Who Holds the Ball? Asynchronous Monetary Policy Normalization in Systemic Economies and the Yield Curve

Karlye Dilts Stedman*

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Preliminary draft. Please do not circulate.

1 Introduction

"The ECBs announcement that it would start full-scale quantitative easing in March had an impact well beyond the markets immediately affected . . . That yields in both the US and the euro area declined despite diverging monetary policies in those economies points at possible spillover effects from European bond markets to those in the US." - BIS March 2015

While the US is normalizing monetary policy (raising interest rates away from the zero lower bound), the European Central Bank (ECB) and Bank of Japan (BOJ) are continuing to pursue quantitative easing (QE) more aggressively than in the past. The former is raising short term rates, while the latter appears to be driving long term bond yields down, generating an inversion of the yield curve, which is often thought to be a sign of future recession and/or volatility. Unconventional monetary policy (UMP) was intended to lower the interest rates on long maturity interest assets in the United States. Keeping these long rates low over long stretches of time may contribute to the build up of vulnerabilities such as excessive leveraged positions and credit risk, and a reversal of expectations can then trigger an increase in volatility. Can the Fed actually "undo" QE as long as large, systemic economies such as the Euro zone and Japan are aggressively pursuing QE?

The object of this paper is to assess the extent to which ongoing QE in the Euro zone and Japan lowers the term premium, and thus longer duration bond yields, in the United States. Using financial futures data in a regression framework represents an improvement over event-dummies in the sense that we get a time varying measure of policy intensity, without the cumbersome timing restrictions required by more structural approaches such as structural vector autoregression. Moreover, the literature largely ignores the use of financial data to identify

*Ph.D. student at the Department of Economics, University of North Carolina at Chapel Hill. E-mail: kdilts@live.unc.edu

monetary policy shocks emanating from the Euro Zone or Japan, specifically. Relatedly, the extant literature on spillovers from other advanced economies to the United States is nascent, due in part to the United States historical imperviousness to international news shocks (Ehrmann and Fratzscher, 2005). Preliminary results indicate that the period of asynchronous exit from zero interest rates represents a deviation from this trend.

The paper proceeds as follows. Section 2 presents stylized facts from the data, highlighting divergent trends in Federal Reserve, European Central Bank (ECB) and Bank of Japan (BOJ) monetary stances and asset price movements. Section 3 reviews the literature on international news, asset price determination and spillovers from unconventional monetary policy between systemic advanced economies (SAEs). Section 4 provides preliminary evidence on spillovers from monetary policy shocks emanating from the ECB to United States bond prices. Section 5 concludes, setting forth future avenues for research.

2 Motivation and literature

[DRAFT]

3 Preliminary Results

3.1 Data

Daily estimates of the expected short rate and the term premium are from Kim and Wright (2005). [1] We use daily data on zero coupon bond yields primarily from Gürkaynak, Sack and Wright (2006) [2] All remaining data come from Bloomberg. Our sample runs from August 30, 2006 to September 30, 2016. Table 1 contains summary statistics for our variables of interest.

To control for policy news emanating from systemic economies other than the monetary policy source country in our main regressions, we use the Citigroup Economic Surprise Index (CESI), which tracks how economic data compare to expectations. The index rises when economic data exceed economists consensus estimates (i.e., is stronger than expected) and falls when data come in below estimates. Finally, the VIX serves as a proxy for global risk aversion.

3.2 Event Study

We begin our analysis with a simple event study surrounding dates of recognized importance regarding monetary policy in the Eurozone. The approach considers changes in asset prices around narrowly defined event windows to estimate the effect of news content on those prices, and then to assess the relative importance of the signaling and portfolio balance channels on the change to US long bond yields. These announcements consist of intent to purchase assets, the

[1] Data available from the Federal Reserve Board at www.federalreserve.gov/econresdata/researchdata.htm.

[2] Data available from the Federal Reserve Board at www.federalreserve.gov/pubs/feds/2006/200628/200628abs.html

Table 1: Summary statistics (daily differences)

Variable	**Mean**	**Std. Dev.**	**N**
Y_{eh}(1 year)	-0.0012	0.0342	2873
Y_{eh}(5 year)	-0.0006	0.0248	2873
Y_{eh}(10 year)	-0.0005	0.0196	2873
Y_{zc}(1 year)	-0.0016	0.0409	2873
Y_{zc}(5 year)	-0.0017	0.0592	2873
Y_{zc}(10 year)	-0.0014	0.0644	2873
YTP (1 year)	-0.0004	0.0201	2873
YTP (5 year)	-0.0007	0.0405	2873
YTP (10 year)	-0.0007	0.0458	2873
Y_{zc}(1 year) - Germany	-0.0017	0.0321	3100
Y_{zc}(5 year) - Germany	-0.002	0.0465	3100
Y_{zc}(10 year) - Germany	-0.0019	0.0472	3100
Y_{zc}(1 year) - Italy	-0.0009	0.1005	3100
Y_{zc}(5 year) -	-0.0002	0.0902	3100
Y_{zc}(10 year) - Italy	0.0004	0.0748	3100
Y_{zc}(1 year) -	-0.0002	0.0113	3100
Y_{zc}(5 year) - Japan	-0.0003	0.0203	3100
Y_{zc}(10 year) - Japan	-0.0002	0.0228	3100
Y_{zc}(1 year) - UK	-0.0015	0.0415	3097
Y_{zc}(5 year) - UK	-0.0016	0.0505	3097
Y_{zc}(10 year) - UK	-0.0016	0.0551	3097
VIX	0.0377	1.9982	3047
EONIA Futures	-0.005	0.1964	2786
EURIBOR Futures	-0.0017	0.0331	3044

timing and planned amount of purchases, and the class of assets eligible for purchase and are listed in Table 12 . For simplicity in setting up our expected return, we appeal to the constant return model:

$$R_{it} = \mu_i + \epsilon_{it} \tag{1}$$

$$\epsilon_{it} \sim N(0, \sigma^2) \tag{2}$$

Where R_{it} is the component-maturity combination of interest. We test changes in the expectations hypothesis-implied interest rate ($\bar{Y}_{eh}$), the zero coupon bond yield (Y_{zc}), and the term premium (YTP) for the one, five and ten year US government bond. Our test utilizes a 70 trading day estimation period (slightly more than three months calendar time) that is cut off 20 trading days before the event of interest. Given the speed at which government securities trade, we use a one day event window in order to increase confidence that our window is not affected contaminated by unrelated news. Denoting R_{i0} the return on the asset of interest on the day of the event and V as the number of days in the estimation period, our abnormal return is,

$$\widehat{AR_{it}} = R_{i0} - \frac{1}{V}\sum_{v=1}^{V} R_{iv} \tag{3}$$

$$t = \frac{\widehat{AR_{it}}}{\sqrt{\frac{1}{V-1}\sum_{v=1}^{V}(R_{iv} - \hat{\mu}_{iv})^2}} \tag{4}$$

The events used in this preliminary analysis include the programs listed in Table 12 . We exclude the date of Mario Draghi's "whatever it takes" speech due to its proximity to the announcement of the OMT program. The results of this exercise can be found in Table 2. The SMP and APP announcements appear to have slightly decreased the average expected short rate of each maturity, but the overall effect on the zero coupon bond yields and term premia are not statistically different from zero except in the short maturities. This result is in keeping with with the previous literature on ECB QE. We see an unexpected result for OMT, wherein zero coupon bond yields are found to have decreased on medium and long maturities through decreases in both the expected average short rate and the term premium. Similarly, we find that the EAPP announcement decreased the zero coupon bond yield and its two components for the five and ten year bonds, while raising the yield on the one year zero coupon bond.

To add an additional dimension to this motivational exercise, we apply the method use in Krishnamurthy and Vissing-Jorgensen (2011) to our events of interest. Thus, we regress the daily changes in the variable of interest on a dummy for the date of each of the announcements, as well as a dummy if there was an announcement on the day previous using robust standard errors and controlling for changes in the VIX:

Variable	SMP	OMT	APP	EAPP
Y_{eh}(1 year)	0.04	0.091*	0.13***	0.179***
	(0.461)	(0.092)	(0.004)	(0.000)
Y_{eh}(5 year)	-0.051*	-0.216*	-0.101**	-0.249***
	(0.069)	(0.051)	(0.016)	(0.000)
Y_{eh}(10 year)	-0.041*	-0.175*	-0.087**	-0.205***
	(0.065)	(0.052)	(0.013)	(0.000)
Y_{zc}(1 year)	0.023	-0.002	0.086**	0.074**
	(0.694)	(0.899)	(0.011)	(0.021)
Y_{zc}(5 year)	-0.102	-0.335**	0.016	-0.273**
	(0.294)	(0.037)	(0.782)	(0.011)
Y_{zc}(10 year)	-0.147	-0.486**	-0.093	-0.481***
	(0.119)	(0.041)	(0.241)	(0.000)
YTP (1 year)	-0.038	-0.088**	0.047*	-0.048
	(0.369)	(0.030)	(0.052)	(0.220)
YTP (5 year)	-0.093	-0.25**	0.025	-0.204**
	(0.216)	(0.034)	(0.574)	(0.015)
YTP (10 year)	-0.119	-0.345**	-0.04	-0.33***
	(0.113)	(0.038)	(0.480)	(0.001)

P-values in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2: Event study results, $t-1$ to t

$$\Delta R_{it} = \alpha + \sum_{i=1}^{4} \beta_i \mathbb{1}[event_i] + \sum_{i=1}^{4} \gamma_i \mathbb{1}[previous_i] + \theta \Delta VIX_t + \epsilon_{it} \tag{5}$$

Where R_{it} denotes the component-maturity pair of interest. We include the VIX in our regressions to control for changes in global risk aversion. We assess the significance of the event overall using an F-test of the two event-related dummies. Our results are depicted in Tables 3 - 5.

There is a lot going on here, so we limit discussion to regressions containing the VIX (additional results available on request). The first pattern worth noting is that all events evince a negative, significant effect on one year bond yields through both the average expected short rate on the term premium. This chiefly suggests the operation of a short term signaling channel in the sense that it appears investors revised upward their estimates for the duration of the ZLB. The sign and significance on the term premium is not particularly compelling on a one year bond, as the term premium on short-duration bonds is expected to be minimal, but its relative contribution to the overall effect could integrated into a future iteration of this paper. In another noteworthy result, and in contrast to our previous exercise, the announcement of the APP appears to have driven up expected medium-maturity average short term yields and term premia, as well as the term premium on the ten year bond. Is it difficult to see why this

VARIABLES	(1) d_y1	(2) d_y1	(3) d_y5	(4) d_y5	(5) d_y10	(6) d_y10
smp	0.0247***	0.0304***	0.0966***	-0.0218*	0.121***	-0.00861
	(0.000712)	(0.00931)	(0.00128)	(0.0131)	(0.00149)	(0.0151)
smp_lag	-0.0145***	-0.0169***	-0.0118***	-0.0169***	-0.00176	-0.00739***
	(0.000712)	(0.000721)	(0.00128)	(0.00134)	(0.00149)	(0.00158)
omt	0.00126*	-0.00699***	0.0205***	0.00279	0.0313***	0.0119***
	(0.000712)	(0.00144)	(0.00128)	(0.00232)	(0.00149)	(0.00272)
omt_lag	-0.00194***	-0.00710***	-0.00175	-0.0129***	-0.00196	-0.0141***
	(0.000712)	(0.00100)	(0.00128)	(0.00174)	(0.00149)	(0.00205)
app	0.00226***	0.00350***	0.0269***	0.0296***	0.0369***	0.0399***
	(0.000712)	(0.000753)	(0.00128)	(0.00123)	(0.00149)	(0.00142)
app_lag	-0.0158***	-0.0184***	-0.00705***	-0.0125***	0.00244	-0.00351**
	(0.000712)	(0.000730)	(0.00128)	(0.00136)	(0.00149)	(0.00160)
eapp	0.00556***	-0.00560***	0.0251***	0.00113	0.0296***	0.00338
	(0.000712)	(0.00190)	(0.00128)	(0.00293)	(0.00149)	(0.00342)
eapp_lag	-0.00744***	-0.00629***	-0.0612***	-0.0587***	-0.0815***	-0.0787***
	(0.000712)	(0.000746)	(0.00128)	(0.00123)	(0.00149)	(0.00142)
d_vix		-0.00454***		-0.00978***		-0.0107***
		(0.000778)		(0.00107)		(0.00123)
Constant	-0.000757	-0.000728	-0.00105	-0.000986	-0.00114	-0.00107
	(0.000712)	(0.000680)	(0.00128)	(0.00120)	(0.00149)	(0.00140)
Observations	2,039	2,039	2,039	2,039	2,039	2,039
R-squared	0.001	0.085	0.002	0.123	0.003	0.110
smp + smp_lag = 0	0	1.03e-06	0	0.00530	0	0.317
omt + omt_lag	0.630	7.01e-09	0	0.0127	0	0.643
app + app_lag	0	0	0	0	0	0
eapp + eapp_lag	0.185	1.66e-09	0	0	0	0

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3: Dummy-based event study results, zero coupon bond yield, one day difference

VARIABLES	(1) d_exp_sr1	(2) d_exp_sr1	(3) d_exp_sr5	(4) d_exp_sr5	(5) d_exp_sr10	(6) d_exp_sr10
smp	0.00173***	-0.0286***	0.0488***	0.000830	0.0386***	0.00161
	(0.000601)	(0.00839)	(0.000572)	(0.00554)	(0.000454)	(0.00443)
smp_lag	-0.0164***	-0.0177***	0.00557***	0.00348***	0.00514***	0.00353***
	(0.000601)	(0.000613)	(0.000572)	(0.000597)	(0.000454)	(0.000474)
omt	-0.00607***	-0.0106***	0.0159***	0.00868***	0.0129***	0.00739***
	(0.000601)	(0.00127)	(0.000572)	(0.000995)	(0.000454)	(0.000793)
omt_lag	-0.00107*	-0.00391***	-0.00133**	-0.00583***	-0.00106**	-0.00453***
	(0.000601)	(0.000866)	(0.000572)	(0.000755)	(0.000454)	(0.000601)
app	-0.00447***	-0.00378***	0.0154***	0.0164***	0.0123***	0.0132***
	(0.000601)	(0.000665)	(0.000572)	(0.000555)	(0.000454)	(0.000443)
app_lag	-0.0165***	-0.0179***	0.00417***	0.00197***	0.00394***	0.00224***
	(0.000601)	(0.000621)	(0.000572)	(0.000603)	(0.000454)	(0.000479)
eapp	0.00133**	-0.00481***	0.00967***	-5.18e-05	0.00754***	3.47e-05
	(0.000601)	(0.00168)	(0.000572)	(0.00125)	(0.000454)	(0.000996)
eapp_lag	0.00713***	0.00777***	-0.0330***	-0.0320***	-0.0264***	-0.0256***
	(0.000601)	(0.000657)	(0.000572)	(0.000553)	(0.000454)	(0.000441)
d_vix		-0.00250***		-0.00396***		-0.00306***
		(0.000703)		(0.000454)		(0.000364)
Constant	-0.000431	-0.000415	-0.000567	-0.000541	-0.000442	-0.000422
	(0.000601)	(0.000589)	(0.000572)	(0.000543)	(0.000454)	(0.000432)
Observations	2,039	2,039	2,039	2,039	2,039	2,039
R-squared	0.000	0.037	0.003	0.102	0.003	0.097
smp + smp_lag = 0	0	1.05e-07	0	0.462	0	0.273
omt + omt_lag	3.30e-09	0	0	0.101	0	0.0391
app + app_lag	0	0	0	0	0	0
eapp + eapp_lag	0	0.0816	0	0	0	0

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Dummy-based event study results, expected short rate, one day difference

VARIABLES	(1) d_ytp1	(2) d_ytp1	(3) d_ytp5	(4) d_ytp5	(5) d_ytp10	(6) d_ytp10
smp	0.0284***	-0.00833	0.0679***	-0.0101	0.0846***	-0.00351
	(0.000432)	(0.00514)	(0.000913)	(0.0103)	(0.00107)	(0.0118)
smp_lag	-0.00739***	-0.00899***	-0.00839***	-0.0118***	-0.00288***	-0.00671***
	(0.000432)	(0.000475)	(0.000913)	(0.00100)	(0.00107)	(0.00118)
omt	0.00391***	-0.00160*	0.0137***	0.00201	0.0206***	0.00741***
	(0.000432)	(0.000885)	(0.000913)	(0.00182)	(0.00107)	(0.00210)
omt_lag	9.85e-06	-0.00344***	-0.000289	-0.00761***	-0.000681	-0.00895***
	(0.000432)	(0.000645)	(0.000913)	(0.00134)	(0.00107)	(0.00156)
app	0.00771***	0.00854***	0.0201***	0.0219***	0.0264***	0.0284***
	(0.000432)	(0.000419)	(0.000913)	(0.000875)	(0.00107)	(0.00103)
app_lag	-0.00369***	-0.00538***	-0.00239***	-0.00597***	0.00272**	-0.00133
	(0.000432)	(0.000482)	(0.000913)	(0.00102)	(0.00107)	(0.00119)
eapp	0.00901***	0.00156	0.0194***	0.00359	0.0225***	0.00465*
	(0.000432)	(0.00113)	(0.000913)	(0.00231)	(0.00107)	(0.00266)
eapp_lag	-0.0182***	-0.0174***	-0.0456***	-0.0440***	-0.0586***	-0.0567***
	(0.000432)	(0.000417)	(0.000913)	(0.000873)	(0.00107)	(0.00103)
d_vix		-0.00303***		-0.00644***		-0.00727***
		(0.000421)		(0.000841)		(0.000965)
Constant	-0.000210	-0.000190	-0.000511	-0.000470	-0.000619	-0.000572
	(0.000432)	(0.000409)	(0.000913)	(0.000865)	(0.00107)	(0.00102)
Observations	2,039	2,039	2,039	2,039	2,039	2,039
R-squared	0.002	0.104	0.002	0.106	0.003	0.098
smp + smp_lag = 0	0	0.00143	0	0.0447	0	0.416
omt + omt_lag	5.96e-06	0.000960	0	0.0750	0	0.673
app + app_lag	3.44e-06	0.000150	0	0	0	0
eapp + eapp_lag	0	0	0	0	0	0

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Dummy-based event study results, term premium, one day difference

might be, given the inclusion of the VIX. In the absence of the VIX, we might say that the ECB's actions infused investors with confidence that it would not allow the Euro Zone to fall further into crisis, inducing the opposite of a "flight to safety" response. More confoundingly, this result holds even when additional news variables are included in the regressions. Finally, only the APP and the EAPP event dates appear to have affected the ten year bond yield, albeit in opposite directions. Notably, both of these programs were announced after US tapering had already begun.

The two exercises agree that there is evidence of ECB monetary policy exerting some effect on long term bond yields. Whether the post-QE period stands as a bright line remains open for debate. To weigh in more decisively on this question, we appeal to more sophisticated techniques of identification and estimation.

3.3 Baseline Regressions

In order to achieve identification of monetary policy shocks, we appeal to Kuttner (2001), Gürkaynak et al (2005) and Rogers et al (2014). Our monetary policy shock measures consist of daily [3] differenced Euribor 3 month futures and Eonia 3 month futures. [4] In future work, we plan to use futures of longer duration assets as a check on attenuation. Figures 1 - 4 show the yields implied by the prices of these contracts during 2010 - 2014 and 2014 - 2016. Given the relative illiquidity of Eonia futures contracts, we take Euribor futures as our primary measure and discuss Eonia results as a robustness check. In our data, a negative monetary policy shock represents a surprise loosening of monetary policy, while a positive change represents a tightening.

Table XX show additional summary statistics for zero coupon bond yields, the average expected short rate and the term premium. Unsurprisingly, it reveals evidence of negative skewness, excess kurtosis, non-normality and serial correlation. Our econometric model will thus need to take these characteristics into account.

Given our interest in the what might be considered different global financial regimes, we consider each major monetary policy announcement as a potential "critical juncture" and run baseline regressions of the form

$$\Delta R_{it} = \alpha_1 + \beta_1 \Delta R_{it-1} + \gamma_1 \mathbb{1}[preX] MP_t^{EU} + \gamma_2 \mathbb{1}[postX] MP_t^{EU} + \\ + \theta_1^{US} S_t^{US} + \theta_2^{JP} S_t^{JP} + \phi \Delta VIX + \delta_1^M Mon + \delta_2^F Fri + \epsilon_{it} \quad (6)$$

[3] Using daily data rather then intraday data may introduce some noise to the analysis; however, money markets are generally less volatile than other financial marketsm limiting the noise. Additionally, using intraday data increases the risk that we lose information through leaks that limit the "firmness" of the announcement time.

[4] The Euro Interbank Offered Rate (Euribor) is a daily reference rate based on the averaged interest rates at which Eurozone banks offer to lend unsecured funds to other banks in the euro interbank market. The Euro OverNight Index Average (Eonia) rate is the 1-day interbank interest rate for the Euro zone. Eonia can be considered as the 1 day Euribor rate.

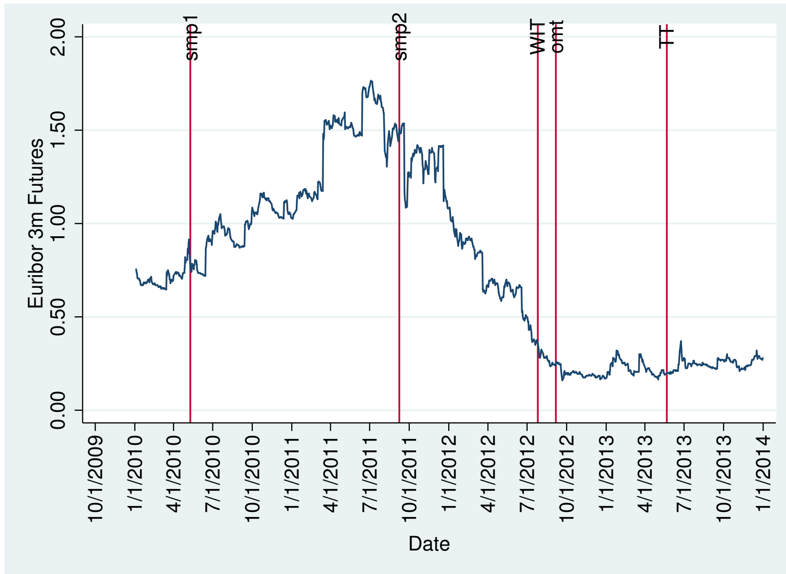

Figure 1: Euribor Futures, 2010 - 2013

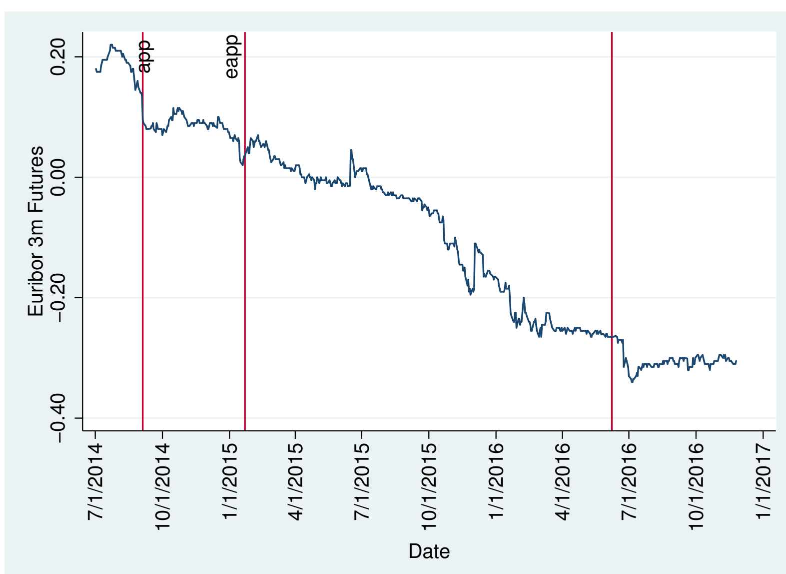

Figure 2: Euribor Futures, 2014 - 2016

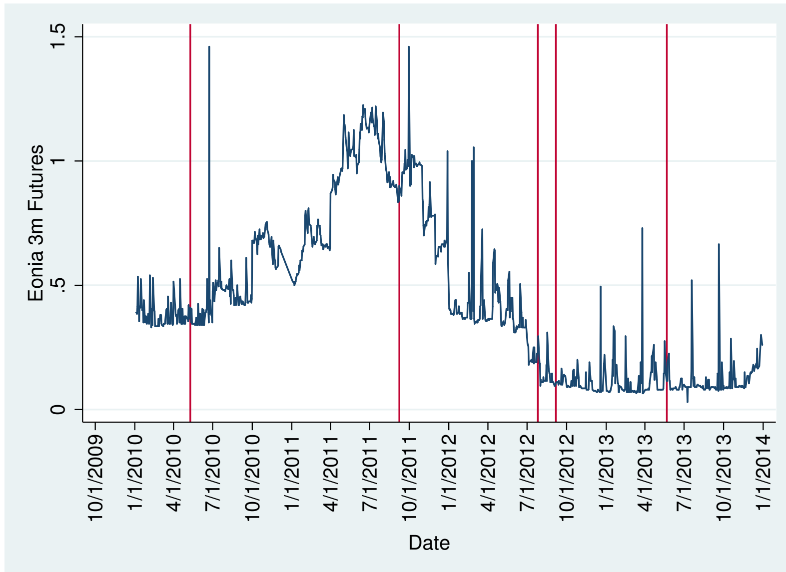

Figure 3: Eonia Futures, 2010 - 2013

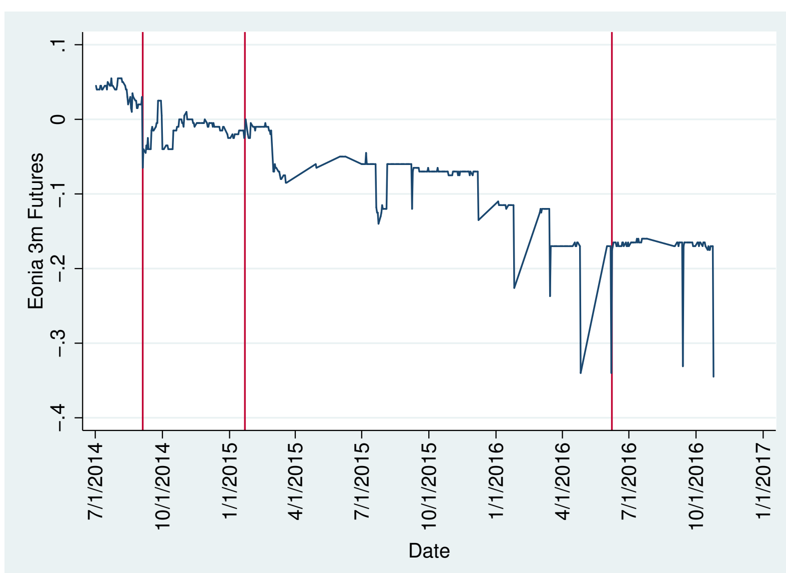

Figure 4: Eonia Futures, 2014 - 2016

Variable	Mean	Skewness	Kurtosis	Jarque-Bera	Q(40)	No. Obs.
$\bar{Y}_{eh}1$	-0.001	-1.566***	34.293***	104013.0***	224.5***	2524
$\bar{Y}_{eh}5$	-0.001	0.004	7.364***	2003.1***	268.2***	2524
$\bar{Y}_{eh}10$	-0.001	0.021	7.272***	1919.3***	289.4***	2524
$Y_{zc}1$	-0.001	-1.614***	36.841***	121533.0***	214.9***	2524
$Y_{zc}5$	-0.002	-0.223***	7.758***	2402.0***	149.6***	2524
$Y_{zc}10$	-0.002	-0.020	6.519***	1302.6***	166.4***	2524
$YTP1$	-0.0004	-0.205***	7.611***	2253.5***	192.3***	2524
$YTP5$	-0.001	-0.065	6.353***	1184.4***	181.4***	2524
$YTP10$	-0.001	0.014	6.378***	1199.9***	187.0***	2524

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Jarque-Bera is the Jarque-Bera test statistic for normality;

Q(40) is the Ljung-box test statistic for serial correlation up to the 40th lag

Table 6: Additional summary statistics

Where S_t^{US} and S_t^{JP} are the CESI for the US and Japan, respectively and the X's are the announcements of the SMP, OMT, US tapering, APP and EAPP. We use dummies for Mondays and Fridays to capture day of the week effects. Per Andersen et al, we use serial correlation and heteroskedasticity robust standard errors with 40 lags (about two trading months) for hypothesis testing. The Bayes Information Criterion selects the AR(1) model, which we verify limits serial autocorrelation of the AR form in the errors sufficiently to rule out bias on that front. We do so using Durbin's alternative test in combination with a regression of the residuals on their lags and squared lags. Our results are depicted in Tables 7 - 11. Let us address the control variables, and then we will address the "splits" in chronological order.

Given the role of US government securities as global "safe assets", it is not surprisingly that an increase in the VIX would lead to an increase in the demand for US bonds, decreasing yields through the term premium. Interestingly, US surprises (wherein the data outperform expectations) generate increases in the term premium; perhaps positive surprises in the US entice movement into riskier substitute assets such, for example, US corporate bonds. Focusing on the period-specific monetary policy shocks, the effect of shocks is not statistically different from zero until after the APP is announced. Two elements of this time period are notable. First, monetary policy from the ECB does not "turn influential" immediately after the taper tantrum in May 2013. Second, monetary policy appears to have an effect on term premia and long term interest rates in the United States only after the ECB increased the aggressiveness of its QE policy substantially. After this latter change, expansionary monetary policy in the Eurozone is associated with a fall in term premia and long term interest rates, indicating the operation of a portfolio balancing channel into US assets.

VARIABLES	(1) d_exp_sr1	(2) d_exp_sr5	(3) d_exp_sr10	(4) d_y1	(5) d_y5	(6) d_y10	(7) d_ytp1	(8) d_ytp5	(9) d_ytp10
mp_euribor_smp	-0.0640	0.0487	0.0401	-0.0398	0.0353	0.0877	-0.00451	0.0233	0.0563
	(0.0676)	(0.0745)	(0.0604)	(0.0474)	(0.129)	(0.188)	(0.0396)	(0.104)	(0.142)
mp_euribor_pre_smp	0.146	0.00537	-0.00136	0.152	0.200	0.139	0.0948	0.146	0.115
	(0.0974)	(0.191)	(0.154)	(0.0981)	(0.368)	(0.480)	(0.119)	(0.280)	(0.351)
d_vix	-0.00212	-0.00377***	-0.00291***	-0.00412***	-0.00916***	-0.0101***	-0.00275***	-0.00597***	-0.00684***
	(0.00132)	(0.000540)	(0.000432)	(0.00142)	(0.00155)	(0.00174)	(0.000602)	(0.00123)	(0.00143)
us_surp	1.09e-05	3.32e-05	2.59e-05	2.93e-05	7.00e-05*	8.15e-05*	1.75e-05**	4.26e-05**	5.23e-05*
	(1.24e-05)	(2.02e-05)	(1.59e-05)	(2.11e-05)	(3.66e-05)	(4.39e-05)	(7.87e-06)	(2.05e-05)	(2.67e-05)
jpy_surp	-1.82e-05*	3.09e-05**	2.48e-05**	-4.51e-06	4.51e-05*	6.92e-05**	1.01e-05	3.28e-05*	4.78e-05**
	(1.01e-05)	(1.31e-05)	(1.04e-05)	(1.17e-05)	(2.73e-05)	(3.38e-05)	(8.50e-06)	(1.96e-05)	(2.42e-05)
mon	0.00111	0.00140	0.00114	0.00222	-0.00144	-0.00121	-0.00188	-0.00301	-0.00269
	(0.00128)	(0.00117)	(0.000922)	(0.00153)	(0.00315)	(0.00339)	(0.00119)	(0.00232)	(0.00253)
fri	0.00485***	0.000740	0.000445	0.00577***	0.00295	0.00109	0.000350	0.000148	-0.000623
	(0.00172)	(0.00165)	(0.00130)	(0.00218)	(0.00365)	(0.00418)	(0.00117)	(0.00251)	(0.00295)
Constant	-0.00148**	-0.000758	-0.000578	-0.00216**	-0.000766	-0.000438	0.000348	0.000539	0.000563
	(0.000616)	(0.000779)	(0.000613)	(0.000864)	(0.00167)	(0.00197)	(0.000526)	(0.00116)	(0.00139)
AR(1)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,930	1,930	1,930	1,930	1,930	1,930	1,930	1,930	1,930

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: HAC Regressions, post-SMP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	d_exp_sr1	d_exp_sr5	d_exp_sr10	d_y1	d_y5	d_y10	d_ytp1	d_ytp5	d_ytp10
mp_euribor_omt	-0.198	0.355	0.285	-0.0281	0.601	0.861	0.144	0.436	0.605
	(0.187)	(0.290)	(0.236)	(0.0920)	(0.453)	(0.676)	(0.140)	(0.372)	(0.506)
mp_euribor_pre_omt	0.0535	0.0181	0.0120	0.0650	0.113	0.0984	0.0465	0.0810	0.0758
	(0.0651)	(0.111)	(0.0891)	(0.0628)	(0.216)	(0.281)	(0.0711)	(0.165)	(0.207)
d_vix	-0.00213	-0.00377***	-0.00291***	-0.00413***	-0.00916***	-0.0101***	-0.00275***	-0.00598***	-0.00684***
	(0.00132)	(0.000541)	(0.000433)	(0.00142)	(0.00155)	(0.00174)	(0.000601)	(0.00123)	(0.00144)
us_surp	1.04e-05	3.33e-05	2.59e-05	2.88e-05	6.94e-05*	8.12e-05*	1.72e-05**	4.22e-05**	5.20e-05*
	(1.24e-05)	(2.03e-05)	(1.60e-05)	(2.12e-05)	(3.68e-05)	(4.41e-05)	(7.90e-06)	(2.06e-05)	(2.68e-05)
jpy_surp	-1.86e-05*	3.10e-05**	2.50e-05**	-4.95e-06	4.48e-05	6.92e-05**	9.84e-06	3.26e-05*	4.78e-05**
	(1.01e-05)	(1.32e-05)	(1.05e-05)	(1.17e-05)	(2.75e-05)	(3.40e-05)	(8.54e-06)	(1.97e-05)	(2.43e-05)
mon	0.00112	0.00140	0.00114	0.00224	-0.00141	-0.00119	-0.00186	-0.00299	-0.00268
	(0.00128)	(0.00117)	(0.000922)	(0.00153)	(0.00316)	(0.00339)	(0.00119)	(0.00232)	(0.00253)
fri	0.00488***	0.000732	0.000438	0.00579***	0.00296	0.00109	0.000359	0.000157	-0.000622
	(0.00172)	(0.00164)	(0.00129)	(0.00218)	(0.00364)	(0.00416)	(0.00117)	(0.00250)	(0.00294)
Constant	-0.00150**	-0.000761	-0.000579	-0.00219**	-0.000801	-0.000464	0.000332	0.000514	0.000542
	(0.000618)	(0.000778)	(0.000612)	(0.000864)	(0.00167)	(0.00197)	(0.000528)	(0.00117)	(0.00140)
AR(1)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,930	1,930	1,930	1,930	1,930	1,930	1,930	1,930	1,930

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8: HAC Regressions, post-OMT

VARIABLES	(1) d_exp_sr1	(2) d_exp_sr5	(3) d_exp_sr10	(4) d_y1	(5) d_y5	(6) d_y10	(7) d_ytp1	(8) d_ytp5	(9) d_ytp10
mp_euribor_us_taper	0.0611	0.105	0.0810	0.127*	0.260	0.282	0.0680	0.156	0.182
	(0.220)	(0.497)	(0.402)	(0.0769)	(0.800)	(1.145)	(0.217)	(0.599)	(0.816)
mp_euribor_pre_us_taper	0.0458	0.0124	0.00751	0.0523	0.101	0.0875	0.0454	0.0776	0.0718
	(0.0656)	(0.0942)	(0.0752)	(0.0719)	(0.206)	(0.255)	(0.0722)	(0.159)	(0.191)
d_vix	-0.00213	-0.00377***	-0.00292***	-0.00413***	-0.00917***	-0.0101***	-0.00275***	-0.00598***	-0.00684***
	(0.00132)	(0.000540)	(0.000433)	(0.00142)	(0.00155)	(0.00174)	(0.000601)	(0.00123)	(0.00144)
us_surp	1.03e-05	3.34e-05	2.60e-05	2.88e-05	6.96e-05*	8.15e-05*	1.72e-05**	4.23e-05**	5.22e-05*
	(1.24e-05)	(2.04e-05)	(1.60e-05)	(2.12e-05)	(3.68e-05)	(4.42e-05)	(7.91e-06)	(2.06e-05)	(2.68e-05)
jpy_surp	-1.86e-05*	3.11e-05**	2.50e-05**	-4.88e-06	4.49e-05	6.93e-05**	9.86e-06	3.26e-05*	4.78e-05**
	(1.01e-05)	(1.31e-05)	(1.04e-05)	(1.17e-05)	(2.75e-05)	(3.39e-05)	(8.54e-06)	(1.97e-05)	(2.42e-05)
mon	0.00113	0.00139	0.00114	0.00224	-0.00142	-0.00121	-0.00187	-0.00300	-0.00269
	(0.00128)	(0.00117)	(0.000923)	(0.00153)	(0.00316)	(0.00339)	(0.00119)	(0.00232)	(0.00253)
fri	0.00487***	0.000731	0.000438	0.00579***	0.00296	0.00109	0.000359	0.000157	-0.000622
	(0.00172)	(0.00164)	(0.00130)	(0.00218)	(0.00364)	(0.00417)	(0.00117)	(0.00250)	(0.00294)
Constant	-0.00151**	-0.000747	-0.000568	-0.00218**	-0.000780	-0.000435	0.000336	0.000526	0.000561
	(0.000618)	(0.000774)	(0.000609)	(0.000864)	(0.00167)	(0.00197)	(0.000529)	(0.00117)	(0.00139)
AR(1)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,930	1,930	1,930	1,930	1,930	1,930	1,930	1,930	1,930

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: HAC Regressions, post-taper tantrum

VARIABLES	(1) d_exp_sr1	(2) d_exp_sr5	(3) d_exp_sr10	(4) d_y1	(5) d_y5	(6) d_y10	(7) d_ytp1	(8) d_ytp5	(9) d_ytp10
mp_euribor_app	-0.0665	0.518	0.413	0.185	0.969**	1.259*	0.265**	0.680*	0.878*
	(0.220)	(0.373)	(0.304)	(0.114)	(0.493)	(0.763)	(0.109)	(0.352)	(0.522)
mp_euribor_pre_app	0.0598	-0.0251	-0.0227	0.0504	0.0365	-0.00253	0.0263	0.0280	0.00620
	(0.0654)	(0.105)	(0.0837)	(0.0686)	(0.218)	(0.276)	(0.0742)	(0.168)	(0.206)
d_vix	-0.00212	-0.00379***	-0.00293***	-0.00413***	-0.00920***	-0.0102***	-0.00276***	-0.00600***	-0.00687***
	(0.00132)	(0.000540)	(0.000433)	(0.00142)	(0.00155)	(0.00174)	(0.000601)	(0.00123)	(0.00144)
us_surp	1.03e-05	3.35e-05*	2.62e-05	2.88e-05	6.99e-05*	8.19e-05*	1.73e-05**	4.25e-05**	5.25e-05*
	(1.24e-05)	(2.04e-05)	(1.60e-05)	(2.12e-05)	(3.68e-05)	(4.41e-05)	(7.91e-06)	(2.06e-05)	(2.68e-05)
jpy_surp	-1.86e-05*	3.11e-05**	2.50e-05**	-4.94e-06	4.49e-05	6.93e-05**	9.87e-06	3.27e-05*	4.79e-05*
	(1.01e-05)	(1.33e-05)	(1.05e-05)	(1.17e-05)	(2.77e-05)	(3.42e-05)	(8.59e-06)	(1.98e-05)	(2.45e-05)
mon	0.00112	0.00141	0.00116	0.00225	-0.00139	-0.00116	-0.00186	-0.00298	-0.00266
	(0.00128)	(0.00117)	(0.000922)	(0.00153)	(0.00315)	(0.00339)	(0.00119)	(0.00232)	(0.00252)
fri	0.00488***	0.000725	0.000433	0.00579***	0.00295	0.00107	0.000356	0.000149	-0.000633
	(0.00172)	(0.00164)	(0.00129)	(0.00218)	(0.00363)	(0.00415)	(0.00117)	(0.00249)	(0.00293)
Constant	-0.00151**	-0.000741	-0.000563	-0.00219**	-0.000770	-0.000419	0.000340	0.000536	0.000573
	(0.000619)	(0.000776)	(0.000610)	(0.000864)	(0.00166)	(0.00197)	(0.000527)	(0.00117)	(0.00139)
AR(1)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,930	1,930	1,930	1,930	1,930	1,930	1,930	1,930	1,930

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 10: HAC Regressions, post-APP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	d_exp_sr1	d_exp_sr5	d_exp_sr10	d_y1	d_y5	d_y10	d_ytp1	d_ytp5	d_ytp10
mp_euribor_eapp	-0.0981	0.703**	0.561**	0.241*	1.296***	1.695***	0.351***	0.908***	1.178***
	(0.248)	(0.320)	(0.264)	(0.146)	(0.346)	(0.601)	(0.0635)	(0.250)	(0.408)
mp_euribor_pre_eapp	0.0603	-0.0314	-0.0277	0.0480	0.0247	-0.0179	0.0232	0.0198	-0.00432
	(0.0643)	(0.103)	(0.0827)	(0.0677)	(0.215)	(0.273)	(0.0732)	(0.166)	(0.203)
d_vix	-0.00212	-0.00379***	-0.00293***	-0.00414***	-0.00921***	-0.0102***	-0.00276***	-0.00601***	-0.00688***
	(0.00132)	(0.000542)	(0.000434)	(0.00143)	(0.00155)	(0.00175)	(0.000602)	(0.00123)	(0.00144)
us_surp	1.03e-05	3.32e-05	2.59e-05	2.87e-05	6.93e-05*	8.11e-05*	1.71e-05**	4.21e-05**	5.19e-05*
	(1.24e-05)	(2.03e-05)	(1.60e-05)	(2.12e-05)	(3.68e-05)	(4.41e-05)	(7.89e-06)	(2.05e-05)	(2.68e-05)
jpy_surp	-1.88e-05*	3.20e-05**	2.57e-05**	-4.71e-06	4.65e-05*	7.14e-05**	1.03e-05	3.37e-05*	4.93e-05**
	(1.01e-05)	(1.31e-05)	(1.04e-05)	(1.17e-05)	(2.75e-05)	(3.40e-05)	(8.55e-06)	(1.97e-05)	(2.43e-05)
mon	0.00112	0.00144	0.00118	0.00226	-0.00134	-0.00110	-0.00185	-0.00294	-0.00262
	(0.00127)	(0.00117)	(0.000922)	(0.00153)	(0.00315)	(0.00339)	(0.00119)	(0.00232)	(0.00252)
fri	0.00488***	0.000739	0.000444	0.00579***	0.00297	0.00111	0.000362	0.000166	-0.000610
	(0.00172)	(0.00163)	(0.00129)	(0.00218)	(0.00363)	(0.00415)	(0.00117)	(0.00249)	(0.00293)
Constant	-0.00151**	-0.000767	-0.000585	-0.00217**	-0.000787	-0.000462	0.000341	0.000525	0.000280
	(0.000620)	(0.000774)	(0.000609)	(0.000864)	(0.00165)	(0.00196)	(0.000521)	(0.00115)	(0.00150)
AR(1)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,930	1,930	1,930	1,930	1,930	1,930	1,930	1,930	1,930

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 11: HAC Regressions, post-EAPP

4 Concluding Remarks and Directions for Future Research

As aforementioned, in future work we plan to execute our main regressions with futures for longer duration assets to allay any concern of attenuation bias. Another desired extension involves estimating our model using GARCH errors, as our variables of interest clearly evince volatility clustering. Finally, for completeness, we will extend our analysis to the other advanced systemic economy currently pursuing QE, Japan.

5 Appendix

Date	Policy Announcement
May 10, 2010	**Securities Markets Program (SMP)** empowered the ECB to purchase bonds – especially sovereign bonds – on the secondary markets. The last purchase under the SMP was made in February 2012. At its peak, the program's volume totaled around €210 billion.
July 26, 2012	"Whatever it takes" speech - Mario Draghi remarks to Global Investment Conference in London
August 2, 2012	**Outright Monetary Transactions program (OMT)** replaces the SMP and allowed the ECB to purchase the sovereign bonds of specific euro area countries on secondary markets with no set ex ante quantitative limits. These purchases are to be "sterilized", in the sense that this money is removed from the money market. "The OMT program is to be phased out once the aims have been achieved or once it has been determined that the requirements have not been met." Outright monetary transactions replaced the securities markets program (SMP) in September 2012.
September 4, 2014	ECB announced it would launch an **Asset Purchase Program (APP)** which involved asset-backed securities and covered bonds and which was extended on January 22, 2015 to include sovereign bond purchases (the EAPP).
January 22, 2015	**Expanded Asset Purchase Program (EAPP)**: "Monthly purchases in public and private sector securities amount to €80 billion on average (from March 2015 until March 2016 this average monthly figure was €60 billion). They are intended to be carried out until the end of 2017 and in any case until the Governing Council sees a sustained adjustment in the path of inflation that is consistent with its aim of achieving inflation rates below, but close to, 2% over the medium term."

Table 12: ECB QE Announcement Dates.
Source: European Central Bank and Deutsche Bundesbank