HIAS-E-126

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The Role of Uncertainty Channel

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November 2022

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Central Bank Information Effects in Japan: The Role of Uncertainty Channel*

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November 28, 2022

Abstract

Central bank information effect have been analyzed in the recent literature on monetary policy. In this study, we apply the identification method by Jarociński and Karadi (2020) to the Japanese data to empirically examine the macroeconomic effects of central bank information shock and pure monetary policy shock. These shocks are identified by combining of high-frequency identification and sign restriction. The empirical results support the presence of central bank information effects in Japan. Particularly, the central bank information shock accompanying monetary tightening decreases economic uncertainty and increases stock prices and output, suggesting that central bank's optimistic outlook is conveyed through contractionary monetary actions. The results of the forecast error variance decomposition indicate that the central bank's information effect may be spread through changes in uncertainty. Finally, the total effect of monetary policy and information shocks on the variables are much larger than that of the shocks identified by the conventional Cholesky decomposition. These findings are important for evaluating the true effects of monetary actions on the economy.

Keywords: Monetary policy, Information effect, High-frequency data, VAR model.

JEL classification: C32, D83, E44, E52, G14.

*This research was funded by Grant-in-Aid for Early-Career Scientists (19K13652). The authors have no conflicts of interest directly relevant to the content of this study. Errors, if any, are entirely the authors' responsibility.

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1 Introduction

Recently, an increasing interest has been paid to central bank (CB) information effect in monetary policy analysis (Melosi, 2017; Nakamura and Steinsson, 2018; Jarociński and Karadi, 2020). The CB information effect refers to monetary policy actions conveying information to private agents about the central bank's economic outlook beyond information about policy changes due to asymmetric information between the central bank and private agents (Romer and Romer, 2000). For instance, an announcement about tightening monetary policy is considered to possibly convey the central bank's optimistic outlook that the economy has sufficiently improved to withstand an increase in the interest rate, thereby leading to expansionary reactions of the variables to tightening monetary actions (see, Nakamura and Steinsson, 2018). These reactions contrast with the conventional reactions to monetary policy shocks expected from theoretical models such as the New Keynesian model, highlighting the importance of considering the CB information effect to correctly identify the effects of monetary policy shocks. In other words, without considering the existence of the CB information effect, the identified monetary policy shock is likely to be a mixed estimate of pure monetary policy shock and CB information shock.

In this paper, we investigate the effects of monetary policy shock in Japan by applying the method of Jarociński and Karadi (2020), in which both pure monetary policy and CB information shocks are separately identified by combining the high-frequency identification (HFI) method and sign restrictions in the structural VAR framework. Although a growing body of literature on the CB information effects focuses on the U.S. and European economies, information effects in Japan are scarcely analyzed and are only mentioned in Kubota and Shintani (2022) and Nakamura et al. (2021). Therefore, this study primarily aims to examine whether the CB information effect is detected in Japan as in the U.S. and Europe. Furthermore, we focus on the transmission mechanism of the CB information effect, which has not been focused in Jarociński and Karadi (2020). Particularly, the transmission through market uncertainty is central to our analysis. Because some studies (e.g., Bauer et al., 2021; Mumtaz and Theodoridis, 2020) indicate the nexus between monetary policy and uncertainty, it is intuitively reasonable to suppose that private agents are more willing to rely on information conveyed from the central bank, which has information superiority, under high uncertainty.

Specifically, our analysis, along with Jarociński and Karadi (2020), proceeds as follows. First, we begin by constructing a novel dataset containing the surprises in the interest rate and equity prices within a 30-min window around the Bank of Japan's (BOJ's) monetary policy meetings (MPMs) from 2007 to 2021. The series of high-frequency surprises is considered as a desirable method to resolve the issues of reverse causality and endogeneity inherent in the VAR analysis conducted thus far, on the ground that variations in asset prices unrelated to the monetary announcements are plausibly eliminated, as emphasized in the seminal paper of Gürkaynak et al. (2005). We then estimate the structural VAR model including the constructed high-frequency surprises of financial variables, uncertainty index, and other macroeconomic variables of interest. As discussed above, both *pure* monetary policy and CB information shocks are separately identified by imposing sign restrictions. Following Jarociński and Karadi (2020), these shocks are distinguished by the signs of co-movements between interest rate and equity prices. Monetary policy shock is assumed to cause a negative co-movement between interest rate and equity price, while the CB information shock is assumed to cause a positive co-movement between them. For comparative purposes, we show the results derived from the recursive restriction using Cholesky decomposition, which corresponds to the conventional analysis ignoring the CB information effect. The effects of monetary policy and the CB information shocks are evaluated qualitatively and quantitatively using impulse response functions (IRFs) and forecast error variance decomposition (FEVD).

The results obtained from the IRFs are as follows. First, a monetary tightening shock raises market uncertainty and lowers stock prices and GDP. This result is consistent with that of existing studies in the literature that monetary tightening (easing) raises (reduces) macroeconomic and market uncertainty. Next, in response to an information shock that occurs when monetary policy is tightened, market uncertainty decreases, and stock prices and GDP rise. This result is intuitive. The CB information shock that occurs during monetary tightening reduces market uncertainty because private sectors anticipate an improvement in economic conditions. Furthermore, this result implies that the CB information shock, which occurs when monetary policy is easing, increases market uncertainty. In other words, monetary easing transmits to private sectors that current economic conditions are bad, and stock prices and GDP will decline. Under the Cholesky decomposition, the effect of monetary policy shock is confounded with that of CB information shock, leading to a small estimate of the impact of monetary policy. However, our results overcome this problem by identifying these two shocks. In addition, we confirm the robustness of our findings against the coverage of the MPMs, measures of uncertainty and macroeconomic variables, and sample period.

The results of the FEVD also show that monetary policy shock identified by our strategy is different from that identified by the Cholesky decomposition. Monetary policy shock under the Cholesky decomposition indicates almost no contribution to the high-frequency movements in TOPIX futures, suggesting that this conventional identification method may fail to capture the true monetary policy shock in terms of the lack of transmission to equity prices. Moreover, the results highlight the significant role of CB information shock contained in monetary announcements, showing the contribution of the CB information shock to about 40% movements in Euroyen and TOPIX futures within the narrow window around the announcement. In addition, the CB information shock shows relatively high contributions to the movements of uncertainty index. Thus, we conclude that the CB information effects propagates through the uncertainty channel. Finally, the total contribution of monetary policy and CB information shocks to financial and macroeconomic variables are estimated to be larger than that of the shocks identified by the Cholesky decomposition. This implies, as in the IRFs analysis, that the identification method using a simple recursive restriction may underestimate the impact of monetary actions in the economy, despite using the HFI method.

These results suggest that the central bank information shock may have different consequences than that intended by policymakers. In other words, monetary easing to stabilize the economy may instead increase uncertainty and worsen economic conditions. Therefore, policymakers need to be careful in communicating information to the private sector.

Our study is related to the following three strands of the literature. The first is related to the discussion on the information effects of monetary policy. Our study is closely related to Jarociński and Karadi (2020), who identify monetary policy and CB information shocks by applying sign restriction to high-frequency data on futures rates and stock prices. Their analysis reveals that CB information shocks bias the results of the standard HFI of monetary policy shocks. We employ a similar approach and identify two shocks. They also present several episodes that indicate high economic uncertainty during the period of high CB information shocks (see Jarociński and Karadi, 2020, p.17). Therefore, we include market uncertainty as a variable and analyze how information effects spill over through uncertainty. Miranda-Agrippino and Ricco (2021) and D'Amico and King (2015) investigate the response of key macroeconomic indicators to monetary policy announcements using Greenbook forecasts and a survey of expectations. These studies generally indicate the existence of information effects.

The second is related to the studies on monetary policy and uncertainty. Bekaert et al. (2013) decompose the VIX into a "risk aversion" and an "uncertainty" component and show that monetary easing policy reduces both risk aversion and uncertainty. Mumtaz and Theodoridis (2020) analyzes the impact of monetary policy shocks on uncertainty from both theoretical and empirical perspectives, and shows that a 1% increase in the policy rate raises the volatility of the unemployment rate and the inflation rate by about 15%. These studies show that monetary policy affects uncertainty. However, they only focus on monetary policy shock and do not separate monetary policy shocks and CB information shocks. Therefore, it is unclear how CB information affects market uncertainty. We fill this gap by separating the two shocks and analyzing their effects on market uncertainty.

The third is related to the analysis of monetary policy in Japan. Nakamura et al. (2021) constructed an index of monetary policy shocks using the three-month Euroyen futures rates. They show that changes within a 30-min window around the monetary policy meetings contain information on asset prices, such as long-term interest rates, and can be used as instruments to estimate the impact of monetary policy on macroeconomic variables. Kubota and Shintani (2022) constructed two factors, called "target factor" and "path factor", following Gürkaynak et al. (2005). These studies apply the standard HFI of monetary policy shocks, but they do not distinguish monetary policy shocks from CB information effects. However, Nakamura et al. (2021) and Kubota and Shintani (2022) suggested the existence of information effects. To the best of our knowledge, the current study is one of the few studies to analyze information effects in Japan.

The remainder of the paper is organized as follows. Section 2 explains the construction of the high-frequency dataset and the VAR framework as well as identification strategy. Section 3 provides the data and specifications for our empirical analysis. Section 4 demonstrates the results of IRFs and FEVDs derived from our benchmark specification. Section 5 confirms the robustness of our main findings by changing the data in the VAR model. Finally, 6 concludes.

2 Econometric Methodology

Following Jarociński and Karadi (2020), we disentangle monetary policy and central bank information shocks by combining high-frequency identification (HFI) and sign restrictions in structural VAR model. We begin by constructing a novel dataset of Japanese high-frequency financial market surprises around the policy announcements after the BOJ's monetary policy meetings (MPMs). The dataset is then used to identify the two shocks by sign restrictions. Specifically, the surprises in interest rate and stock prices around the BOJ's announcements are collected, and sign restrictions on the co-movements among them are used to distinguish between two shocks of interest. We follow Jarociński and Karadi (2020) and assume that monetary policy shock causes negative co-movements between interest rate and equity prices, whereas information shock causes negative co-movements between the two. This section explains how we build a dataset on high-frequency surprises in financial market and implement the identification of the shocks in the VAR model.

2.1 High-frequency surprises

Our measures of the surprises in financial market are the changes in Euroyen futures rates and TOPIX equity futures. These asset-price changes are collected in the narrow windows around the BOJ's announcements by using tick-by-tick data. To accurately identify the impacts of the CB announcements, we need to know the exact timings of announcements and focus on the reactions within a narrow window. Among various types of CB announcements, we consider the statements of monetary policy decisions (MPD) released immediately after the MPMs. The BOJ has been recording the release times of the MPD statements in minutes since July 2007; thus, we focus on 190 events with unique timestamps in our sample period from July 2007 to December 2021. In addition, consistent with previous studies, the surprises are measured in a 30-min window, starting 10 min before and 20 min after the announcements (e.g., Gürkaynak et al., 2005; Nakamura and Steinsson, 2018; Kubota and Shintani, 2022).[1]

The tick-by-tick data of Euroyen futures rates and TOPIX futures are obtained from the *CQG Data Factory* and *JPX Data Cloud*, respectively. The VAR analysis below uses monthly aggregates of the intraday surprises in interest rate and stock prices; thus, the surprises measured in the tick-by-tick data are transformed into monthly frequencies in the VAR analysis. Specifically, a minute-by-minute weighted average prices is first computed by multiplying the prices and transaction volumes for every minute on each MPM day. There are multiple contracts with different maturities in the Euroyen futures rates; thus, the prices of the contract month with the highest trading volume are selected for constructing a minute-by-minute weighted average price. We then calculate the changes in prices around the announcements, and finally add them for each month to produce monthly frequency price-change data.

Figure 1 shows, as in Jarociński and Karadi (2020), the scatter-plot of the surprises in the Euroyen and TOPIX futures. Similarly, positive co-movements between interest rates and stock prices are observed in Quadrants I and III of this figure. This co-movement can be attributed to the CB information effect. For example, on September 8, 2006, the BOJ announced that it would maintain the level of short-term interest rates. At the time, the BOJ was aiming to break away from zero-interest rate policy[2]. However, the rise in the CPI published in August 2006 had contracted. Although this contraction reduced the market's expectations of an interest rate hike, the market expected the BOJ to raise interest rates in the future, and futures rates rose despite no change in the BOJ's policy. Although this rise in futures rates depressed stock prices, stock prices rose because the BOJ was simultaneously projecting a positive outlook for a gradual economic recovery.

[1]The Japanese market has a lunch break, and there are cases in which a 30-min window is entirely or partially included in the lunch break. In such cases, we measure the 30-min window by trading hours, as in Kubota and Shintani (2022).

[2]The BOJ had raised short-term interest rates to 0.25% on July 14, 2006.

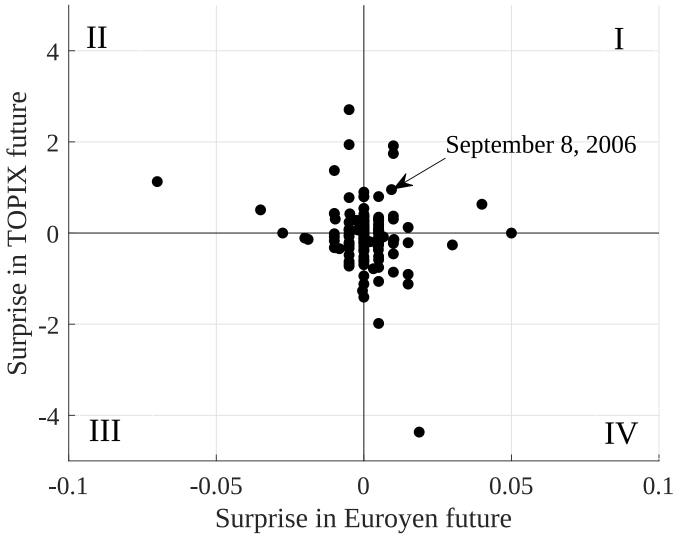

Figure 1: Scatter plot of Euroyen futures and TOPIX futures surprises

2.2 VAR model with sign restrictions

Let m_t and y_t be a vector of surprises in interest rate and stock prices and a vector of financial and macroeconomic variables observed in month t, respectively. As noted above, the surprises in the interest rate and stock prices are incorporated into the VAR model by aggregating their intraday movements on the day of the MPM announcement monthly. Therefore, our VAR model is formulated as follows:

$$\begin{pmatrix} m_t \\ y_t \end{pmatrix} = \begin{pmatrix} 0 \\ c_y \end{pmatrix} + \sum_{p=1}^{P} \begin{pmatrix} 0 & 0 \\ B_{YM}^p & B_{YY}^p \end{pmatrix} \begin{pmatrix} m_{t-p} \\ y_{t-p} \end{pmatrix} + \begin{pmatrix} u_t^m \\ u_t^y \end{pmatrix}, \begin{pmatrix} u_t^m \\ u_t^y \end{pmatrix} \sim \mathcal{N}(0, \Sigma). \tag{1}$$

where $u_t = [u_t^m, u_t^y]'$ is the reduced-form residuals, which follows the normal distribution with variance-covariance matrix Σ. m_t is assumed to have zero mean without any lag dependence, which is justified if surprises in financial variable are unpredictable, as in Jarociński and Karadi (2020). We estimate equation (1) by using a Bayesian method. As discussed in the seminal paper of Uhlig (2005), the posterior distribution for the VAR coefficients and the inverse of variance-covariance matrix can be given by the Normal-Wishart distribution under the diffuse priors.

Given the posterior draws of coefficients and variance-covariance matrix, the structural shocks are identified by the sign restriction method. We use QR decomposition proposed by Rubio-Ramírez et al. (2010). Specifically, we first calculate a lower triangular matrix A_0 using the Cholesky decomposition of Σ and generate the orthonormal matrix Q such as $QQ' = I$ by the QR decomposition of the random matrix whose elements are drawn from the standard normal distribution. Subsequently, multiplying A_0 by Q provides the new contemporaneous matrix, $A = A_0 Q$. For each combination of VAR coefficients and variance-covariance matrix, we randomly generate Q matrix 100 times and save the draw if all the sign restrictions are satisfied for the generated matrix A. The process of generating the coefficients and variance matrix is repeated until we have 5000 valid draws.

Table 1 summarizes sign restrictions adopted in this study. As discussed above, monetary policy and central bank information shocks are identified by the signs of high-frequency co-movements between the interest rate and stock prices. First, a tightening monetary policy shock is assumed to increase the interest rate and decrease stock prices, leading to a negative co-movement between the interest rate and stock prices. Second, CB information shock along with a tightening monetary policy is assumed to have positive effect on stock prices, meaning that the announcement about a tightening policy conveys the BOJ's positive economic outlook to the private agents. Finally, shocks other than monetary policy and central bank information shocks are assumed to have no effects on surprises in both the interest rate and stock prices.[3] These sign and zero restrictions can fully distinguish monetary policy and CB information shock from other possible structural shocks. In addition, all restrictions are only imposed on the surprise in interest rate and stock prices. Thus we let the data determine the responses of the variables included in y_t.

[3]To achieve zero restrictions on high-frequency surprises in interest rate and equity, we specify the matrix Q, following Jarociński and Karadi (2020), as

$$Q = \begin{pmatrix} Q^* & 0 \\ 0 & I \end{pmatrix},$$

where only Q^* is generated by the QR decomposition of arbitrary 2×2 matrix.

Table 1: Sign restrictions

	Monetary policy	CB information	Other
Interest rate	≥ 0	≥ 0	0
Stock prices	≤ 0	≥ 0	0
Other variables	$*$	$*$	$*$

Notes: The marks ≥ 0 and ≤ 0 literally indicate non-negative and non-positive sign restrictions, respectively. Similarly, zero restriction is represented by 0. The asterisk mark, $*$, means no restrictions on the variables.

3 Data and specification

Our sample period is from July 2006 to December 2021 because of the data availability. We can obtain the exact release times of the BOJ's statements after the MPMs from July 2006. The BOJ held 190 meetings during our sample period, including scheduled and unscheduled meetings. For each MPM, we collect surprises in Euroyen and TOPIX futures within 30-min window. However, the vector of macroeconomic variables in the VAR model comprises uncertainty index, stock prices, output measure, and prices, with the uncertainty index and stock prices capturing changes in expectations, and output and prices measuring the macroeconomic impact of the shock. In the benchmark analysis, we use Nikkei Volatility Index (Nikkei VI), Tokyo Stock Price Index (TOPIX), monthly real GDP published by *Japan Center of Economic Research*, and consumer price index (CPI, all items less fresh food). The variables other than the CPI are included in their natural logarithms multiplied by 100, while the CPI is included in the form of the year-on-year inflation rate. As shown in Section 5, the robustness is also checked by limiting the events only to scheduled MPMs, using the other measure of the variables, and changing the sample period.

Regarding the model specification, the VAR model in equation (1) is estimated with a constant term and 12 lags. The information criterion selects the shorter lags (actually only one lag), but we select 12 lags to capture the dynamics of the variables sufficiently. In addition, draws in which the roots of the VAR coefficients lie within the unit circle are saved in the sampling process to ensure stationarity of the VAR system.

4 Empirical results

4.1 Impulse responses

Figure 2 depicts the impulse responses to monetary policy and CB information shocks in the first and second column, respectively. First, we observe almost opposite signs of the responses in financial and macroeconomic variables to monetary policy and CB information shocks, meaning that two structural shocks are clearly distinguished by sign restrictions imposed on high-frequency movements in the interest rate and stock prices. Furthermore, the responses to CB information shock are clearly different from the "*conventional*" responses to monetary policy shock, which is usually expected from a theoretical model. This evidence supports the presence of CB information effects in the BOJ's monetary announcements.

A closer look at the responses shown in Figure 2 reveals the following results. The first column shows the impulse responses to a monetary shock. As described in Section 2.2, this tightening shock is a combination of the rise of Euroyen futures rate and the drop in TOPIX equity futures within a narrow window. After the sudden drops, Nikkei VI positively reacts to the shock in the short or medium run. This is due to the nervous perception of private agents in response to the shock. The result that the uncertainty measure rises regarding a monetary tightening shock is consistent with that of Bekaert et al. (2013).[4] With monetary policy tightening, stock prices show a long term and statistically significant downturn. Output and price levels significantly increase in the short run and decline in the medium run. In summary, at least for the medium-term, impulse responses to a monetary shock are consistent with conventional responses expected from theoretical models.

[4] Bekaert et al. (2013) show that the uncertainty measure declines immediately in response to a monetary easing shock and rises in the medium to long term. The difference between their results and ours may be due to the order of variables and use of real interest rates.

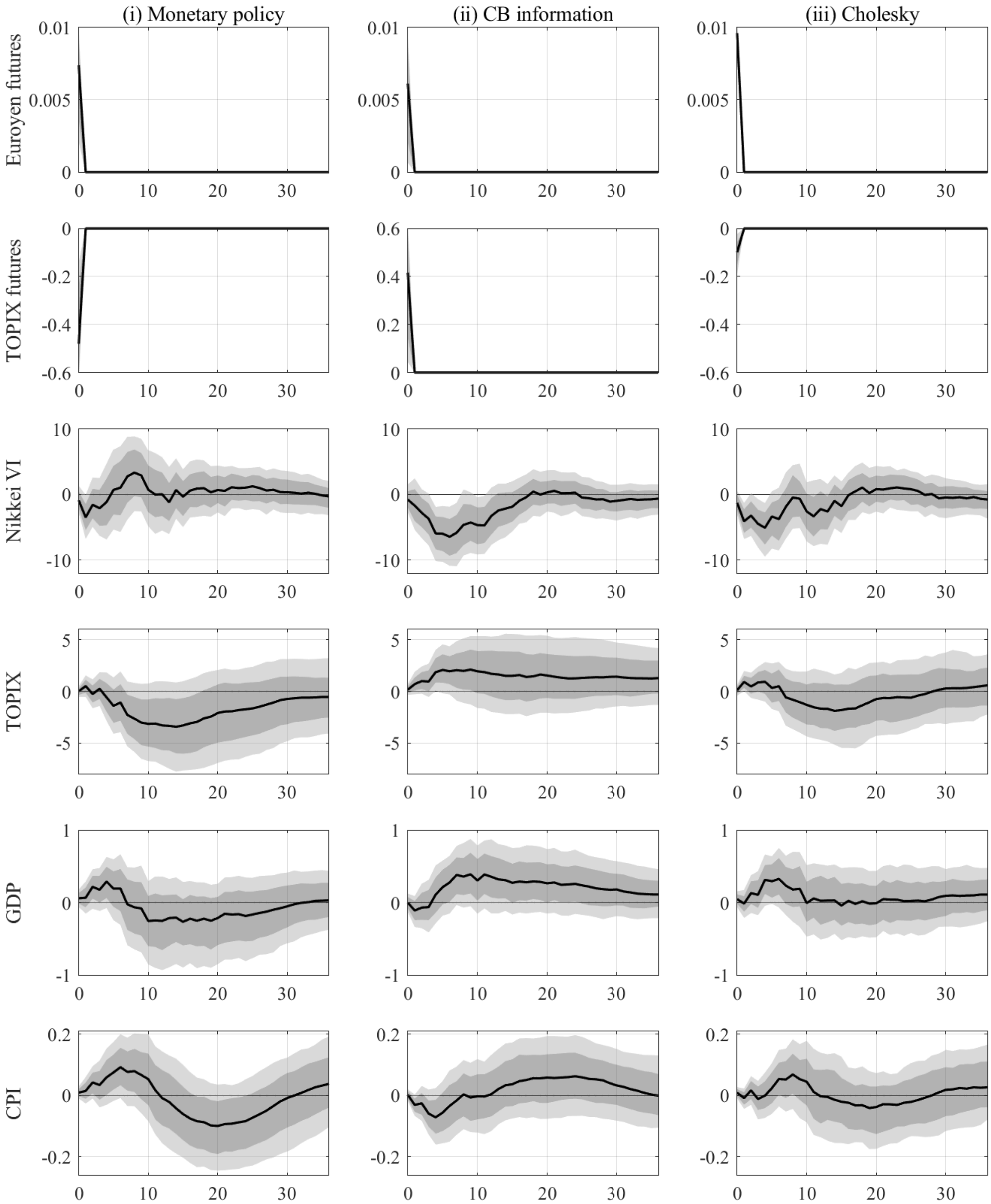

Figure 2: Impulse responses

Notes: The dashed line indicates the median of impulse response functions. The dark and light shaded areas correspond to 68% and 90% credible intervals, respectively.

The second column shows the impulse responses to a CB information shock. The CB information shock accompanying a tightening monetary policy is associated with a fall in Euroyen futures rates and rise in TOPIX equity futures. As mentioned above, we observe the responses in the opposite direction to a monetary policy shock. The shock has a negative statistically significant impact on Nikkei VI in the short and medium run. This response is due to the transmission of optimistic news to private agents that the economy is in good condition to tighten the financial market. This information shock leads to the statistically significant increment of the stock price. Moreover, both the output and price level increase in the medium run. These effects are contrary to those of a monetary policy shock.

The third column represents the impulse responses of a monetary policy shock identified by a Cholesky decomposition. These effects are mixtures of shocks identified by a sign restriction. As signs of the responses are opposite between a monetary policy shock and a CB information shock, the effect of a monetary policy shock identified by the Cholesky decomposition is relatively neutral.

4.2 Forecast error variance decomposition

Table 2 presents the results of forecast error variance decomposition (FEVD), which allows us to quantitatively assess the contributions of each structural shock on the variables. The results indicate that the monetary policy shocks identified by us is different from those which are derived from standard recursive restriction in quantitative perspective. Notably, monetary policy shocks from our identification, shown in the top panel (i), contribute to the high-frequency movements in both the Euroyen and TOPIX futures, while shocks from recursive restrictions, shown in the bottom panel (iii), only contribute to the movement in the Euroyen futures. As monetary announcements are likely to affect stock prices immediately, the standard HFI fails to capture the contemporaneous effects on stock prices and thus may only estimate a part of monetary policy shocks. In addition, our results demonstrate the quantitative role of CB information shocks in monetary announcements, shown in the middle panel (ii). About 40% of the movements in both Euroyen and TOPIX futures are explained by CB information shocks, implying that the CB information effects contained in monetary announcements has relevant role in high-frequency movements of asset prices.

Table 2: Forecast error variance decomposition

(i) Monetary policy shock						
Horizons	Euroyen futures	TOPIX futures	Nikkei VI	TOPIX	GDP	CPI
1	0.59	0.57	0.01	0.00	0.00	0.01
5	0.59	0.57	0.07	0.02	0.06	0.04
10	0.59	0.57	0.12	0.11	0.10	0.11
20	0.59	0.57	0.14	0.21	0.15	0.19
30	0.59	0.57	0.15	0.21	0.16	0.21
(ii) CB information shock						
Horizons	Euroyen futures	TOPIX futures	Nikkei VI	TOPIX	GDP	CPI
1	0.41	0.43	0.00	0.00	0.00	0.00
5	0.41	0.43	0.13	0.06	0.04	0.05
10	0.41	0.43	0.25	0.12	0.12	0.08
20	0.41	0.43	0.27	0.12	0.17	0.11
30	0.41	0.43	0.26	0.12	0.18	0.13
(iii) Cholesky						
Horizons	Euroyen futures	TOPIX futures	Nikkei VI	TOPIX	GDP	CPI
1	1.00	0.03	0.01	0.00	0.00	0.00
5	1.00	0.03	0.15	0.03	0.05	0.02
10	1.00	0.03	0.14	0.05	0.09	0.06
20	1.00	0.03	0.17	0.09	0.10	0.10
30	1.00	0.03	0.17	0.10	0.11	0.11

Notes: The figures in the table indicates the median estimates of each variable in selected horizon.

The results of the FEVD also proves the influence of the shocks on the financial and macroeconomic variables. Importantly, the standard HFI scheme using the Cholesky decomposition possibly underestimates the effects of monetary actions. The total contribution of two-shocks, (i) monetary policy shock and (ii) CB information shock, on the variables always exceed the contribution of "monetary policy shock" identified by (iii) the Cholesky decomposition. Let us suppose, as in Romer and Romer (2000), Melosi (2017), Nakamura and Steinsson (2018), and Jarociński and Karadi (2020), that monetary announcements convey the CB's information. Thus, the monetary policy shock identified in the conventional manner captures only a part of it. Second, the contribution of monetary shocks on macroeconomic variables is estimated to be relatively high compared with the estimates reported in previous studies on the Japanese economy. For example, Shibamoto (2007) reports that monetary policy shock contributes to 5% and 10% of forecast error variances in output and prices at the 60-month horizon, respectively. More recently, Nagao et al. (2021) document that 3% of forecast error variances in both output and prices are explained by monetary policy shock at the 24-month horizon. In contrast, the results in Table 2 show that each monetary shock contributes about 10% more to output and prices in the medium- and long-run horizon. Future studies should address whether these differences between are due to differences in identification methods used in this study and previous studies. Nevertheless, as noted in the first point, we confirm that the sum of contributions of monetary policy and CB information shocks exceeds that of the shock identified by the Cholesky decomposition. Finally, as shown in the middle panel (ii), CB information shocks steadily contribute to the movement of Nikkei VI, suggesting that CB information effects are transmitted to the economic activities through channels of uncertainty.

5 Robustness check

This section conducts robustness analyses to check whether main findings continue to hold under the exclusion of unscheduled meetings, different measures of variables, and the use of different sample periods. Figure 3 displays the IRFs obtained with various specifications along with the ones obtained with the benchmark specification. The benchmark IRFs and confidence intervals associated with them are represented by thick solid lines and shaded areas, respectively. The IRFs under the different specification lie within the confidence bands of the benchmark; thus, our benchmark results are robust without depending on the specifications.

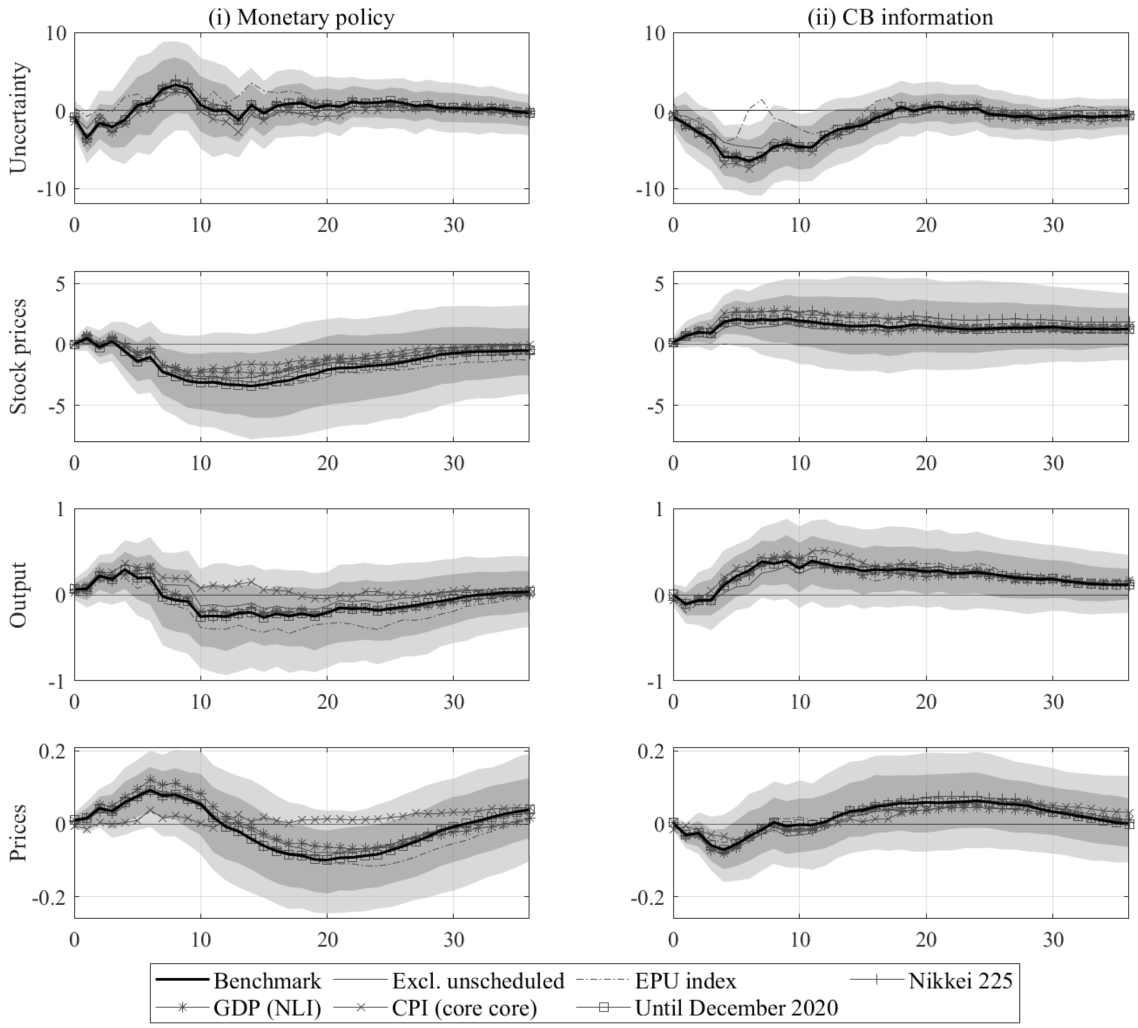

Figure 3: Impulse responses: Robustness checks

Notes: The thick solid line and shaded areas correspond to the benchmark results. The impulse responses obtained in the robustness analyses are drawn by the thin, dashed or the accented lines.

Specifically, the first robustness analysis checks whether the result may change by excluding unscheduled meetings from the sample. As discussed in Nakamura and Steinsson (2018) and Kubota and Shintani (2022), the unscheduled meetings may have been caused by the structural shocks other than monetary policy and CB information shocks. Furthermore, we replace the variables in the VAR model with a possible alternative measure to check the robustness. All the variables incorporated into the estimation are representative proxies for the variables originally employed in the benchmark analysis, and the details on the data are provided in Appendix A. The IRFs obtained in the robust analysis are within the confidence interval of the benchmark IRFs, with the exception that the response of the EPU index, alternatives of Nikkei VI, to the CB information shock is slightly outside the shaded areas. For this exceptional response, the IRFs of other variables is confirmed to trace the benchmark ones, despite using the EPU index as the uncertainty measure. Finally, we limit the sample period until December 2020 because the Euroyen futures have been barely traded in 2021, with high-frequency surprises in Euroyen futures taking zero for that year.[5] The IRFs obtained from this sample period follow those of the benchmark, confirming the robustness independent of the sample period. Overall, our main findings are robust to changes in the definition of MPMs, data, and sample period.

6 Conclusion

This study examined the effects of monetary policy shocks in Japan by separately identifying pure monetary policy and the CB information shock based on the method of Jarociński and Karadi (2020). Our empirical results show that a monetary tightening shock raises economic uncertainty and lowers stock prices and output, consistent with the effects of monetary policy shown in previous studies. However, the CB information shocks associated with monetary tightening reduce economic uncertainty and increase stock prices and output, suggesting that the optimistic outlook of the central bank is transmitted through monetary tightening. Furthermore, the variance decomposition of forecast errors indicates the significant contribution of CB information shock to economic uncertainty index, leading to the possibility that central bank information effects may be transmitted through changes in uncertainty. Our findings emphasize that CB information effects are crucial for evaluating the effects of monetary policy.

Finally, the relationship between the level of uncertainty and the two shocks should be evaluated in future studies. Several studies have suggested that the effects of monetary policy shocks differ with the level of uncertainty (Castelnuovo and Pellegrino, 2018; De Pooter et al., 2021). Therefore, we can discuss the relationship with uncertainty by examining whether the CB information effects are similar to those of monetary policy

[5] The TOPIX futures were traded even in 2021, so that the structural shocks in 2021 were likely to be identified based on the movements in the TOPIX futures.

shocks. Second, the effect of shocks over time should be analyzed. Hoesch et al. (2022) points out that the CB information effect weakened around the early to mid-2000s since. Furthermore, BOJ has adopted various policies such as QQE and NIRP. Therefore, it is also important to examine how the impacts of monetary policy shocks and CB information effects vary according to the policy.

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A Data Appendix

A.1 Dates of monetary policy meeting

As described in Section 2.1, we focus on 190 BOJ's statement released after the MPMs held during the period from July 2007 to December 2021. The dates and times of BOJ's press releases are collected from the BOJ's website: `https://www.boj.or.jp/en/mopo/mpmdeci/state_all/index.htm/`. The BOJ's MPMs have been scheduled 14 times a year until 2015 and 8 times a year after 2016; in addition, the BOJ sometimes holds unscheduled meetings depending on the economic situation. In the benchmark, we include both scheduled and unscheduled meetings in our sample, and also check the robustness using only on the scheduled meetings.

A.2 High frequency financial variables

We use high-frequency data of Euroyen futures rates and TOPIX futures as the Japanese counterparts of high-frequency interest rate and equity prices in Jarociński and Karadi (2020). The data for Euroyen futures and TOPIX futures are downloadable from the *CQG Data Factory* (`https://www.cqgdatafactory.com/`) and *JPX Data Cloud* (`http://db-ec.jpx.co.jp/?__lang=en`), respectively. Both data sources provide a tick-by-tick data that records prices for every transaction.

A.3 Monthly financial and macroeconomic data

In addition to high-frequency surprises, our VAR model comprises four types of monthly financial and macroeconomic data: uncertainty measure, stock prices, output, and prices.

We use Nikkei VI, TOPIX, monthly real GDP, and CPI (all item, less fresh food) in the benchmark analysis, and the robustness is also checked by replacing the variables with other indicators. All the data included in y_t are collected from the *Nikkei NEEDS-Financial Quest* provided by *Nikkei Media Marketing Inc.*, unless specifically mentioned.

Uncertainty index

The uncertainty measure in the benchmark is Nikkei VI, which represents the one-month-ahead expected volatility of the Nikkei 225 computed based on prices of Nikkei 225 futures and Nikkei 225 options. The higher value in Nikkei VI implies that the market participants expect the larger fluctuation in the stock market. In the robustness analysis, we use the Japan Economic Policy Uncertainty Index, which is constructed by Saxegaard et al. (2022) and released from https://www.policyuncertainty.com/japan_monthly.html. The EPU index is a newspaper-based uncertainty index. Specifically, this index represents the relative frequency of occurrence of articles related to "policy uncertainty" that is constructed by dividing the number of articles reporting about policy uncertainty by the total number of articles.

Stock prices

As for the stock prices, we use the TOPIX (Tokyo Stock Price Index) in the benchmark and Nikkei 225 average (Nikkei 225) in the robustness analysis. Both TOPIX and Nikkei 225 are the representative stock market indices of Japan. TOPIX is a weighted average of the stock prices of companies listed on the First Section of the Tokyo Stock Exchange (TSE), while the Nikkei 225 is composed of 225 stocks selected from the stocks listed on the First Section of the TSE (recently, the Prime Market of the TSE).

Output

In the System of National Accounts published by the government, GDP is only released on a quarterly basis. Thus, we use the monthly estimates of GDP constructed by private think tanks. The GDP in the benchmark is released by *Japan Center for Economic Research* while that in the robustness analysis is by *NLI research Institute* established by *Nippon Life Insurance Company.*

Prices

Two types of consumer price indice (CPI) are used for our analyses. The CPI for all items less fresh food, known as core CPI, is employed in the benchmark, while the CPI for all items, less food (less alcoholic beverages) and energy, known as core core CPI, is employed in the robustness analysis. We obtain the consumption tax adjusted CPI from the website of *Statistics Bureau of Japan*: https://www.stat.go.jp/data/cpi/1.html (Japanese page only).