

Forward Guidance and Asset Prices

Yıldız Akkaya* Refet S. Gürkaynak† Burçin Kısacıkoglu‡
Jonathan H. Wright§

April 21, 2015

Abstract

This paper examines the effects of forward guidance at the zero lower bound on the term structure of interest rates in a shadow-rate macro-finance term structure model. The effects on the yield curve are found to depend on the type of forward guidance and on the current level of the shadow rate. The more negative the shadow rate, and so the further away liftoff is, the less effective is forward guidance. Forward guidance affects both the expected path of future short rates, but also term premia. Our model allows us to estimate these effects separately. We also conduct an event-study in which we break out FOMC announcements into surprises concerning the future path of the funds rate, and uncertainty around that path, and then estimate the impacts of each on equity and currency markets.

*Department of Economics, Bilkent University, 06800 Ankara, Turkey. yakkaya@bilkent.edu.tr.

†Department of Economics, Bilkent University, 06800 Ankara, Turkey and CEPR. refet@bilkent.edu.tr.

‡Department of Economics, Johns Hopkins University, Baltimore MD 21218. bkisaci1@jhu.edu.

§Department of Economics, Johns Hopkins University, Baltimore MD 21218. wrightj@jhu.edu.

1 Introduction

Forward guidance about the path of future short-term interest rates arose as an important policy tool for many central banks when the zero lower bound (ZLB) became binding in the Great Recession. The original perspective on forward guidance (Eggertsson and Woodford, 2003) involves a central bank making a commitment to low future spot rates, thereby reducing longer term interest rates via the expectations hypothesis. Indeed, the Federal Reserve influenced expectations of future rates and uncertainty around those expectations via their statements well before the Great Recession, especially from 2003 to 2005. But forward guidance became much more important at the ZLB. After reaching the ZLB in December 2008, the FOMC first used rather vague forward guidance, as they had done from 2003 to 2005. The FOMC stated that exceptionally low interest rates were likely to be appropriate for an “extended period”. Then in August 2011 it transitioned to “calendar-based” forward guidance in which it stated that liftoff was not expected until at least mid-2013. In December 2012, it switched to “threshold-based” forward guidance, in which the conditions for liftoff were that the unemployment rate hit 6.5 percent, or that the forecast of inflation reach 2.5 percent. As the unemployment rate has fallen below 6.5 percent, the FOMC has reverted to vaguer forward guidance. See Campbell et al. (2012) and Filardo and Hoffmann (2014) for more detailed accounts of forward guidance.

Forward guidance has similarly been an important element of the ZLB toolkit of the Bank of England and the Bank of Japan. The European Central Bank was reluctant to adopt forward guidance¹, but has now come to use it as well.

The theoretical mechanism by which forward guidance circumvents the ZLB is

¹Former president Trichet stated that the ECB would never pre-commit.

by constraining monetary policy to be easier than it otherwise would be in the future, overcoming a time-consistency problem (Kydland and Prescott, 1977). It is essentially a commitment to be the opposite of the conservative central banker of Rogoff (1985): it is a promise that monetary policy will be more accommodative than the central bank would *ex-post* desire (Eggertsson and Woodford, 2003; Woodford, 2012). There is a tension between the theory and practice of forward guidance. At the ZLB, central banks would like to see easier financial conditions, but central banks have never said that they are constraining their own future actions, and saying so would be politically difficult. Without tying the central bank's hands, forward guidance can only work if private sector agents misunderstand the central bank's reaction function, or if the central bank has a different view of future macroeconomic conditions and can furthermore persuade private sector agents that its forecast is superior². While these circumstances could arise, such forward guidance can only be a solution to the problem of the ZLB under very particular conditions and only to a limited extent. Indeed, while convincing the private sector that the economic outlook is weak might persuade investors that rate hikes are far off, it seems a rather counterproductive strategy to promote an economic recovery. In practice, we suspect that central banks fervently hope that forward guidance is interpreted as a commitment, while at the same time protesting that it is nothing of the sort.

This paper is an empirical analysis of forward guidance in the context of the US. Unlike Eggertsson and Woodford (2003), we note that forward guidance does not have to operate via the expectations hypothesis alone: it can also increase or reduce term premia. Forward guidance seems likely to remain important after liftoff from the ZLB. We would like to study the effectiveness of forward guidance at and away

²Campbell et al. (2012) refer to forward guidance that resolves the time-consistency problem as *Odyssean* and forward guidance that communicates information about the economic outlook as *Delphic*.

from the ZLB and understand the mechanisms through which it affects long-term interest rates and other asset prices.

We approach the empirical analysis of forward guidance by estimating a macro-finance term structure model which is standard, except that it incorporates the ZLB and a shadow short term interest rate, as proposed by Black (1995). The shocks have a structural interpretation. The shadow short rate is set via a Taylor rule and can go negative, but the actual short rate is the maximum of the shadow short rate and the lower bound. We model forward guidance as anticipated monetary policy shocks as in Laseen and Svensson (2011) and Del Negro et al. (2012). We use our model to estimate how different types of forward guidance can affect both the expected path of policy and term premia. The effects of forward guidance can depend on how far the shadow rate is below zero—the more negative is the shadow rate, the less effect most forms of forward guidance will have. The intuition is simple: if investors do not expect liftoff for some time, then a credible commitment to keep interest rates at the ZLB for some time doesn't change much.

As a supplementary empirical exercise, we use an event study methodology that examines both the effects of surprises about the future path of policy and surprises about the level of monetary policy uncertainty on asset prices.

The plan for the remainder of this paper is as follows. Our term structure model and the resulting estimates of the effects of forward guidance are given in section 2. Section 3 contains the event study analysis, and section 4 concludes.

2 Effects of forward guidance in a term structure model

Our main approach in this paper involves estimating a macro-finance term structure model, incorporating the ZLB. In our model, the shadow short rate follows a Taylor rule:

$$s_t = \rho_0 + \rho_1 u_t + \rho_2 \pi_t + f_t \quad (1)$$

where u_t is the unemployment rate, π_t is inflation (core PCE, year-over-year) and f_t is a monetary policy surprise. The actual short rate is:

$$r_t = \max(s_t, \underline{r}) \quad (2)$$

where \underline{r} is the zero lower bound (which need not necessarily be exactly zero). The state vector is $X_t = (u_t, \pi_t, f_t)'$, which follows a VAR(1) under the physical (P) measure:

$$X_t = \mu + \Phi X_{t-1} + \Sigma \varepsilon_t \quad (3)$$

where the structural shocks ε_t are iid(0,1),

$$\Phi = \begin{pmatrix} \phi_{11} & \phi_{12} & \phi_{13} \\ \phi_{21} & \phi_{22} & \phi_{23} \\ 0 & 0 & \phi_{33} \end{pmatrix} \quad (4)$$

and

$$\Sigma = \begin{pmatrix} \Sigma_{11} & 0 & 0 \\ 0 & \Sigma_{22} & 0 \\ 0 & 0 & \Sigma_{33} \end{pmatrix} \quad (5)$$

This means that f_t does not respond to any other elements of the state. The monetary policy shock is the last element of ε_t . Exactly the same model applies under the risk-neutral (Q) measure except that under this measure the state vector instead follows the process:

$$X_t = \mu^Q + \Phi^Q X_{t-1} + \Sigma \varepsilon_t \quad (6)$$

where μ^Q and Φ^Q are unrestricted. This is like the model in Ang et al. (2011), except that it does not allow for time-variation in ρ_1 and ρ_2 , but does instead incorporate the ZLB constraint. Ignoring the ZLB, the model implies that bond yields are affine functions of X_t , that are available in closed form. Treating observed yields as being measured with error, the model can then easily be estimated via the Kalman filter. But once one takes account of the ZLB, bond prices do not exist in closed form. Instead, we can note that the price of an n -period zero-coupon bond is:

$$P_t(n) = E_t^Q(\exp(-\sum_{i=0}^{n-1} r_{t+i})) \quad (7)$$

and we compute this by simulation, taking draws of X_t from equation (6) and then working out the implied path of short-rates using equations (1) and (2).

Our yield data consist of 1 and 6 month T-Bill yields and 1-5 year zero coupon yields. The 1 month T-Bill yield was treated as the short rate. Our estimation strategy follows Bauer and Rudebusch (2013). We first estimated the model given by equations (1)-(5) using monthly data from January 1990 to December 2007. Over this period, we neglected the zero lower bound (ZLB). We estimated ρ_0 , ρ_1 and ρ_2 by OLS, hence recovered X_t and estimated μ , Φ and Σ . Finally, treating each yield other than the 1 month yield as being measured with error with standard deviation σ_i , we estimated μ^Q , Φ^Q and the σ_i s by maximum likelihood.

Table 1 shows the estimated standard deviation of the yield measurement error. The measurement error ranges from 40 to 100 basis points. This measurement error could surely be reduced by adding in a latent factor, but that would make macroeconomic interpretation harder.

Next, we held these parameters fixed, and used the unscented Kalman filter (Julier and Uhlmann, 1997) to extract smoothed estimates of the state over the period since January 2008, using simulations to price bonds at the ZLB, as described above. We set the effective lower bound, \underline{r} , to 10 basis points per annum³.

The implied shadow rate is $\hat{\rho}_0 + \hat{\rho}_1 u_t + \hat{\rho}_2 \pi_t + \hat{f}_t$ where $\hat{\rho}_0$, $\hat{\rho}_1$ and $\hat{\rho}_2$ are estimates of ρ_0 , ρ_1 and ρ_2 and \hat{f}_t is the smoothed estimate of f_t . Note that at the ZLB, f_t is not observable even conditional on the parameters. The implied shadow rate is shown in Figure 1. In effect, the term structure model is inferring the shadow rate from the yield curve—the further out the term structure interest rates are close to zero, the more negative is the shadow rate. So the shadow rate is effectively a measure of how far out Fed communications have pushed the expected time of liftoff. Figure 1 also shows the shadow rate implied by the Taylor rule in the absence of any monetary policy surprise, $\hat{\rho}_0 + \hat{\rho}_1 u_t + \hat{\rho}_2 \pi_t$.

In early 2008, the ZLB was not yet binding. The shadow rate was the actual rate⁴. Moreover, the actual shadow rate was below the Taylor rule shadow rate. In late 2008 and early 2009, the Taylor rule shadow rate fell sharply below zero, whereas the shadow rate declined a bit less. By late 2009, the shadow rate was a bit above the Taylor rule shadow rate. But then in 2011, the shadow Taylor rule

³For institutional reasons, the Federal Reserve never tried to drive short rates all the way to zero, and instead targeted a federal funds rate in the range 0-25 basis points.

⁴Recall that the short-rate considered here is the one-month T-Bill yield. The one-month T-Bill yield is typically slightly below the federal funds rate, because the federal funds rate is an uncollateralized interbank rate with some credit risk, and also because Treasury Bills have some tax advantages. The gap widens out at times of financial stress. Early in 2008, one-month T-Bill rates were quite a bit below the federal funds rate.

started climbing back to zero, while the shadow rate stayed around -4 percent until 2013. Mechanically, this is because the ZLB became binding further out the term structure, a point demonstrated by Bauer and Rudebusch (2013) and Swanson and Williams (2014). Substantively, this is the effect of forward guidance. By mid-2012, the shadow rate Taylor rule was calling for short rates around zero, but the Fed had signalled that lift-off was quite some time off, keeping longer-term yields down. The model interprets this as a shadow rate that is still negative because of a negative value of f_t .

At the end of the sample, in December 2013, we can study the effects of a few counterfactual forward guidance experiments. Each of these is interpreted as announcing monetary policy shocks (shocks to future f_t s). It is important to remember that there was already considerable forward guidance in place in December 2013, as represented in the model by the fact that the shadow rate was around 250 basis points below the shadow rate Taylor rule. Our counterfactual experiments involve the incremental effects of *additional* forward guidance as follows:

1. Volatility forward guidance. For the next two years, there will be no shocks to f_t ($\Sigma_{33} = 0$).
2. Shocks to the shadow rate. A sequence of monetary policy shocks will lower the shadow rate s_t by 1 percent for 2 years.
3. Unconditional commitment. A sequence of monetary policy shocks are promised such that the short rate will be kept at the ZLB for two years.
4. Conditional commitment. A sequence of monetary policy shocks are promised such that the short rate will be kept at zero until the first time that the unem-

ployment rate hits 5.5 percent.⁵

These policies all involve modeling forward guidance as anticipated monetary policy shocks as in Laseen and Svensson (2011) and Del Negro et al. (2012)⁶. The forward guidance is assumed to be perfectly credible in each case. Agents learn about these future shocks today, and the yield curve consequently jumps. In each case, after 2 years (or when the unemployment rate hits 5.5 percent for case 4), normal shocks resume. Importantly, this doesn't mean that the level of short rates immediately jumps back to where it would have been in the absence of any forward guidance—under policies 2-4 one would expect monetary policy to be more accommodative for sometime after normal shocks resume than it would have been in the absence of any forward guidance, because of persistence in monetary policy. Any one of these policies should lower near-term uncertainty about future rates. Indeed, as the FOMC sharpened its forward guidance from 2010 to 2012, uncertainty about future short-term US interest rates, as measured from interest rate options, fell sharply, especially on days of monetary policy announcements (Bauer, 2012). At the same time, interest rates became unresponsive to macroeconomic news further out the term structure (Swanson and Williams, 2014).

The four panels of Figure 2 show the model estimates of the effects of each of these four policies on the yield curve in December 2013. Each panel shows the difference between model-implied yields with one of these policies and model-implied yields without any of these policies. Results are shown both under the Q and P measures.

⁵Note that this does not correspond to the numerical threshold for unemployment in forward guidance given by the FOMC—that threshold was 6.5 percent. By December 2013, the unemployment rate was 6.7 percent, and so a 6.5 percent threshold was moot. But in that month, the FOMC stated that the funds rate would stay at zero “well past the time that the unemployment rate declines below 6-1/2 percent.” Minneapolis Fed President Narayana Kocherlakota proposed a 5.5 percent threshold for liftoff.

⁶Laseen and Svensson (2011) and Del Negro et al. (2012) were considering DSGE models, not an affine term structure model as in the present paper.

The results under the Q measure show the effects on actual yields. The results under the P measure can be interpreted as showing the effects on average expected future short rates over different horizons. The difference between the two is the effect on the term premium.

Volatility forward guidance lowers expected future rates. This arises because of the ZLB. In the absence of forward guidance, a large enough positive shock to the shadow rate would raise expected short rates, whereas a negative shock to the shadow rate cannot do anything to short rates. Removing shocks consequently lowers the expected path of policy. But, as can be seen in Figure 2, volatility forward guidance also operates through reducing term premia. Volatility forward guidance can lower yields by up to 25 basis points, with the peak effect occurring at the 2-3 year maturity. Akkaya (2014) considers a DSGE model of stochastic monetary policy uncertainty and shows, via a third order perturbation solution, that forward guidance affects real variables as much through reducing monetary policy uncertainty as through reducing the level of interest rates. There the mechanism works via consumers' risk aversion and precautionary savings. Filardo and Hoffmann (2014) suggest that forward guidance might lower term premia via reducing uncertainty, and our results are consistent with their conjecture. Volatility forward guidance may be politically appealing because it doesn't involve a change in the mean reaction function. At the same time, it does not directly map into any of the forms of forward guidance that the Fed or other central banks have employed.

A shock to the shadow rate is also a rather vague form of forward guidance, that can be interpreted as simply setting a higher bar for liftoff than would be implied by direct application of the Taylor rule (equation (1)). This policy lowers expected future short rates, but actually raises term premia. On net, longer-term bond yields drop slightly under this policy. A possible economic intuition for the increase in

term premia is that more accommodative monetary policy increases the inflation risk premium.

Unconditional commitment corresponds to calendar-based forward guidance, although no central bank has issued such guidance without some kind of escape clause. The effects on short-term yields are limited, because the shadow rate starts out too far below zero for it to matter. But yields with maturities from about two to five years drop by about 50 basis points. Conditional commitment corresponds to threshold-based forward guidance. This has a smaller effects on the yield curve than unconditional commitment, but the effect is still sizeable. With both policies 3 and 4, average expected future short rates decline by more than yields, as the forward guidance policy causes term premia to rise.

We also consider the effects of applying the same four policies in December 2012. As can be seen in Figure 1, in December 2012, the shadow rate was a good bit lower than it was a year later. That in turn alters the effects of the forward guidance. The four panels of Figure 3 show the model-implied effects of each of these policies in December 2012. The volatility forward guidance, shock to the shadow rate, and unconditional commitment all have effects in the same direction, but of smaller magnitude, than in December 2013 (Figure 2). Intuitively, this is because the further the shadow rate is below zero, the less impact monetary policy shocks over the next two year are going to have. On the other hand, the conditional commitment has about the same effect on longer term yields in December 2012 as it does in December 2013, though the effects on shorter term yields are smaller in December 2012. Intuitively, this is because conditional commitment will affect the expected future policy path at *some* horizon no matter what the level of the shadow rate, though the more negative is the shadow rate, the more delayed the effect on the policy path will be. In this paper, we assume all policies to be perfectly credible. But in practice, of course, the

further out commitment is tying the hands of a central bank, the less credible it is likely to be.

Finally, we consider the effects of applying the first two types of forward guidance: volatility forward guidance and forward guidance concerning shocks to the shadow rate in December 2007, before the ZLB applied. The effects of these shocks depend very little on the state vector once short rates are above zero, and so we can think of these as impulse responses at any time when the ZLB is far from binding. Away from the ZLB, commitment to keep rates at zero is of course not a meaningful experiment, which is why we consider only the first two types of forward guidance. The results are shown in Figure 4. The volatility forward guidance has no effect. This is because away from the ZLB, eliminating shocks is as likely to raise as to lower the expected path of future short rates. Away from the ZLB, shocks to the shadow rate are effectively shocks to the short rate and they consequently have a much larger effect on the yield curve than we found for shocks to the shadow rate in Figures 2 and 3.

3 Event-study analysis of monetary policy shocks at the ZLB

As noted above, forward guidance may jointly reduce both the expected path of future monetary policy and uncertainty around this path. In this section, we use an event-study methodology to examine the separate effects on equity and currency markets of news about the path of future monetary policy and news about the uncertainty surrounding that path.

It has long been understood that monetary policy announcements are complicated and contain much more information than just the decision about the target federal

funds rate. Before the ZLB era, Gürkaynak et al. (2005) considered two measures of the information content of a monetary policy announcement—the “target surprise” and the “path surprise”. The target surprise is the unexpected component of the decision about the target federal funds rate; the path surprise is the orthogonalized jump in four-quarter ahead interest rate futures, reflecting the content of the Fed’s statement. In this paper, we propose updating this methodology to the ZLB period. There are no longer shocks to the federal funds target—no FOMC meeting since December 2008 has made any change to the target funds rate, nor did investors assign any probability to funds rate changes. But there were path surprises, which we define as the change on FOMC announcement days in the eighth eurodollar futures contract⁷. And, we add a new element of monetary policy announcements—the “uncertainty surprise”. This can be measured from the change in options-implied volatility on the eighth eurodollar futures contract on the day of the monetary policy announcement, orthogonalized with respect to the path surprise. The orthogonalization is important because at the ZLB, a downward shift in the expected path of policy will mechanically lower interest rate uncertainty. We use the event-study methodology to estimate the effects of each of path and uncertainty shocks on stock prices. This is a model-free way of assessing the separate impacts of changes in the expected path of monetary policy, and changes in uncertainty about that path. The event study regression is

$$y_t = \beta_1 Path_t + \beta_2 Uncertainty_t + \varepsilon_t \quad (8)$$

where y_t is the change in an asset price on the day of a monetary policy announcement, and $Path_t$ and $Uncertainty_t$ represent the path surprise and orthogonalized

⁷The eighth contract is a bet on interest rates about two years ahead. Nearer term futures contracts are less sensitive to incremental forward guidance because for much of the ZLB period, nearer-term expectations were already stuck near zero (Swanson and Williams, 2014).

uncertainty surprise, both as defined above.

The results are shown in Table 2 for three assets: S&P returns and the dollar exchange rates viz-a-viz the euro and yen (both defined as dollars per unit foreign currency). These asset returns are important, because the stock market wealth channel and exchange rate channel are two important ways in which unconventional monetary policy can be hoped to support economic activity. The regression is run over the period from January 2009 to March 2014, a period with a total of 42 FOMC announcements. The sample size is fairly small, but there were a number of sizeable surprises over this period. The path and uncertainty surprises are both estimated to have a negative effect on stock prices. This means that the equity market is boosted by both a lower futures-implied path and by less interest rate uncertainty. However, the effect of the path surprise is only statistically significant at the 10 percent level, whereas the effect of the uncertainty surprise is statistically significant at the 1 percent level. Uncertainty shocks seem to have a separate (and more strongly identified) effect on equity markets. On the other hand, the path surprise is estimated to have a negative effect on the euro and yen exchange rates (a lower futures-implied path implies a weaker dollar) which is significant at the 5 percent level, but uncertainty surprises are not estimated to have any significant effects on currency returns. We do not show the effects of path and uncertainty surprises on long-term interest rates—path surprises have a significant positive effect on long-term interest rates while uncertainty surprises do not, but this is almost by construction, since the path surprise is a measure of the change in the slope of the yield curve. It should also be borne in mind that our path and uncertainty surprises reflect news both about future policy expectations/uncertainty and about bond risk premia. The event study approach does not allow these to be separated out.

4 Conclusions

We have examined forward guidance in a macro-finance shadow rate term structure model. We find that it affects yields both via changing the expected future path of policy and via changing term premia, although these two effects may go in opposite directions. We have evaluated the effects of different types of forward guidance. Most forms of forward guidance are more effective if the shadow rate is close to zero than if it is substantially negative, but of course a central bank is most likely to be uncomfortable about an additional commitment to accommodative monetary policy when liftoff is near. In other words, forward guidance is most effective when liftoff is near precisely because it constrains the central bank to make a commitment that it may well regret *ex-post*. We also considered an event study analysis of the effects of monetary policy shocks at the ZLB. We split the monetary policy news into orthogonal path and uncertainty surprises. We find that monetary policy announcements that reduce interest rate uncertainty significantly boost the stock market.

Table 1: Measurement Error in Yields

Maturity	Standard Deviation (percent per annum)
6 months	0.42
1 year	0.42
2 year	0.80
3 year	0.57
4 year	0.68
5 years	0.98

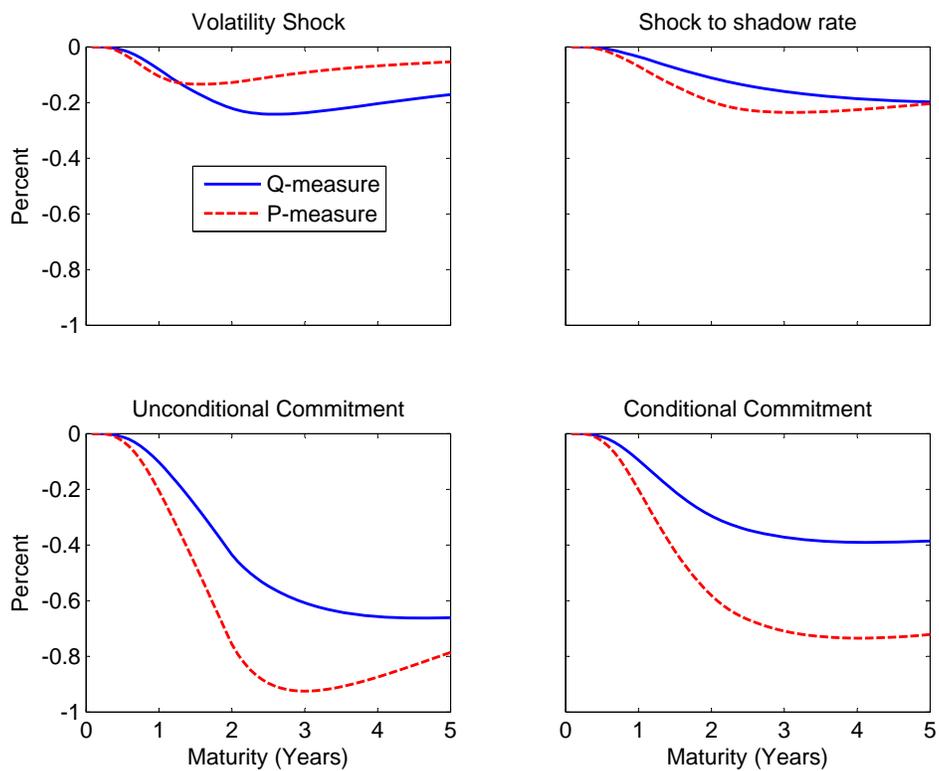
Note: This table shows the maximum likelihood estimates of the yield fitting error standard deviation (in percent per annum) over the pre-ZLB sample (January 1990-December 2007). By construction, the one month yield always fits perfectly.

Table 2: Event Study Results

	S&P	Euro	Yen
Path Surprise	-3.33* (1.87)	-3.38** (1.70)	-2.96** (1.41)
Uncertainty Surprise	-25.37*** (5.77)	0.09 (7.37)	1.51 (5.16)

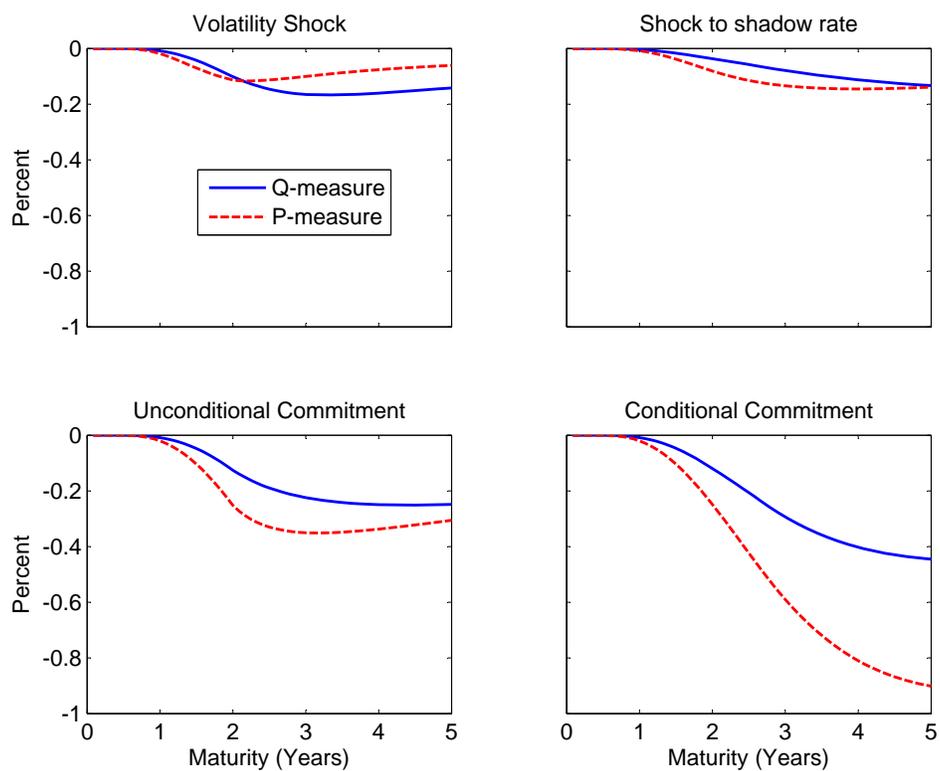
Note: This table shows the estimates from the estimation of equation (7). The path surprise is defined as the change in the eighth eurodollar futures contract on the days of FOMC announcements, and the uncertainty surprise is defined as the orthogonalized change in the implied volatility from options on this contract. The surprises are both measured in percentage points; stock and currency returns are measured as 100 times log daily changes. Heteroskedasticity-robust standard errors are given in parentheses. One, two and three asterisks denote statistical significance at the 10, 5 and 1 percent levels, respectively. The sample period is all FOMC meetings from January 2009 to March 2014, inclusive, for a total of 42 observations.

Figure 2: Effects of Counterfactuals on the Yield Curve: December 2013



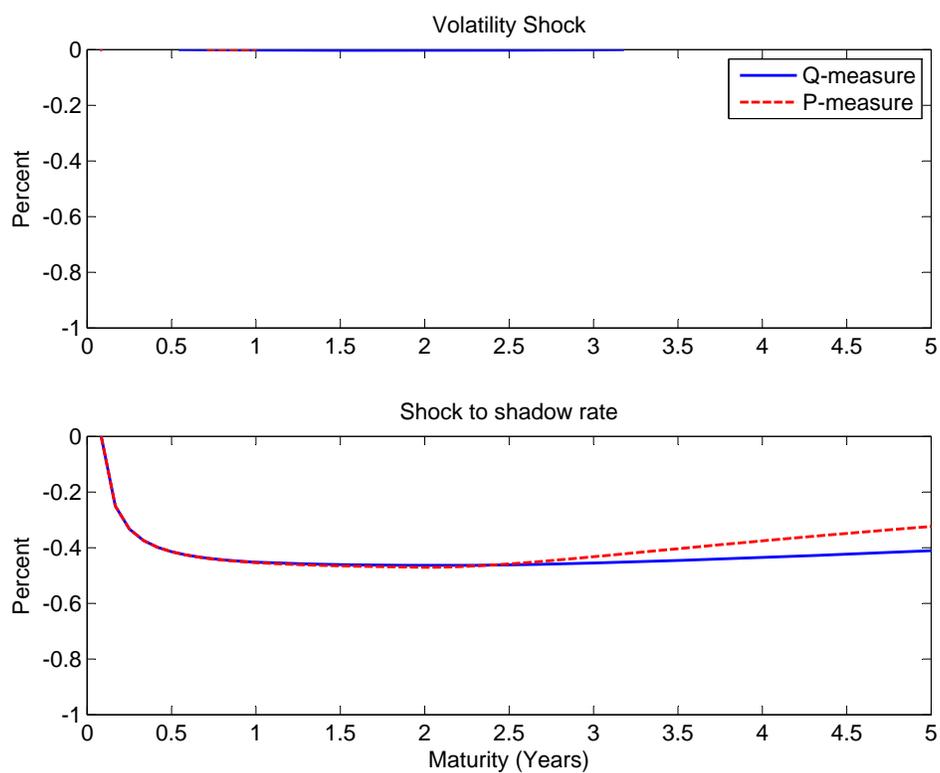
Note: This figure plots the estimated effects of counterfactual policies 1-4, described in the text, on the term structure of interest rates under the P and Q measures. Results under the Q measure correspond to the predicted effects on yields; results under the P measure correspond to the predicted effect on expected future average short rates. These calculations assume that the state vector is initially as estimated in December 2013.

Figure 3: Effects of Counterfactuals on the Yield Curve: December 2012



Note: As for Figure 2, except that these calculations assume that the state vector is initially as estimated in December 2012.

Figure 4: Effects of Counterfactuals on the Yield Curve: December 2007



Note: As for Figure 2, except that these calculations assume that the state vector is initially at its value in December 2007. Results are only shown for counterfactual policies 1 and 2. Impulse responses are very similar if the state vector is set to its value at any time when the ZLB is far from binding.

References

- Akkaya, Yildiz**, “Uncertainty of Interest Rate Path as a Monetary Policy Instrument,” 2014. working paper.
- Ang, Andrew, Jean Boivin, Sen Dong, and Rudy Loo-Kung**, “Monetary Policy Shifts and the Term Structure,” *Review of Economic Studies*, 2011, 78, 429–457.
- Bauer, Michael D.**, “Monetary Policy and Interest Rate Uncertainty,” 2012. San Francisco Fed Economic Letter.
- **and Glenn D. Rudebusch**, “Monetary Policy Expectations at the Zero Lower Bound,” 2013. Federal Reserve Bank of San Francisco Working Paper 2013-18.
- Black, Fisher**, “Interest Rates as Options,” *Journal of Finance*, 1995, 50, 1371–1376.
- Campbell, Jeffrey R., Charles Evans, Jonas D.M. Fisher, and Alejandro Justiniano**, “Macroeconomic Effects of Federal Reserve Forward Guidance,” *Brookings Papers on Economic Activity*, 2012, 1, 1–80.
- Eggertsson, Gauti and Michael Woodford**, “The Zero Lower Bound on Interest Rates and Optimal Monetary Policy,” *Brookings Papers on Economic Activity*, 2003, 1, 139–211.
- Filardo, Andrew and Boris Hoffmann**, “Forward Guidance at the Zero Lower Bound?,” *BIS Quarterly Review*, 2014, March, 37–53.
- Gürkaynak, Refet S., Brian Sack, and Eric T. Swanson**, “Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements,” *International Journal of Central Banking*, 2005, 1, 55–93.
- Julier, Simon J. and Jeffrey K. Uhlmann**, “A New Extension of the Kalman Filter to Non-linear Systems,” *Proceedings SPIE Signal Processing, Sensor Fusion, and Target Recognition VI*, 1997, 3068, 182–193.
- Kydland, Finn E. and Edward C. Prescott**, “Rules rather than Discretion: The Inconsistency of Optimal Plans,” *Journal of Political Economy*, 1977, 85, 473–490.
- Laseen, Stefan and Lars E.O. Svensson**, “Anticipated Alternative Policy-Rate Paths in Policy Simulations,” *International Journal of Central Banking*, 2011, 7, 1–35.
- Negro, Marco Del, Marc Giannoni, and Christina Patterson**, “The Forward Guidance Puzzle,” 2012. Federal Reserve Bank of New York Staff Report 574.
- Rogoff, Kenneth**, “The Optimal Degree of Commitment to an Intermediate Monetary Target,” *Quarterly Journal of Economics*, 1985, 100, 1169–1189.
- Swanson, Eric T. and John C. Williams**, “Measuring the Effect of the Zero Lower Bound on Medium- and Longer-term Interest Rates,” *American Economic Review*, 2014, 104, 3154–3185.
- Woodford, Michael**, “Methods of Policy Accommodation at the Interest-Rate Lower Bound,” *Federal Reserve Bank of Kansas City Jackson Hole Symposium Conference Volume*, 2012.