related unconventional monetary policy actions era, indicating potential gains from monetary policy coordination.

Keywords: Monetary policy spillovers; Dynamic connectedness, TVP-VAR

JEL codes: C32; C50; E52

1 Introduction

The issue of monetary policy spillovers can be traced as far back as to the 18th century in David Hume's *Essays, Moral, Political, and Literary* ((Coeuré, 2016)). Theoretical models have rigorously analyzed the international spillovers of monetary policy, and reviewed the case for and against monetary policy coordination since the mid-1980s (see Taylor, 2013, for a detailed review of this literature). In general, as noted by Engel (2016), this literature tends to point towards limited spillovers, with the desirability of cooperation across monetary authorities being highly model specific, and some potentially important shocks causing the propagation poorly understood.

In addition, from a political economy perspective, the complexity of cooperation due to differences in legal and institutional differences is also believed to prevent cooperation (Ostry and Ghosh, 2016). In the wake of recent global financial crisis and the “Great Recession”, Cook and Devereux (2016) focussing on the effects of the Zero Lower Bound (ZLB) and related unconventional monetary policy actions (such as Quantitative Easing (QE)), tends to suggest that spillovers, during the ZLB, can be larger than in normal times and the gains from monetary policy coordination possibly greater. In sum, a relevant empirical hypothesis that needs to be tested is whether monetary policy spillovers are higher during episodes of crises when compared to normal times?

This is exactly the question we aim to answer by analysing the spillover of monetary policy across the United States (US), the Euro Area, Japan and the United Kingdom (UK), using a full-fledged time-varying parameter vector autoregressive (TVP-VAR) model of Antonakakis and Gabauer (2017). This approach is an extension of the popular

rolling-window method of [Diebold and Yilmaz \(2012\)](#), which has been used widely to analyze spillovers across variables and countries over time. The TVP-VAR improves the methodology provided by [Diebold and Yilmaz \(2012\)](#) substantially, because there is no need to arbitrarily set the rolling window-size, there is no loss of observations, and it is not sensitive to outliers.

As indicated above, in the wake of global financial crisis and the ZLB situation that ensued thereafter, central banks in the economies of our concern pursued unconventional monetary policies, such as QE. QE in turn involves a multitude of measures such as large scale asset purchases, maturity extension programs, and efforts of forward guidance in order to manage expectations of a prolonged period of low policy rates ([Tillmann \(2016\)](#)). But understandably, to compare across the conventional and unconventional regimes of monetary policy decisions, we would need a common metric capturing the stance of monetary policy. We circumvent this apparent empirical difficulty by considering the Shadow Short Rate (SSR), which is the nominal interest rate that would prevail in the absence of its effective lower bound, with it derived by modelling the term structure of the yield curve.

The main advantage of the SSR is that it is not constrained by the ZLB and thus allows us to combine the monetary policy instrument data from the ZLB (unconventional) period with the data from the non-ZLB (conventional) era. For our spillovers analysis we rely on the daily SSR data,¹ as developed by [Krippner \(2013\)](#), over the period of 2nd

¹Alternative measures of the SSR for the US, the UK and the Euro Area have also been developed by [Wu and Xia \(2016\)](#). However, besides being only available at monthly frequency and unavailable for Japan which also witnessed the ZLB situation, the SSR estimates derived by [Krippner \(2013\)](#) are more robust than those obtained by [Wu and Xia \(2016\)](#), as shown by [Krippner \(2017\)](#).

January, 1995 to 22nd September, 2017. Note that, alternative measures of the SSR for the US, the Euro Area and the UK have also been developed by [Wu and Xia \(2016\)](#). However, besides being only available at monthly frequency and unavailable for Japan (which also witnessed the ZLB situation), the SSR estimates derived by [Krippner \(2013\)](#) have been shown to be relatively more robust ([Krippner, 2017](#)). In addition, given the large literature that exists on the impact of domestic and international (conventional and unconventional) monetary policy on macroeconomic variables are primarily at lower (monthly or quarterly) frequency (see [Claessens et al., 2016](#), for a detailed literature review in this regard), knowledge of monetary policy spillovers at a higher frequency is likely to be more beneficial to policy makers in determining the direction in which the economy is headed in the future. Further, with asset prices available at higher frequencies and deemed as leading indicators for economic activity ([Armesto et al., 2010](#)) and inflation ([Breitung and Roling, 2015](#)), the likely effect of the daily movements of the monetary policy instrument on asset market movements, is also going to carry valuable information for decision makers of the economy. Hence, the decision to use daily SSRs to conduct our spillover analysis is well warranted.

To the best of our knowledge, this is the first attempt to compare international monetary policy spillovers across conventional and unconventional monetary policy regimes for four developed economies using a TVP-VAR model. The only study that is to some extent similar to ours is that by [Claus et al. \(2016\)](#), whereby the authors used a constant parameter latent factor model, and hence, a sub-sample based analysis to show that there is significant evidence of spillovers across monetary policies of the US and Japan, with

the effect being stronger during the unconventional monetary policy regime.

The results of our empirical analysis suggest that, international monetary policy shocks is an important source of domestic monetary policy fluctuations. Moreover, the magnitude of international monetary policy spillovers behaves heterogeneously overtime, with peaks reached during the “Great Recession”. In addition, the dominant transmitters of international monetary policy shocks are the Euro Area and the US, while Japan and the UK are the dominant receivers of international monetary policy shocks. Interestingly enough, international monetary policy shocks originating from the US are the largest during the zero lower bound and the related unconventional monetary policy actions era, indicating potential gains from monetary policy coordination.

The rest of the paper is organized as follows: Section 2 lays out the basics of the methodology, while Section 3 presents the data and discusses the results. Finally, Section 4 concludes this study.

2 Methodology

2.1 TVP-VAR

In order to explore the transmission mechanism of monetary policy in a time-varying fashion we use the TVP-VAR methodology of Antonakakis and Gabauer (2017) that extends the originally proposed connectedness approach of Diebold and Yilmaz (2012); ?, by allowing the variances to vary via a stochastic volatility Kalman Filter estimation with forgetting factors introduced by Koop and Korobilis (2014). By doing so, the TVP-VAR approach overcomes the burden of the often arbitrarily chosen rolling-window-size, that

could lead to very erratic or flattened parameters, and loss of valuable observations.

In particular, the TVP-VAR model can be written as follows,

$$\mathbf{Y}_t = \boldsymbol{\beta}_t \mathbf{Y}_{t-1} + \boldsymbol{\epsilon}_t \quad \boldsymbol{\epsilon}_t | \mathbf{F}_{t-1} \sim N(\mathbf{0}, \mathbf{S}_t) \quad (1)$$

$$\boldsymbol{\beta}_t = \boldsymbol{\beta}_{t-1} + \boldsymbol{\nu}_t \quad \boldsymbol{\nu}_t | \mathbf{F}_{t-1} \sim N(\mathbf{0}, \mathbf{R}_t) \quad (2)$$

where \mathbf{Y}_t represents an $N \times 1$ conditional volatilities vector, \mathbf{Y}_{t-1} is an $Np \times 1$ lagged conditional vector, $\boldsymbol{\beta}_t$ is an $N \times Np$ dimensional time-varying coefficient matrix and $\boldsymbol{\epsilon}_t$ is an $N \times 1$ dimensional error disturbance vector with an $N \times N$ time varying variance-covariance matrix, \mathbf{S}_t . The parameters $\boldsymbol{\beta}_t$ depend on their own values $\boldsymbol{\beta}_{t-1}$ and on an $N \times Np$ dimensional error matrix with an $Np \times Np$ variance-covariance matrix.

The time-varying coefficients and error covariances are used to estimate the generalised connectedness procedure of [Diebold and Yilmaz \(2014\)](#) that is based on generalised impulse response functions (GIRF) and generalised forecast error variance decompositions (GFEVD) developed by [Koop et al. \(1996\)](#) and [Pesaran and Shin \(1998\)](#). In order to calculate the GIRF and GFEVD, we transform the VAR to its vector moving average (VMA) representation, based on the Wold representation theorem as follows:

$$\mathbf{Y}_t = \boldsymbol{\beta}_t \mathbf{Y}_{t-1} + \boldsymbol{\epsilon}_t \quad (3)$$

$$\mathbf{Y}_t = \mathbf{A}_t \boldsymbol{\epsilon}_t \quad (4)$$

$$\mathbf{A}_{0,t} = \mathbf{I} \quad (5)$$

$$\mathbf{A}_{i,t} = \boldsymbol{\beta}_{1,t} \mathbf{A}_{i-1,t} + \dots + \boldsymbol{\beta}_{p,t} \mathbf{A}_{i-p,t} \quad (6)$$

where $\boldsymbol{\beta}_t = [\boldsymbol{\beta}_{1,t}, \boldsymbol{\beta}_{2,t}, \dots, \boldsymbol{\beta}_{p,t}]'$ and $\mathbf{A}_t = [\mathbf{A}_{1,t}, \mathbf{A}_{2,t}, \dots, \mathbf{A}_{p,t}]'$ and hence $\boldsymbol{\beta}_{i,t}$ and $\mathbf{A}_{i,t}$ are

$N \times N$ dimensional parameter matrices.

The GIRFs represent the responses of all variables following a shock in variable i . Since we do not have a structural model, we compute the differences between a J -step-ahead forecast where once variable i is shocked and once where variable i is not shocked. The difference can be accounted to the shock in variable i , which can be calculated by

$$GIR_t(J, \boldsymbol{\delta}_{j,t}, \mathbf{F}_{t-1}) = E(\mathbf{Y}_{t+J} | \boldsymbol{\epsilon}_{j,t} = \boldsymbol{\delta}_{j,t}, \mathbf{F}_{t-1}) - E(\mathbf{Y}_{t+J} | \mathbf{F}_{t-1}) \quad (7)$$

$$\boldsymbol{\Psi}_{j,t}^g(J) = \frac{\mathbf{A}_{J,t} \mathbf{S}_t \boldsymbol{\epsilon}_{j,t}}{\sqrt{S_{jj,t}}} \frac{\boldsymbol{\delta}_{j,t}}{\sqrt{S_{jj,t}}} \quad \boldsymbol{\delta}_{j,t} = \sqrt{S_{jj,t}} \quad (8)$$

$$\boldsymbol{\Psi}_{j,t}^g(J) = S_{jj,t}^{-\frac{1}{2}} \mathbf{A}_{J,t} \mathbf{S}_t \boldsymbol{\epsilon}_{j,t} \quad (9)$$

where J represents the forecast horizon, $\boldsymbol{\delta}_{j,t}$ the selection vector with one on the j th position and zero otherwise, and \mathbf{F}_{t-1} the information set until $t - 1$. Afterwards, we compute the GFEVD that can be interpreted as the variance share one variable has on others. These variance shares are then normalised, so that each row sums up to one, meaning that all variables together explain 100% of variable's i forecast error variance.

This is calculated as follows

$$\tilde{\phi}_{ij,t}^g(J) = \frac{\sum_{t=1}^{J-1} \Psi_{ij,t}^{2,g}}{\sum_{j=1}^N \sum_{t=1}^{J-1} \Psi_{ij,t}^{2,g}} \quad (10)$$

with $\sum_{j=1}^N \tilde{\phi}_{ij,t}^g(J) = 1$ and $\sum_{i,j=1}^N \tilde{\phi}_{ij,t}^g(J) = N$. Using the GFEVD, we construct the total

connectedness index by

$$C_t^g(J) = \frac{\sum_{i,j=1, i \neq j}^N \tilde{\phi}_{ij,t}^g(J)}{\sum_{i,j=1}^N \tilde{\phi}_{ij,t}^g(J)} * 100 \quad (11)$$

$$= \frac{\sum_{i,j=1, i \neq j}^N \tilde{\phi}_{ij,t}^g(J)}{N} * 100 \quad (12)$$

This connectedness approach shows how a shock in one variable spills over to other variables. First, we look at the case where variable i transmits its shock to all other variables j , called *total directional connectedness to others* and defined as

$$C_{i \rightarrow j,t}^g(J) = \frac{\sum_{j=1, i \neq j}^N \tilde{\phi}_{ji,t}^g(J)}{\sum_{j=1}^N \tilde{\phi}_{ji,t}^g(J)} * 100 \quad (13)$$

Second, we calculate the directional connectedness variable i receives it from variables j , called *total directional connectedness from others* and defined as

$$C_{i \leftarrow j,t}^g(J) = \frac{\sum_{j=1, i \neq j}^N \tilde{\phi}_{ij,t}^g(J)}{\sum_{i=1}^N \tilde{\phi}_{ij,t}^g(J)} * 100 \quad (14)$$

Finally, we subtract *total directional connectedness to others* from *total directional connectedness from others* to obtain the *net total directional connectedness*, which can be interpreted as the ‘power’ of variable i , or, its influence on the whole variables’ network.

$$C_{i,t}^g = C_{i \rightarrow j,t}^g(J) - C_{i \leftarrow j,t}^g(J) \quad (15)$$

If the net total directional connectedness of variable i is positive, it means that variable i influences the network more than being influenced by that. By contrast, if the net total directional connectedness is negative, it means that variable i is driven by the network.

3 Data and Empirical Results

3.1 Data

With policy rates in the ZLB range for a prolonged period of time post the financial crisis, posed a great challenge to empirical researchers dealing with monetary policy to find alternative quantitative measures that are able to describe monetary policy at the ZLB. One such measure is the Shadow Short Rate (SSR). The SSR used in this paper is developed by [Krippner \(2013\)](#), based on a two-factor model of term-structure, at a daily frequency for the four economies of our concern, and is available for download from the website of the Reserve Bank of New Zealand.² The two-factor yield curve-based framework developed by [Krippner \(2013\)](#) essentially removes the effect that the option to invest in physical currency (at an interest rate of zero) has on yield curves, resulting in a hypothetical “shadow yield curve” that would exist if physical currency were not available. The process allows one to answer the question: “what policy rate would generate the observed yield curve if the policy rate could be taken negative?” The “shadow policy rate” generated in this manner, therefore, provides a measure of the monetary policy stance after the actual policy rate reaches zero.

We collect daily observations of the SSRs for the United States, the Euro Area, Japan and the United Kingdom over the period January 2, 1995 to September 22, 2017. The sample size is purely driven based on data availability. [Figure 1](#) plots the shadow short rates.

[Insert [Figure 1](#) around here]

²The data can be downloaded from the following [link](#).

The interest rates are converted to stationary series by taking the first differences. The transformed series are plotted in Figure 2 and descriptive statistics are presented in Table 1.

[Insert Figure 2 around here]

[Insert Table 1 around here]

3.2 Empirical Results

In Table 2, we report the estimates of the connectedness indices for each series based on the TVP-VAR methodology. Summarizing the information in Table 2, we observe that own-country monetary policy spillovers explain the highest share of forecast error variance, as the diagonal elements receive higher values compared to the off-diagonal elements. For instance, innovations in monetary policy in the Euro Area explain 15.3% and 14.3% of the xx-day-ahead forecast error variance of monetary policy in the UK and the US, respectively, but only 4.4% in Japan. Moreover, the most important transmitters of monetary policy shocks are the Euro Area followed by the US, while UK and Japan are the most important receivers of monetary policy shocks. These results are supported by the estimated net directional spillovers reported in the last row of Table 2. In addition, according to the total directional connectedness index (TCI) reported at the lower right corner of Table 2, which effectively distils the various directional spillovers into one single index, on average, 17.9% of the forecast error variance in monetary policy shocks comes from spillovers of shocks across countries.

[Insert Table 2 around here]

We now turn our attention to the interpretation of the spillover plots based on the time-varying estimates of the various spillover indices according to the TVP-VAR model. Figure 3 presents the results for the time-varying total connectedness index. According to this figure, we observe a large variation in the total connectedness index, which turns out very responsive to (extreme) economic events such as the Asian crisis in 1997, the introduction of the Euro, the Great Recession and the subsequent European sovereign debt crisis. In particular, monetary policy spillovers reached unprecedented heights during the Great Recession, a period characterized by intense unconventional monetary policy interventions primarily.

[Insert Figure 3 around here]

Figure 4 presents the dynamic directional connectedness of monetary policy shocks from each of the series to others, while Figure 5 presents the dynamic directional connectedness of monetary policy shocks to each series from others. According to these two figures, directional spillovers from or to each series range between 0% to 25% and are of bilateral nature. Nevertheless, they behave rather heterogeneously overtime and follow a similar pattern as the one found for the total connectedness index. For instance, directional monetary policy spillovers peak during the Great Recession, especially those originating from the Euro Area and the US.

[Insert Figure 4 around here]

[Insert Figure 5 around here]

A similar picture emerges when looking at the dynamic net directional connectedness plots as depicted in Figure 6. According to Figure 6, we see that Japan and the UK are mostly net receivers of monetary policy shocks during our sample period. EU is a net transmitter of monetary policy shocks since the introduction of Euro into circulation and up to the Great Recession, and from 2012 onward, while a net receiver of monetary policy shocks in the remaining periods. Finally, the US is on the receiving ends of monetary policy transmission from 1995 to 2000 and from the period of the Great Recession onward, and on the receiving ends since the introduction of the Euro and up to the onset of the the Great Recession.

[Insert Figure 6 around here]

Finally, focusing on the net pairwise directional connectedness of monetary policy shocks, i.e. monetary policy shocks spillovers across pairs of countries, which are presented in Figure 7, we observe the following empirical regularities. First, in net terms, monetary policy spillovers are of greater magnitude between pairs of European countries and between the Euro Area (UK) and the US, compared to pairs of countries where the Japan is one of them. The Euro Area seems to be the dominant net transmitter of monetary policy shocks to the UK (since the introduction of the Euro) and to the US (from the inception of the Euro and up to the Great Recession), while the US is the dominant net transmitter of monetary policy shocks to the UK, especially since the Great Recession.

[Insert Figure 7 around here]

In an attempt to examine whether the transmission of monetary policy spillovers differs between periods of conventional monetary policy and unconventional monetary policy (zero lower bound), we split the sample into two subperiods: (a) from January 2, 1995 to November 30, 2008 (conventional monetary policy sample of no- zero interest rate policy in the US) and (b) December 1, 2008 to September 22, 2017 (unconventional monetary policy sample of zero interest rate policy in the US, with the SSR turning negative for the first time on the starting date of the sub-sample).

The results of this analysis are reported in Table 3. According to these results, we observe that, despite that overall monetary policy spillovers do not change dramatically between the ZLB (unconventional) period and the non-ZLB (conventional) era, as indicated by the TCI in the lower right corner in panel a and panel b of Table 3, the US is the dominant transmitter of monetary policy spillovers during the ZLB era while a net receiver of shocks in the pre- ZLB era. In other words, the introduction of unconventional monetary policy in the US since December 2018 was associated with a significant increase in international monetary policy spillovers originating from the US. In particular, monetary policy shocks in the US explain 9.1%, 2% and 6.9% of the forecast error variance of monetary policy shocks in the Euro Area, Japan and the UK, respectively, during the era of conventional monetary policy, while 13.2%, 2.3% and 17.6% of the forecast error variance of monetary policy shocks in the Euro Area, Japan and the UK, respectively, since the ZLB era. Before the introduction of unconventional policy measures in the US (i.e. until November 2008), Euro Area was the dominant transmitter of international monetary policy shocks followed by the US. However, with the introduction of unconventional

monetary policy during the ZLB era, the US became the main transmitter of international monetary policy shocks. This is line with the study of [Cook and Devereux \(2016\)](#) who find that spillovers, during the ZLB, can be larger compared to those during normal times.

[Insert Table 3 around here]

These results have important policy implications in the sense that, during episodes of severe crises adding international dimensions in a particular country's monetary policy design could reduce the impact of domestic policy failures or make it easier for policy makers to deviate from optimal domestic policy, and get one closer to the global optimal [Engel \(2016\)](#). In other words, there could be possible gains from coordinating monetary policy decisions, especially in the wake extraordinary situations like those observed during the recent global financial and the European debt crises.

4 Conclusion

In this study we examined the international transmission of monetary policy shocks across the US, the Euro Area, UK and Japan over the period of 1995 to 2017 based on a TVP-VAR methodology. The results of our empirical analysis suggest that, nternational monetary policy shocks is an important source of domestic monetary policy fluctuations. Moreover, the magnitude of international monetary policy spillovers behaves heterogeneously overtime, with peaks reached during the "Great Recession". In addition, the dominant transmitters of international monetary policy shocks are the Euro Area and the US, while Japan and the UK are the dominant receivers of international monetary policy shocks. Interestingly enough, international monetary policy shocks originating from the

US are the largest during the zero lower bound and the related unconventional monetary policy actions era, indicating potential gains from monetary policy coordination.

While we restricted ourselves to the analysis of monetary policy spillovers across four developed economies only, as part of future research, it would be interesting to analyze the spillovers across a larger set of developed and developing countries.

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Figure 1: Shadow short rates

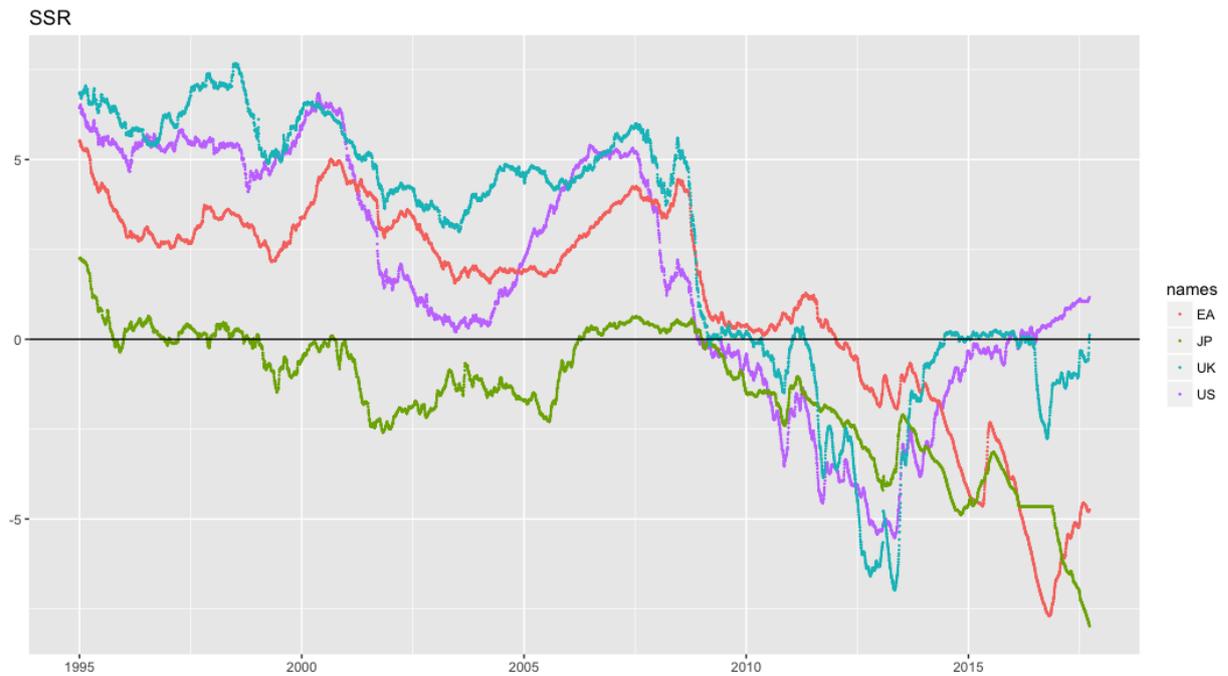


Figure 2: First difference of shadow short rates

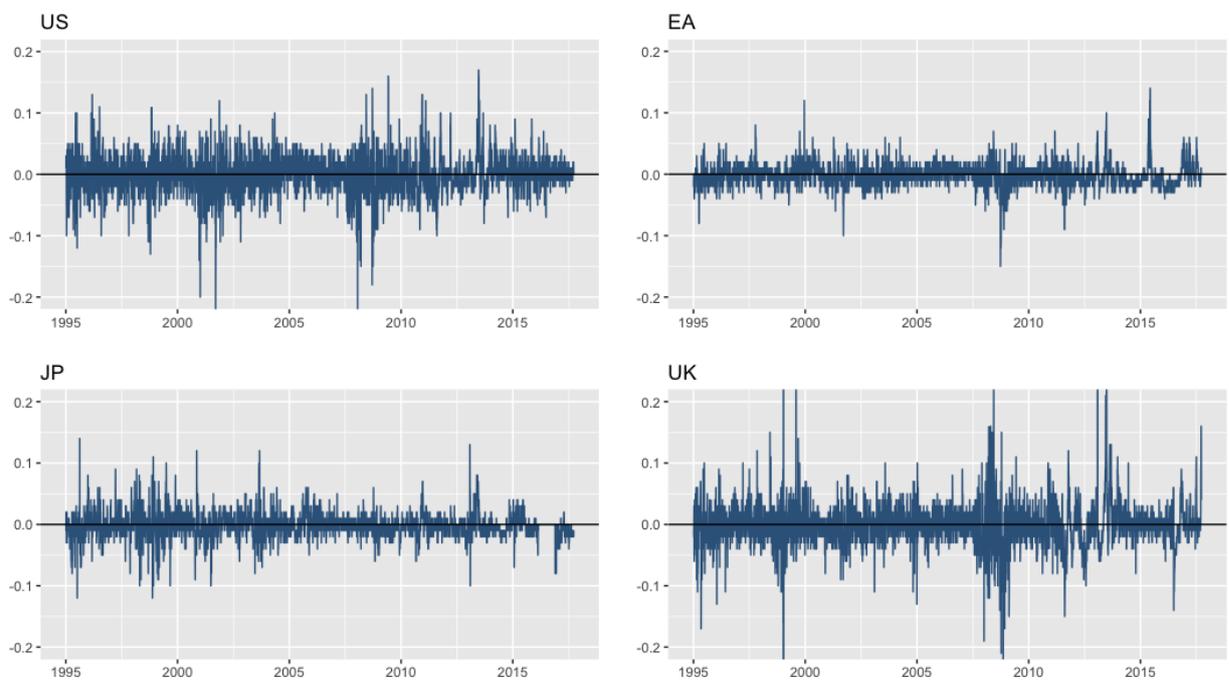


Figure 3: Total connectedness

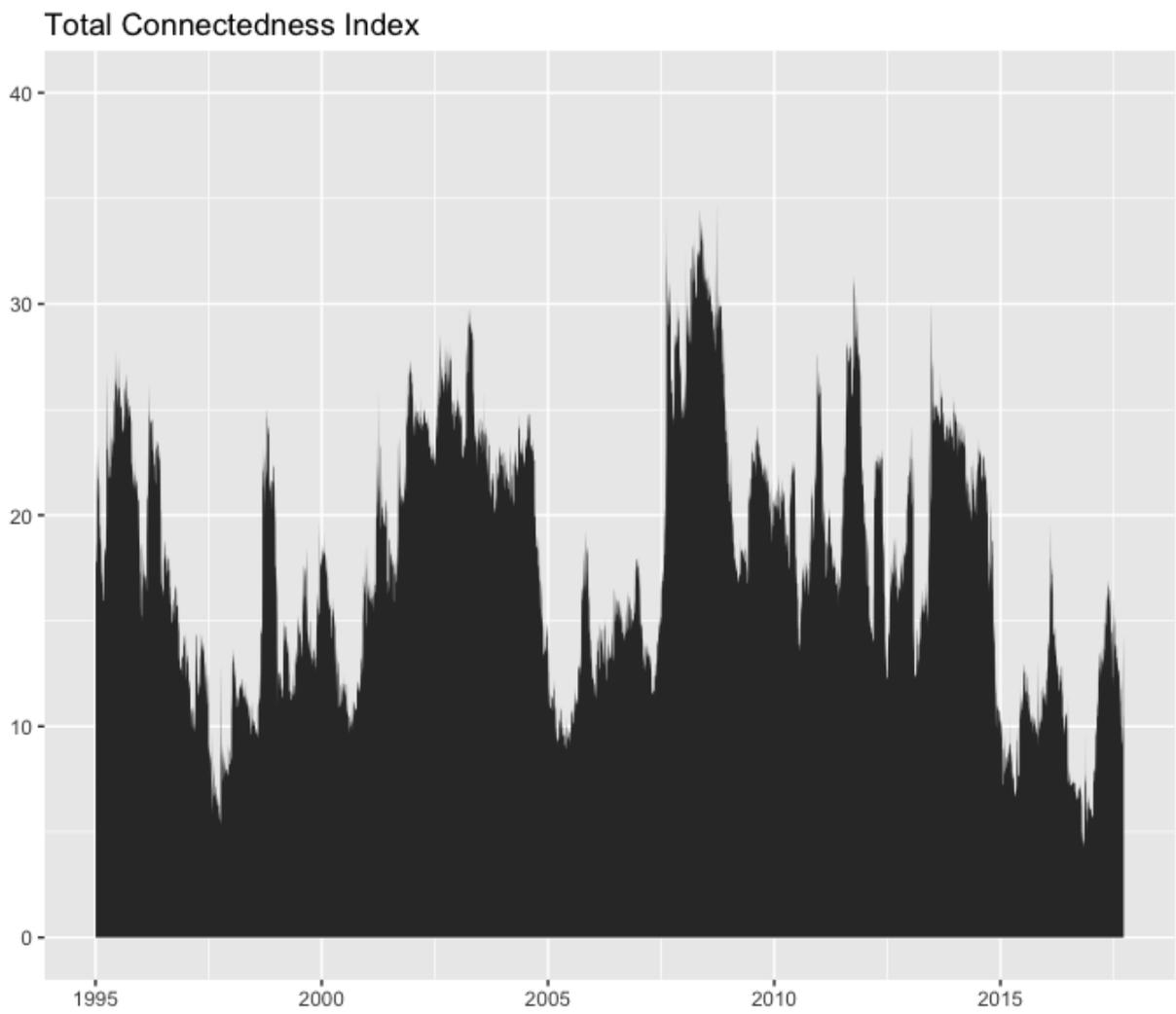


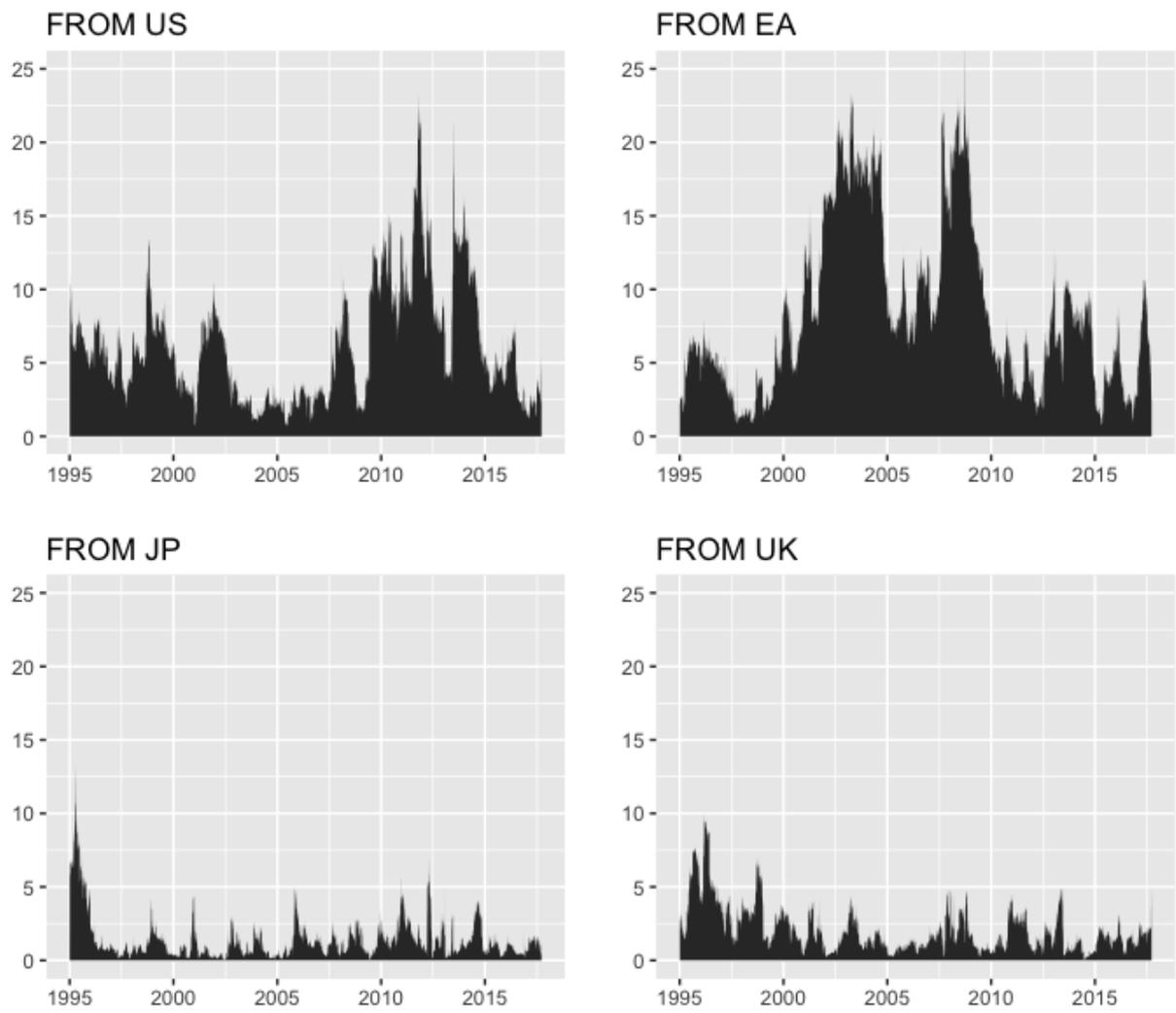
Figure 4: Directional connectedness *from* country i to others

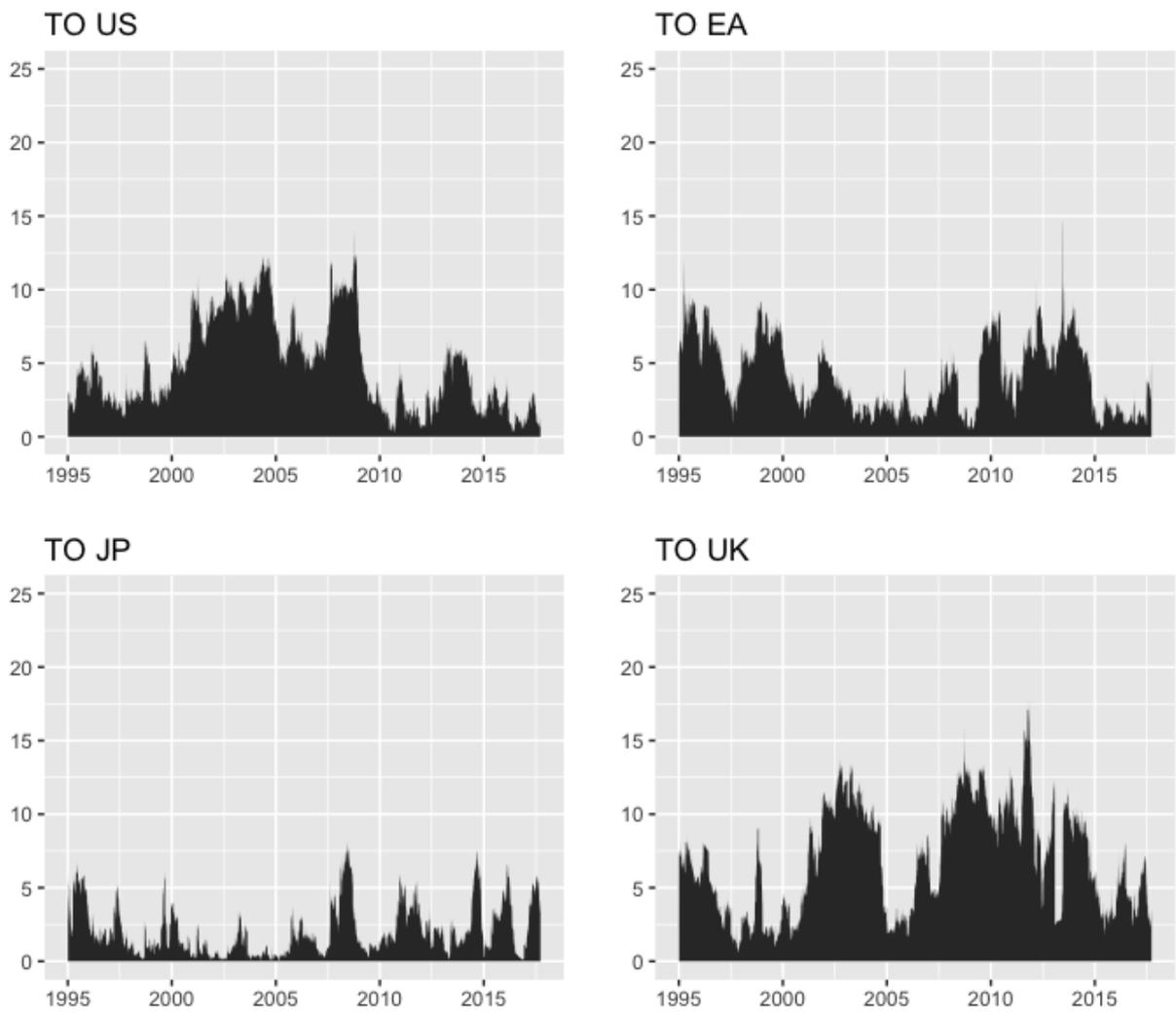
Figure 5: Directional connectedness *to* country *i* from others

Figure 6: Net directional connectedness

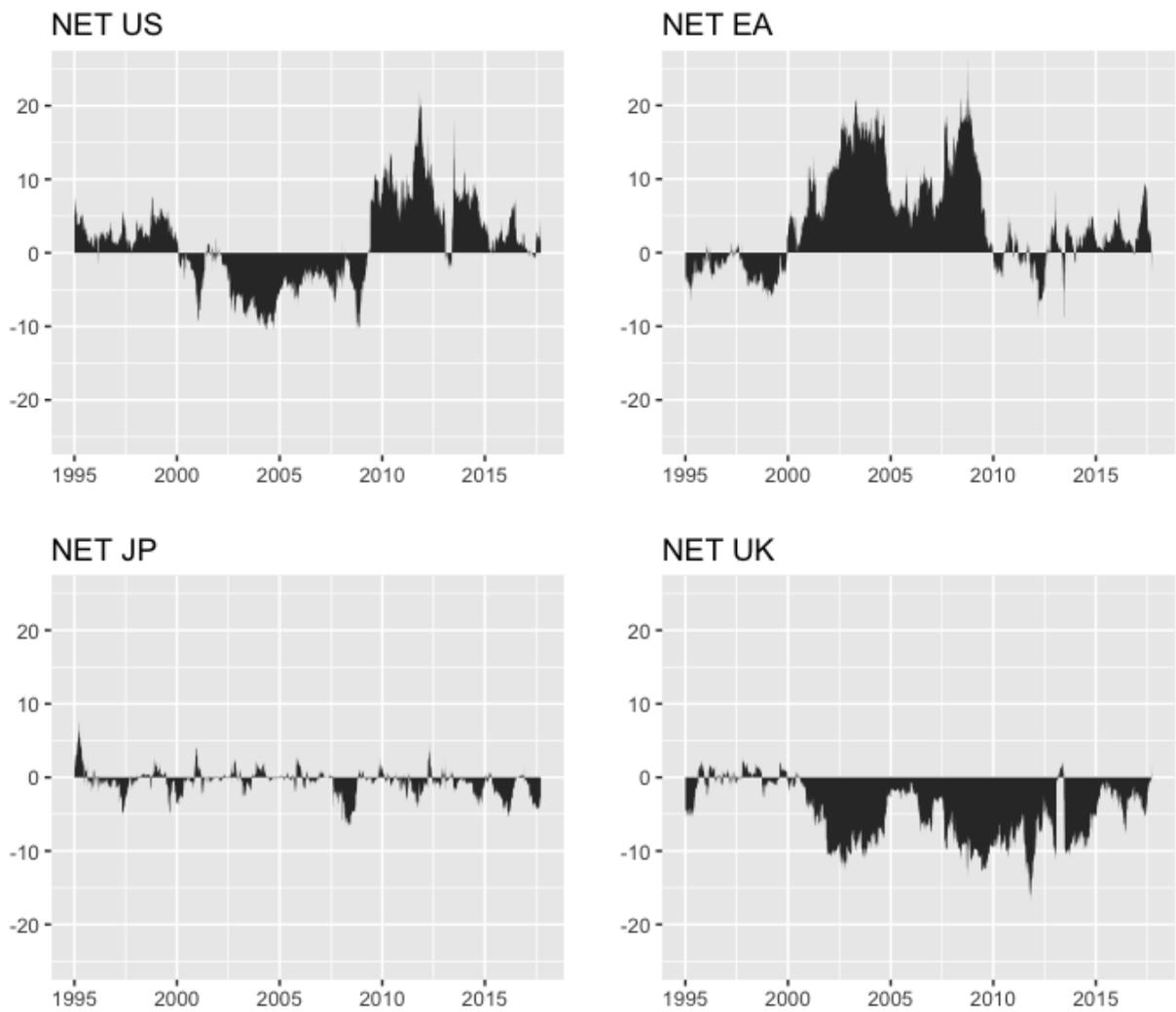


Figure 7: Net pairwise directional connectedness

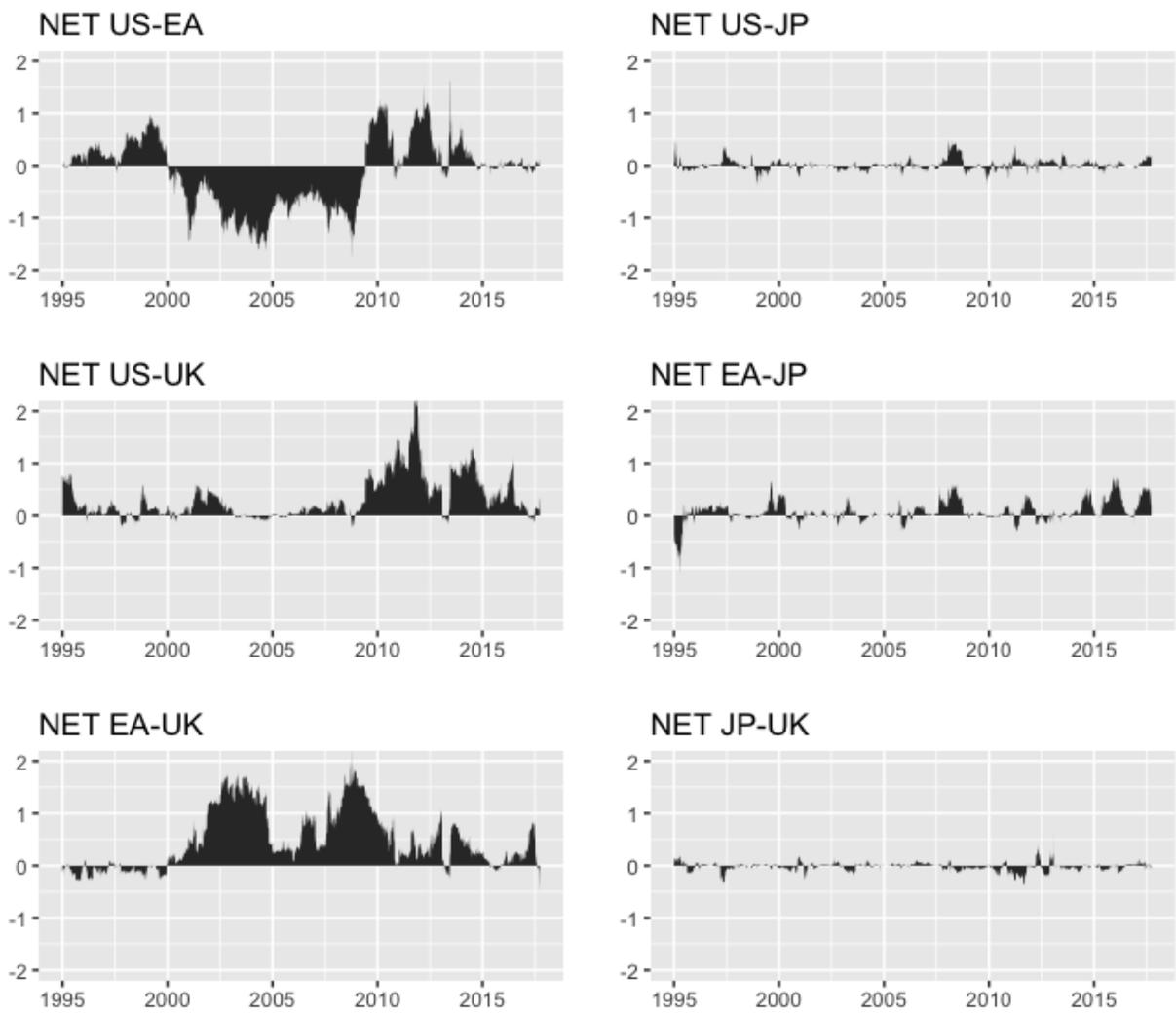


Table 1: Descriptive statistics

	US	EU	JP	UK
Mean	-0.001	-0.002	-0.002	-0.001
Variance	0.001	0.0003	0.0004	0.001
Skewness	-0.183***	0.405***	0.374***	0.861***
Kurtosis	7.194***	8.914***	7.792***	23.563***
JB	4,377.7***	8,799.2***	5,809.1***	105,151.7***
ERS	-22.071***	-16.339***	-22.306***	-20.649***
$Q(10)$	4,359.604***	12,296.500***	6,850.743***	5,442.093***
$Q^2(10)$	2,559.140***	8,567.538***	3,513.103***	2,397.681***

Note: Q and Q^2 are Ljung-Box statistics. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 2: Dynamic connectedness table

To (i)	From (j)				FROM
	US	EU	JP	UK	
US	80.3	14.3	1.7	3.7	19.7
EU	10.7	83.6	2.6	3.2	16.4
JP	2.1	4.4	91.9	1.7	8.1
UK	11.0	15.3	1.0	72.7	27.3
Contribution TO others	23.8	33.9	5.3	8.5	71.5
Contribution including own	104.1	117.5	97.2	81.2	TCI
Net spillovers	4.1	17.5	-2.8	-18.8	17.9

Table 3: Dynamic connectedness table - Conventional versus unconventional monetary policy

Panel A: Conventional monetary policy era (02.01.1995-30.11.2008)					
To (<i>i</i>)	From (<i>j</i>)				FROM
	US	EU	JP	UK	
US	74.4	19.2	1.6	4.7	25.6
EU	9.1	84.0	2.8	4.1	16.0
JP	2.0	3.8	92.9	1.3	7.1
UK	6.9	16.9	0.8	75.4	24.6
Contribution TO others	17.9	39.9	5.2	10.1	73.2
Contribution including own	92.4	124.0	98.2	85.5	TCI
Net spillovers	-7.6	24.0	-1.8	-14.5	18.3

Panel B: Unconventional monetary policy era (01.12.2008-22.09.2017)					
To (<i>i</i>)	From (<i>j</i>)				FROM
	US	EU	JP	UK	
US	89.6	6.6	1.9	1.9	10.4
EU	13.2	82.9	2.3	1.7	17.1
JP	2.3	5.2	90.3	2.2	9.7
UK	17.6	12.7	1.3	68.5	31.5
Contribution TO others	33.0	24.5	5.4	5.9	68.8
Contribution including own	122.6	107.3	95.7	74.3	TCI
Net spillovers	22.6	7.3	-4.3	-25.7	17.2