Unconventional Monetary Policy and Uncertainty*

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Abstract

Using a structural factor-augmented VAR and a large novel database of daily time series, we examine the impact of unconventional monetary policy on financial and economic uncertainty. Our findings indicate that expansionary unconventional monetary shocks lead to large reductions in uncertainty across markets. A surprise unconventional monetary easing lowers equity market, policy, housing and mortgage market, exchange rate, and Treasury market uncertainty. Research results further suggest that these reductions in uncertainty differ in magnitude across asset classes and are largest for equity markets. Last, we find that these effects on uncertainty diminish quickly and dissipate after approximately 100 days.

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At the height of the Great Recession, uncertainty reached unprecedented levels leading to higher unemployment, delayed investment, reduced productivity, and the threat of economic depression.[1] To stem this rise in uncertainty and combat the crisis, the Federal Reserve employed exceptional and unconventional monetary policy tools such as Quantitative Easing (QE). Yet in the face of Fed's policy ambitions, both researchers and policymakers questioned the effectiveness of the new policy tools, their impact on uncertainty, and their benefits for the real economy.[2] As elevated levels of uncertainty adversely affect investment, employment, and productivity (Bernanke (1983) and Bloom (2009)), determining the impact of the Fed's recent policies on uncertainty is crucially important to understanding how unconventional monetary policy affects the real economy.

In this paper, we use a structural factor-augmented vector autoregression (FAVAR) model (Bernanke, Boivin, and Eliasz (BBE; 2005) and Boivin, Giannoni, and Mihov (BGM; 2009)) and a large dataset of daily financial and economic time series to study the impact of unconventional monetary policy on uncertainty. We follow the recent literature, including Bloom (2009) and Baker, Bloom, and Davis (BBD; 2013), and measure uncertainty through a set of VIX implied volatility indices and various news-based proxies. Our results indicate that a surprise unconventional monetary policy easing lowers uncertainty across markets. More specifically, we find that expansionary unconventional monetary policy shocks reduce uncertainty in equity, housing and mortgage, currency, and Treasury-bond markets. These results further extend to both large- and small-cap

[1] See Baker, Bloom, and Davis (2013). Bloom (2009) shows that uncertainty shocks delay investment, dampen productivity, and increase unemployment.

[2] Some went as far as to suggest that Fed policies actually *increased* economic uncertainty. For example, Congressman Kevin Brady, the Vice Chairman of the Joint Economic Committee in Congress, suggested in September of 2012 that unconventional monetary policy may be ineffective as it creates "short-term uncertainty in the market." Similarly in March of 2013, John Taylor contended that Fed "policies have been a drag on the recovery...[as these] policies *create uncertainty*" (emphasis added). Both Taylor and Brady have argued that the Fed's unconventional has not been beneficial to for the real economy. In Europe, the *Financial Times* (2015) argued ECB QE had failed to raise capital expenditures. "A Review of Recent Monetary Policy;" John Taylor; Testimony Before The U.S. House of Representatives; March 5, 2013. "Fed Approach on Quantitative Easing Receives Partisan Criticism;" *Bloomberg News;* September 13, 2012. "The printing press rolls...but spending lags. *Financial Times;* September 15, 2015.

stocks, a longer-run measure of uncertainty, and to economic policy uncertainty. For example, an expansionary unconventional monetary policy shock that lowers the yield on the 10-year Treasury by 10 basis points is associated with a reduction in the VIX index, a common measure of economic uncertainty in the literature (Bloom (2009)), of nearly 16.3 points.[3] This result, which is highly significant, is also economically meaningful and large in magnitude as the standard deviation of the daily VIX index over the sample period was 10.5 points. Moreover, research results also suggest that the effects of unconventional monetary policy shocks on uncertainty differ in magnitude across markets and are largest for equity markets. A surprise unconventional monetary easing that reduces the yield on the 10-year Treasury by 10 basis points lowers uncertainty in equity markets by more than one standard deviation, but leads to a less than one standard deviation decrease in uncertainty in housing and mortgage markets, Treasury markets, exchange rate markets, and for economic policy uncertainty. Lastly, we also find that the effects of the policy shocks attenuate fairly quickly and nearly completely dissipate after 100 days, suggesting that multiple rounds of unconventional monetary easing may be needed in order to facilitate a period of low economic and financial market uncertainty like that experienced in the wake of the recent US Quantitative Easing program.[4]

In addition to the VIX index, our dataset includes a number of other implied volatility series that are used as uncertainty proxies in the markets for large- and small-cap stocks, technology stocks, US Treasuries, and exchange rates; three news-based measures that track policy, equity, and housing and mortgage market uncertainty; and 23 other variables spanning equity, debt, currency, and real estate markets that are used as controls.

[3]See also Baker, Bloom and Davis (2013), Caggiano, Castelnuovo, and Groshenny (2014), and the references therein. These papers typically use the VIX index as a measure of economic and financial uncertainty.

[4]In the aftermath the Fed's unconventional monetary stimulus program, measures of uncertainty, such as VIX index, were at multi-year lows. Many financial market practitioners attributed the lows in the VIX index to the Quantitative Easing stimulus programs pursued between 2008 and 2013. See, for example, the following articles: "Quantitative easing is like a 'huge glass of warm milk' for VIX". *MarketWatch* April 17, 2013; and "Stocks in Summer Slumber as VIX Tumbles Most Since 2012". *Bloomberg News*. August 29, 2014.

The news-based uncertainty measures are compiled as in BBD and track the frequency of news articles that reference economic uncertainty in the context of economic policy, equity markets, or housing and mortgage markets. Together, the implied volatility and news-based variables allow us to capture changes in uncertainty across asset classes and ensure that our results are robust to uncertainty proxies constructed using different data methodologies.

The advantages of the FAVAR model in the assessment of unconventional monetary policy shocks on uncertainty are manifold. First, the FAVAR model allows us to entertain several proxies of uncertainty that span multiple asset classes and data methodologies all within a single econometric framework. Thus, through the FAVAR framework, we can study the effects of unconventional monetary policy on uncertainty in the various markets of potential importance to both practitioners and policymakers. Second, the FAVAR methodology accommodates numerous time series, yielding a model that minimizes the potential omitted variable bias issues often found in standard VARs and more accurately measures unconventional monetary policy shocks.[5] Further, our econometric framework allows us to combine the FAVAR model with an identification strategy that exploits the fact that dates of unconventional monetary announcements occur by an accident of the calendar and therefore are exogenously determined (Wright (2012)).[6] Intuitively, our key identification assumption is that news regarding monetary policy shocks surfaces in a "lumpy manner" (Wright (2014)). Technically, this assumption asserts that the variance-covariance matrix of VAR innovations is heteroskedastic across monetary policy event and non-event days. Overall, this identification strategy is beneficial for our purposes as it only requires the dates when monetary policy news was released and thus circumvents the need to measure market expectations regarding Fed monetary policy statements; an important feature in our application as measuring expectations for monetary policy across

[5] See the "Price Puzzle" issue of Sims (1992) and BBE for more details.

[6] See also Rigobon and Sack (2003, 2004, 2005), and Rigobon (2003). For other applications, see Gilchrist and Zakrajšek (2013), Rogers, Scotti, and Wright (2014).

markets in the context of uncertainty would be a markedly difficult task. Last, our setup also allows for other shocks to occur on monetary policy event days and yields impulse response functions (IRFs) that describe the initial response and longer-run impact of monetary policy shocks. This latter benefit may be important during our sample period as some asset prices may react slowly to monetary announcements during times of low liquidity (Krishnamurthy and Vissing-Jorgenson (2011)).

Through this econometric approach, our aim is to quantify the total effect of unconventional monetary policy actions on uncertainty. These monetary policy actions are inclusive of large-scale asset purchases (e.g. Quantitative Easing (QE)), forward guidance regarding the future direction of monetary policy, and other policies pursued by the Federal Reserve over the recent period. Hence, our goal is somewhat different than event studies that also consider the effects of unconventional monetary policy.[7] These event studies often aim to identify the effects of different Federal Reserve policies. But event studies cannot provide estimates for the persistence of monetary policy shocks, must measure market expectations regarding Fed policies (a notably difficult task), and are vulnerable to endogeneity concerns if other macroeconomic or financial market shocks occur around Federal Reserve Open Market Committee (FOMC) statements.

This paper builds on a large recent literature that attempts to measure the effects of unconventional monetary policy.[8] We extend the recent unconventional monetary policy literature and examine impact of unconventional monetary policy on uncertainty. In other related work, Bekaert, Hoerova, and Lo Duca (2013) examine the effects of conventional monetary policy on risk aversion and uncertainty using a four-variable structural monthly VAR. Bekaert, Hoerova, and Lo Duca do extend their baseline analysis to a sample that includes the recent financial crisis, but find that their results become less

[7]See Glick and Leduc (2013), Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgenson (2011), and Swanson (2011).

[8]See, for example, Doh (2010), Fuster and Willen (2010), Hancock and Passmore (2011, 2012, 2014), Hamilton and Wu (2012), Duygan-Bump et al. (2013), D'Amico and King (2013), Swanson and Williams (2014), Eser and Schwaab (2015), Lutz (2015), and Wu and Xia (2015).

statistically significant for this full sample period. They note that this result is due to the difficulty in measuring unconventional monetary policy shocks. Overall, our paper extends Bekaert, Hoerova, and Lo Duca (2013) in two key directions: (1) We build a structural FAVAR model using daily data to assess the effects of unconventional monetary shocks on uncertainty during the recent period of economic and financial distress; and (2) our paper employs multiple measures of uncertainty, allowing us to asses the effects of unconventional monetary policy on uncertainty across markets and asset classes.

Lastly, our work also contributes to the growing recent literature that aims to determine the factors that lead to changes in economic uncertainty.[9] Indeed, we find that unconventional monetary policy shocks can lead to large changes in uncertainty, in that a surprise monetary easing that lowers the yield on the 10-year Treasury by 10 basis points reduces the VIX index, a widely used measure of uncertainty, by over 16 points.

1 Econometric Methodology

This section outlines our strategy to measure the impact of unconventional monetary policy on uncertainty. First, we discuss the FAVAR model of BBE and BGM. Section 1.1 below then describes our identification strategy based on the heteroskedasticity of the variance-covariance matrix of the VAR innovations across monetary policy event and non-event days.

To estimate the FAVAR model, this paper follows BBE and BGM and assumes that financial markets are affected by a set of fundamental interest rates, a vector of observed factors, and a basket of latent factors. Together, we assume that the latent and observed factors capture the dynamics of financial markets over the sample period. Prior to estimation, we first must select the key time series to be included in the set of observed

[9]See Alexopoulos and Cohen (2009), Bachmann, Elstner, and Sims (2013), Mumtaz and Theodoridis (2012), Gilchrist, Sim, and Zakrajsek (2014), Leduc and Liu (2013), Colombo (2013), Nodari (2013), Mumtaz and Surico (2013), and Caggiano, Castelnuovo, and Groshenny (2014). For studies that consider news-based uncertainty measures see, for example, Antonakakis, Chatziantoniou, and Filis (2012), Born and Pfeifer (2012), Brogaard and Detzel (2012), Azzimonti and Talbert (2013), Benati (2013), Henzel and Rengel (2013), Orlik and Veldkamp (2014), and Shoag and Veuger (2014).

factors. Here, our approach is based on Wright (2012). More specifically, we let the set of observed factors consist of the 2-year Treasury, the 10-year Treasury, the five-year TIPS breakeven, the forward five-to-ten-year TIPS breakeven, and the Moody's Aaa and Baa seasoned corporate bond yields. These interest rate series are described in more detail below in section 2. In section 4, we consider a number of alternative specifications for the vector of observed factors in the estimation of our FAVAR model. Overall, these supplementary results are similar to those found throughout the rest of this paper.

After specifying the set of observed factors, we can then estimate the FAVAR model and identify the structural unconventional monetary policy shocks. First, let the set of informational time series be all time series in the dataset except for the variables that constitute the observed factors. Thus, the set of informational time series consists of 27 variables and includes our proxies for economic and financial uncertainty. We describe these variables and the entire dataset in more detail in section 2.

The first step in our estimation procedure is to extract a set of common components from the set of informational time series. Specifically, let X_t be a de-meaned $N \times 1$ vector of "informational times series" at time t that includes all variables in the dataset except for the series that constitute the observed factors. Moreover, assume that financial markets are affected by a $(K + 6) \times 1$ vector of common factors, C_t, that contains the latent and observed factors:

$$C_t = \begin{bmatrix} F_t \\ S_t \end{bmatrix} \tag{1}$$

where F_t is the $K \times 1$ vector of latent factors and S_t is the set of observed factors. As suggested above, the common component, C_t, is assumed capture the dynamics of financial markets over the sample period. Then, in accordance with step (1) above, we extract the latent factors and estimate the corresponding factor loadings via the following observation equation using principal component analysis:

$$X_t = \Lambda C_t + e_t \tag{2}$$

where Λ is the $N \times (K+6)$ matrix of factor loadings and e_t is an $N \times 1$ vector of idiosyncratic components. Here, we follow BGM and impose the constraint that S_t is one of the common factors.[10]

Next, we use C_t, the common component, to estimate a reduced-form VAR via the following measurement equation:

$$C_t = \Phi(L)C_{t-1} + v_t \tag{3}$$

where $\Phi(L)$ is a conformable polynomial lag of finite order and v_t is a $(K+6) \times 1$ vector of reduced-form errors. Moreover, as in Wright (2012), we let the reduced-form errors be a linear combination of the structural shocks:

$$v_t = \sum_{i=1}^{K+6} R_i \eta_{i,t} \tag{4}$$

where $\eta_{i,t}$ is the ith structural shock at time t and R_i is a $(K+6)\times 1$ vector to be estimated. As in Wright (2012), we assume that the structural shocks are independent over both i and t. Further, as is standard in the VAR literature, assume that the parameters Λ, $\Phi(L)$, and $\{R_i\}_{i=1}^{K+6}$ are all constant over time.

1.1 Identification and Impulse Response

We identify the structural monetary policy shocks from equation 4 by assuming that the variance of the monetary shock differs across monetary policy event and non-event days as in Rigobon (2003), Rigobon and Sack (2003, 2004, 2005), and Wright (2012). The aforementioned events include all FOMC statements and major policy speeches. As noted above, our identification assumption relies on the fact monetary policy announcements occur by accident of the calendar and therefore are exogenously determined.

We order the structural monetary policy shock first (for convenience) and let the monetary shock have zero mean and variance equal to σ_1^2 on policy event days and σ_0^2

[10] As in BGM, we impose this constraint using the following algorithm: (1) extract the first K principal components from X_t, denoted $F_t^{(0)}$; (2) regress X_t on $F_t^{(0)}$ and S_t to obtain $\tilde{\lambda}_S^{(0)}$, the regression coefficient on S_t; (3) define $\tilde{X}_t^{(0)} = X_t - \tilde{\lambda}_S^{(0)} S_t$; (4) calculate the first K principal components of $\tilde{X}_t^{(0)}$ to get $F_t^{(1)}$; (5) Repeat steps (2) to (4) multiple times.

on non-event days.[11] Our key assumption of heteroskedasticity across event and non-event days thus asserts that $\sigma_0^2 \neq \sigma_1^2$. Further, assume that all other structural shocks are identically distributed with zero mean and unit variance on all days. This latter assumption relies on the notion that monetary policy announcements occur by an accident of the calendar so that the other structural shocks should be independent across monetary policy event and non-event days.[12]

To identify the structural monetary shocks and compute the impulse response functions, we first need to determine R_1, the parameter vector that relates the structural shocks to the reduced-form errors. Let Σ_1 and Σ_0 be the variance-covariance matrices for the reduced-form VAR errors on event and non-event days, respectively. Then, from equation 4 we see that

$$\Sigma_1 - \Sigma_0 = R_1 R_1' \sigma_1^2 - R_1 R_1' \sigma_0^2 = R_1 R_1' (\sigma_1^2 - \sigma_0^2) \tag{5}$$

Note that since $(\sigma_1^2 - \sigma_0^2)$ and $R_1 R_1'$ are not separately identified, we follow Wright (2012) and normalize $(\sigma_1^2 - \sigma_0^2)$ to be equal to 1. Then solving the following minimum distance problem yields an estimate for R_1:

$$\hat{R}_1 = \underset{R_1}{\text{argmin}} [vech(\hat{\Sigma}_1 - \hat{\Sigma}_0) - vech(R_1 R_1')]' [\hat{V}_0 + \hat{V}_1]^{-1} [vech(\hat{\Sigma}_1 - \hat{\Sigma}_0) - vech(R_1 R_1')] \tag{6}$$

Here, $\hat{V}_0$ and $\hat{V}_1$ are the estimates of the variance-covariance matrices of $vech(\hat{\Sigma}_0)$ and $vech(\hat{\Sigma}_1)$, respectively. No other model assumptions are required as we are not attempting to identify the other structural shocks.

Next, we calculate the dynamic responses for the observed and latent factors based on the VAR described in equation 3 in the usual way. Then the IRFs for the variables that constitute the set of informational time series, X_t, can be calculated by simply vector multiplying the factor loadings obtained from equation 2 by the dynamic responses for the latent and observed factors. Since the FAVAR framework relies upon "generated

[11] As we are identifying the structural monetary policy shocks by assuming heteroskedasticity across monetary policy event and non-event days, the order of the variables in our VAR is for convenience only. See Wright (2012) for more details.

[12] See Wright (2012) and Gabriel and Lutz (2014) and the references therein for more details.

regressors," confidence intervals are computed using the two-step and stationary block bootstrap techniques of Kilian (1998) and Politis and Romano (1994). As in Wright (2012), we set the block length to 10 days. Note that we also apply the Kilian bias correction to the VAR point estimates.

Lastly, we employ statistical tests to ensure that the variance-covariance matrices of reduced-form errors are indeed heteroskedastic across event and non-event days and that there is a single monetary shock. First, we assess the null hypothesis that $\Sigma_0 = \Sigma_1$. The relevant test statistic is as follows:

$$[vech(\hat{\Sigma}_1 - \hat{\Sigma}_0)]'[\hat{V}_0 + \hat{V}_1]^{-1}[vech(\hat{\Sigma}_1 - \hat{\Sigma}_0)] \tag{7}$$

Clearly, a rejection of the null will indicate heteroskedasticity across event and non-event days. The null will be evaluated based on a bootstrapped distribution. To test for a single monetary shock we evaluate the hypothesis that $\Sigma_1 - \Sigma_0 = R_1 R_1'$; where failure to reject the null will provide support for a single monetary shock. The corresponding test statistic is

$$[vech(\hat{\Sigma}_1 - \hat{\Sigma}_0) - vech(R_1 R_1')]'[\hat{V}_0 + \hat{V}_1]^{-1}[vech(\hat{\Sigma}_1 - \hat{\Sigma}_0) - vech(R_1 R_1')] \tag{8}$$

Significance is evaluated based a bootstrapped distribution using the two-step bias adjusted bootstrap of Kilian (1998).

2 Data

We consider 48 monetary policy events and daily data from November 2008 to December 2013, where the most important events are listed in table 1. These events include all FOMC events and major speeches by the Fed Chair and cover QE1, QE2, QE3, and the recent so-called "taper" period where the FOMC indicated that it would reduce its extraordinary monetary stimulus. Thus, our dataset covers nearly a full cycle of US unconventional monetary policy.[13] In our main results, we identify the structural monetary policy shocks using all 48 events over the sample period; section 4 below extends

[13] The list of event days is extended from Glick and Leduc (2013) and Wright (2012).

our main analysis and uses just the 15 major events listed in table 1 for identification.

To assess the effects of unconventional monetary policy on uncertainty, we consider a broad dataset within the our structural FAVAR model. The data include uncertainty measured through the VIX index and related implied volatility measures, news based uncertainty proxies, and several other macro and financial and variables. In appendix C, we show a complete list of the variables used in this study, the variable definitions, data transformations, and the data sources. The data are measured at the daily frequency. We discuss the most relevant data in the following sections in turn.

2.1 Uncertainty–VIX Indices

First, we consider uncertainty via the VIX indices. The standard VIX index is defined as the expected variance of S&P500 returns over the next 30 days and is measured from S&P500 options.[14] As in Bloom (2009) and Caggiano, Castelnuovo, and Groshenny (2014), the VIX index will serve as a broad indicator for uncertainty over the sample period.

Along with the standard VIX index, we also use implied volatility proxies that cover large cap stocks (the Dow Jones Industrial Average (DJIA) VIX), the Nasdaq100 (Nasdaq VIX), small cap stocks (Russell 2000 VIX), longer term implied volatility over a 93 day period (VIX 3 Month), Dollar/Euro implied volatility in the currency market (Euro VIX), and an expected volatility measure based on 10-year US Treasuries (Treasury VIX). Together, this comprehensive set of implied volatility proxies allows us to asses the effects of unconventional monetary policy on uncertainty in a broad set of asset classes that span multiple markets.

Following Bekaert, Hoerova, and Lo Duca (2013), we consider the log of the VIX indices. Table 2 shows the correlations of the daily log-transformed VIX indices. The top five rows of the table display the correlations of the VIX indices that track implied

[14]For more information on the VIX methodology, see the website for the Chicago Board Options Exchange.

volatility for the S&P500 (the standard VIX index), the Nasdaq100, the Russell2000, and the DJIA. These results also include the VIX 3 Month, which captures the implied volatility of the S&P500 over a longer time period. As expected, these series are all strongly related over the sample with correlation coefficients that all exceed 0.9. Thus, uncertainty over the cross-section of stocks appears to be closely related. The next two rows show the correlations between the Treasury VIX or the Euro VIX and the other implied volatility measures. While the Treasury VIX and the Euro VIX are correlated with the equity market uncertainty proxies, the coefficients are all relatively smaller in magnitude and range between approximately 0.75 and 0.9. Finally, the correlation between the Treasury VIX and the Euro VIX is 0.75.

2.2 News Based Uncertainty

In addition to the VIX indices, this study also employs news-based uncertainty measures as in Baker, Bloom, and Davis (BBD; 2013). These measures cover economic policy uncertainty, as well as uncertainty in equity and housing markets. The policy and equity market uncertainty variables are from BBD, while we build an indicator of housing and mortgage market uncertainty by extending BBD's methodology. BBD construct their economic policy uncertainty index (henceforth, Policy Uncertainty) at the daily frequency by identifying the number of news articles from the NewsBank Access World News database that contain the words "uncertainty" or "uncertain," and "economic" or "economy" along with a government related term including "legislation," "deficit," "regulation," "congress," "federal reserve," or "white house." They then standardize the number of articles that match their search criteria by the number of articles written. Similarly, BBD construct the equity market uncertainty index (henceforth, Equity Uncertainty) by identifying the portion of NewsBank articles that contain the words "uncertain" or "uncertainty," "economic" or "economy," and one of the following terms: "equity market," "equity price," or "stock market."

To build our housing uncertainty index, we extend BBD's methodology to housing and mortgage markets. We query the NewsBank database for the portion of news articles that contain the words "uncertainty" or "uncertain," and "economic" or "economy" along with the housing or mortgage related keywords "housing market," "housing price," "house price," or "mortgage rate." In line with BBD, this measure will represent uncertainty in housing and mortgage markets (henceforth, Housing and Mortgage Uncertainty).

Lastly, as with the VIX indices described above, we consider the log the news-based uncertainty measures. Then, the news-based uncertainty measures are standardized to have zero mean, unit variance and so that higher values indicate increased uncertainty.

The last three rows of table 2 show the correlation coefficients between the news-based uncertainty proxies and the various VIX indices. Overall, the results indicate that the news-based uncertainty measures are positively correlated with the VIX indices, but the coefficients are relatively small in magnitude. For example, the correlation between Policy Uncertainty and the VIX index is 0.33, while that between Equity Uncertainty and the VIX is 0.37. These correlations are all statistically significant at the 1 percent level. Lastly, the news-based uncertainty measures are all loosely positively correlated with coefficients that range from 0.25 to 0.37. As above, all of these correlation coefficients are all statistically significant at the 1 percent level.

2.3 Other Data

In addition to the uncertainty proxies, a number of other daily time series are used to capture the evolution of financial markets over the sample period. These series span debt, equity, and real estate markets. The complete dataset is listed in table 5 of the data appendix. Our data include key interest rate series including the 2-year zero coupon Treasury, the 10-year zero coupon Treasury, the five-year TIPS breakeven, the five-to-ten-year forward TIPS breakeven, the Moody's Aaa and Baa Corporate Bond yields. Our data also contain key equity return series including those that track the S&P500,

DJIA, Russell2000, and Nasdaq100; and key housing and real estate series such as the log of the ABX and CMBX indices, the yields on Fannie Mae MBS, and the Fannie Mae commitment rate. The ABX and CMBX series track the cost to insure subprime-mortgage and commercial real estate debt, respectively, and decrease as investors become more bearish on housing or commercial real estate performance. Further, the Fannie commitment rate is the required net yield on home mortgages to be sold to Fannie Mae by mortgage lenders. Lastly, we include a basket of exchange rates to track the response of the dollar to an unconventional monetary policy shock. In total, the set of controls includes 23 important financial time series and thus is likely to span the information sets used by practitioners and policymakers over the sample period.

3 Main Results

Using our dataset consisting of 33 daily time series ranging from November 2008 to December 2013, we estimate the FAVAR model and identify structural monetary policy shocks through the assumption of heteroskedasticity across monetary policy event and non-event days. Here, we consider 48 policy events in total that cover QE1, QE2, QE3, and the recent taper period. Below in section 4, we consider a number of robustness checks and extensions including those that entertain alternative factor and lag specifications and only major monetary events. The results are similar across model specifications.

3.1 Estimation of Latent Factors

To estimate the FAVAR model and calculate the corresponding impulse response functions, we first must specify the number of latent factors in the observation equation. Here, we follow BBE and BGM and use five latent factors. Below in section 4, we consider both larger and smaller factor specifications; the results are similar. In total, the five latent factors and the six observed factors combine to yield 11 total elements in C_t, the common component. From there, we estimate equation 2 via principal components and retain the factor loadings and the common component.

Table 3 shows the portion of the variation of the informational time series explained by the common component as measured by the R^2 and adjusted R^2 statistics. In general, the common component appears to capture the evolution of financial markets over the sample period. As the common component explains over 85 percent of the variation in the equity return series, the real estate variables, and the exchange rates. The R^2 statistics are all above 0.8 for the VIX indices and the common component explains over 50 percent of the variation in the news-based uncertainty measures. Altogether, these results suggest that five latent factors is sufficient to capture the dynamics of the key financial variables over the sample period.

3.2 Estimation of the VAR and Identification of the Structural Monetary Policy Shocks

Next, we estimate the reduced-form VAR in equation 3 with the common component, C_t. Using the Bayesian Information Criterion (BIC), one lag is chosen for the VAR. Below in section 4, we show the results from a VAR with three lags as suggested by the Akaike Information Criterion (AIC); the results are similar.

To test for heteroskedasticity in the VAR innovations across monetary policy event and non-event days, we evaluate the null that $\Sigma_0 = \Sigma_1$ relative to the relevant bootstrapped distribution via the test statistic in equation 7. We reject this null with a bootstrapped Wald statistic of 10.05 and a corresponding p-value of 0.03. Thus, this test suggests that the VAR innovations are heteroskedastic across monetary policy event and non-event days. We also test the null of a single monetary policy shock using the test statistic in equation 8. The bootstrapped Wald Statistic is approximately 0 with a p-value of 0.99 and hence we fail to reject the null of a single monetary policy shock.

3.3 Impulse Response

Finally, once the structural monetary policy shocks have been identified, impulse response functions can be traced out. First, we compute the IRFs for the latent and observed factors. Then, the IRFs for the variables that constitute the informational time series are calculated by simply multiplying the factor loadings from the observation equation by the dynamic responses from the latent and observed factors. 90 percent bootstrapped confidence intervals are constructed using the Kilian bias-corrected bootstrap procedure. Recall that we also apply the Kilian bias correction to the point estimates. For the financial variables, we trace out these impulse response functions for 750 periods, equivalent to approximately three years of daily data. As the effects of the unconventional monetary policy shocks on uncertainty diminish relatively quickly, we trace out these IRFs for only 250 periods. The two following sub-sections describe these IRFs in turn. Further, since the size of the structural monetary shock is not identified, we normalize the monetary shock to lower the yield on the 10-year Treasury by 10 basis points instantaneously.

3.3.1 Financial Market Variables

First, we examine the impact of unconventional monetary policy shocks on key debt, equity, and real estate variables. The corresponding impulse response functions are in figure 1. The first column of figure shows the IRF plots for the key interest rate series that constitute the observed factors. The results indicate that an unconventional monetary policy shock that immediately lowers the yield on the 10-year Treasury by 10 basis points reduces the yield on the 2-year Treasury by approximately 15 basis points after 1 day, reduces the yield on Baa corporate bonds by nearly 14 basis points after 40 days, and increases proxies for inflation expectations as the forward five-to-ten-year TIPS breakeven rate increases by approximately 20 basis points immediately. These effects, however, die off rather quickly as the estimated half-life for the dynamic response in the 2-year Treasury is 26 days, while that for the forward five-to-ten-year TIPS breakeven is just 13 days. Similarly, the impact of the shock on the Baa yields nearly completely diminishes after approximately 150 days. In general, these dynamic responses are similar to those obtained by Wright (2012) and correspond with the event study results of Krishnamurthy and Vissing-Jorgenson (2011).

The middle column shows the dynamic responses for the equity market return proxies and exchange rate variables. The equity market variables include the returns on the S&P500, the Dow Jones Industrial Average, the Russell2000 index of small-cap stocks, and technology laden Nasdaq100. Clearly, an expansionary unconventional monetary policy shock has a large and positive effect on equity prices: A surprise unconventional monetary easing that lowers the yield on the 10-year Treasury by 10 basis points instantaneously is associated with an increase in the returns on the S&P500 and DJIA of 14.3 and 12.6 percentage points, respectively; an increase in the Russell2000 of over 18 percent; and a jump in the Nasdaq100 of over 14 percent. In total, these findings match the views of practitioners and policymakers who have both asserted that expansionary unconventional monetary policy actions lift asset prices in equity markets.[15] Next, we consider IRFs for the exchange rate variables. As evidenced by the the bottom two plots in the middle column of the figure, a surprise unconventional monetary policy easing is associated with a weaker dollar relative the British Pound and the Euro. Similarly, Glick and Leduc (2013), who consider the effects of unconventional monetary policy on the dollar within an event study, also find that the QE leads to a depreciation of the dollar. The effects of the monetary shock on the dollar, however, attenuate fairly fast and nearly completely dissipate after approximately 150 days.

The final plots in the third column show the dynamic responses for key housing and mortgage market interest rates and for CDS measures that track the cost to insure subprime-mortgage or commercial real estate backed debt. First, the top two plots in the right column of figure 1 show the dynamic responses for the yields on the Fannie Mae MBS and the Fannie Mae commitment rate, the required net yield on home mortgages to be sold to Fannie Mae by mortgage lenders. These results imply that an expansionary unconventional monetary policy shock that lowers the 10-year Treasury by 10 basis points

[15]See, for example, “Monetary policy and inequality.” Ben Bernanke. June 1, 2015.

reduces Fannie MBS yields by 26 basis points after 1 day and the Fannie commitment rate over 30 basis immediately. Yet the impact of the shock dies off quickly as the estimated half-lives for the Fannie MBS and Fannie commitment rate IRFs are just 33 and 20 days, respectively. Next, as evidenced by the following two plots in the right column of the figure, unconventional monetary policy shocks lead to large reductions in the cost to insure AAA rated subprime debt, but have less of an impact on the default risk for lower rated mortgage backed securities.[16] This result is further supported by the IRF for the ABX Risk Premium, which is spread between the AAA ABX index and the AA ABX index. Lastly, as seen by the dynamic response for the AAA CMBX index, an expansionary unconventional monetary policy shock lowers the cost to insure high-grade commercial real-estate backed debt. Overall, the results in this section are consistent with previous studies that consider the effects of monetary policy on key interest rate series, the dollar, and real estate markets.[17]

3.3.2 Uncertainty

The dynamic responses for the uncertainty variables are presented in figure 2. Recall from section 2 that we consider ten proxies for uncertainty over the sample period including the equity market and economic policy uncertainty indices of BBD and various VIX volatility indices from the Chicago Board Options Exchange.

The first plot in the top-left panel of the figure shows the IRF for the VIX index. As noted above and by Bloom (2009) and Caggiano, Castelnuovo, and Groshenny (2014), the VIX is used throughout the literature as a broad measure of economic uncertainty. The findings in the plot indicate that in response to an unconventional monetary policy shock that lowers the yield on the 10-year Treasury by 10 basis points, the log of the VIX falls by 59 basis points. This translates into a 16.26 point reduction in the levels VIX

[16] Note that the ABX and CMBX indices increase as the cost to insure housing or real-estate backed debt falls.

[17] See Wright (2012) and Krishnamurthy and Vissing-Jorgenson (2011), and Glick and Leduc (2013)

index. As the standard deviation of the daily levels VIX index over the sample period was 10.5 points, these findings imply that expansionary unconventional monetary policy shocks lead to large and economically meaningful initial reductions in uncertainty.[18]

The research results also indicate that effects of the monetary shock on the VIX enervate relatively quickly. Indeed, the estimated half-life of dynamic response for the VIX is just 8 days. Yet after the sharp initial attenuation in the effect of the shock, the IRF for the VIX then dies off more slowly as the upper confidence bound for the IRF crosses the zero line after 50 days and the effect of the shock, in terms of the point estimates, nearly completely dissipates after 100 days. Overall, the limited long-term impact of a monetary shock on the VIX implies that multiple rounds of unconventional monetary easing may have been necessary to engender the recent period of low economic uncertainty experienced in the wake of the Federal Reserve's QE stimulus program.

The following three plots in the left panel of the figure show the dynamic responses for the news-based measures that track policy, equity market, and housing and mortgage market uncertainty. First, the results indicate the an unconventional monetary policy shock that lowers the yield on the 10-year Treasury by 10 basis points leads to an initial increase in the log of Policy Uncertainty of approximately 0.08 standard deviations. This result is likely due to the way that the Policy Uncertainty variable is constructed. Recall that the Policy Uncertainty variable is the frequency of news articles that mention keywords related to economic policy uncertainty. Thus in the wake of expansionary unconventional monetary policy shocks, news reporters often aim to explain the justification of monetary policy actions. Thus, the initial increase in Policy Uncertainty is likely a result of news reporters describing the economic environment leading up to the policy decision. From there, the IRF for the log of Policy Uncertainty falls by 0.71 standard

[18]Theses results are also in line with observations by private sector practitioners who have suggested that multiple rounds of unconventional monetary policy stimulus have resulted in substantially lower levels in the VIX index. See, for example, the following articles: "Quantitative easing is like a 'huge glass of warm milk' for VIX". *MarketWatch* April 17, 2013; and "Stocks in Summer Slumber as VIX Tumbles Most Since 2012". *Bloomberg News.* August 29, 2014.

deviations; yielding a total change in Policy Uncertainty of -0.63 standard deviations 2 days after the expansionary monetary shock. This latter effect is statistically significant as the total change in the upper confidence bound is -0.42 standard deviations. Then the impact of the monetary shock wears off quickly and nearly completely dissipates after 50 days. The next two plots show the effects in the Equity and Housing and Mortgage Uncertainty. The results indicate that a surprise unconventional monetary easing that reduces the yield on the 10-year Treasury by 10 basis points lowers the log of Equity Uncertainty by 1.15 standard deviations and the log of Housing and Mortgage Uncertainty by 0.44 standard deviations. Further, as above, our results indicate that effects die off quickly. Indeed, the effects of the shock on Equity Uncertainty nearly completely dissipate after 50 days, while the dynamic response for Housing Uncertainty becomes insignificant just a few days after the monetary shock. The relatively quicker attenuation of the effects of the monetary shock on the news-based proxies coincides with our expectations given the substantially lower autocorrelation in these news-based proxies compared to our other measures of uncertainty.[19] In total, the results for the news-based proxies indicate that expansionary unconventional monetary policy shocks are associated with large reductions in Equity Uncertainty, but the estimated effects are relatively smaller in magnitude for Policy and Housing and Mortgage Uncertainty.

The last plot in the left column of figure 2 shows the dynamic response for the log of the Treasury VIX. The path of the IRF indicates that an unconventional monetary policy shock that lowers the yield on the 10-year Treasury by 10 basis points reduces the log of the Treasury VIX by over 14 basis points after 2 days. Note that the standard deviation of the log of the daily Treasury VIX is 0.29. Thus, the monetary shock leads to a reduction in Treasury uncertainty that is less than one standard deviation in magnitude. This suggests that the effects of a surprise unconventional monetary easing are smaller

[19]Similarly, there is low autocorrelation in the news-based sentiment measures of Garcia (2013) and Tetlock (2007).

for Treasury uncertainty relative to equity market uncertainty as this same shock leads to a decrease in equity uncertainty of more than one standard deviation. Moreover, the initial impact of the shock attenuates less quickly in Treasury markets relative to equity markets as the estimated half life for the Treasury VIX IRF is 21 days. In comparison, as noted above, the estimated half-life for the IRF in the VIX index is just 8 days. Lastly, the upper confidence bound crosses the zero line after 55 days and the effect of the shock nearly completely dies off after 100 days.[20]

The top plot in the right panel shows the IRF for the log of the Euro VIX. Our findings indicate that the log of Euro VIX falls by over 28 basis points after the first day. In comparison, the standard deviation of the log of the Euro VIX is 0.29. Thus, unlike the standard VIX index, the results indicate that an unconventional monetary policy shock that lowers the yield on the 10-year treasury by 10 basis points leads to a reduction in the Euro VIX of just less than one standard deviation. A surprise unconventional monetary policy easing therefore leads to larger reductions in equity market uncertainty than exchange rate market uncertainty. These effects die off with an estimated half-life of approximately just 27 days, suggesting that the initial impact of the shock lasts longer in Treasury markets than in equity markets.

In the following three plots in the right column of figure 2, we present the dynamic responses for the DJIA VIX, the Russell2000 VIX, and the Nasdaq VIX. In general, the results are similar to those obtained above using the standard VIX index based on the S&P500: An expansionary unconventional monetary policy shock dampens uncertainty in the markets for large stocks (DJIA VIX), small stocks (Russell2000 VIX), and technology stocks (Nasdaq VIX). Also in line with the above equity uncertainty proxies, we find that the results attenuate relatively quickly with estimated half-lives for the dynamic responses for the DJIA VIX, the Russell2000 VIX, and the Nasdaq VIX of just 8, 12, and 9 days,

[20]Note that in an event study, Rogers, Scotti, and Wright (2014) find that forward guidance reduces interest rate volatility as measured by the move index.

respectively. Finally, the effects of the shock nearly completely dissipate after 100 days.

The last plot in the bottom-right panel of the figure shows the dynamic response for the VIX 3 Month. Recall that VIX 3 Month index is the implied volatility for the S&P500 over the next 93 days; yielding a longer-term proxy for uncertainty over the sample period.[21] Congruent with our above results, the findings indicate that an unconventional monetary policy shock that reduces the yield on the 10-year Treasury by 10 basis points dampens the log of the VIX 3 Month index by nearly 42 basis points. From there, the effects of the shock attenuate fairly fast with an estimated half-life of 13 days. Then, the upper confidence bound crosses the zero line after 54 days and the effect of the shock (as measured by the point estimates) nearly completely diminishes after approximately 100 days.

Overall, the dynamic responses from this section imply that expansionary unconventional monetary policy shocks lead to large reductions in economic and financial market uncertainty. These results span various markets and data methodologies. Yet we find that the reductions in uncertainty differ in magnitude across asset classes, are largest for equity markets, and that the initial impact of the shock persists the longest in Treasury and currency markets. Last, our results indicate that the effects of unconventional monetary policy shocks on uncertainty diminish relatively quickly and dissipate within approximately 100 days.

3.4 Forecast Error Variance Decomposition

Another way to assess the impact of unconventional monetary policy shocks on uncertainty is through the forecast error variance decomposition (FEVD). The FEVD is used throughout the VAR literature and is the portion of the forecast error variance attributable to the monetary policy shocks. We calculate the FEVD for both the observed factors and for the informational time series. For the interest rate series that constitute

[21] In comparison, the standard VIX index captures the implied volatility of the S&P500 over the next 30 days.

the observed factors, we calculate the FEVD in the usual way. Then to compute the forecast error variance decomposition for the informational time series, we employ the modified the FEVD formula from BBE. In this alternate specification, the FEVD formula is augmented with factor loadings from the observation equation. Hence, we modify the typical FEVD computation for each time series in the set of informational series so that the structural monetary policy shock is assessed only relative to the common component and not the idiosyncratic component. This approach is advantageous as it should provide a more accurate measure of the relative importance of monetary policy shocks. As the size of the monetary shocks are not identified, we normalize the shocks to account for 50 percent of the one-day forecast error variance in the S&P500 stock returns. Note that as the FAVAR common component explains a large portion of the variation of the informational time series, the results using the typical FEVD formula for the informational time series are similar.[22]

In table 4, we present the FEVD for the observed factors and for the informational time series across various forecast horizons. First, the top panel displays our findings for the key interest rate series that make up the observed factors. In general, these results are similar to those obtained by Wright (2012): Unconventional monetary policy shocks that account for 50 percent of the one-day forecast error variance in the S&P500 returns, contribute 5.9, 0.9, 1.5, 2.8, 2.6 and 14.4 percent to the one-day forecast error variation in the 2- and 10-year Treasuries, the Aaa and Baa corporate bond yields, and the five-year and forward-five-to-ten-year TIPS breakeven rates. Moreover, the monetary shocks explain a smaller portion of the forecast error variation in the corporate yields and breakeven rates at longer horizons. These monetary shocks also explain 8.5 and 1.3 percent of the forecast error variance in the 2- and 10-year Treasuries after 750 days.

The next panel shows the results for the key financial market variables in the set of

[22]The typical FEVD computation can be obtained for the variables in the set of informational time series by simply multiplying the R^2 values from table 3 by the FEVD calculations listed in table 4. For more details, see BBE and Wright (2012).

informational time series. Unconventional monetary policy shocks that explain 50 percent of the one-day forecast error variance in the S&P500 returns contribute 0.1 percent, 5.9 percent, and 1.3 percent to the one-day forecast error variance for the 10-year yield curve, the 30-year yield curve, and the corporate default spread; around 50 percent to the one-day forecast error variation in the other stock return series; over 16 percent to the forecast error variance in the dollar-pound and dollar-euro exchange rates; and 6 percent and 15 percent to the variation in the forecast error for the Fannie Mae MBS yields and the Fannie Mae commitment rate. Further, in terms of the yield curve measures, the stock return proxies, and the housing market interest rates, the effects of the monetary shocks appear to dissipate at longer horizons. Overall, these findings are congruent with our above IRF results and thus suggest that monetary policy shocks have a large initial impact on key financial market variables.

The bottom panel of table 4 presents the FEVD results for the uncertainty measures. First, the top row of the bottom panel shows the portion of the forecast error variance in the VIX index that is attributable to unconventional monetary policy shocks. Our findings indicate that unconventional monetary policy shocks that explain 50 percent of the one-day forecast error variance in the S&P500 returns account for 29.5 percent of the variation in the one-day forecast error for the VIX index. Further, these effects, which are large in magnitude and economically meaningful, attenuate at longer horizons. The next three rows display the FEVD results for the news-based uncertainty proxies. Findings indicate that unconventional monetary policy shocks explain a relatively smaller portion of the forecast error variance in news-based uncertainty measures compared to the results obtained for market based proxies such as the VIX index. Yet, in line with our above results obtained from the impulse response functions, unconventional monetary policy shocks appear to have a larger impact on equity market uncertainty and a relatively smaller effect on policy and housing and mortgage market uncertainty.

The remaining rows in the bottom panel of the table list the FEVD results for the market specific VIX indices. Here, unconventional monetary policy shocks have a large impact on uncertainty across asset markets, but the size of the estimated effect differs across asset classes. Indeed, unconventional monetary policy shocks that contribute 50 percent to the one-day forecast error variance in the S&P500 returns explain 27.3, 30.4, 29.7, and 32.7 percent of the variation in the one-day forecast error for the DJIA VIX, the Russell2000 VIX, the Nasdaq VIX, and the VIX 3 Month. The monetary shocks thus appear to have a slightly larger impact on uncertainty in the market for small cap stocks and for longer-run measures of uncertainty. The monetary shocks also contribute 10.2 and 28 percent to the one-day forecast error variance in the Treasury VIX and the Euro VIX, respectively. Hence, unconventional monetary policy shocks explain a larger portion of the initial forecast error variance for uncertainty in equity markets relative to Treasury markets.

Overall, the findings in this section are congruent with our results obtained using impulse response functions: Unconventional monetary policy shocks have a large initial impact on uncertainty across markets, but these effects differ in magnitude across asset classes and are largest for equity markets.

4 Extensions and Robustness Checks

In this section, we extend our baseline analysis to assess the robustness of the results. These extensions include several alternative specifications for the latent and observed factors, a different lag specification for the reduced-form VAR, and a more strict definition of monetary events that only includes the most important dates as suggested by table 1. Overall, the findings based on these extensions, which are in appendix D, are similar to those discussed above, indicating that our results are robust to various alternative specifications and a different set of dates used in the identification of the structural monetary policy shocks.

4.1 Alternate Latent Factor Specifications

First, we consider alternate latent factor specifications. Figures 3, 4, and 5 in appendix D show the dynamic responses for the uncertainty variables for models that employ 7, 3, and 2 latent factors, respectively. Overall, the paths of the IRFs are similar to those found above, but the effects of the unconventional monetary policy shocks are larger in magnitude when we use 7 latent factors and slightly smaller for the model with only 2 latent factors. The results also diverge from those discussed above in a couple of other instances: (1) When 7 latent factors are used, the initial responses by Housing Uncertainty and the Treasury VIX to the monetary shock are initially positive; and (2) the IRF for policy for Policy Uncertainty is initially negative in all three alternate latent factor specifications.

4.2 Other Observed Factor Specifications

Next, figures 6, 7, 8 in appendix D, show the results when (1) only government bonds are used as observed factors; (2) the S&P500 and the VIX are included in the set of observed factors (and the corporate bond yields are relegated to the set of informational time series); and (3) when the 3-year Treasury, rather than the 2-year Treasury is included in the set of observed factors. In this last specification, we replace the 2-year Treasury with the 3-year Treasury as Swanson and Williams (2013) provide some recent evidence that the 2-year Treasury was constrained the zero-lower bound over our sample period. In total, the results are qualitatively similar and shape of the IRFs matches those described above, but the estimated size of the effect is smaller in magnitude.

4.3 AIC VAR Lag-Length Specification

In figure 9, we show dynamic responses when we select 3 lags for the reduced-form VAR as suggested by minimizing the Akaike Information Criterion (AIC). Overall, the findings indicate that expansionary unconventional monetary policy shocks lower uncertainty across markets. Yet when we use this alternate lag length specification, the initial effect of the shock on uncertainty is smaller in magnitude.

4.4 Major Monetary Policy Events

Lastly, we entertain an alternative set of events in the identification of the structural monetary shocks. More specifically, only the major announcements listed in table 1 are used as monetary policy event days. These events include the announcements surrounding the various rounds of QE and the subsequent taper period. Figure 10 shows the results. In general, the results are qualitatively similar to those discussed above, but the effects are larger in magnitude. This latter finding is congruent with Wright (2012) who also finds larger effects when considering only major unconventional monetary events in the identification of structural monetary shocks.

5 Conclusion

During the recent period of unconventional monetary stimulus, both practitioners and policymakers questioned the real economic effects of non-standard policy tools, such as Quantitative Easing.[23] Hence, determining the effects of unconventional monetary policy on uncertainty is crucial to disentangling the effects of unconventional monetary policy on the real economy as lower uncertainty is associated with higher levels output, employment, and productivity. In this paper, we use a structural factor-augmented vector autoregression (FAVAR) model and a large database of daily time series to assess the impact of unconventional monetary policy shocks on various measures of economic and financial uncertainty over nearly a fully cycle of US unconventional monetary policy. Our results indicate that expansionary unconventional monetary policy shocks lower uncertainty in equity, housing and mortgage, Treasury, and currency markets. These findings further extend to large- and small-cap stocks, a longer term measure of uncertainty, and to economic policy uncertainty. Thus, the Fed's recent monetary interventions appear to be associated with lower levels of uncertainty across markets. Further, these reductions

[23]See, for example "Fed Approach on Quantitative Easing Receives Partisan Criticism." *Bloomberg News.* September 13, 2012.

in uncertainty differ in magnitude across asset classes and are largest for equity markets. Lastly, the results indicate that the effects of unconventional monetary policy shocks on uncertainty attenuate fairly quickly and nearly completely dissipate after approximately 100 days. In total, our findings highlight the importance of unconventional monetary policy shocks in the determination of uncertainty during the recent period of economic and financial distress.

Further, in late 2015 and early 2016, the Fed's departure from its unconventional monetary policy stimulus coincided with an increase in uncertainty and the threat of economic recession.[24] Although this period extends beyond our sample, these changes may be explained in part by the results in this paper as they suggest that contractionary unconventional monetary policy shocks increase financial and economic uncertainty. We leave a deeper analysis of these recent events for further research.

[24]See, for example, "Are We Headed for Recession?" *Bloomberg News;* January 21, 2016.

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A Tables

Table 1: Major QE Events

Event Date	Time (EST)	QE Round	Event	Event Description
11/25/2008	8:15 AM	1	QE1 Announcement	FOMC announces planned purchases of $100 billion of GSE debt and up to $500 billion in MBS
12/1/2008	1:40 PM	1	Bernanke Speech In Texas	Bernanke announces that the Fed may purchase long-term US Treasuries
12/16/2008	2:15 PM	1	FOMC Statement	FOMC first suggests that long-term US Treasuries may be purchased
1/28/2009	2:15 PM	1	FOMC Statement	FOMC indicates that it will increase its purchases of agency debt and long-term US Treasuries
3/18/2009	2:15 PM	1	FOMC Statement	FOMC announces that it will purchase an additional $750 billion in agency MBS, up to an additional $100 billion of agency debt, and up to $300 billion of long-term US Treasuries
8/10/2010	2:15 PM	2	FOMC Statement	FOMC announces that it will roll over the Fed's holdings of US Treasuries
8/27/2010	10:00 AM	2	Bernanke Speech In Jackson Hole	Bernanke signals that monetary easing will be continued
9/21/2010	2:15 PM	2	FOMC Statement	FOMC announces that it will roll over the Fed's holdings of US Treasuries
10/15/2010	8:15 AM	2	Bernanke Speech at Boston Fed	Bernanke signals that monetary easing will be continued
11/3/2010	2:15 PM	2	FOMC Statement	FOMC announces it plan to purchase $600 billion of long-term US Treasuries by the end of the 2011 Q2
8/31/2012	10:00 AM	3	Bernanke Speech at Jackson Hole	Bernanke announces intention for further monetary easing
9/13/2012	12:30 PM	3	FOMC Statement	FOMC announces that it will expand its QE policies by purchasing mortgaged-backed securities at a rate of $40 billion per month
12/12/2012	12:30 PM	3	FOMC Statement	FOMC extends monthly purchases to long-term Treasuries and announces numerical threshold targets
5/22/2013	10:00 AM	Taper	Bernanke Congressional Testimony	Bernanke first signals that FOMC may reduce its quantitative stimulus
6/19/2013	2:15 PM	Taper	Bernanke Press Conference & FOMC statement	Bernanke suggests that the FOMC will moderate asset purchases later in 2013
12/18/2013	2:00 PM	Taper	FOMC Statement	FOMC announces that it will reduce its purchases of longer term Treasuries and mortgage-backed securities by $10 billion dollars per month

Notes: Major FOMC announcements or speeches by Chairman Bernanke. Event dates, times, and descriptions updated from Glick and Leduc (2013).

Table 2: Correlations of Uncertainty Variables

	VIX	Nasdaq VIX	VIX 3 Month	Russell2000 VIX	DJIA VIX	Treasury VIX	Euro VIX	Policy Uncertainty	Equity Uncertainty	Housing Uncertainty
VIX	1.000***									
	(0.000)									
Nasdaq VIX	0.994***	1.000***								
	(0.000)	(0.000)								
VIX 3 Month	0.988***	0.984***	1.000***							
	(0.000)	(0.000)	(000.0)							
Russell2000 VIX	0.987***	0.984***	0.986***	1.000***						
	(0.000)	(0.000)	(0.000)	(0.000)						
DJIA VIX	0.997***	0.992***	0.983***	0.981***	1.000***					
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)					
Treasury VIX	0.780***	0.766***	0.779***	0.776***	0.768***	1.000***				
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)				
Euro VIX	0.870***	0.868***	0.884***	0.888***	0.860***	0.753***	1.000***			
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)			
Policy Uncertainty	0.327***	0.337***	0.318***	0.308***	0.328***	0.135***	0.310***	1.000***		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
EquityUncertainty	0.372***	0.370***	0.343***	0.344***	0.382***	0.184***	0.284***	0.356***	1.000***	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
HousingUncertainty	0.220***	0.228***	0.195***	0.210***	0.227***	0.106***	0.226***	0.372***	0.249***	1.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: Correlations of the log-transformed Uncertainty variables. p-values are listed in parentheses. One, two, and three asterisks represent statistical significance at the 10, 5 and 1 percent levels, respectively.

Table 3: Portion of the Variation of the Informational Time Series explained by the Latent and Observed Factors

	R^2	R^2 Adj
10 Year Yield Curve	1.000	1.000
30 Year Yield Curve	0.955	0.955
BAA Corp - AAA Corp	1.000	1.000
S&P500 Returns	0.984	0.984
DJIA Returns	0.953	0.952
Russell2000	0.934	0.934
Nasdaq100	0.934	0.933
ABX AAA	0.897	0.896
ABX AA	0.887	0.886
ABX Risk Premium	0.894	0.893
CMBX AAA	0.922	0.921
USD/JPY	0.902	0.902
USD/EURO	0.909	0.908
USD/GBP	0.882	0.881
Fannie MBS	0.976	0.976
Fannie MBS - 30 Year Treas	0.823	0.822
Fannie Commitment Rate	0.965	0.964
Uncertainty Measures		
VIX	0.977	0.976
Policy Uncertainty	0.629	0.625
Equity Uncertainty	0.580	0.577
Housing Uncertainty	0.592	0.589
Treasury VIX	0.817	0.816
Euro VIX	0.897	0.896
DJIA VIX	0.973	0.973
Russell2000 VIX	0.967	0.967
Nasdaq VIX	0.965	0.965
VIX 3 Month	0.981	0.981

Notes: R^2 and adjusted R^2 statistics from a regression of a given variable in the set of the informational time series (left column) on the five latent factors and the set of observed factors.

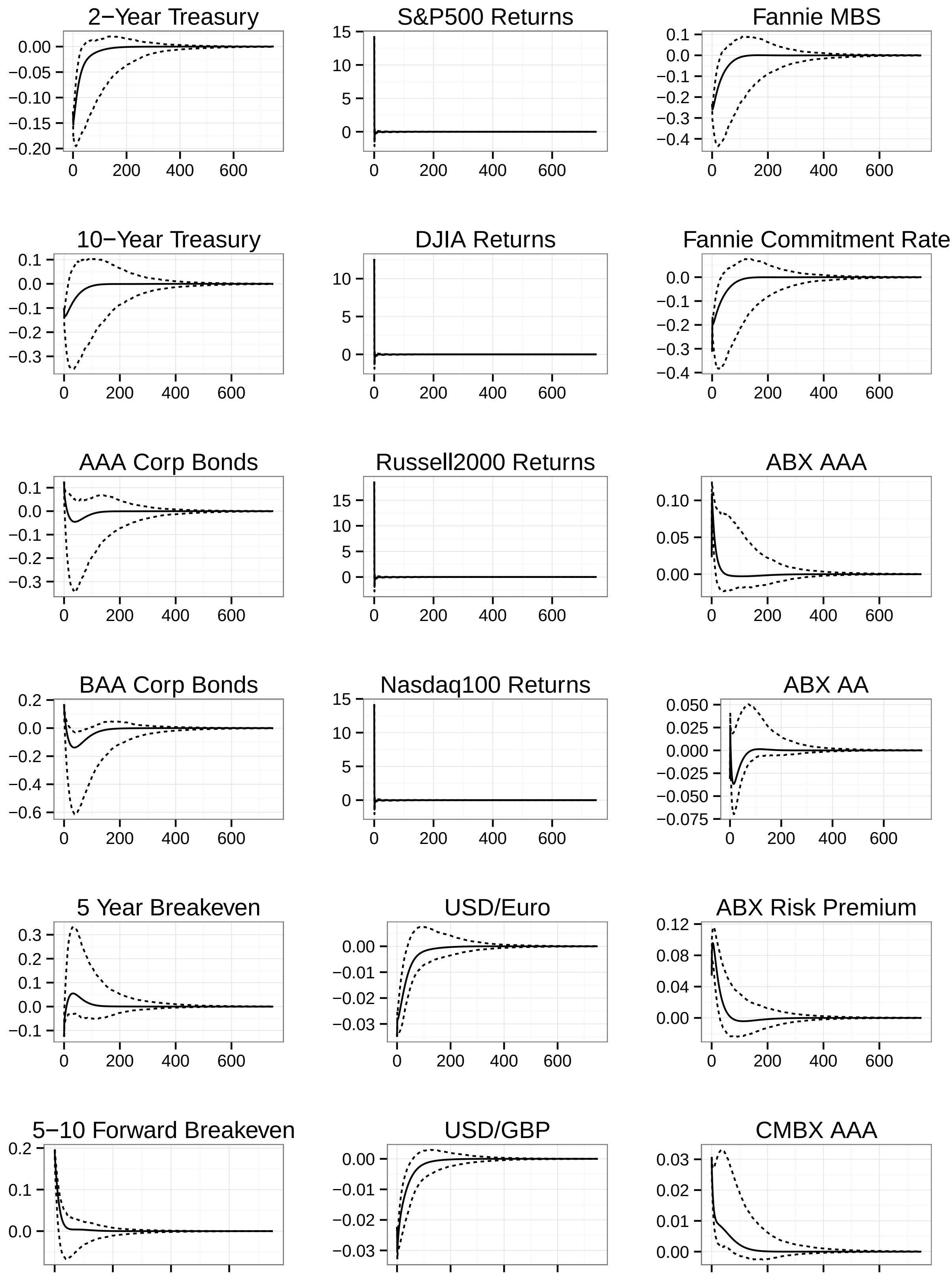
Table 4: Forecast Error Variance Decomposition

	Forecast Horizon (In Days)						
	1 Day	25 Days	50 Days	100 Days	250 Days	500 Days	750 Days
2 Year Treasury	0.059	0.099	0.092	0.087	0.085	0.085	0.085
10 Year Treasury	0.009	0.018	0.016	0.014	0.013	0.013	0.013
Corporate Aaa Yields	0.015	0.003	0.005	0.006	0.006	0.006	0.006
Corporate Baa Yields	0.028	0.015	0.039	0.058	0.060	0.060	0.060
5 Year Breakeven	0.026	0.004	0.008	0.010	0.009	0.009	0.009
5-10 Forward Breakeven	0.144	0.103	0.095	0.093	0.093	0.093	0.093
	Informational Time Series						
10 Year Yield Curve	0.001	0.001	0.002	0.001	0.001	0.001	0.001
30 Year Yield Curve	0.059	0.033	0.026	0.021	0.020	0.019	0.019
BAA Corp - AAA Corp	0.013	0.027	0.048	0.053	0.049	0.049	0.049
S&P500 Returns	0.500	0.498	0.498	0.498	0.498	0.498	0.498
DJIA Returns	0.500	0.499	0.498	0.498	0.498	0.498	0.498
Russell2000	0.500	0.498	0.498	0.498	0.498	0.498	0.498
Nasdaq100	0.503	0.501	0.500	0.500	0.500	0.500	0.500
ABX AAA	0.002	0.048	0.039	0.036	0.035	0.035	0.035
ABX AA	0.004	0.017	0.022	0.022	0.022	0.022	0.022
ABX Risk Premium	0.017	0.111	0.099	0.091	0.089	0.089	0.089
CMBX AAA	0.109	0.101	0.106	0.109	0.108	0.108	0.108
USD/JPY	0.031	0.064	0.053	0.050	0.050	0.050	0.050
USD/EURO	0.194	0.202	0.198	0.182	0.171	0.171	0.171
USD/GBP	0.162	0.301	0.296	0.282	0.272	0.272	0.272
Fannie MBS	0.063	0.081	0.068	0.055	0.050	0.050	0.050
Fannie MBS - 30 Year Treas	0.195	0.212	0.204	0.196	0.194	0.194	0.194
Fannie Commitment Rate	0.153	0.074	0.064	0.053	0.049	0.049	0.049
	Uncertainty Measures						
VIX	0.295	0.277	0.270	0.266	0.264	0.264	0.264
Policy Uncertainty	0.000	0.011	0.011	0.011	0.011	0.011	0.011
Equity Uncertainty	0.024	0.045	0.045	0.045	0.045	0.045	0.045
Housing Uncertainty	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Treasury VIX	0.102	0.158	0.157	0.148	0.140	0.140	0.140
Euro VIX	0.280	0.314	0.305	0.299	0.296	0.296	0.296
DJIA VIX	0.273	0.251	0.244	0.241	0.240	0.240	0.240
Russell2000 VIX	0.304	0.289	0.280	0.275	0.272	0.272	0.272
Nasdaq VIX	0.297	0.283	0.274	0.269	0.268	0.268	0.268
VIX 3 Month	0.327	0.319	0.308	0.303	0.301	0.300	0.300

Notes: This table shows the forecast error variance decomposition (FEVD) for the observed factors and the informational time series. The FEVD is the portion of the forecast error variance explained by the monetary policy shock. The size of the monetary shock is normalized so that the monetary shock contributes 50 percent to the 1 day forecast error variance in the S&P500 returns. The FEVD for the informational time series is calculated as in BBE.

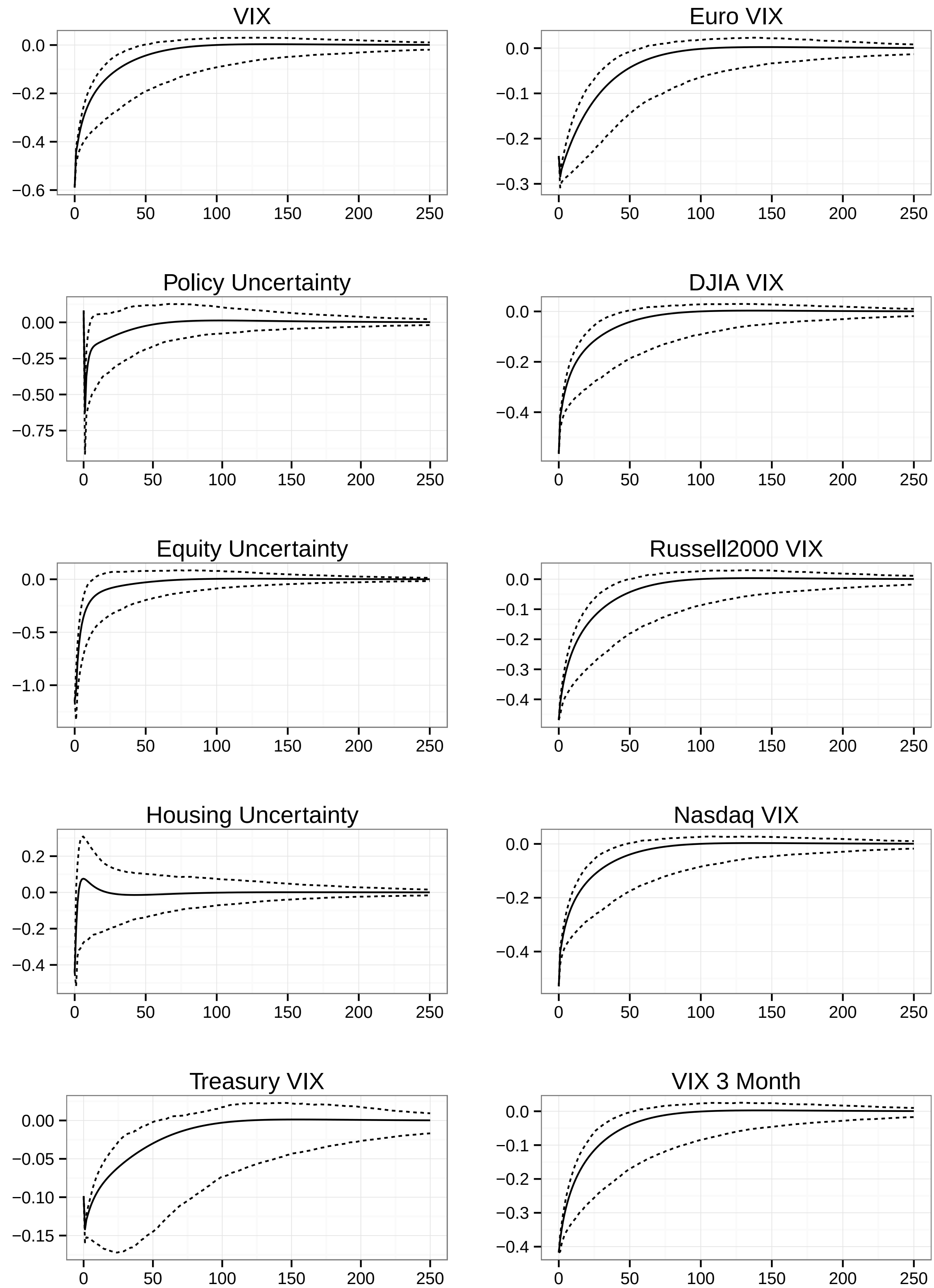
B Figures

Figure 1: Estimated Impulse Responses of Financial Market variables to an Identified Unconventional Monetary Policy Shock – Full Sample



Notes: The IRFs are traced out for 750 periods and normalized so that the initial decrease in the 10-year Treasury is 10 basis points.

Figure 2: Estimated Impulse Responses of Uncertainty variables to an Identified Unconventional Monetary Policy Shock – Full Sample



Notes: The IRFs are traced out for 250 periods and normalized so that the initial decrease in the 10-year Treasury is 10 basis points.

C Appendix: Data

Table 5: Data List

Variable	Description	Source	Symbol	Transformation
	Observed Factors			
2 Year Treasury	USD Treasury Actives Zero Coupon Yield 2 Year	Bloomberg	I02502Y	none
10 Year Treasury	USD Treasury Actives Zero Coupon Yield 10 Year	Bloomberg	I02510Y	none
5 Year Breakeven	Five-year TIPS breakeven	Bloomberg		none
5-10 Forward Breakeven	Five-to-ten-year forward TIPS breakeven	Bloomberg		none
Aaa Corporate Bond Yields	Moody's Seasoned Aaa Corporate Bond Yield	Bloomberg	MOODCAAA	none
Baa Corporate Bond Yields	Moody's Seasoned Baa Corporate Bond Yield	Bloomberg	MOODCBAA	none
	Intformational Time Series			
10 Year Yield Curve	Yield Curve – 10 Year Treasury versus 2 Year Treasury	Bloomberg		none
30 Year Yield Curve	Yield Curve – 30 Year Treasury versus 2 Year Treasury	Bloomberg		none
MOODCBAA - MOODCAAA	BAA - AAA Corporate Bond Risk Premium	Bloomberg		none
S&P500	S&P500 Stock Market Index	FRED	SP500	return
Dow Jones Industrial Average	DJIA Stock Market Index	FRED	DJIA	return
Russell2000	Russell2000 Stock Market Index	Yahoo	RUT	return
Nasdaq100	Nasdaq100 Stock Market Index	Yahoo	NDX	return

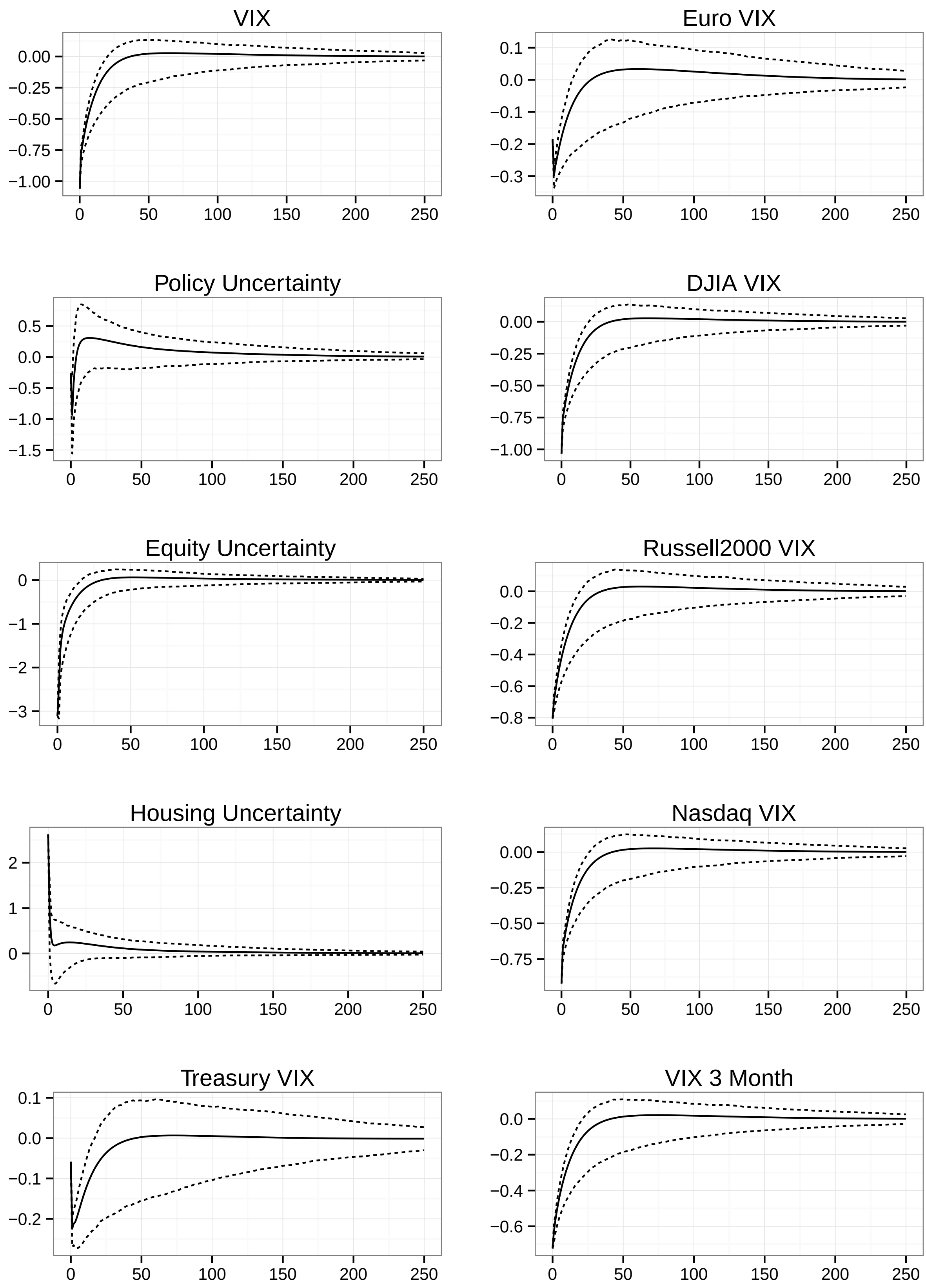
Notes: **Continued on next page.** Observed factors and informational time series. Transformations from Wright (2012), BBE, BGM, Bekaert, Hoerova, and Lo Duca (2012), and Stock and Watson (2002).

Table 5 Continued

Variable	Description	Source	Symbol	Transformation
	Informational Time Series			
ABX AAA	ABX Index for AAA rated securities issued in the second half of 2007	Bloomberg	ABX.HE.AAA.07-2	log
ABX AA	ABX Index for AA rated securities issued in the second half of 2007	Bloomberg	ABX.HE.AA.07-2	log
ABX AAA - ABX AA	MBS CDS Risk Premium	NA		none
CMBX AAA	CMBX Index for AAA rated securities for the second half of 2006	Bloomberg	CBX3A11	log
FM 30 Year Fixed Commitment rate - 60 Day	Fannie Mae Commitment Rates 30 Year Fixed Rate 60 Day	Bloomberg	FCR3060	none
Fannie Mae MBS	Fannie Mae 30-year Current-coupon MBS	Bloomberg	MTGEFNCL	none
MTGEFNCL - DGS30	Fannie Mae MBS Risk Premium	NA		none
US/Euro exchange rate		Bloomberg	USDEUR	none
US/UK exchange rate		Bloomberg	USDGBP	none
US/Yen exchange rate		Bloomberg	USDJPY	none
VIX	CBOE Volatility Index - VIX	FRED	VIXCLS	log
Treasury VIX	CBOE 10-year U.S. Treasury Note Volatility Index	CBOE	VXTYN	log
Euro VIX	CBOE EuroCurrency ETF Volatility Index	FRED	EVZCLS	log
DJIA VIX	CBOE DJIA Volatility Index	FRED	VXDCLS	log
Russell2000 VIX	CBOE Russell 2000 Volatility Index	FRED	RVXCLS	log
Nasdaq VIX	CBOE NASDAQ 100 Volatility Index	FRED	VXNCLS	log
VIX 3 Month	CBOE S&P500 3-Month Volatility Index	FRED	VXVCLS	log
Policy Uncertainty	BBD Policy Uncertainty Index	BBD	NA	log
Equity Uncertainty	BBD Equity Uncertainty Index	BBD	NA	log
Housing & Mortgage Uncertainty	Housing and Mortgage Market Uncertainty Index	NewsBank	NA	log

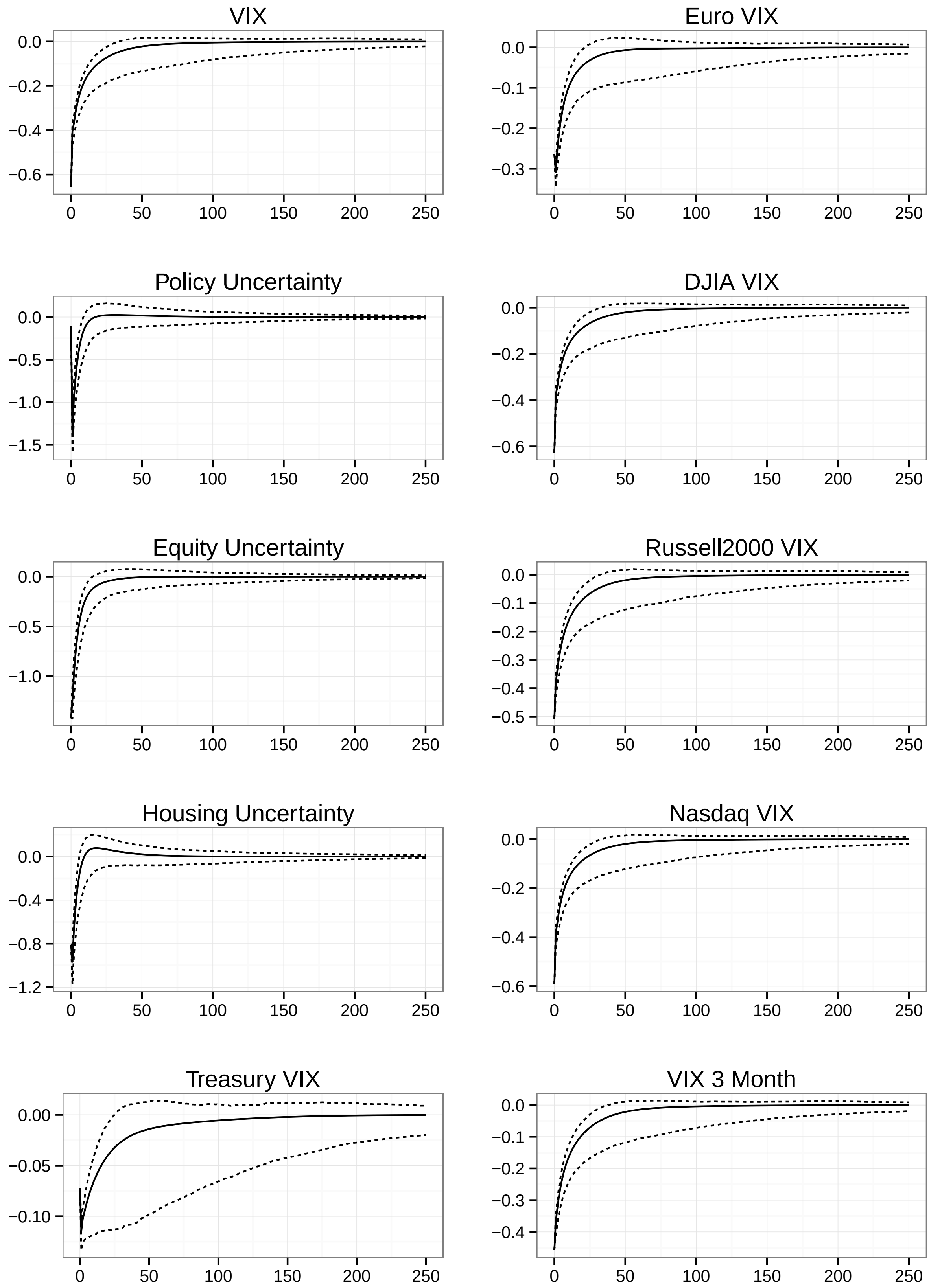
D Appendix: Extensions and Robustness Checks

Figure 3: Estimated Impulse Responses of Uncertainty Variables to an Identified Unconventional Monetary Policy Shock – 7 Latent Factors



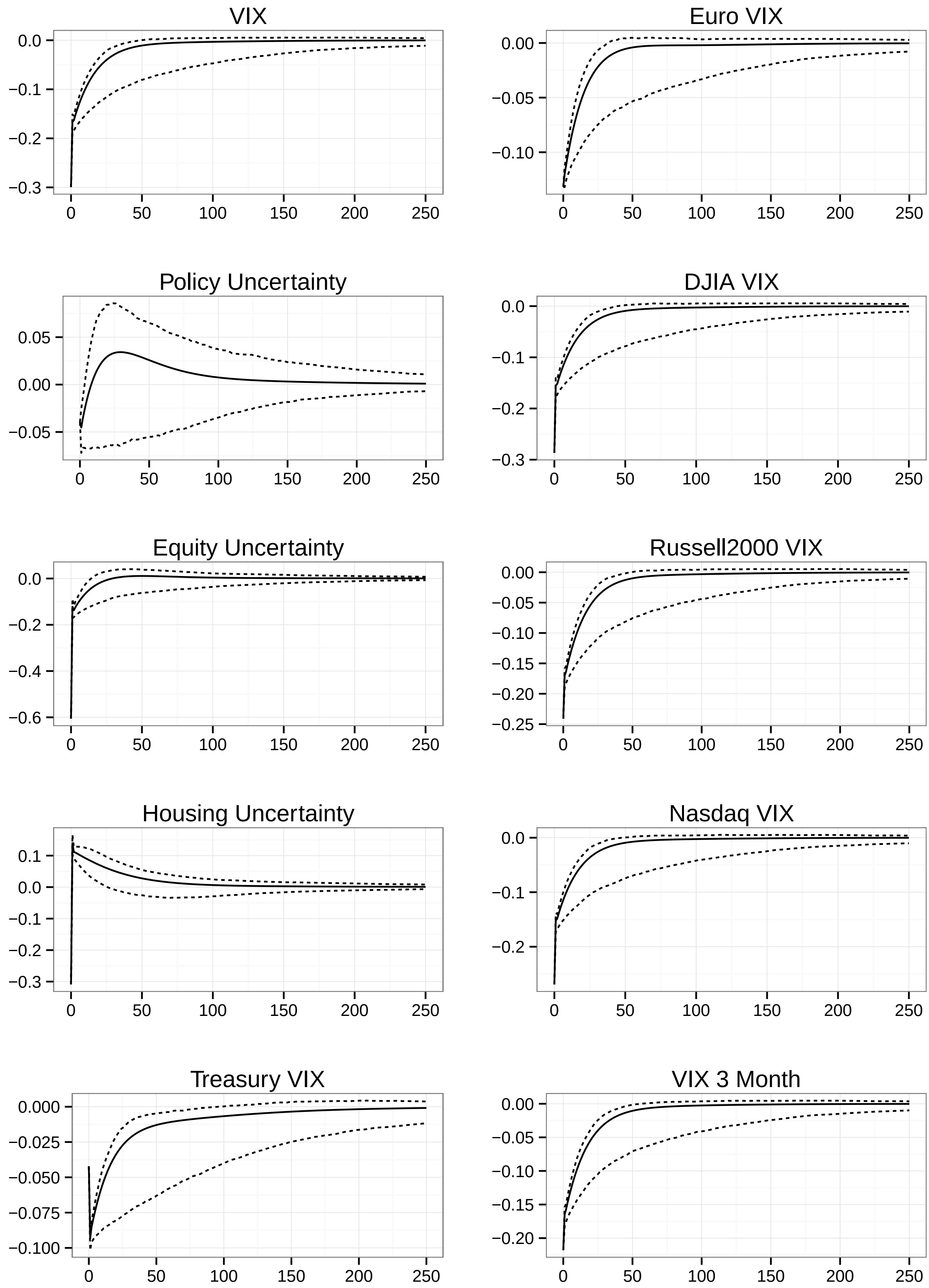
Notes: See the notes to figure 2.

Figure 4: Estimated Impulse Responses of Uncertainty Variables to an Identified Unconventional Monetary Policy Shock – 3 Latent Factors



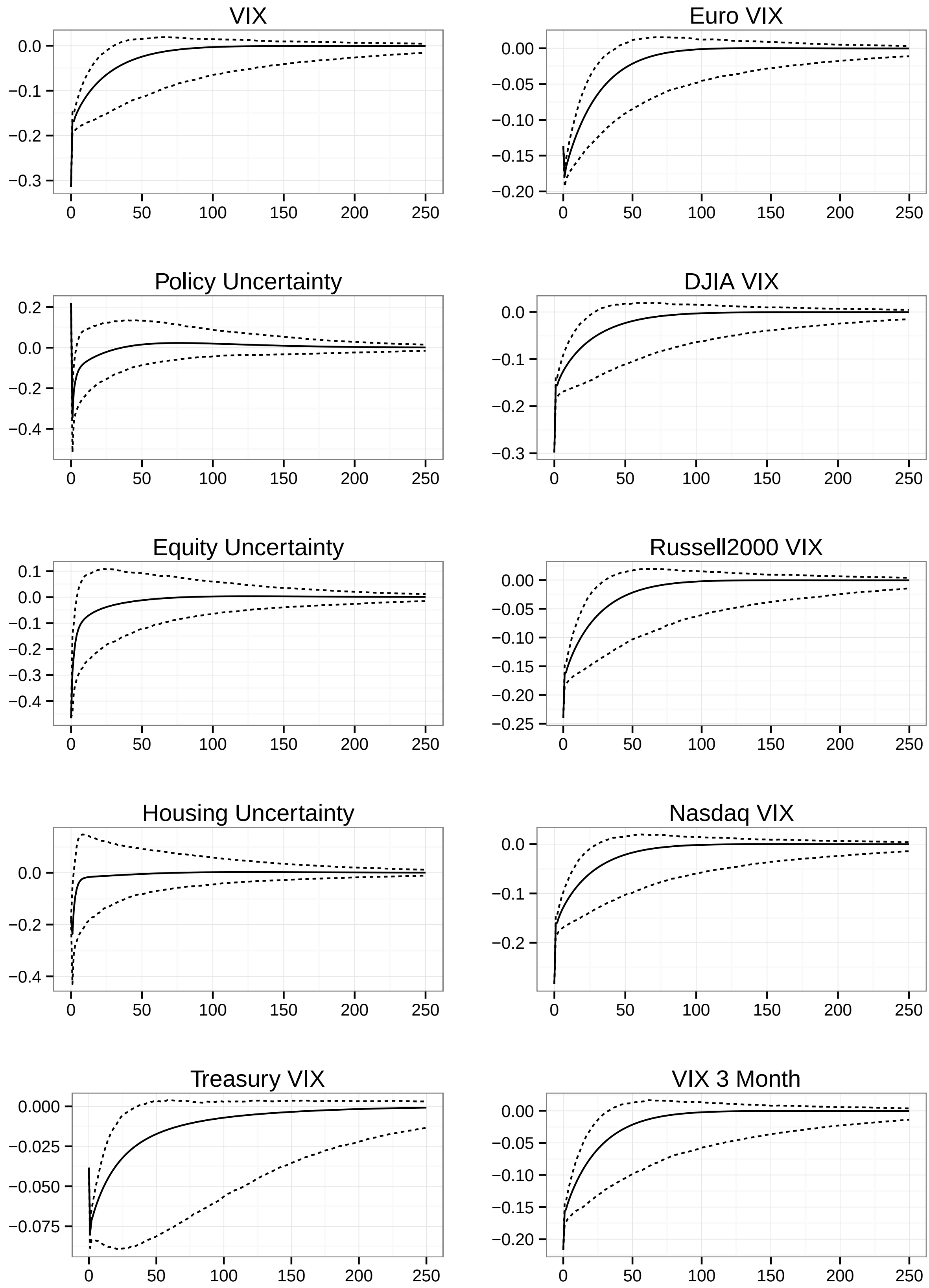
Notes: See the notes to figure 2.

Figure 5: Estimated Impulse Responses of Uncertainty Variables to an Identified Unconventional Monetary Policy Shock – 2 Latent Factors



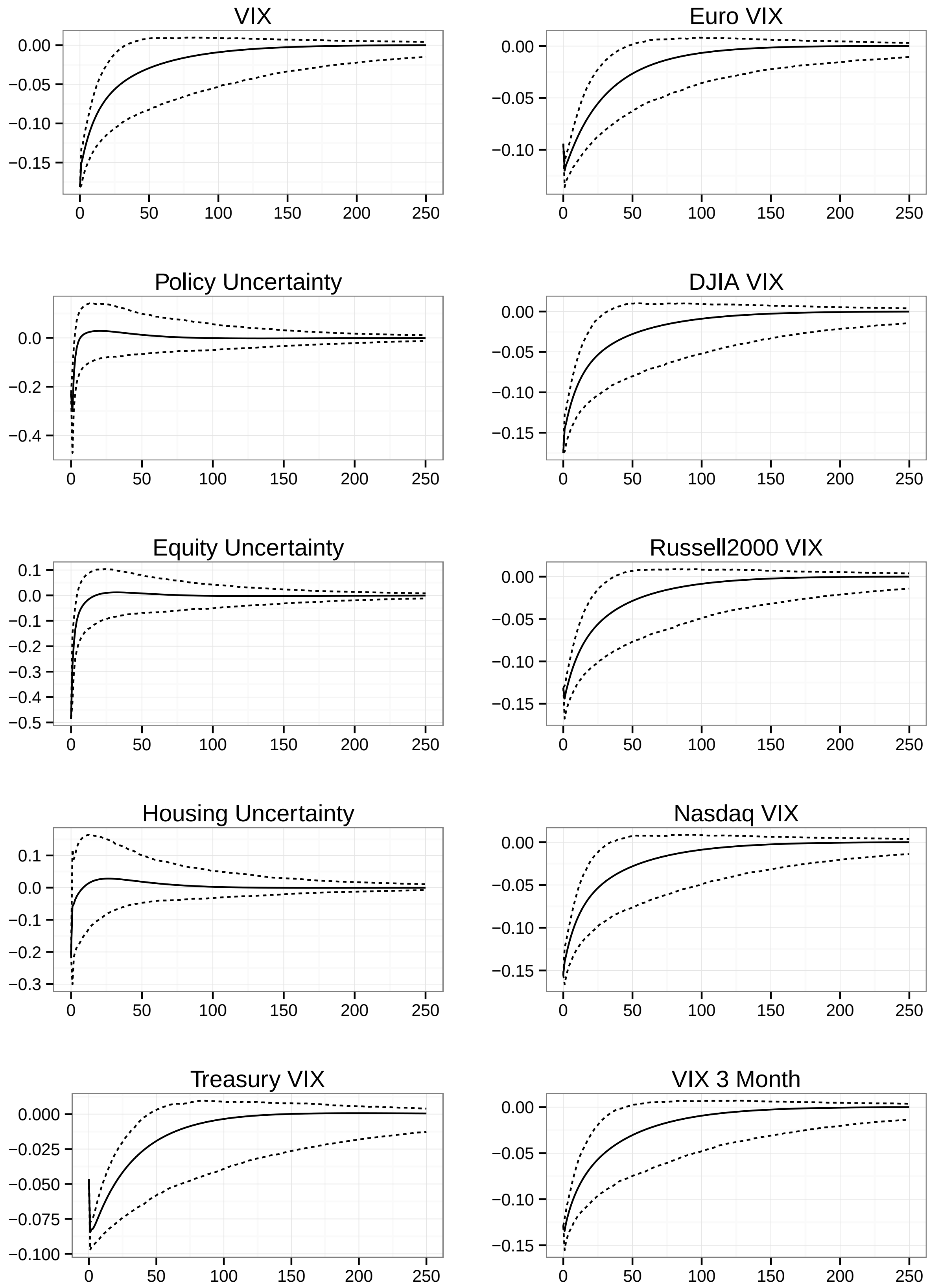
Notes: See the notes to figure 2.

Figure 6: Estimated Impulse Responses of Uncertainty Variables to an Identified Unconventional Monetary Policy Shock – Only Yields on Government Bonds used as observed factors



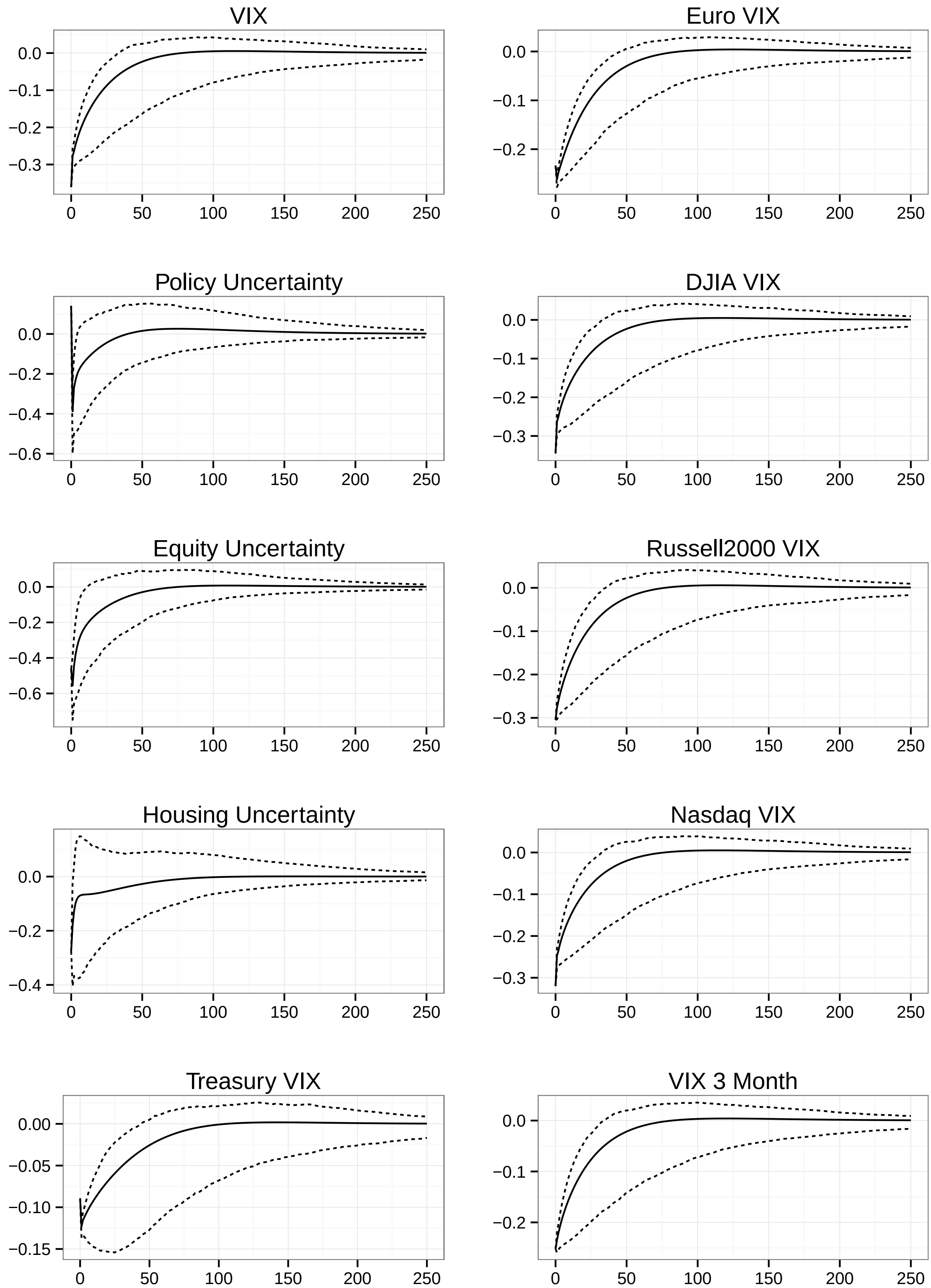
Notes: See the notes to figure 2.

Figure 7: Estimated Impulse Responses of Uncertainty Variables to an Identified Unconventional Monetary Policy Shock – The VIX and S&P500 returns as observed factors



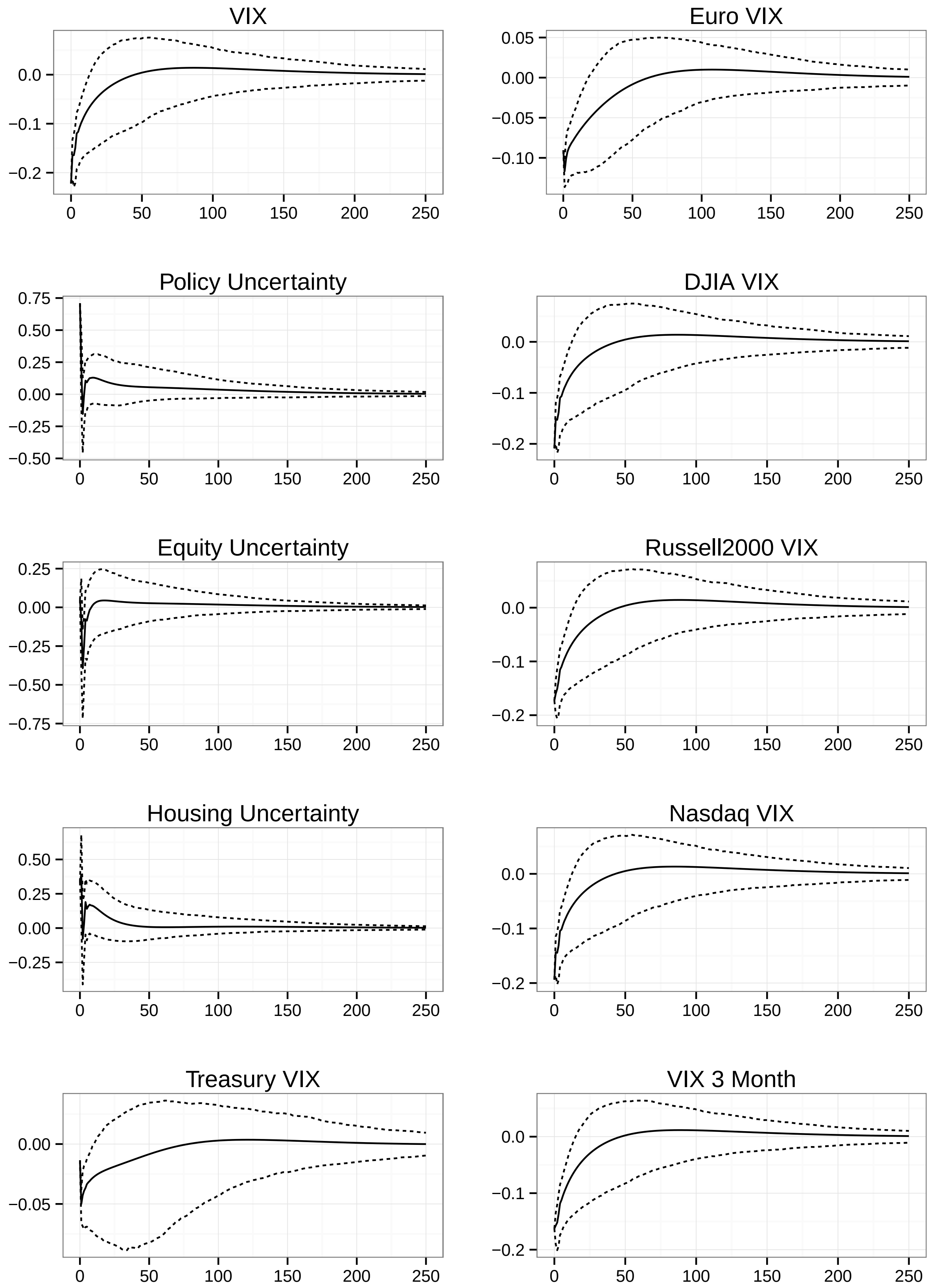
Notes: See the notes to figure 2.

Figure 8: Estimated Impulse Responses of Uncertainty Variables to an Identified Unconventional Monetary Policy Shock – The 3-year Treasury instead of the 2-year Treasury in the set of observed factors



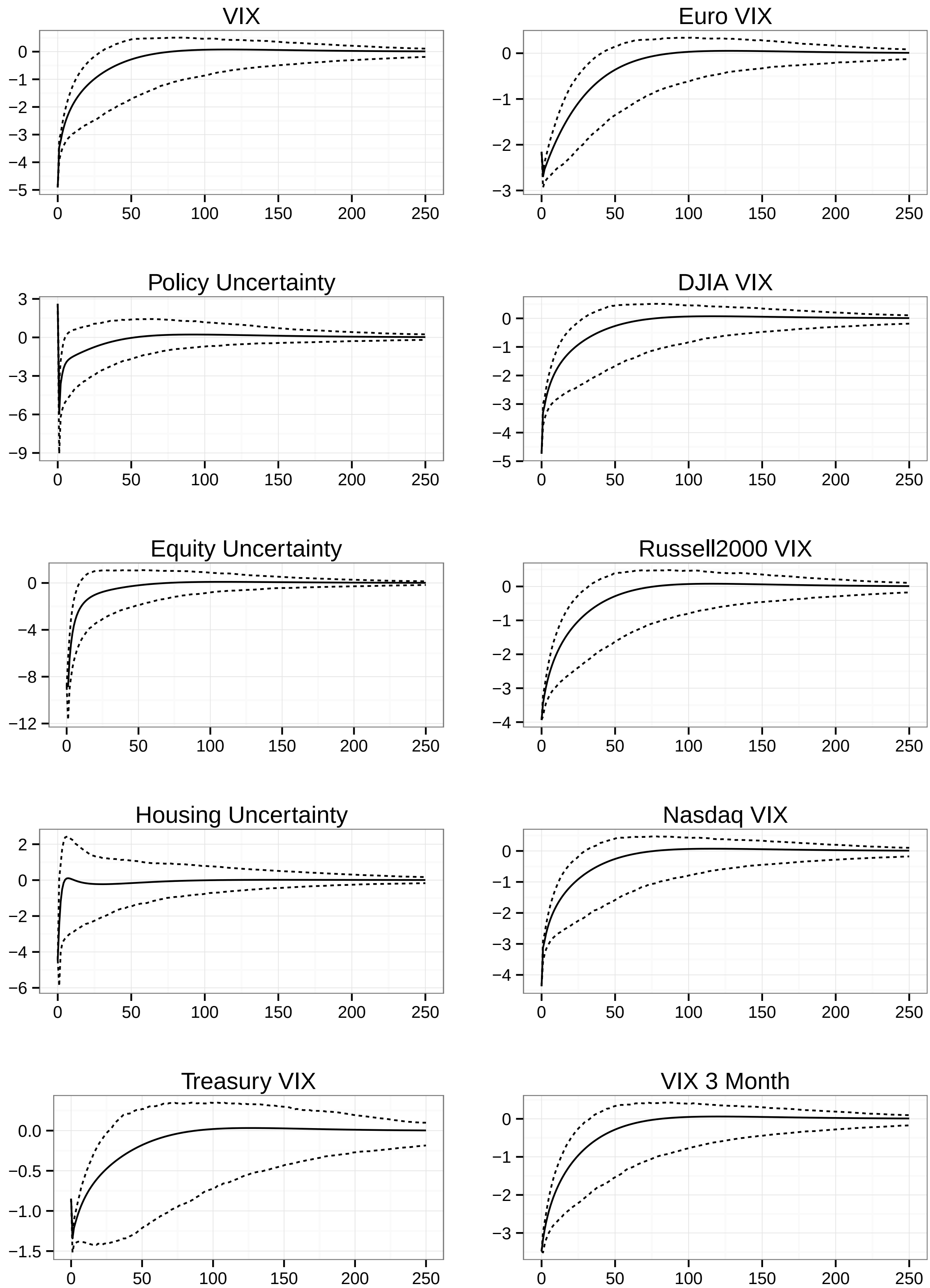
Notes: See the notes to figure 2.

Figure 9: Estimated Impulse Responses of Uncertainty Variables to an Identified Unconventional Monetary Policy Shock – 3 Lags (AIC) in the VAR



Notes: See the notes to figure 2. 3 lags as selected by the AIC are used in the VAR.

Figure 10: Estimated Impulse Responses of Uncertainty variables to an Identified Unconventional Monetary Policy Shock – Major Events



Notes: See the notes to figure 2. Only major events are used in the identification of monetary policy shocks.