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Comparing U.S. and European Market Volatility Responses to Interest Rate Policy Announcements

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ABSTRACT

We examine the response of U.S. (VIX) and German (VDAX) implied volatility indices to the announcement of interest rate policy decisions by the Federal Open Market Committee (FOMC) and the European Central Bank (ECB). We confirm prior findings that VIX declines on FOMC meetings days. We present new findings that indicate that VDAX declines on FOMC meeting days, but is not related to ECB meeting days. VIX is unrelated to ECB meeting days. Taken collectively, our results indicate a prominent position for the FOMC in determining uncertainty levels both domestically and abroad relative to no relation between uncertainty levels and the ECB.

JEL classification: G14, E44

Keywords: FOMC, ECB, VIX, VDAX, Monetary policy, Volatility spillover

I. Introduction

Central bank communication has received much attention from researchers and the popular press. Interest rate decisions are of particularly noteworthy given their far-reaching effects. While the relation between central bank communication and the equities market has received considerable focus, relatively little is known about the relation of communication to forward looking volatility. Option implied volatility allows us to infer what the market expects future volatility to be. Option implied volatility indices are frequently described as uncertainty or fear indices. VIX has been linked to “fear” Whaley (2009) and has been used to measure uncertainty in Nikkinen et al. (2007) and Bialkowski et al. (2008). Nikkinen and Sahlstrom (2004), Chen and Clements (2007), Vahamaa and Aijo (2011) and Krieger et al. (2012) document VIX declines on FOMC (Federal Open Market Committee) meeting days in the U.S. market and conclude that FOMC meetings are generally uncertainty resolving, rather than uncertainty creating. However, the impact of other, non-U.S., central bank communications on volatility is unaddressed by the previous literature. Similarly, the literature has not addressed cross-border volatility responses to foreign central bank announcements. We consider these issues in this paper by examining similarly constructed volatility indices in the U.S. and Germany and scheduled rate decisions by the FOMC and ECB (European Central Bank).

Our results confirm previous work finding that FOMC meeting days are uncertainty resolving in the U.S. as VIX drops on scheduled meeting days. Counter to this result, however, we find that ECB meeting days do not impact the German implied volatility index (VDAX). In short, ECB rate decisions neither create nor resolve uncertainty locally. ECB meeting days are unrelated to VIX indicating that ECB rate decisions are not related to uncertainty in U.S. markets

either. Conversely, in our cross-border analysis, we find that FOMC meeting days do, in fact, appear to resolve uncertainty in German markets as VDAX declines on meeting days.

Our paper adds to the discussion on central bank communication and forward looking volatility. We are the first, to our knowledge, to document the lack of relation between ECB meetings and local volatility as well as the volatility reduction of FOMC meetings in European markets (i.e., Germany). The results suggest that the ECB and FOMC differ in terms of the market response to their interest rate decisions. This may be due to factors discussed in more detail later including differences in meeting frequency and generally more neutral tone of ECB meetings relative to FOMC meetings.

The paper proceeds as follows. Section II reviews the literature and develops hypotheses, Section III discusses data and methodology, Section IV discusses the results and Section V concludes.

II. Literature Review and Hypotheses

There is substantial literature that establishes a relation between FOMC announcements and U.S. financial markets. For instance, Bomfim (2003), Wang et al. (2006), Basistha and Kurov (2008), Chulia et al. (2010), and Kurov (2010) find stock market return and volatility reactions to central bank communications. More related to our focus, recent literature has documented the relation between FOMC scheduled meetings and VIX changes. Nikkinen and Sahlstrom (2004), Chen and Clements (2007), Vahamaa and Aijo (2011) and Krieger et al. (2012) find evidence of VIX declines following FOMC announcements. However, the focus and approach of the papers differ. Vahamaa and Aijo (2011), for instance, conclude that positive rate surprises are uncertainty inducing while negative surprises resolve uncertainty. Krieger et al. (2012) find that VIX declines on FOMC meeting days, regardless of pre-meeting VIX levels or the nature of the

FOMC's decision (increase, decrease, or no change to rates). Further, Krieger et al. (2012) provide evidence that the VIX decline on FOMC meeting days is not mechanically due to high volatility meeting days dropping from the VIX calculation. This is consistent with Ederington and Lee (1996) who suggest that scheduled announcements reduce the information uncertainty of the market. Overall, the literature's impression of VIX changes on FOMC meeting days is that VIX will decline. As a starting point we begin our analysis herein by briefly reexamining the VIX-FOMC scheduled meeting relationship with the following null hypothesis.

Hypothesis 1 – VIX changes are unrelated to scheduled FOMC meeting days.

There is substantial literature that establishes a relation between ECB announcements and European-U.S. exchange rate markets. For instance, Conrad and Lamla (2010) examine the EUR-USD exchange rate response to ECB communications and find that communications about price developments is most related to movements in the exchange rate. Jansen and De Haan (2005) find that the conditional mean of the EUR-USD exchange rate is influenced by monetary policy decisions of the ECB.

However, the literature has not addressed, to the best of our knowledge, the relation between ECB meetings and implied volatility. Jiang et al. (2012) note that in a single-country setting the effect of news announcements on implied volatility depends on whether the release is scheduled or unscheduled. The sample in their analysis includes ECB meetings, but they simultaneously consider many other announcements and do not isolate ECB meetings.

To the extent that the ECB and FOMC are similar, we may expect to find European implied volatility decline on ECB meeting days. This may be due to the same type of information uncertainty resolution evidenced in the U.S. However, the ECB and FOMC may differ in key

ways and the expected relation may differ in predictable ways as we discuss in the paragraphs to follow.

There are several similarities and differences between the ECB and FOMC in terms of structure and function that may yield predictions about volatility responses to ECB meeting days. With respect to similarities, both the ECB and FOMC use the control of key interest rates to influence the macro economy in their respective geographic areas. These rate decisions typically come at scheduled meetings with dates known well in advance, and the final decision is made available to the public.¹ Both the ECB and FOMC are generally transparent in their decisions with key information released before and after each scheduled meeting. Additionally, we identify two findings from Ehrmann and Fratzscher (2007) with respect to the relation between ECB meeting days and European implied volatility. The first is the predictability result. The authors create a measure of predictability based on short-term interest rate changes on meeting days. The empirical results indicate that the FOMC and ECB interest rate decisions are equally predictable with mean meeting surprises which are not statistically significantly different from each other. To the extent that interest rate predictability and other institutional similarities drives volatility responses to central bank rate announcements, this indicates that there should be no difference in uncertainty resolution between FOMC and ECB meeting days.

Key differences between the ECB and FOMC may also be relevant to the response of European implied volatility and ECB meeting days. For instance, the second result of interest from Ehrmann and Fratzscher (2007) is related to communication. They note that the Federal Reserve is marked by communication from multiple individuals with varying opinions while the ECB follows an approach in which committee members have a high degree of consistency in

¹ Both the ECB and FOMC use unscheduled meetings in certain circumstances, the results of which are also made public.

their public comments. Moreover, the tone of public statements differs between the two central banks. Specifically, they find that ECB statements are “neutral” at nearly twice the rate of FOMC meetings (62% vs. 32%) based on a content analysis of rate decision communications.² This indicates that ECB meeting communications are less likely to reduce information uncertainty than FOMC meetings. We note that the vote of both the ECB and FOMC is nearly always unanimous, so it is in the communication that the two differ. Thus, as the extent of information provided by a meeting might drive the relation between central bank announcements and implied volatility, we would expect ECB meeting days to resolve less uncertainty than FOMC meeting days given the generally more neutral tone of ECB announcements. Additionally, there is at least one other important difference between the ECB and FOMC – meeting frequency. The FOMC is scheduled to meet 8 times a year while the ECB is scheduled to meet 12 times a year.³ The more frequent ECB meetings may be associated with less “build up” of uncertainty following the previous meeting which may make the relative importance of each individual ECB meeting less meaningful than a given FOMC meeting. This would suggest a weaker relation between uncertainty resolution and ECB meetings. We test the following hypothesis which we interpret based on the discussion of ECB and FOMC similarities and differences, including predictability and communication above.⁴

Hypothesis 2 - VDAX changes are unrelated to scheduled ECB meeting days.

² For instance, ECB communication often notes that rates are “appropriate” which is interpreted by Ehrmann and Fratzscher (2007) as neutral.

³ Technically, the ECB is scheduled to meet twice a month but the rate decision is usually only taken at the first meeting. In the early years of the ECB, rate decisions were made more frequently.

⁴ There are, of course, many other similarities and differences between the ECB and FOMC not discussed here. We have included those areas which we believe are most likely to be related to the response of the market with respect to volatility.

While domestic responses to central bank announcements have received some attention in the literature, considerably less focus has been given to the potential of a spillover effect into other markets beyond home country. Specifically, it is unclear what, if any, relation exists between FOMC meetings and *European* financial markets or between ECB meetings and *U.S.* markets. We offer predictions and hypotheses for these issues, which to our knowledge have been heretofore unaddressed.

Although the literature from central bank announcement effects is silent, Jiang et al. (2012) examine volatility spillover between Europe and the U.S. more generally. They also test if controlling for various announcements eliminates the observed spillover. Their results indicate positive volatility spillover from the U.S. into Germany, but the reverse is not true (i.e., German volatility does not spillover into the U.S.). Specifically, they find that lagged daily VIX changes are related to present daily VDAX changes. Further, they find that aggregate scheduled (unscheduled) news events do not (do) affect VIX or VDAX and the spillovers remain after controlling for news. To the extent that central bank rate decisions are similar to other announcements, we might then expect no relation between scheduled FOMC meetings and German implied volatility or between scheduled ECB meetings and U.S. implied volatility.

However, Ehrmann and Fratzscher (2005) find that European interest rates react to U.S. macroeconomic and monetary policy news and vice versa. This relation strengthened in the last five years of their sample ending in 2003. They attribute the strong spillover to “increased real integration of the two economies” and note that the U.S. news is generally released before European news which creates a leading indicator relation for U.S. news releases. Additionally, earlier findings in domestic markets (Nikkinen and Sahlstrom (2004), Chen and Clements (2007), Vahamaa and Aijo (2011) and Krieger et al. (2012)) indicate that even scheduled

monetary policy meetings move volatility. Furthermore, Lucca and Moench (2011) find that the return of the DAX equity index is 43 basis points higher on FOMC meeting days than on other days. Thus, it appears possible that FOMC meeting days may indeed affect German markets and vice versa. We investigate the international relationships regarding market volatility and scheduled central bank rate announcements.

Hypothesis 3 - VIX changes are unrelated to scheduled ECB meeting days.

Hypothesis 4 - VDAX changes are unrelated to scheduled FOMC meeting days.

III. Data and Methodology

Our sample covers the period from January of 1999 through December of 2012. The range of this sample is dictated by the fact that the ECB did not issue interest rate decisions prior to January of 1999. We identify FOMC⁵ and ECB⁶ meeting days and interest rate decisions from the organizations' respective websites. During the period examined, there are 112 scheduled FOMC meeting dates and 204 scheduled ECB meeting dates. We obtain historical VIX data from the Chicago Board Options Exchange website.⁷ Historical VDAX data is from the website of Deutsche Borse.^{8,9} Both VIX and VDAX are calculated as the implied 30 day volatility of the underlying index (S&P 500 and DAX) which makes direct comparison possible. Although other European implied volatility indices have been created, the VDAX has been in existence since the start of the ECB in 1999 and has been the focus of prior European research.¹⁰

⁵ <http://www.federalreserve.gov/monetarypolicy/fomccalendars.htm>

⁶ <http://www.ecb.europa.eu/press/govcdec/mopo/previous/html/index.en.html>

⁷ <http://www.cboe.com/micro/vix/historical.aspx>

⁸ <http://www.boerse-frankfurt.de/en/equities/indices/vdax+new+DE000A0DMX99>

⁹ We focus on German volatility as the data is available from the first ECB meeting through the present period.

¹⁰ See for example, Jiang et al. (2012) and Lucca and Moench (2011).

Our initial analysis focuses on changes in VIX and VDAX on FOMC and ECB meeting days. Our formal test of the relation between scheduled central bank meetings and implied volatility is in the form of a seemingly unrelated VAR(1) regression. Our model is based on that of Jiang et al. (2012) who examine volatility spillover between the U.S. and Europe. However, unlike Jiang et al. (2012), the focus of our paper is on scheduled central bank meetings only, as opposed to many general news releases and the differences between scheduled and unscheduled meetings. We first estimate the following equation which establishes the volatility spillover results:

$$\Delta IV_t = C + \varphi \Delta IV_{t-1} + \mu_t, \quad (1)$$

where $\Delta IV_t = IV_t - IV_{t-1}$ is a (2 x 1) vector of changes in the implied volatility indices for the U.S. and Germany, C is a vector of constants, and φ is a (2 x 2) matrix of coefficients. We generalize equation (1) to include indicator variables for FOMC and ECB meeting days. This generalized model allows us to test the relation between scheduled FOMC and ECB meeting days and implied volatility in the U.S. and Germany while controlling for volatility spillover.

As part of our analysis, we also consider whether the responses of volatility indices to scheduled announcements of interest rate policy are driven by whether the contents of the announcements are expected or unexpected. In doing so, we seek to better delineate whether the clarity provided by the announcement or the specific policy announced is more tantamount. In order to proceed, we utilize the surprise element of Fed Funds rate announcements developed by Krueger and Kuttner (1996), Kuttner (2001), and Soderstrom (2001).

To construct this surprise element we consider an FOMC meeting taking place on day d of month m . The unexpected Fed Funds rate target is calculated from the change in the rate implied by the current-month futures contract as:

$$\Delta i^u = \frac{D}{D-d} (f_{m,d}^0 - f_{m,d-1}^0) \quad (2)$$

where Δi^u is the unexpected target rate change, D is the number of days in the month, and $f_{m,d}^0$ is the current-month futures rate. The expected component of the rate change is then calculated as the actual change less the surprise target funds rate change:

$$\Delta i^e = \Delta i - \Delta i^u \quad (3)$$

The 30-day federal funds futures data we use are from 1999 to 2012. For each scheduled FOMC meeting day we calculate the expected and unexpected component of the Fed Funds target rate movement. We extract the data from the futures prices of *The Wall Street Journal* archives. The sample includes 112 scheduled FOMC meetings.

IV. Results

We first identify changes of the VIX and VDAX volatility indices on scheduled FOMC and ECB meeting days. Panel A of Table 1 presents the mean and median change in VIX and VDAX on scheduled FOMC meeting days. We test the two-tailed hypotheses that each index's change on scheduled meeting days is equal to zero over the period of January 1999 to December 2012. The results suggest that VIX declines on scheduled FOMC meeting days (significant at the 1% level). The mean raw (percentage) change in VIX level is -0.703 (-2.78%) and the median change is -0.540 (-2.57%). Thus, based on these preliminary tests, we reject null Hypothesis 1. These results are consistent with Nikkinen and Sahlstrom (2004), Chen and Clements (2007), Vahamaa and Aijo (2011) and Krieger et al. (2012) who document VIX declines on FOMC meeting days.

[Insert Table 1 Here]

Interestingly, the results in Panel A of Table 1 indicate that VDAX also declines on scheduled FOMC meeting days. The mean (median) change is significant at the 10% (5%) level given a two-sided test. The mean and median raw VDAX changes are -0.225 and -0.230, respectively, while the mean and median changes, in percentage terms, are -0.72% and -1.03%, respectively. Thus, we have evidence to reject null Hypothesis 3. We are the first, to our knowledge, to document the specific decline in foreign market volatility (VDAX) on FOMC meeting days. Lucca and Moench (2011) focus on the German equity market (DAX), rather than on implied volatility, and find that the DAX sees higher returns on FOMC meeting days than non-meeting days. Our results indicate that FOMC meetings are associated with a reduction of German information uncertainty (i.e., lower expected future volatility) as well.

The decline in VDAX on FOMC meeting days in Panel A of Table 1 is not as strong or consistent as the drop in VIX on FOMC meeting days. For instance, the VIX declines about 75% of the time on FOMC meeting days (83 out of 112) whereas the VDAX declines only about 60% of the time on FOMC meeting days (67 out of 112). The economic and statistical significance of the VDAX decline is also not as strong as that of VIX. Collectively, this unsurprisingly suggests that FOMC meeting days are more strongly linked with information uncertainty reduction in the U.S. relative to Germany. Yet, the existence of uncertainty reduction in Germany on FOMC meeting days is still a compelling result. Similar to Ehrmann and Fratzscher (2005) who find that the money markets of the U.S. and Europe are interdependent, our results indicate a strong link between U.S. monetary policy and the German economy.

Panel B of Table 1 presents results for VIX and VDAX changes on ECB meeting days. For both the VIX and VDAX, implied volatility is statistically unrelated to ECB meeting days.

Thus, the ECB does not appear to reduce uncertainty in either the German or U.S. market and our evidence fails to support rejection of null Hypotheses 2 and 4. The difference between implied volatility reactions for the FOMC and ECB may be due to differences in the way the two groups operate. The results are inconsistent with the predictability findings from Ehrmann and Fratzscher (2007) who find that the FOMC and ECB are similarly predictable. This similarity would suggest no difference in uncertainty resolution between FOMC and ECB meeting days. Our results are more consistent with the communication result of Ehrmann and Fratzscher (2007). They find that 62% of all ECB statements are “neutral” while only 32% of all FOMC statements were “neutral.” The higher frequency of ECB interest rate decision related meetings may also drive volatilities lack of response to such decisions. Overall, the lack of VIX response to ECB meetings is not surprising given that the literature has found that U.S. news in general drives European markets more than the other way around (Ehrmann and Fratzscher, 2005, and Jiang et al., 2012). However, the lack of VDAX response to ECB is somewhat unexpected. The literature generally finds that ECB communications warrant a response in European markets (i.e., Conrad and Lamla, 2010 who find exchange rate reaction to ECB meetings).

Table 2 sorts meeting days based on the VIX and VDAX levels at the time of the scheduled FOMC and ECB meeting days. Relatively higher implied volatility indices are related to higher levels of uncertainty. During periods which experience higher levels of uncertainty, the possibility of greater uncertainty reduction following FOMC and ECB meetings exists. Consistent with Krieger et al. (2012) we find that VIX declines on FOMC meeting days are more extreme when VIX is higher. ECB meeting influence on VIX is not systematically related to the level of VIX at the time of the meetings. This is consistent with the insignificant relation between VIX and ECB meetings in Table 1.

Table 2 also shows that VDAX declines on FOMC meeting days regardless of the pre-FOMC VDAX level. The response, however, is not systematically greater for higher levels of VDAX. Overall, the results are consistent with FOMC meetings reducing information uncertainty in the German market. Finally, the direction and magnitude of VDAX changes on ECB meeting days is not consistent with any trend. This is consistent with the lack of a significant relation in Table 1. Here and throughout Table 2 we do not provide tests of statistical significance given that the sample is split into small samples.

[Insert Table 2 Here]

Table 3 shows the results for the VAR(1) model in equation (1). This model controls for volatility spillover between the U.S. and German market identified in Jiang et al. (2012). Panel A of Table 3 recreates the basic volatility spillover result from that paper. We confirm that lagged VIX is positively related to contemporaneous VDAX, which indicates volatility spillover from the U.S. to Germany. We further confirm the absence of volatility spillover from Germany to the U.S.

In Panel B of Table 3 we add indicator variables for FOMC and ECB meeting days. The results indicate that FOMC meeting days are associated with a decline in VIX (significant at the 1% level). This is consistent with Table 1 and the prior literature. FOMC meeting days are also associated with a decline in VDAX (significant at the 10% level). This is consistent in sign and significance with Table 1 as well and indicates that FOMC meeting days reduce German market information uncertainty. The ECB meeting day indicator is not significantly related to changes in either VIX or VDAX.

[Insert Table 3 Here]

The results above do not consider the content of the central bank meeting, simply its occurrence. In Table 4 we isolate the changes in VIX and VDAX relative to the content of the rate decision of the ECB and FOMC (i.e., increase, decrease, or no change). In Panel A of Table 4 we find that VIX declines on FOMC meeting days regardless of the content of the meeting. Similarly, VDAX declines on FOMC meeting days regardless of the content of the meeting. While they do not isolate FOMC meeting announcements our results are inconsistent with Jiang et al. (2012) who find that implied volatility declines only on scheduled information release days from the U.S. to Europe. Our results suggest this does not depend on the content of the meeting. Here and throughout Table 4 we do not provide tests of statistical significance as the subsamples created are small and the tests would have a considerable lack of power.

Panel B of Table 4 presents results for VIX and VDAX changes on ECB meeting days. Consistent with results in Tables 1 and 3 there is no identifiable relation between ECB meeting days and VIX changes. The results for VDAX changes on ECB days indicate that ECB meetings are generally uncertainty reducing when rates decline or are unchanged (declines 58% and 59% of the time, respectively) and are uncertainty inducing when rates increase (increases 54% of the time). Thus, unlike the relation between the FOMC and VIX which is not dependent on the content of the meeting, the relation between the ECB and VDAX is contingent on the rate decision.

[Insert Table 4 Here]

Jiang et al. (2012) focus on scheduled vs. unscheduled news in their study of volatility spillover between the U.S. and Europe. The motivation for this analysis is that surprise information is more likely to be reflected in volatility indices than non-surprise information. Their results confirm this reasoning. However, in the context of central bank meetings, Krieger

et al. (2012) document that the VIX declines on FOMC meetings days regardless of whether or not the results of those meetings is a surprise. Additionally, Vahamaa and Aijo (2011) emphasize the surprise component of FOMC meetings in their analysis. In Table 5, we generalize this analysis to include VDAX responses to FOMC meetings based on surprise. Given that the ECB meetings were unrelated to VIX or VDAX, we focus only on FOMC meetings for this analysis.

[Insert Table 5 Here]

In Table 5 we confirm the results of Krieger et al. (2012) in that VIX declines (statistically significant) on all categories of surprise for FOMC meetings. The economic magnitude of the decline is indeed greater for surprise meetings however. Like the VIX, mean and median VDAX show declines on all categories of surprise for FOMC meetings. However, median (mean) declines are only statistically significant for no surprise (negative surprise only) meetings. This suggests that the relation between VDAX and FOMC meetings is more sensitive to the content of the meeting than the relation between VIX and FOMC meetings. Nonetheless, the sign of the VDAX changes is negative for all groups and the surprise groups have relatively small samples (i.e., 25 observations for the non-significant positive surprise group).

Ehrmann and Fratzscher (2005) note that the interdependence between U.S. and European interest rates strengthened very late in their sample, which ended in 2003. They also concluded that one likely source for interdependence was due to increasingly interdependent economies related to globalization. In Table 6, we generalize this idea to our particular focus. Specifically, we split our sample into three groups based on the period examined (1999-2002, 2003 to 2007, and 2008 to 2012) and examine VIX and VDAX changes on FOMC meeting days in each period. As in Table 5, we focus only on FOMC meeting days given the lack of relation between implied volatility and ECB meeting days observed in earlier tables.

[Insert Table 6 Here]

The results in Table 6 indicate that VIX declines on FOMC meeting days in all sub-periods examined. The economic significance is roughly double in the most recent period. This is likely due to the financial crisis which overlaps the 2008-2012 period.¹¹ The results for VDAX changes on FOMC meetings days by sub-period reveal two interesting findings. First, during the earliest period examined (1999-2002) VDAX actually increases on FOMC meeting days. Although the result is not statistically significant, VDAX increases for 24 of 37 (65%) of meetings during this period. Second, VDAX declines on FOMC meeting days in the most recent sub-periods. This result is statistically significant in median (mean) results for both groups (2003-2007 only). In both the 2003-2007 and 2008-2012 period, VDAX declines on 27 of the 40 FOMC meeting days. Overall, the results suggest that as the economies of the U.S. and Germany have become relatively more interdependent, the FOMC has played an increasing role in the dynamics of German implied volatility.

V. Conclusion

We consider the similarities and differences between the volatility responses by U.S. and European markets to news of governmental interest rate policy. We determine that market volatility tends to decline when scheduled interest rate policy announcements are made in the U.S. This is the case regardless of whether (and to what degree) the announcement actually releases unexpected information. This effect has remained consistent for a number of years.

There are significant differences between U.S. and European effects, however. Both U.S. and European market volatility levels decline substantially in response to U.S. interest rate policy

¹¹ This is consistent with Krieger et al. (2012) who find that VIX declines are economically larger when VIX levels prior to the meeting are relatively higher.

announcements (FOMC meetings) but do not respond to ECB meeting announcements. The U.S. market volatility measure, VIX, is more responsive to U.S. interest rate policy announcements, but there is a spillover effect into the German market volatility measure, VDAX, which serves as a European proxy.

Our conjecture is that U.S. FOMC meetings provide more uncertainty resolution than the corresponding European ECB meetings, and thus market volatility is reduced to a greater degree in response. This may be due to the less neutral tone of typical announcements of FOMC meetings or the market's relative attentiveness to U.S. interest rate policy, even in Europe.

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Table 1 VIX and VDAX changes on schedule FOMC and ECB meeting days

This table presents changes in the VIX and VDAX levels on the day of scheduled FOMC and ECB meetings. Changes in the absolute level in VIX and VDAX, as well as the percentage changes relative to the previous day are reported. The sample period is 1999-2012. T-test results of the mean change and sign-rank tests of the median change are reported. ***, **, and * denote statistical significance at the 1%, 5%, and 10%, respectively.

	Mean Change	Median Change	Mean % Change	Median % Change
Panel A: 112 scheduled FOMC meetings from January 1999 to December 2012				
VIX	-0.703***	-0.540***	-2.78%***	-2.57%***
t-stat	(-4.05)		(-4.85)	
VIX increases	29			
VIX decreases	83			
VDAX	-0.225*	-0.230**	-0.72%*	-1.03%**
t-stat	(-1.89)		(-1.86)	
VDAX increases	45			
VDAX decreases	67			
Panel B: 204 scheduled ECB meetings from January 1999 to December 2012				
VIX	0.109	-0.145	0.003	-0.008%
t-stat	(0.84)		(0.62)	
VIX increases	91			
VIX decreases	113			
VDAX	0.017	-0.210	0.001	-0.01%
t-stat	(0.12)		(0.23)	
VDAX increases	89			
VDAX decreases	115			

Table 2 Mean VIX and VDAX changes by pre-meeting level

This table presents statistics for the changes in mean VIX and VDAX levels on the day of scheduled FOMC and ECB meetings. The meeting days are sorted based on the VIX or VDAX level prior to the day of the meeting. Panel A shows results for mean VIX changes on FOMC meeting days. Panel B shows results for mean VIX changes on ECB meeting days. Panel C shows results for mean VDAX changes on FOMC meeting days. Panel D shows results for mean VDAX changes on ECB meeting days. The sample period is 1999-2012.

	Pre-FOMC meeting VIX level				
	Sub 15	15-20	20-25	25-30	over 30
Panel A: VIX changes January 1995 to December 2012					
n	24	24	33	15	16
VIX change	-0.46	-0.55	-0.56	-0.98	-1.33
VIX % change	-3.14%	-2.72%	-2.24%	-3.20%	-3.02%
	Pre-ECB meeting VIX level				
	Sub 15	15-20	20-25	25-30	over 30
Panel B: VIX changes January 1999 to December 2012					
n	35	51	57	32	29
VIX change	0.06	-0.25	-0.3	-0.07	1.94
VIX % change	0.58%	-1.04%	-1.21%	-0.15%	5.83%
	Pre-FOMC meeting VDAX level				
	Sub 15	15-20	20-25	25-30	over 30
Panel C: VDAX changes January 1995 to December 2012					
n	8	23	32	23	26
VDAX change	-0.17	-0.22	-0.07	-0.41	-0.28
VDAX % change	-1.15%	-1.12%	-0.17%	-1.26%	-0.40%
	Pre-ECB meeting VDAX level				
	Sub 15	15-20	20-25	25-30	over 30
Panel D: VDAX changes January 1999 to December 2012					
n	13	43	64	44	40
VDAX change	0.13	-0.42	-0.29	-0.05	1.04
VDAX % change	1.07%	-2.14%	-0.97%	-0.02%	2.88%

Table 3 Seemingly unrelated regressions

This table presents results from the VAR(1) model in equation (1). ΔVIX_t ($\Delta VDAX_t$) is the change in the implied VIX (VDAX) volatility index between t-1 and 5, and C is a constant. Panel A (B) presents results without (with) FOMC and ECB meeting day indicators. FOMC (ECB) indicators are equal to one on the day of a scheduled FOMC (ECB) meeting day and are zero otherwise. T-statistics are reported in parentheses and adjusted R^2 is reported. ***, **, and * denote statistical significance at the 1%, 5%, and 10% level, respectively. The model is estimated for 1999-2012.

Panel A: Volatility spillover

	ΔVIX_t	$\Delta VDAX_t$
ΔVIX_{t-1}	-0.136*** (-6.77)	0.180*** (14.30)
$\Delta VDAX_{t-1}$	0.008 (0.38)	-0.101*** (-7.49)
C	-0.002 (-0.06)	-0.034* (-1.77)
Adj. R^2	0.02	0.06

Panel B: Volatility spillover with FOMC and ECB meeting days

	ΔVIX_t	$\Delta VDAX_t$
ΔVIX_{t-1}	-0.136*** (-6.77)	0.180*** (14.31)
$\Delta VDAX_{t-1}$	0.012 (0.55)	-0.100*** (-7.44)
FOMC	-0.690*** (-4.07)	-0.198* (-1.86)
ECB	0.069 (0.54)	-0.072 (-0.90)
C	0.017 (0.53)	-0.023 (-1.15)
Adj. R^2	0.02	0.06

Table 4 Implied volatility changes relative to rate movement

This table presents frequencies of the occurrence of VIX and VDAX declines and increases, relative to the type of interest rate movements on FOMC (Panel A) or ECB (Panel B) meeting days. Mean and median VIX changes are reported for each category. The sample period is 1999-2012.

Panel A: FOMC Meeting Days

	Rate Change < 0	Rate Change = 0	Rate Change > 0
VIX fall count	11	55	17
VIX rise count	7	21	6
Mean VIX change	-0.840	-0.716	-0.557
Median VIX change	-0.410	-0.620	-0.470
VDAX fall count	9	45	13
VDAX rise count	9	31	10
Mean VDAX change	-0.547	-0.170	-0.145
Median VDAX change	-0.100	-0.310	-0.130

Panel B: ECB Meeting Days

	Rate Change < 0	Rate Change = 0	Rate Change > 0
VIX fall count	10	88	15
VIX rise count	9	69	13
Mean VIX change	-0.193	0.1002	0.383
Median VIX change	-0.01	-0.16	-0.23
VDAX fall count	11	93	13
VDAX rise count	8	64	15
Mean VDAX change	-0.253	-0.059	0.6485
Median VDAX change	-0.3	-0.24	0.14

Table 5 Implied volatility changes relative to surprise

This table presents frequencies of the occurrence of VIX and VDAX declines and increases, relative to the surprise of the FOMC meeting. Mean and median VIX and VDAX changes are reported for each category. Significance levels for statistical tests of VIX and VDAX changes are reported based on two-sided tests (t-test for means, sign-rank test for medians). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The sample period is 1999-2012.

	Surprise < 0	Surprise = 0	Surprise > 0
VIX Fall Count	22	42	18
VIX Rise Count	6	17	7
Mean VIX Change	-0.914***	-0.647***	-0.601*
Median VIX Change	-0.805***	-0.500***	-0.520*
VDAX Fall Count	14	39	14
VDAX Rise Count	14	20	11
Mean VDAX Change	-0.435*	-0.099	-0.288
Median VDAX Change	0.020	-0.280*	-0.440

Table 6 Implied volatility changes by period on FOMC meeting days

This table presents frequencies of the occurrence of VIX and VDAX declines and increases on FOMC meeting days, for three different sub-periods of our sample. Mean and median VIX and VDAX changes are reported for each category. The full sample period is 1999-2012. T-test results of the mean change and sign-rank tests of the median change are reported. ***, **, and * denote statistical significance at the 1%, 5%, and 10%, respectively.

	1999-2002	2003-2007	2008-2012
VIX Fall Count	25	28	29
VIX Rise Count	7	12	11
Mean VIX Change	-0.525***	-0.544**	-1.006**
Median VIX Change	-0.540***	-0.420***	-0.790***
VDAX Fall Count	13	27	27
VDAX Rise Count	24	13	13
Mean VDAX Change	0.153	-0.384***	-0.369
Median VDAX Change	0.175	-0.345***	-0.455*