Online Appendix

"Inflation, Business Cycle, and Monetary Policy: The Role of Inflationary Pressure" by Masahiko Shibamoto

A.1 Information content of financial and macroeconomic variables for future inflation

We present empirical evidence on the information content of financial and macroeconomic variables for inflation dynamics. Specifically, we examine inflation predictability using the following predictive regression model:

$$\pi_{t+h} = \sum_{k=1}^{K} \sum_{j=0}^{4} \delta_{k,j}^{h} y_{k,t-j} + \sum_{j=0}^{4} \delta_{\pi,j}^{h} \pi_{t-j} + \mu^{h} + e_{t+h}^{\pi}, \tag{1}$$

where e_{t+h}^{π} is a zero-mean forecast error for h-quarter-ahead inflation. We estimate the regression (1) by ordinary least squares (OLS). As candidate variables, we consider five macroeconomic variables: real gross domestic product (GDP) (gdp), shadow policy rate (sr), 10-year treasury yield (lr), dividend/stock price (dy), and effective exchange rate (er). To statistically examine the significant information content of candidate financial and macroeconomic variables for inflation dynamics, we estimate the marginal impact of each predictor at quarter t on the inflation rate h-quarter-ahead, $\delta_{k,0}^{h}$ for each $k = gdp, sr, lr, dy$, and er. We also compute White (1980) heteroskedasticity-robust F statistics for the test under the null hypothesis that the coefficients on the zero-to-four-quarter lags of $y_{k,t}$ for each $k = gdp, sr, lr, dy$, and er are all equal to zero. Table A1 shows the results.

A.2 Empirical results for the UCSV model

In this subsection, we confirm the time-series property of the trend inflation in Japan. Then, we compare the trend inflation with the time series of inflation dynamics due to inflationary pressure shocks to verify that inflationary pressure shocks identified as shocks that capture medium-term inflation variations encapsulate stochastic changes in low-frequency movements of trend inflation.

We follow the methodology proposed by Stock and Watson (2007) to measure the trend of CPI inflation. They specify inflation π_t as the sum of the stochastic trend component s_t and

Table A1: Predictive content of financial and macroeconomic variables for future inflation

Dependent variable		π_{t+1}	π_{t+4}
Predictor			
Real GDP	$\delta_{gdp,0}$	0.18*	-0.04
(100 × log)		(0.08)	(0.11)
	F-stat	2.78	2.41
		[0.02]	[0.04]
Shadow policy rate	$\delta_{sr,0}$	0.54**	0.06
(%)		(0.18)	(0.26)
	F-stat	2.68	1.82
		[0.02]	[0.11]
10-year treasury yield	$\delta_{lr,0}$	0.04	0.58**
(%)		(0.24)	(0.21)
	F-stat	1.85	3.48
		[0.11]	[0.01]
Dividend/stock price	$\delta_{dy,0}$	-0.59	-2.48*
(log)		(1.12)	(0.99)
	F-stat	0.57	1.80
		[0.73]	[0.12]
Effective exchange rate	$\delta_{er,0}$	-0.040*	-0.043*
(100 × log)		(0.017)	(0.021)
	F-stat	1.78	1.43
		[0.12]	[0.22]
R^2		0.64	0.46
Sample end		2018Q3	2017Q4

Notes: We run predictive regression model (1) for each h-quarter-ahead inflation described in the upper header on the financial and macroeconomic variables. The zero-to-four-quarter lags of consumer price index (CPI) inflation and the constant are included as control variables in the regression model. $\delta_{k,0}$ for $k = gdp, sr, lr, dy$, and er report the point estimates for the coefficient on the predictor at quarter t described in the left header. The numbers in parentheses are White (1980) heteroskedasticity-robust standard errors for least squares. **and *indicate statistical significance at the 1% and 5% levels, respectively. F-stat reports White (1980) heteroskedasticity-robust F-statistics testing the restriction that coefficients on the zero-to-four-quarter lags of the predictor described in the left header are all equal to zero. The numbers in brackets are the p-values of the test. The sample spans from the first quarter of 1983 through the quarter depending on the regression described in the last row.

the transitory component η_t^T in the unobserved components with stochastic volatility (UCSV) model as follows;

$$\pi_t = s_t + \eta_t^T, \text{where } \eta_t^T = \sigma_{T,t}\zeta_{T,t}, \quad (2)$$

$$s_t = s_{t-1} + \eta_t^S, \text{where } \eta_t^S = \sigma_{S,t}\zeta_{S,t}, \quad (3)$$

$$\log(\sigma_{T,t}^2) = \log(\sigma_{T,t-1}^2) + \nu_{T,t}, \quad (4)$$

$$\log(\sigma_{S,t}^2) = \log(\sigma_{S,t-1}^2) + \nu_{S,t}, \quad (5)$$

where $\zeta_t = (\zeta_{T,t}, \zeta_{S,t})' \sim$ i.i.d.$N(0, I_2)$, $\nu_t = (\nu_{T,t}, \nu_{S,t})' \sim$ i.i.d.$N(0, 0.04I_2)$. We apply the UCSV model to the CPI inflation and compute the estimates of the posterior distribution for parameters $\sigma_{S,t}, \sigma_{T,t}$ and stochastic trend s_t using the Markov Chain Monte Carlo (MCMC) algorithm.

Figure A1 plots the smoothed estimates of $\sigma_{S,t}$ and $\sigma_{T,t}$ from the UCSV model. In estimating the UCSV model, we use the longer sample from the second quarter of 1970. We set a vague prior for the initial condition and lower bounds of 0.0085(=sample variance of changes in CPI inflation×0.002) on the variances of permanent and transitory innovations in implementing the MCMC method.

The UCSV model captures the time-series evolution of the permanent and transitory sources of fluctuations in Japan's CPI inflation since the 1980s. The estimates in Figure A1 show significant movements in the standard deviations of permanent and transitory innovations over time. In particular, we can see that the volatility of permanent innovation $\sigma_{S,t}$ was high in the early 1980s but gradually moderated through the mid-2000s. In contrast, the volatility of transitory innovations $\sigma_{T,t}$ slightly changed from the early 1980s to the mid-2000s, but a surge in volatility can be observed in the second half of 2000.

Figure A2 plots the fitted values of CPI inflation from the vector autoregressive (VAR) model due to identified inflationary pressure shocks and the trend inflation. We measure the trend inflation as the smoothed estimates of the stochastic trend of the actual CPI inflation using the UCSV model.

By comparing the actual CPI inflation with the extracted inflation trend, we can visually confirm the two distinctive properties of the inflationary pressure shocks in inflation dynamics. First, inflation dynamics due to the identified inflationary pressure shocks are eliminated from

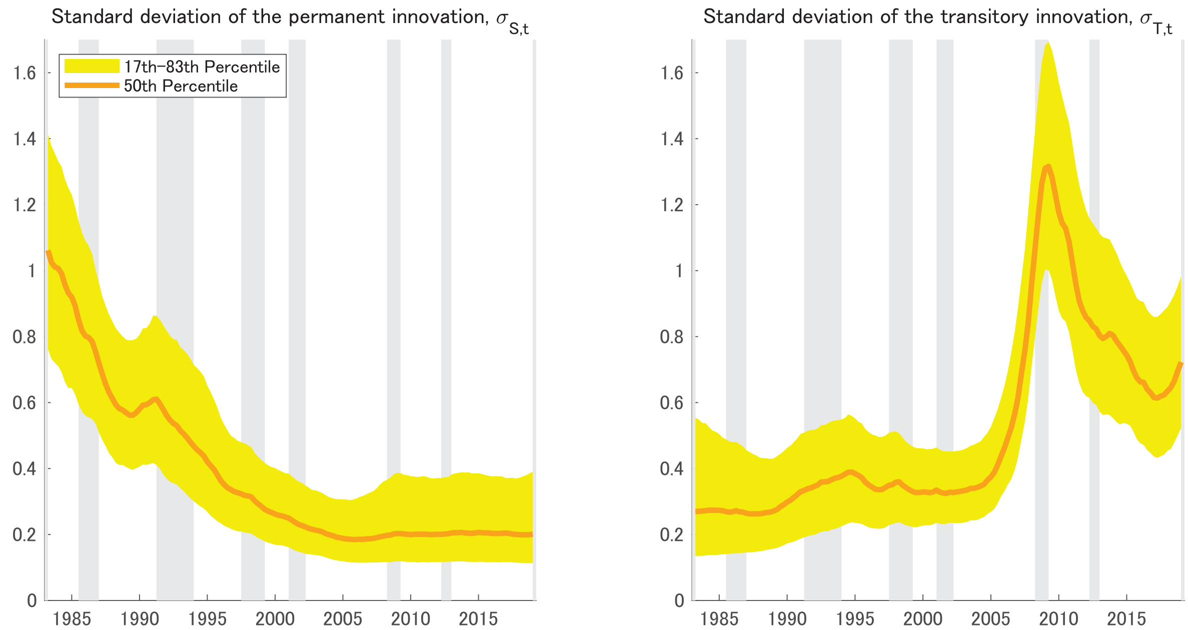

Figure A1: Estimates of the standard deviations of the permanent and transitory innovations of the CPI inflation using the UCSV model

Notes: The figure shows the 17%, 50%, and 83% quantiles of the posterior distributions of the standard deviations of the permanent and transitory innovations of the CPI inflation from the first quarter of 1983 to the fourth quarter of 2018.

variations owing to the transitory component. Reflecting the estimated evolution of volatilities of the transitory and permanent components, as shown in Figure A2, we can see that the stochastic trend dominated inflation dynamics until the mid-2000s; however, the deviation from the trend was more significant in the latter part of the period. This tendency holds within the dynamics due to inflationary pressure shocks.

Second, inflation dynamics due to identified inflationary pressure shocks are broadly in line with the stochastic changes in the inflation trend. As shown in Figure A2, the estimated stochastic trend captures the low-frequency movements in actual inflation. These timings of stochastic changes in the trend are broadly consistent with those of inflation dynamics that can be explained by the inflationary pressure shocks identified by the VAR model. This result suggests that inflationary pressure shocks capture the driving forces of stochastic changes in the trend underlying inflation dynamics.

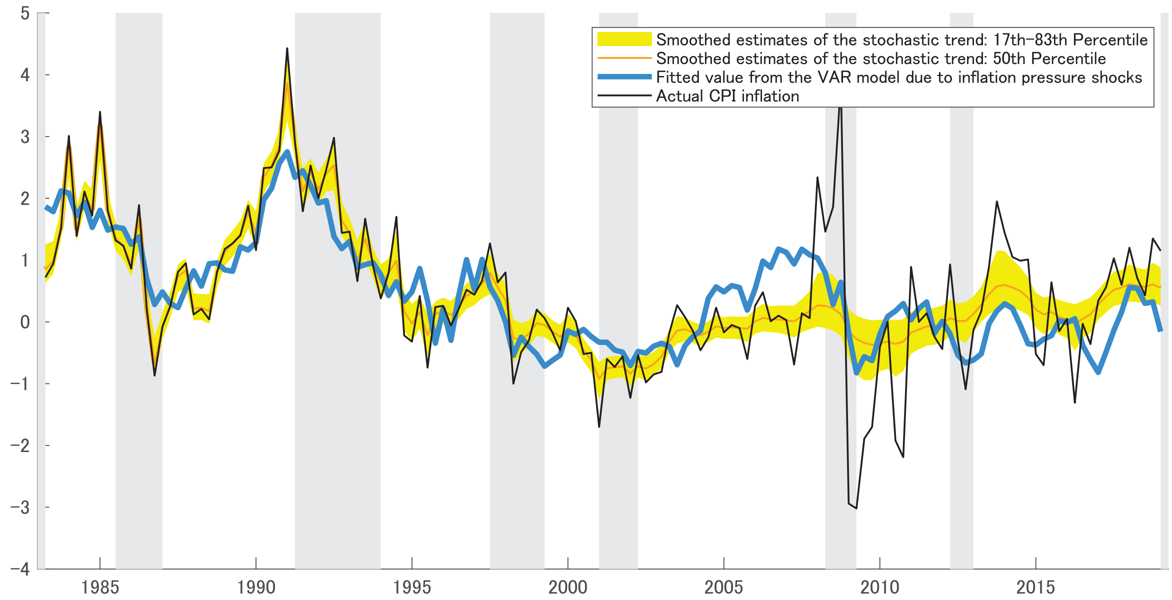

Figure A2: Comparison of inflation dynamics due to inflationary pressures and the trend inflation

Notes: The sample period spans from the first quarter of 1983 to the fourth quarter of 2018. The blue bold line indicates the series explained by the inflationary pressure shocks using the VAR model. We set the lag length to five quarters in the reduced-form VAR estimation. Trend inflation is measured as the 17%, 50%, and 83% quantiles of the posterior distributions of the smoothed estimates of the stochastic trend of the CPI inflation using the UCSV model.

A.3 Robustness check and sensitivity analysis

In this subsection, we re-estimate the model under several alternative settings to examine the robustness and sensitivity of our empirical findings.

Different truncation horizon in the identification problem

Figures A3 and A4 report the estimated impulse response functions to an inflationary pressure shock identified, under which we set the horizon in the identification problem at $h = 4$ and $h = 40$, respectively.

Using alternative price indexes as the measure of inflation

Figures A5 and A6 report the estimated impulse response functions to an inflationary pressure shock in the VAR model where we use the quarterly CPI for all items (Headline CPI) and CPI for all items excluding fresh food and energy (CPIxFE), respectively, in constructing the measure of inflation.

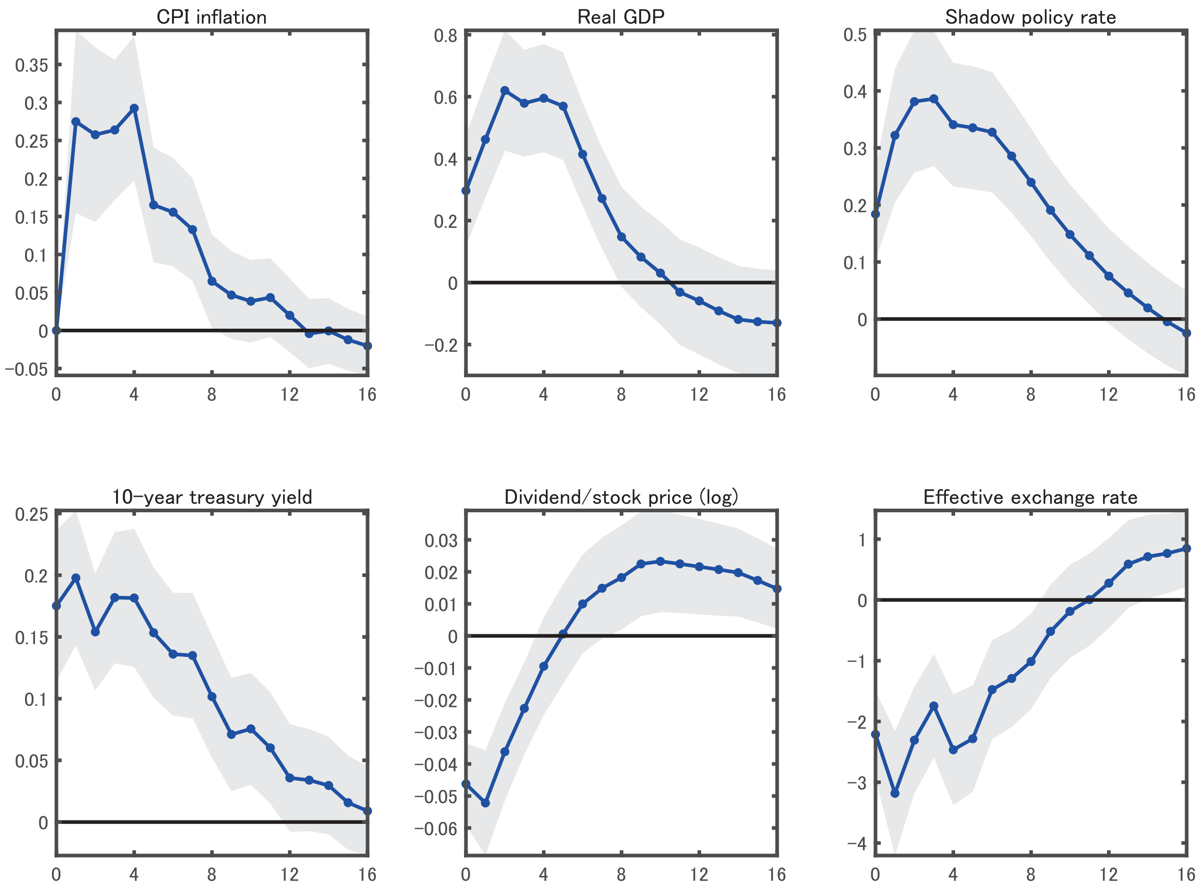

Figure A3: Estimated responses to an inflationary pressure shock: Truncation horizon $h = 4$

Notes: The solid line with circles represents the point estimates of the impulse responses to one standard deviation inflationary pressure shock. The shaded areas denote one-standard-error bands, calculated using 1000 bootstrap samples. We set the lag length to five quarters in the reduced-form VAR estimation. Estimation samples span from the first quarter of 1983 to the fourth quarter of 2018.

Using GDP gap as the measure of real output

Figure A7 report the estimated impulse response functions to an inflationary pressure shock in the VAR model, where we use the GDP gap retrieved from the Cabinet Office (%) as the measure of real output.

Subsample analysis using data through the fourth quarter of 2007

Figure A8 shows the estimated impulse response functions to an inflationary pressure shock using a subsample from the first quarter of 1983 to the fourth quarter of 2007.

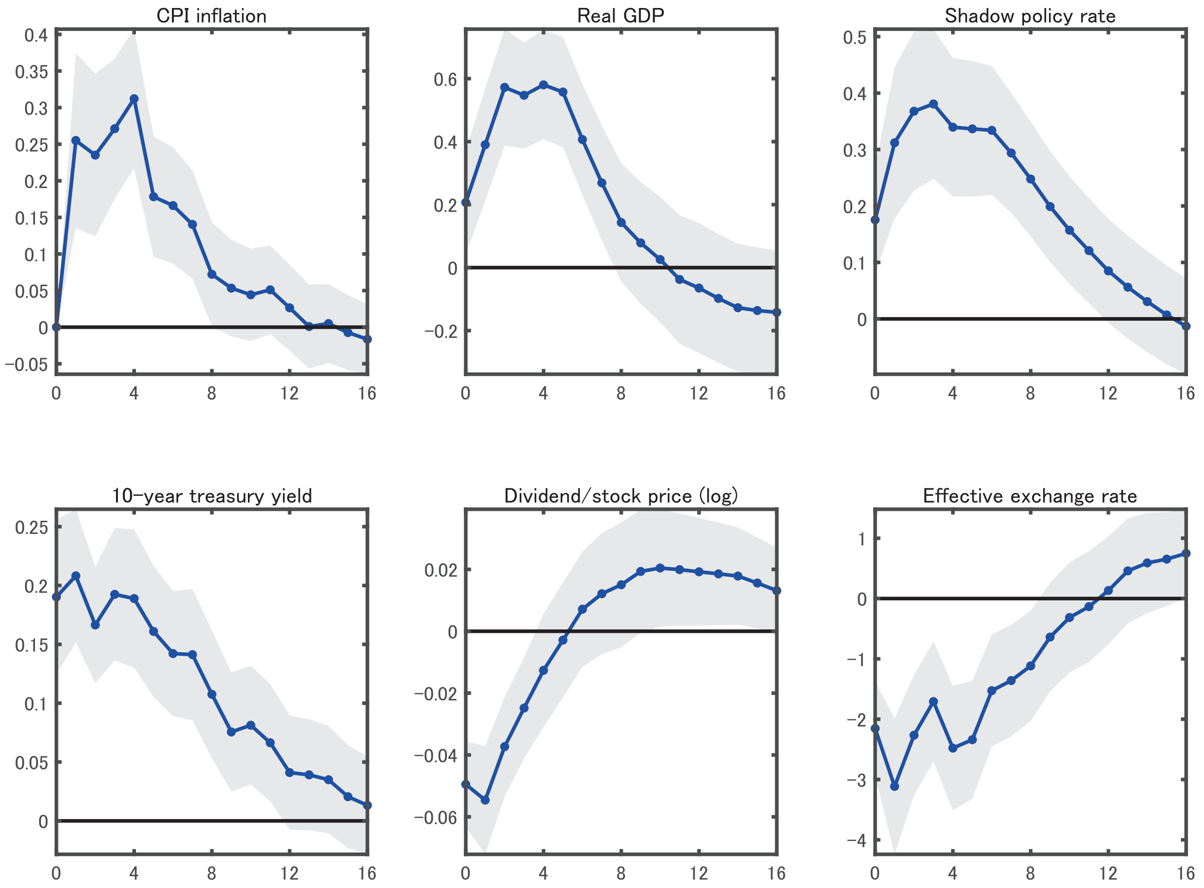

Figure A4: Estimated responses to an inflationary pressure shock: Truncation horizon $h = 40$

Notes: The solid line with circles represents the point estimates of the impulse responses to one standard deviation inflationary pressure shock. The shaded areas denote one-standard-error bands, calculated using 1000 bootstrap samples. We set the lag length to five quarters in the reduced-form VAR estimation. Estimation samples span from the first quarter of 1983 to the fourth quarter of 2018.

References

Stock, James H., and Mark W. Watson. 2007. "Why Has Inflation Become Harder to Forecast?" *Journal of Money, Credit and Banking* 39 (1): 3–34.

White, Halbert. 1980. "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity." *Econometrica* 48 (4): 817–838.

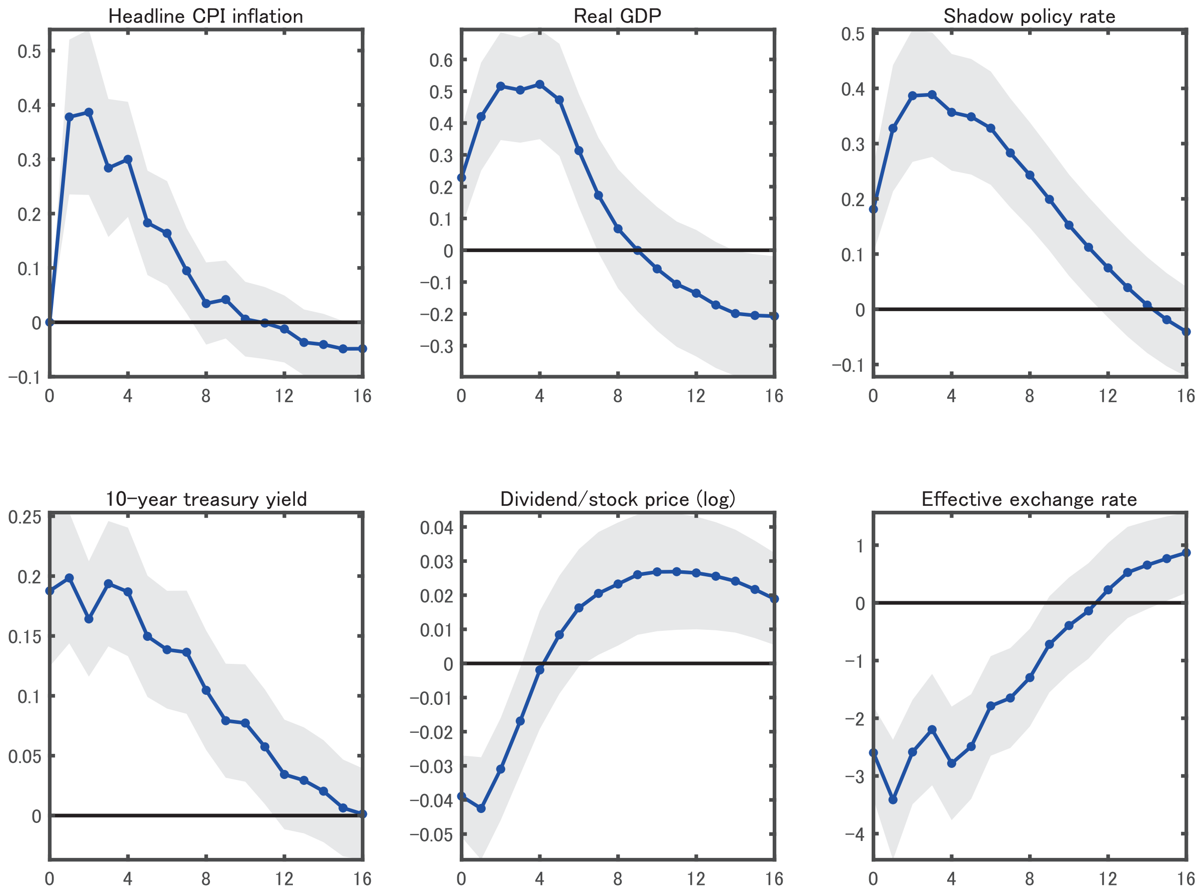

Figure A5: Estimated responses to an inflationary pressure shock: Headline CPI inflation

Notes: The solid line with circles represents the point estimates of the impulse responses to one standard deviation inflationary pressure shock. The shaded areas denote one-standard-error bands, calculated using 1000 bootstrap samples. We set the lag length to five quarters in the reduced-form VAR estimation. Estimation samples span from the first quarter of 1983 to the fourth quarter of 2018.

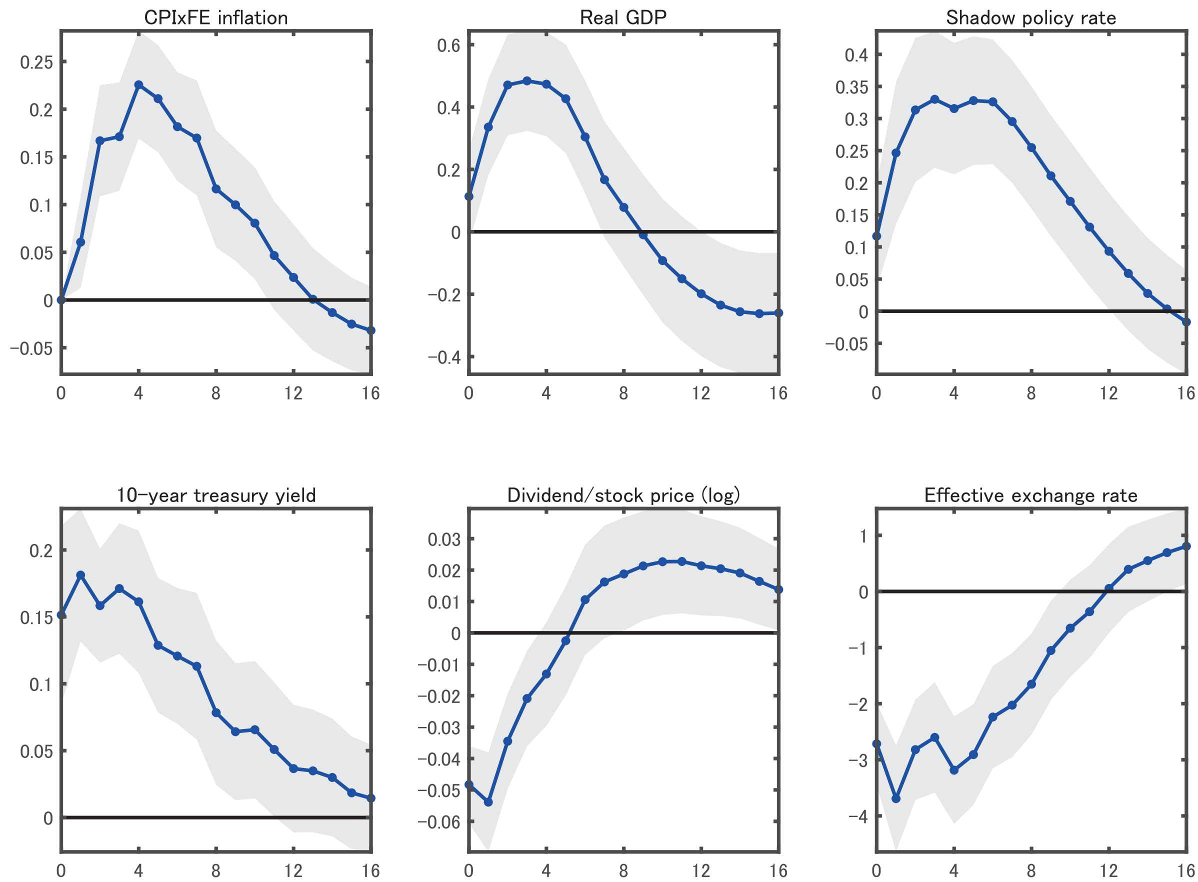

Figure A6: Estimated responses to an inflationary pressure shock: CPIxFE inflation

Notes: The solid line with circles represents the point estimates of the impulse responses to one standard deviation inflationary pressure shock. The shaded areas denote one-standard-error bands, calculated using 1000 bootstrap samples. We set the lag length to five quarters in the reduced-form VAR estimation. Estimation samples span from the first quarter of 1983 to the fourth quarter of 2018.

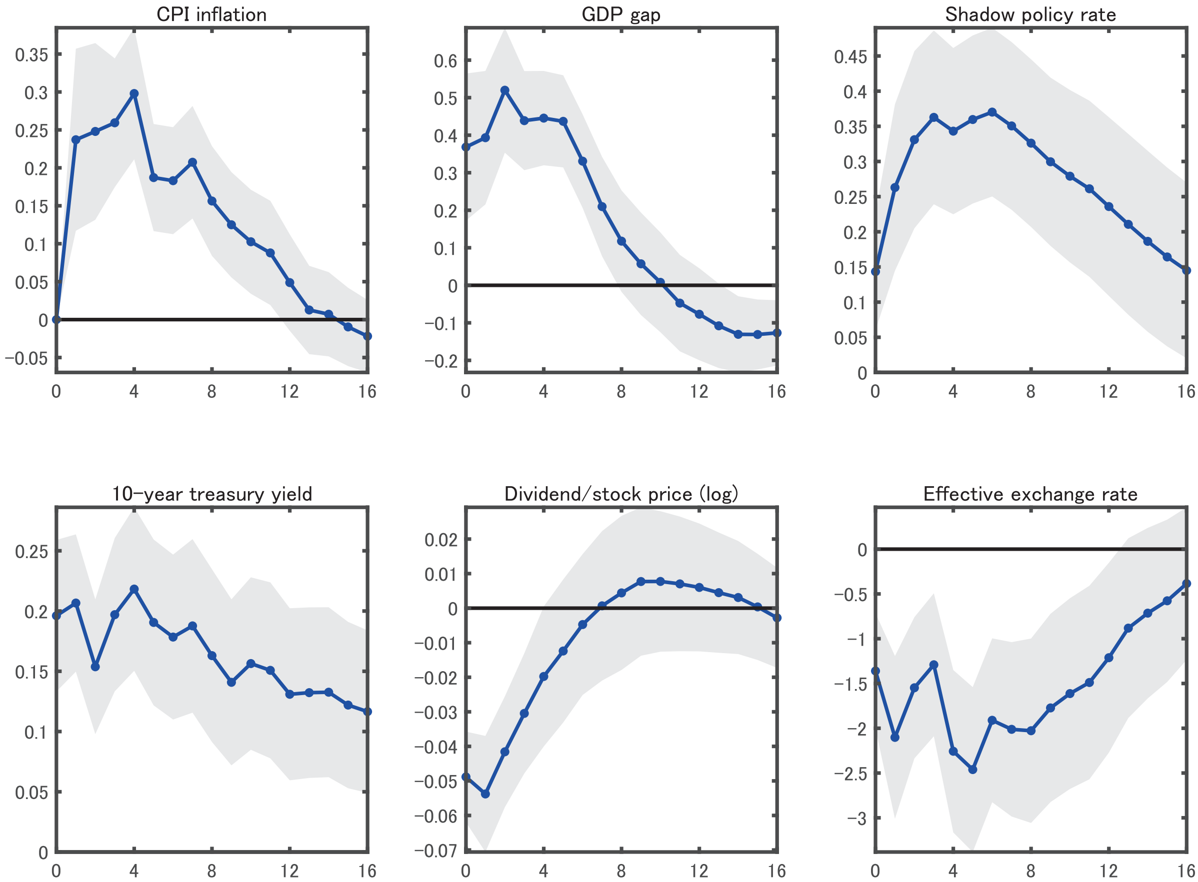

Figure A7: Estimated responses to an inflationary pressure shock: GDP gap

Notes: The solid line with circles represents the point estimates of the impulse responses to one standard deviation inflationary pressure shock. The shaded areas denote one-standard-error bands, calculated using 1000 bootstrap samples. We set the lag length to five quarters in the reduced-form VAR estimation. Estimation samples span from the first quarter of 1983 to the fourth quarter of 2018.

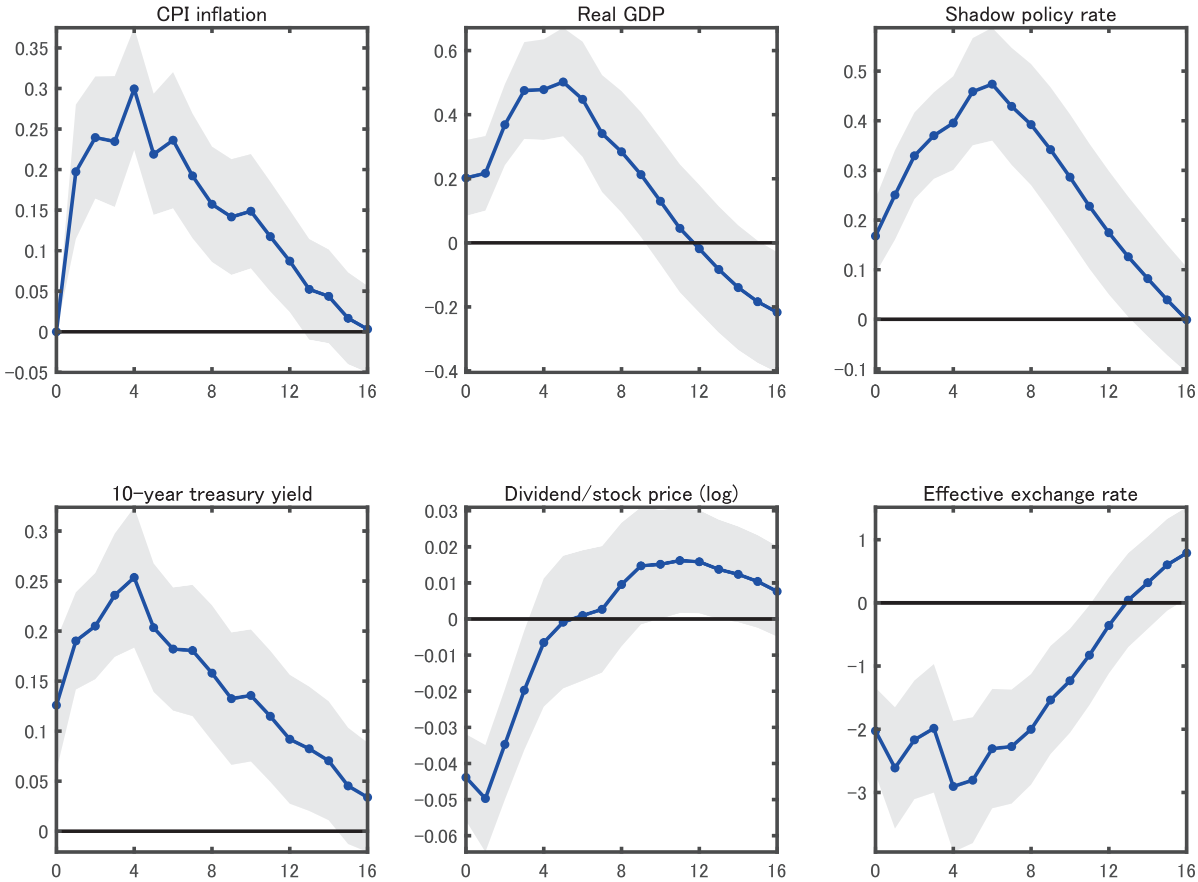

Figure A8: Estimated responses to an inflationary pressure shock: Subsample 1983:I–2007:IV

Notes: The solid line with circles represents the point estimates of the impulse responses to one standard deviation inflationary pressure shock. The shaded areas denote one-standard-error bands, calculated using 1000 bootstrap samples. We set the lag length to five quarters in the reduced-form VAR estimation. Estimation samples span from the first quarter of 1983 to the fourth quarter of 2007.