Online Appendix

Government Spending Multipliers under the Zero Lower Bound: Evidence from Japan

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Robustness

This section shows that our baseline results about the output multiplier, reported in Section III.B, are robust to various regression specifications and definitions of variables.

A1. Additional Predictors of Future Government Spending

In Section III.C, we illustrated that it is important to use forecast data to compute the multipliers. We investigate here whether our results are robust to adding more predictive variables to the set of controls in equation (1) of the main text.

Other JCER Forecasts. We add several additional variables from the JCER database. First, we add the government spending component of the fiscal packages approved by the Japanese government to equation (1). The Japanese government implements fiscal packages from time to time. These packages often contain several measures such as tax cuts, spending, and special transfers. We use the spending component of these packages when these fiscal packages are passed. We also use the information from the supplementary budget for the central government, which are additional budget items approved during a fiscal year. Figure A3 plots these data for the supplementary budget and fiscal packages as a percentage of GDP. The estimated multipliers, when these data are added as controls, are similar to the baseline.

Second, we add a one-year-ahead forecast of the annual government spending growth rate, formally, $F_t\left(\ln G_{t+4} - \ln G_t\right)$, to equation (1) to control for the possibility that agents know the amount of annual spending but do not know the exact timing. Third, we add one- to four-quarters-ahead forecasts of the quarterly government spending growth rate. Fourth, we include the one-quarter-ahead forecast of output as a variable that can summarize the expected future state of the economy. Fifth, we include the one-year-ahead forecast of the annual output growth rate. Because expected government spending can potentially react to expected changes in output, it may be important to control for expected output.

We report in Table A1 and Figure A4 the estimated multipliers when each of these variables is added one-by-one to equation (1). The point estimates of the output multipliers in both the normal and ZLB periods estimated with additional control variables are close to those in the baseline. The one-standard-deviation

confidence intervals for the multipliers in the normal period do not overlap with those in the ZLB periods in most cases. Overall, these results suggest that the JCER forecast of future government spending used in our baseline estimation contains much of the information available in the additional variables discussed here. These results also provide more evidence that the output multiplier in the ZLB period is substantially different from that in the normal period.

Other Forecast Sources. We add other forecast sources into our estimation of unexpected government spending shocks. In particular, the OECD Economic Outlook has released annual forecasts for government spending in May and November every year since 1983. The Japanese Cabinet Office's Economic Outlook database contains annual government spending forecast published in December from 1980. The quarterly IMF forecast publishes government spending forecast from 2003. In Figure A2, we plot the actual cumulative growth rate of government spending along with its one-quarter-ahead forecasts from the JCER, the OECD, and the Japanese Cabinet Office's Economic Outlook. This plot suggests that the JCER and the OECD forecasts track the actual government spending well before 2000 but less so after 2000.

We re-estimate equation (1) to include all of the available one-quarter-ahead forecasts of government spending from these sources and compute the multipliers for different horizons in Table A1. The multipliers in the normal period estimated with additional data are similar to those in the baseline. Although the estimates for the multipliers in the ZLB period are slightly higher than the baseline, the difference is small. The differences between the multipliers in the ZLB period and in the normal period are significant at shorter horizons. Overall, these results are in line with the baseline estimation.

Other Macroeconomic Predictors. We add several other macroeconomic variables in equation (1). First, we add four lags of contracted public work orders, orders received for public construction, and the excess returns of construction sector stock prices to control for expected government investment. Second, we consider variables that can include information on the state of the economy and the fiscal stance, such as real exchange rates and the index of leading indicators. The results remain similar to the baseline estimates. For example, in Figure A5, we report the estimates of cumulative multipliers of output in the specification with orders received for public construction and contracted public work orders.

A2. Variations of the Baseline Specification

We show that the baseline results are robust to changes in the baseline specification.

First, we estimate a version of specification (2) with a quadratic trend since time series estimates can be sensitive to trends. Table A1 displays the output multipliers in this case. We find that the multipliers estimated with a trend are similar to those in the baseline, although the output multiplier estimated with

a trend in the normal time is somewhat larger at longer horizons than in the baseline.

Second, we perform an alternative transformation of government spending and output by dividing them by potential output to calculate the multipliers. The motivation for this approach is as follows: In our baseline estimation, we normalize government spending changes by past GDP. A potential problem with this transformation is that fluctuations in output can bias the estimated multiplier. Instead, we estimate equation (3) for $(Y_{t+h}-Y_{t-1})/\overline{Y}_{t-1}$ and $(G_{t+h}-G_{t-1})/\overline{Y}_{t-1}$, where $\overline{Y}_t$ is potential output, computed using the Hodrick-Prescott (HP) filter with the smoothing parameter of 1600. The multipliers estimated in this case, reported in Table A1, are close to our baseline.

Third, one potential concern with our estimation is that we use the residuals $\widehat{\epsilon}_t$ of equation (1) to proxy for $shock_t$ without taking into account the uncertainty of the estimates. We address this concern and implement a one-step estimation of the effects of unexpected government spending on output. Formally, we estimate the following version of equation (3):

$$\sum_{j=0}^{h} x_{t+j} = \alpha_h^x + M_h \sum_{j=0}^{h} \frac{G_{t+j} - G_{t-1}}{Y_{t-1}} + \gamma_h^x F_{t-1} \Delta \ln G_t + \psi_h^x(L) y_{t-1} + \epsilon_{t+h}^x,$$

for $h = 0, 1, 2, \ldots$, where we instrument $\sum_{j=0}^{h} (G_{t+j} - G_{t-1}) / Y_{t-1}$ with the current growth rate of government spending because the regression includes both forecast and lags of control variables. This approach has the same interpretation as our two-step procedure. The results obtained from this estimation are shown in Table A1. The multipliers are virtually identical to our baseline estimates. The standard errors of the one-step and the baseline estimations are also similar.

Fourth, we estimate the output multiplier from a five-variable structural vector autoregression (SVAR). The five variables are government spending forecast, government spending, tax revenue, output growth, and the unemployment rate. As in the baseline, we include four lags of these variables in the SVAR. The SVAR results are close to the baseline estimation using the local projection method. Figure A7 compares the impulse responses of government spending and output to a government spending shock in the normal and ZLB periods obtained using the SVAR and the local projection method. The differences in the multipliers are statistically significant as in the baseline estimation.

Fifth, we estimate specification (3) by adding lags of extracted government spending shocks to alleviate the concern that our shocks are serially correlated. The results are close to the benchmark and plotted in Figure A8.

Finally, we estimate a fifteen-year rolling-window regression version of our baseline specification between 1967Q1 and 2014Q1. This allows us to check if there is evidence that the change in output multiplier occurred around the start of the ZLB period. Figure A9 plots the multiplier at different horizons. The multi-

plier is time-varying. Between 1967 and 1984, the cumulative output multiplier is about 1.2 on impact and increases to about 3 at a two-year horizon. This result shows that the multiplier can be larger than one during the 1960s and 1970s when the Japanese economy was under the fixed exchange rate regime. After the collapse of the fixed exchange rate regime, the multiplier is below unity for all years up to 1997. This result is consistent with the finding in Ilzetzki, Mendoza and Végh (2013) that the multiplier is larger in the fixed exchange rate regime than in the flexible exchange rate regime. The multiplier becomes higher than unity starting in 1995. This tendency is similar across all horizons. Overall, the rolling regression results are consistent with our baseline estimates and suggests that the multiplier is larger in the ZLB period than in the period before 1995.

A3. Alternative Inflation Measures

In the main text, we reported results for the GDP deflator and CPI. In addition, we report the responses of core CPI inflation here. Because both total CPI and core CPI were affected by the consumption tax hikes in 1989 and 1997, we also consider the responses of inflation adjusted for these consumption tax changes following Hayashi and Koeda (2014): We adjust the annual inflation rates from April 1989 to March 1990 and from April 1997 to March 1998 for the consumption tax increases, then recover the CPI level consistent with the adjusted annual inflation rates. The responses of inflation calculated from these series are plotted in Figure A11. The inflation responses using either tax-adjusted inflation or core CPI resemble the baseline. The tax-adjusted CPI inflation responses are positive for the first five quarters in the ZLB period. When food and energy are excluded, core CPI inflation also increases significantly in the ZLB period on impact.

REFERENCES

Hayashi, Fumio, and Junko Koeda. 2014. "Exiting from QE." *NBER Working Paper No. 19938.*

Ilzetzki, Ethan, Enrique G. Mendoza, and Carlos a. Végh. 2013. "How big (small?) are fiscal multipliers?" *Journal of Monetary Economics*, 60(2): 239–254.

Table A1—Output Multiplier: Robustness

Normal			ZLB		
On impact	4 quarter	8 quarter	On impact	4 quarter	8 quarter
The baseline					
0.61	0.12	-0.56	1.54	2.67	1.70
(0.23)	(0.58)	(0.34)	(0.43)	(1.11)	(0.94)
No forecast data					
0.38	-0.19	-0.49	1.49	2.43	1.53
(0.18)	(0.44)	(0.38)	(0.42)	(1.01)	(0.86)
Add fiscal packages					
0.75	0.29	-0.29	1.63	2.53	1.52
(0.27)	(0.65)	(0.35)	(0.47)	(1.09)	(1.06)
Add one-quarter-ahead GDP forecast					
0.57	0.05	-0.57	1.45	2.57	1.58
(0.23)	(0.56)	(0.40)	(0.43)	(1.11)	(0.95)
Add one- to four-quarters-ahead of G					
0.54	0.29	-0.36	1.64	2.89	2.10
(0.27)	(0.56)	(0.37)	(0.45)	(1.29)	(1.08)
Add four-quarters-ahead annual G					
0.57	-0.06	-0.72	1.66	2.72	1.80
(0.22)	(0.53)	(0.31)	(0.43)	(1.12)	(1.00)
Add four-quarters-ahead annual GDP					
0.57	-0.16	-0.75	1.41	2.67	2.37
(0.23)	(0.57)	(0.30)	(0.43)	(1.27)	(1.33)
Add OECD, IMF and Government Outlook forecasts					
0.58	0.19	-0.41	1.66	3.42	2.47
(0.21)	(0.54)	(0.30)	(0.60)	(1.81)	(1.35)
Quadratic trend					
0.69	0.52	0.77	1.89	5.13	5.74
(0.29)	(0.54)	(0.73)	(0.52)	(2.52)	(3.71)
Normalized by potential output					
0.61	0.11	-0.58	1.54	2.68	1.66
(0.23)	(0.57)	(0.32)	(0.43)	(1.12)	(0.96)
One-step estimation					
0.61	0.12	-0.56	1.54	2.58	1.54
(0.23)	(0.52)	(0.33)	(0.41)	(1.06)	(0.83)

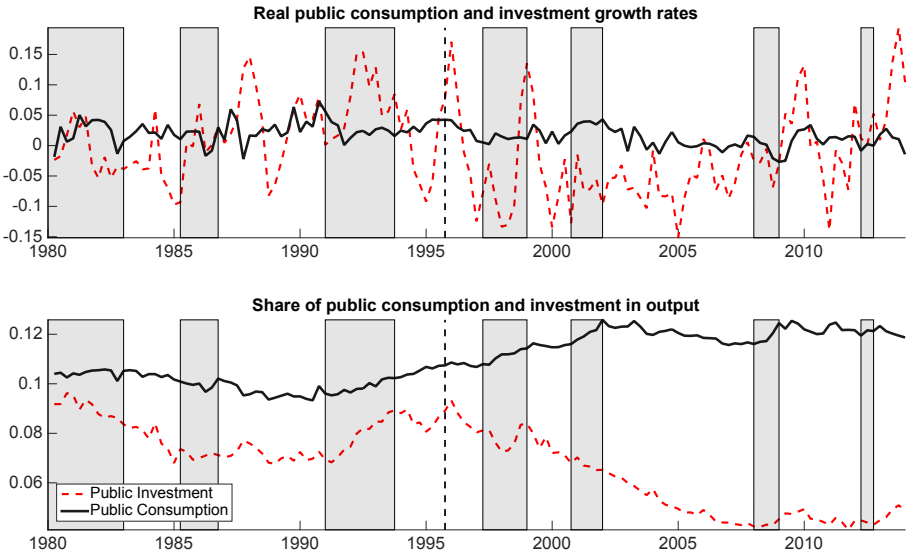
Note: Panel "The baseline" reproduces results from Table 1. Panel "No forecast data" reports the estimates without controlling for expectations data. Panel "Add fiscal packages" are the results with the fiscal packages added in the baseline estimation. "Add one-quarter-ahead output forecast" reports the results when we add a one-quarter-ahead forecast of the output growth rate to identify spending shocks. Panel "Add one- to four-quarters-ahead of G" reports results when forecasts of government spending from horizons one to four quarters ahead are included. Panels "Add four-quarters-ahead annual G" and "Add four-quarters-ahead annual GDP" report the cases when we add four-quarters-ahead forecast of annual spending growth rate and GDP growth rate into the estimation, respectively. Panel "Add OECD, IMF and Government Outlook" reports results with additional one-quarter-ahead forecasts from different sources into the estimation. Panel "Quadratic trend" shows the results when the time trend is added in the baseline. Panel "Normalized by potential output" reports the estimates when output and government spending changes in the baseline specification are divided by potential output. Panel "One-step estimation" estimates the output multiplier in one regression by adding a one-quarter-ahead forecast of government spending to the control variables. All numbers in parentheses are the standard errors.

Table A2—Multipliers of Inflation and Interest rates

	On impact	Horizon 4	Horizon 8
GDP deflator inflation			
Normal	-0.02	-0.05	-0.22
	(0.08)	(0.13)	(0.15)
ZLB	-0.01	-0.01	0.10
	(0.22)	(0.11)	(0.09)
CPI inflation			
Normal	-0.16	-0.34	-0.36
	(0.11)	(0.15)	(0.13)
ZLB	0.68	0.20	0.15
	(0.19)	(0.26)	(0.26)
GDP deflator inflation expectation			
Normal	-0.02	-0.23	-0.99
	(0.25)	(0.18)	(0.25)
ZLB	-0.04	0.79	0.37
	(0.12)	(0.33)	(0.29)
CPI inflation expectation			
Normal	-0.19	(0.25)	-0.21
	(0.20)	(0.08)	(0.19)
ZLB	0.10	0.40	0.44
	(0.13)	(0.21)	(0.47)
Short-term interest rate			
Normal	-0.10	0.37	0.12
	(0.16)	(0.26)	(0.59)
ZLB	-0.02	0.07	0.10
	(0.02)	(0.03)	(0.05)
Long-term interest rate			
Normal	-0.27	-0.10	-0.52
	(0,08)	(0.13)	(0.25)
ZLB	-0.14	0.03	-0.07
	(0.05)	(0.09)	(0.08)

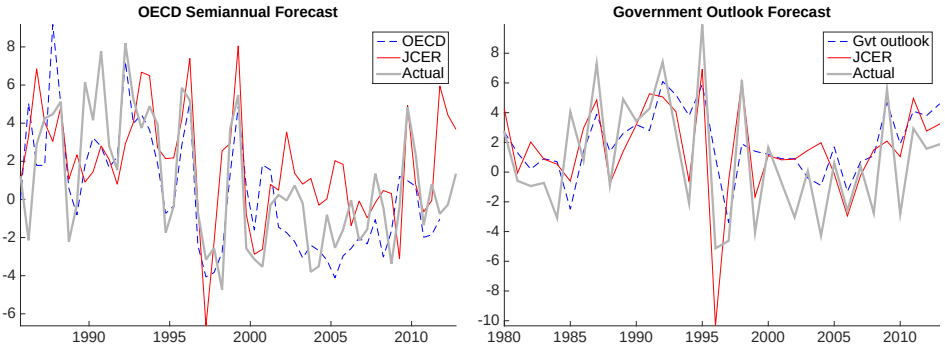
Note: This table reports the multipliers of inflation and inflation expectations, and the impulse responses of short-term and long-term nominal interest rates to an increase in government spending by 1 percent of output. All numbers in parentheses are the standard errors.

FIGURE A1. COMPONENTS OF GOVERNMENT SPENDING IN JAPAN



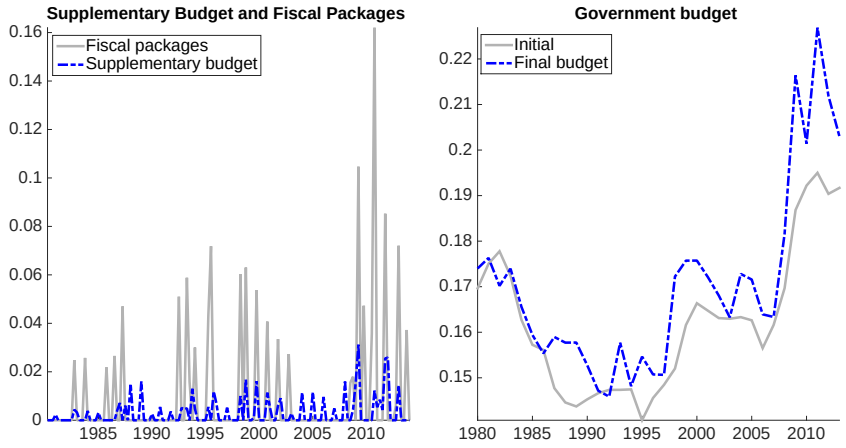
Note: The shaded areas are Cabinet Office recession dates.

FIGURE A2. OTHER ANNUAL FORECASTS OF GOVERNMENT SPENDING



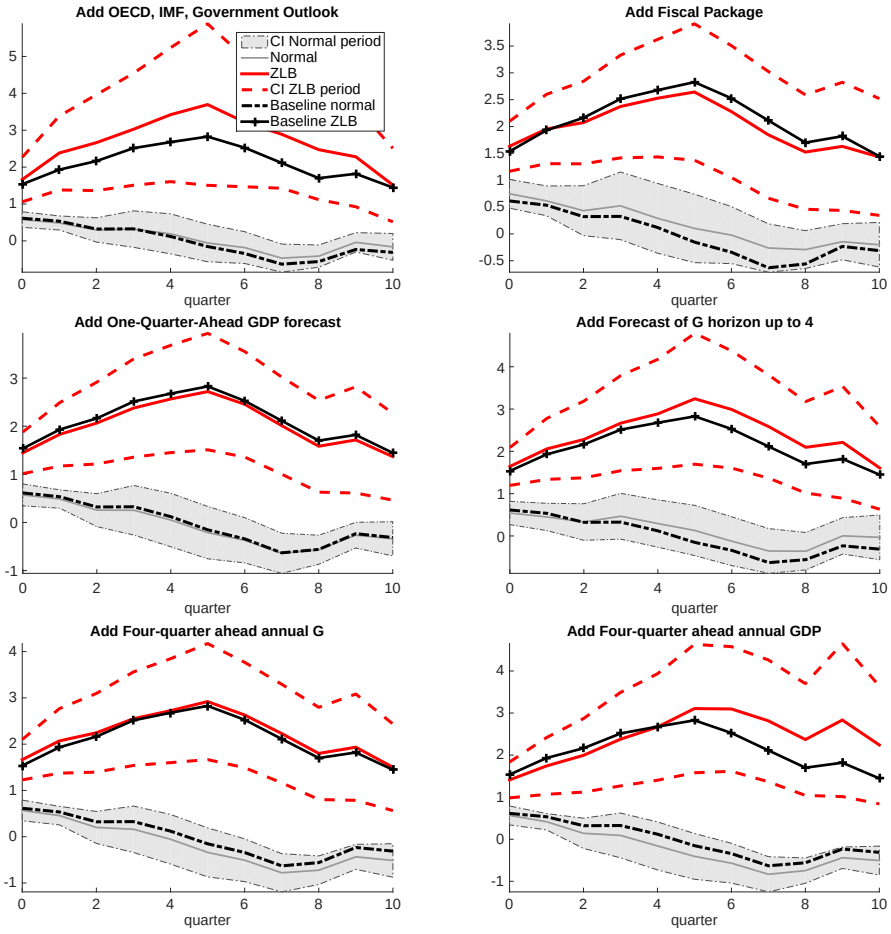
Note: The figures plot the semiannual forecast of government spending from the OECD (in the left figure), and the annual forecast of government spending from the Japanese Cabinet Office's Economic Outlook (in the right figure) against the same horizon JCER forecast and the actual government spending data.

FIGURE A3. SUPPLEMENTARY BUDGET, FISCAL PACKAGES AND TOTAL GOVERNMENT BUDGET IN JAPAN



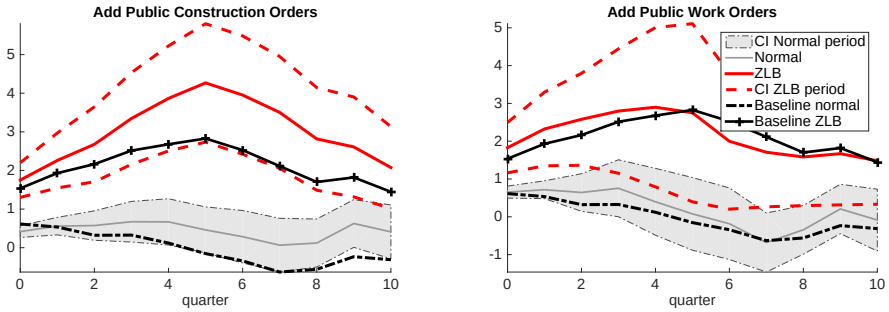
Note: Supplementary budget for the central government, fiscal packages, and government budgets for the central government are calculated as a ratio of nominal GDP.

FIGURE A4. OUTPUT MULTIPLIERS: ADDING OTHER SOURCES OF REAL-TIME INFORMATION



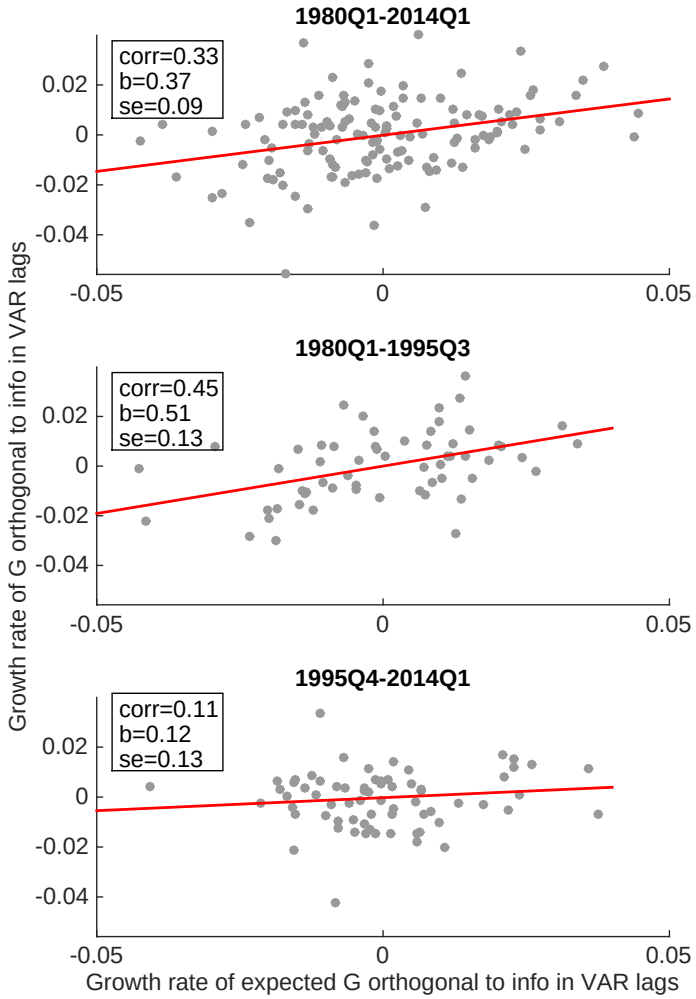
Note: This figure plots the output multiplier when we add several series to the controls. The black lines are the estimates in the ZLB (with plus signs) and in the normal period (dotted) in the baseline.

FIGURE A5. CUMULATIVE OUTPUT MULTIPLIERS: MORE CONTROLS



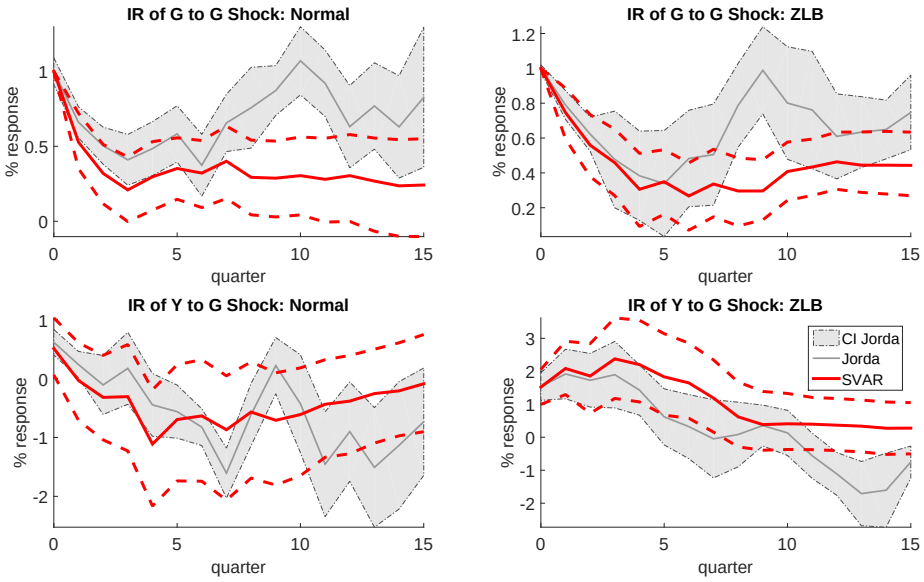
Note: The figure plots the cumulative output multipliers when we add orders received for public construction (left panel) and contracted public work orders (right panel).

FIGURE A6. PREDICTABILITY OF GOVERNMENT SPENDING SHOCKS WITHOUT CONTROLLING FOR EXPECTATIONS



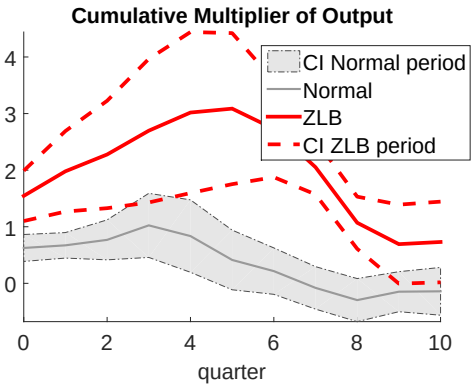
Note: The figure plots residuals from the projection of the growth rate of government spending predicted in JCER forecasts (horizontal axis) and actual growth rate of government spending (vertical axis) on the information contained in the lags of output, government spending and tax revenues. *corr* denotes the correlation between the two series, b is the regression coefficient, and *se* is the standard errors of the regression coefficient. Specifically, we estimate the following specification: $x_t = \alpha^g + \psi^g(L)y_{t-1} + \epsilon_t^g$, for two cases. In the first case, the dependent variable x_t is the realized government spending growth rate, $\Delta \ln G_t$; we obtain the residuals, $\widehat{\epsilon}_{1,t}^g$. In the second case, the dependent variable x_t is the one-quarter-ahead forecast of government spending, $F_{t-1}\Delta \ln G_t$; the residuals for this case are $\widehat{\epsilon}_{2,t}^g$. We then calculate the correlation between $\widehat{\epsilon}_{1,t}^g$ and $\widehat{\epsilon}_{2,t}^g$. A non-negative correlation implies that some of the government spending shocks identified without forecast data are predictable. For the entire sample 1980Q1–2014Q1, the correlation between the two residuals is 0.34 and statistically significant, suggesting that there is some forecastability of government spending shocks $\widehat{\epsilon}_{1,t}^g$ identified without forecast data. This correlation is 0.45 in the normal period but only 0.11 for the ZLB period between 1995Q4 and 2014Q1. This result suggests that the changes in government spending are less predictable in the ZLB period than in the normal period.

FIGURE A7. SVAR IMPULSE RESPONSES



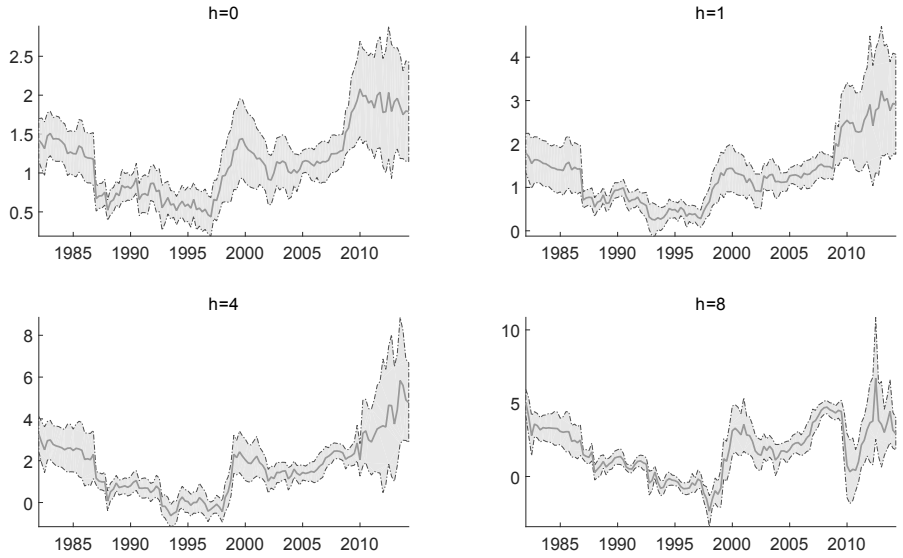
Note: The figure plots the output and government spending impulse responses to a 1 percent government spending shock in the ZLB period and the normal period estimated from a 5-variable structural vector autoregression.

FIGURE A8. OUTPUT MULTIPLIER WITH $shock_t$ LAGS



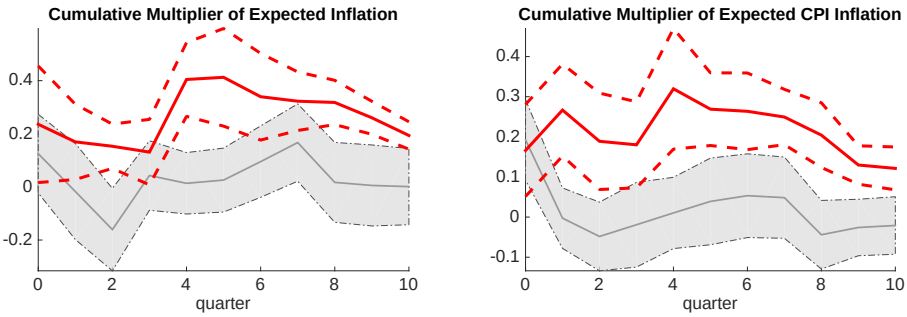
Note: This figure plots the multiplier of output when we include four lags of $shock_t$ in the estimation.

FIGURE A9. OUTPUT MULTIPLIER: ROLLING ESTIMATION



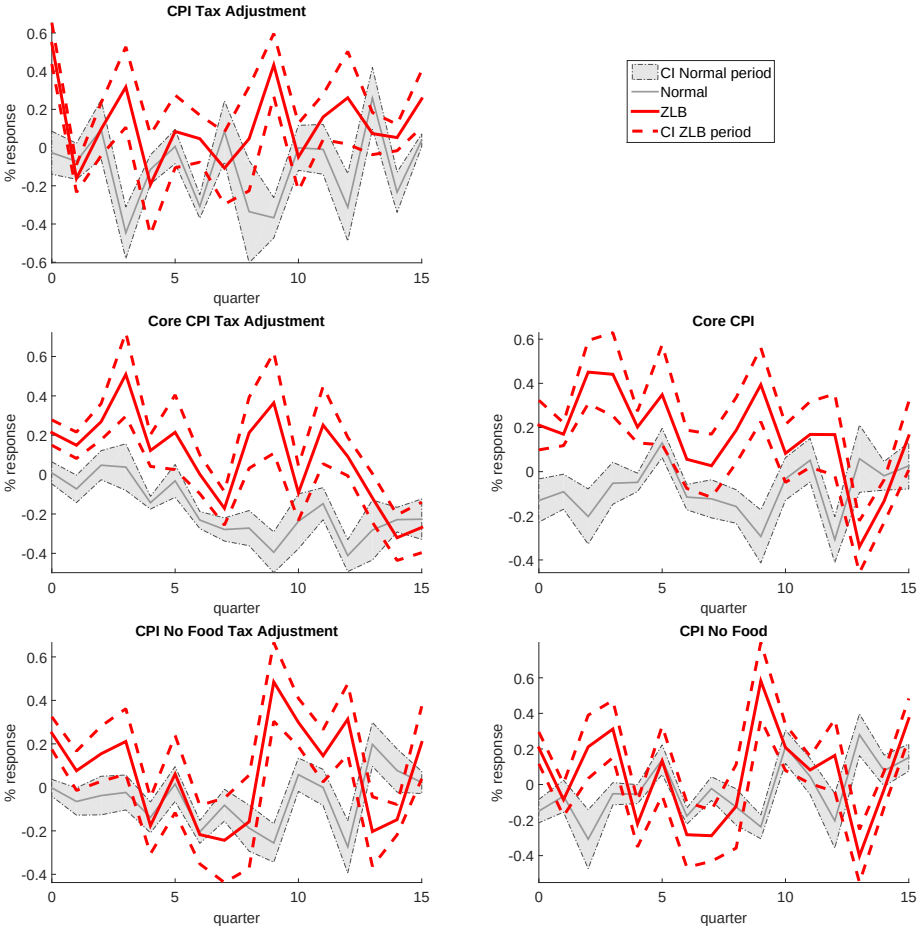
Note: The year of a reported multiplier corresponds to the last year of the 60-quarter window. For example, a multiplier reported for 1990Q1 is estimated over the period 1975Q1–1990Q1. Each plot corresponds to the output multiplier at a different horizon h (in quarters). The grey areas are one-standard-deviation error bounds.

FIGURE A10. ONE-QUARTER-AHEAD INFLATION EXPECTATIONS MULTIPLIER



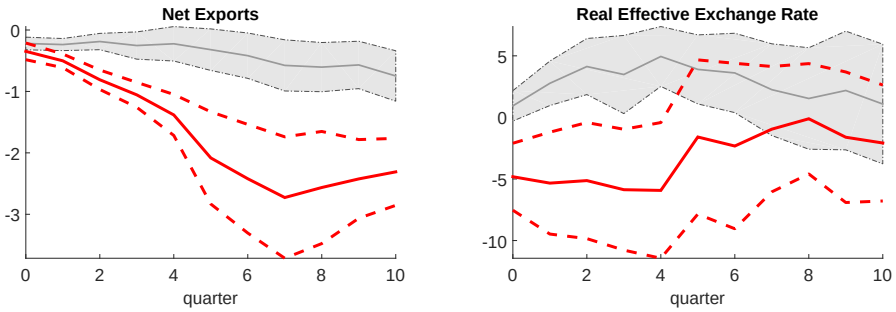
Note: "One-quarter-ahead inflation expectation" is the inflation expectation from the GDP deflator forecast, $F_{t-1}\pi_t$, and "One-quarter-ahead CPI inflation expectation" is the inflation expectation from the CPI forecast, $F_{t-1}\pi_t^{CPI}$.

FIGURE A11. DIFFERENT INFLATION DATA



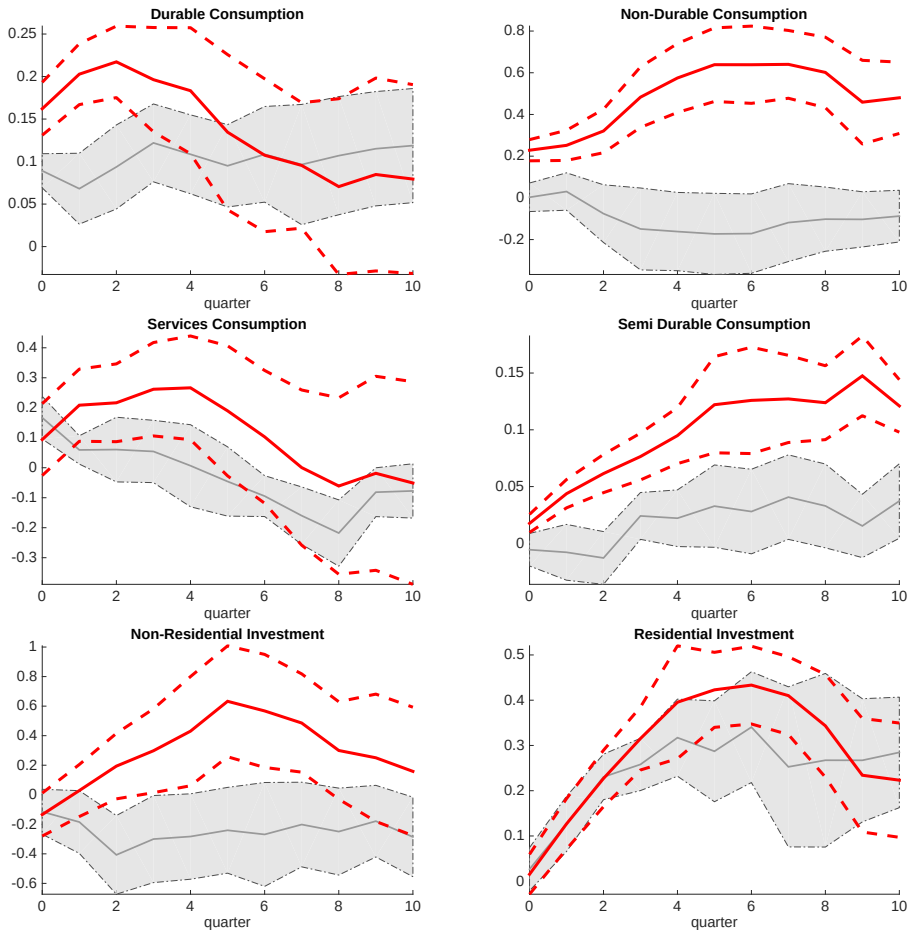
Note: This figure plots the impulse responses of the inflation rate calculated from CPI, core CPI (excluding food and energy) and CPI no food (excluding fresh food), along with the measures of CPI inflation adjusted for consumption tax changes.

FIGURE A12. CUMULATIVE MULTIPLIERS OF NET EXPORTS AND REAL EXCHANGE RATE MULTIPLIERS



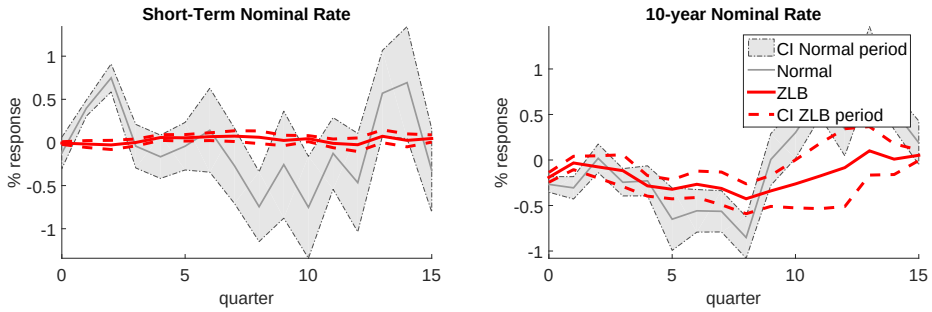
Note: An increase in the real exchange rate is an appreciation.

FIGURE A13. COMPONENTS OF CONSUMPTION AND INVESTMENT MULTIPLIERS



Note: This figure plots the cumulative multipliers for the consumption of durables, non-durables, services, as well as residential and non-residential investment. The estimation specification is the same as consumption and investment in the baseline.

FIGURE A14. IMPULSE RESPONSES OF INTEREST RATE WITHOUT TREND



Note: This figure plots the responses of the nominal interest rate when there is no trend in the specification.