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

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Abstract

Using a rich data set on government spending forecasts, we estimate the effects of unexpected government spending both when the nominal interest rate is near zero lower bound (ZLB) and outside of the ZLB period in Japan. The output multiplier is 1.5 on impact in the ZLB period, while it is 0.7 outside of the ZLB period. We estimate that the government spending shocks increase both private consumption and investment during the ZLB period but crowd them out in the normal period. The unemployment rate decreases in the ZLB period, while it does not respond significantly during the normal period. We argue that these results are not driven by the amount of slack in the economy. We estimate a positive but mild inflation response in both periods. A calibrated standard New Keynesian model with a fundamental-driven ZLB period can match our empirical findings.

JEL classification: E32, E62, E5.

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1 Introduction

How large is the output multiplier, defined as the percentage increase in output to an increase in government spending by one percent of GDP, during the periods when nominal interest rates are at the zero lower bound? The recent global financial crisis, which forced the central banks in many developed countries to reduce their short-term nominal interest rates close to the zero bound, brought this question to the center of policy debates.

The theoretical literature provides a wide range of answers. In the real business cycle theory, the output multiplier is below one and independent of the zero lower bound. In the New Keynesian models, the output multiplier in the zero lower bound period ranges from a negative to a large positive number. For example, Woodford (2010), Eggertsson (2011) and Christiano et al. (2011) show that the multiplier can be substantially larger than one in a standard New Keynesian model in which the ZLB period is caused by a fundamental shock. In this environment, temporary government spending is inflationary, which stimulates private consumption and investment by decreasing the real interest rate. As a result, the output multiplier can be well above three. At the same time, Mertens and Ravn (2014) argue that the output multiplier during the ZLB period is quite small in a New Keynesian model in which the ZLB period is caused by non-fundamental confidence shocks. In this situation, government spending shocks are deflationary, which increases real interest rates and reduces private consumption and investment. As a result, the output multiplier during the ZLB period is lower than one; it can be negative and is lower than outside of the ZLB period.

Empirical estimation of the multiplier during the ZLB period is challenging. One reason is that in most countries, the ZLB periods are short and often coincide with large recessions, making it difficult to distinguish evidence of the ZLB period from that of the recession. For example, Auerbach and Gorodnichenko (2012a) find that the multiplier is significantly larger in recession than in expansion using post-WWII data in the United States. Ramey and Zubairy (2014) extend U.S. data back to 1889, which includes ZLB periods, and find that the high value of the multiplier is sensitive to the inclusion of the World War II period in the sample.

This paper contributes to the literature by estimating the effects of government spending shocks on the economy when the nominal interest rate is at the zero lower bound (the ZLB period) and outside of the ZLB period (the normal period) using Japanese data between 1980Q1 and 2014Q1. We use the fact that Japan has more information on the ZLB periods than other countries. The nominal interest rate in Japan has been near the zero bound since 1995Q4. During this period, Japan goes through four business cycles, so we can distinguish evidence coming from the ZLB period from evidence coming from recessions. We exploit a rich dataset that includes not only standard macroeconomic variables but also forecasts of government spending and other variables. Our identification relies on the assumption that government spending does not react to output changes within the same quarter. We address the concern that government spending can be anticipated by constructing *unexpected* government spending changes. In addition, we use inflation forecast data to study the behavior of ex-ante real interest rates after a government spending shock.

Using Jorda (2005) local projection method, we find that the output multiplier is 1.5 on impact in the ZLB period while it is 0.7 in the normal period. At longer horizons, the output multiplier increases to over two in the ZLB period while it becomes negative in the normal period. We estimate that the government spending shocks increase both private consumption and investment during the ZLB period. In contrast, private consumption and investment are crowded out in the normal period. The unemployment rate decreases in the ZLB period, while it does not respond significantly during the normal period. In our baseline specification, the differences between the ZLB and normal periods multipliers of output and investment are marginally statistically significant, and the differences between the two periods for consumption and unemployment multipliers are statistically significant at conventional levels. In some of the robustness checks, we find that the output multipliers difference is statistically significant. We find mixed evidence on the inflation responses. While the responses of inflation measured by the GDP deflator are mild in both periods, CPI inflation responds more positively and significantly in the ZLB period than in the normal period. Expected inflation measured by the one-period ahead forecast of inflation increases but insignificantly in both periods. The short term nominal interest rate in the normal period increases significantly while it remains constant in the ZLB period. This result implies that the real interest rate does not increase as much in the ZLB period as in the normal period in response to government spending shocks.

Our analysis suggests that the difference between the multiplier in the ZLB period and that in the normal period is not driven by the effects of government spending in recessions. We exploit the information from data on Japan which contain several business cycles during the ZLB period. The Japanese economy was in recession half of the time during the normal period but only a third of the time during the ZLB period. Therefore, the multiplier during the ZLB period would be smaller than the multiplier during the normal period if the only fundamental difference is that the multipliers are larger in recessions. However, we find a larger multiplier in the ZLB period than in the normal period.

We also consider the possibility that government spending has an automatic stabilizer component, i.e., it responds to the output changes within a quarter. Potential contemporaneous reaction of government spending to output biases the multipliers estimates. However, if the elasticity of this reaction is the same across the ZLB and normal periods, the bias is approximately the same across the two periods, and our estimates of the difference in multipliers remain roughly unchanged. To explain the difference in the multipliers in the ZLB period and the normal period, the elasticity of government spending to changes in current output has to be substantially different across the two periods.

We further show that including forecast data when identifying government spending shocks can change the estimated multiplier in a non-trivial way, implying that it is important to control for the expectational effects. Some of the government spending shocks identified without forecast data are expected, especially in the normal period. In fact, the output multiplier obtained without controlling for forecast data is smaller than our baseline estimate in the normal period. We also consider several forecast horizons of government spending and output in Japan to control for the information timing and the possibility that government spending may react to future expected changes in output. In all of these cases, we find that the baseline result that the multiplier in the ZLB period is larger than that in the normal period holds. Furthermore, the difference between the multipliers are even more significant in the short term.

We demonstrate that our empirical findings can be consistent with a New Keynesian model calibrated with Japanese data. In this model, temporary government spending increases are inflationary. In the normal period, monetary policy responds to an increase in government spending by considerably raising the nominal interest rate. This results in a decline in private consumption, so the output multiplier is less than one. In the ZLB period caused by fundamental shocks, monetary policy does not react to government spending shocks. Inflation expectation increases and the real interest rate decreases, stimulating private consumption. So, the multiplier in the ZLB period is above one. There are two key assumptions in the model that help us match a high output multiplier and a small inflation response in the ZLB period. First, the heterogeneous labor market assumption increases the degree of complementarities between price setters' optimal choices, resulting in a sufficiently flat Phillips curve. Second, government spending is elevated only within the ZLB period, which ensures that government spending has the largest impact on the economy. With these two features, the New Keynesian model where the ZLB period occurs due to fundamental shocks can explain the difference in the multipliers, depending on the monetary policy regimes that we document in the data.

Related Literature. Our paper contributes to a large body of work in macroeconomics that estimates the effects of government spending shocks on the economy. For example, Blanchard and Perotti (2002), Ramey (2011b) and Barro and Redlick (2011), Fisher and Peters (2010) and many other papers identify the multipliers for the U.S. using different identification schemes such as the institutional information approach in a structural vector autoregression, military spending, war dates and stock returns. Ramey (2011a) provides a comprehensive survey. The papers in this literature often find the output multiplier to be smaller than one. We also estimate the output multiplier to be smaller than one in the normal period in Japan.

A recent literature estimates the output multiplier in different states of the economy. For example, Auerbach and Gorodnichenko (2012a,b, 2014) explore the difference in the output multiplier during recessions and expansions using U.S., OECD and Japanese data. Our paper instead focuses on comparing the multipliers in the zero lower bound period and in the normal period. We argue the difference is not due to the nonlinear effects of government spending during expansion and recession. We also exploit more data on Japan. For example, we include quarterly forecast data of government spending in order to control for expectations throughout our sample between 1980Q1 and 2014Q1. Furthermore, we adjust the published government spending data to exclude transfers.

Few papers estimate the output multiplier in the zero lower bound periods. Ramey (2011b) estimates that the multiplier is not higher within the period between 1939 and 1951 in the United States. Crafts and Mills (2012) estimate that the multiplier is below one in the U.K. during the 1922 -1938 period when the nominal interest rate is near zero. We differentiate ourselves by presenting the evidence from the recent and long ZLB experience in Japan.

We also complement Ramey and Zubairy (2014) who examine United States data from 1889, which include two ZLB periods during 1932Q2-1951Q1 and 2008Q4-2013Q4. They argue that the main government spending shocks during the ZLB periods occurred after the start of WWII and at the start of the Korean War in 1950, which can confound the effects of government spending shocks in states with rationing with those in states with the ZLB. When they exclude World War II from the sample, the multiplier is higher during the ZLB periods than during the normal periods. Instead, we present new evidence using Japanese data with a long spell of the ZLB occurring in the recent past. There was no rationing in the economy in the period we consider. We also avoid the periods with gold standard and the fixed nominal exchange rate regime, which can affect the estimates of the multipliers. We examine not only output but also other aggregate variables such as consumption, investment, inflation, and interest rates. Importantly, we exploit the fact there were several business cycles during the ZLB period in Japan to argue that our estimated multipliers are not driven by the difference in government spending multipliers during recessions and booms.

A recent literature estimates the local multiplier using data from different regions with common monetary policy. The local multiplier measures the changes in relative output of one region to another in response to an increase in relative government spending. For example, Nakamura and Steinsson (2014) estimate the local multiplier for states within the United States and Bruckner and Tuladhar (2014) for Japanese prefectures. However, Nakamura and Steinsson (2014) note that the local multiplier is not the same as the aggregate multiplier in the ZLB. The reason is that the long-term real interest rate falls in the ZLB setting while it does not in the regions with common monetary policy. In contrast to these papers, we directly estimate the aggregate multiplier in the ZLB period.

We are also related to the literature testing the ZLB predictions of New Keynesian models. Wieland (2013) examines if negative aggregate supply shocks, proxied by oil price shocks and the Great East Japan earthquake, are expansionary during the ZLB periods. He finds that oil price spikes decrease output but also decrease the real interest rate in the ZLB period. He concludes that these results are not consistent with a calibrated standard New Keynesian model with a fundamental-driven ZLB period. We focus on the effects of government spending shocks in the ZLB period and in the normal period. Our empirical evidence can be consistent with a calibrated New Keynesian model in which the ZLB period is caused by fundamental shocks. We also complement the work of Dupor and Li (2015) by focusing on the responses of both output and inflation to the government spending shocks. While Dupor and Li (2015) argue that inflation does not move sufficiently in the United States for the New Keynesian mechanism to generate a larger multiplier under ZLB, we show that the multiplier can be large and consistent with the empirical evidence using Japanese data even without much response from inflation in a model with a sufficiently flat Phillips Curve. Our model and analyses build on Woodford (2010), Eggertsson (2011), and Christiano et al. (2011).

The rest of the paper proceeds as follows. Section 2 presents our empirical evidence including the identification strategy. We discuss Japan and the data for our study in Section 3. Section 4 describes the baseline results about the effects of government spending changes on the aggregate economy. Section 5 discusses how we distinguish the effects of government spending in the ZLB period with those in the recession. We show the importance of including forecast in Section 6 followed by several robustness checks in Section 7. We then relate our empirical findings to the theoretical literature in Section 8. Section 9 concludes.

2 Measurement of Multipliers

Our identification strategy relies on *both* the institutional information about government spending *and* the real-time information regarding expectations of fiscal variables. The institutional information approach assumes that government spending does not respond to output within a quarter. Blanchard and Perotti (2002) and subsequent studies such as Auerbach and Gorodnichenko (2012b,a) and Ilzetzki et al. (2013) among others have used this assumption to identify government spending shocks. The basis to use this identification for Japanese data is that there is a time lag for fiscal policy to be approved by the government. Another way to identify government spending shocks is to use the large military-spending build-ups in the United States using military spending data such as Barro (1981), Barro and Redlick (2011) and Ramey and Zubairy (2014). However, Japanese military spending accounts for a small fraction, only 1% of GDP. Furthermore, Japanese military spending data have little variation over time, so it is not possible to use the military spending identification approach.

In addition, we include a measure of the expected government spending to extract *unexpected* government spending shocks. As emphasized by previous literature such as Ramey (2011a), it is important to control for expected changes in government spending. The identified government spending shocks obtained from the standard institutional approach can be predictable since this approach, which includes government spending, tax revenues and output, does not control for expected changes in government spending. Since agents can respond immediately to news about government spending shocks, the estimation without controlling for expected changes in government spending does not capture all of the effects of government spending and biases the results. In our case, at the zero lower bound, the identified shocks can be long-term expected changes of government spending outside of the ZLB, which can have substantially different effects on the economy from the unexpected government spending shocks occurring during the ZLB. Therefore, it it essential to include forecast data on government spending and purge the fiscal variables of the predicted government spending shocks.

We then implement the identification of government spending shocks using the local projection method by Jorda (2005), which estimates impulse response functions by directly projecting a variable of interest on lags of variables usually entering a VAR. This method avoids restrictions present in the VAR analysis.[1] Our two-step estimation is as follows. First, we identify the unexpected innovations in government spending by estimating the following specification:

$$\Delta \ln G_t = \alpha + \gamma F_{t-1} \Delta \ln G_t + \psi(L) y_{t-1} + \epsilon_t, \tag{1}$$

where $\Delta \ln G_t$ is the log difference of government spending, $F_{t-1}\Delta \ln G_t$ is the one period ahead forecast of $\Delta \ln G_t$, and y_{t-1} is a vector of controls with the lag operator $\psi(L)$. The estimated residuals, $\widehat{\epsilon}_t$, are the *unexpected* government spending orthogonal to the expected component of government spending and information in the control variables. All variables are per capita. If one believes that the forecast incorporates all information available to agents, there is no need to add y_t as additional regressors in equation (1). However, to account for the possibility that households' information set may be different from that of forecasters, and as we discuss below, the timing of our forecast data, we include a vector of controls in the baseline.[2]

In the second step, we estimate the following specification at each horizon h:

$$x_{t+h} = \alpha_h^x + \beta_h^x shock_t + \psi_h^x(L) y_{t-1} + \epsilon_{t+h}^x \text{ for } h = 0, 1, 2, ... \tag{2}$$

where x_t is a variable of interest and $shock_t$ is the government spending shocks, proxied by the estimated $\widehat{\epsilon}_t$. Then, β_h^x is the response of x at horizon h to an unexpected government spending shock.[3] In all of the following results, the standard controls are the growth rates of government spending, tax revenue and output. Four lags of the controls enter the regression specification.

To estimate the effects of government spending on output in both normal and ZLB periods, we

[1] See Jorda (2005) and Stock and Watson (2007) for more details. This implementation has been used in Auerbach and Gorodnichenko (2012a), Auerbach and Gorodnichenko (2012b), Ramey and Zubairy (2014) and others.

[2] We exclude the control y_t in one of the robustness exercises and the baseline results do not change.

[3] Another way to implement Jorda (2005) in one step is to identify the unexpected government spending shocks and their effects on the variable of interest x by modifying equation (2) as follows:

$$x_{t+h} = \alpha_h + \beta_h^x \Delta \ln G_t + \gamma_h^x F_{t-1} \Delta \ln G_t + \psi^x(L) y_{t-1} + \epsilon_{t+h}^x \text{ for } h = 0, 1, 2, ...$$

In this case, β_h^x can still be interpreted as the response of x to a shock in government spending orthogonal to the one-period ahead forecast and controls. One advantage of the baseline approach over this one-step approach is that we use the same extracted shocks in estimating the multipliers of different macroeconomic variables, so we choose to follow Auerbach and Gorodnichenko (2012a). We show in the Section 7 that this one-stage implementation is the same as our two-step approach.

estimate equation (2) for two variables of interest: output and government spending, i.e.:

$$\frac{Y_{t+h} - Y_{t-1}}{Y_{t-1}} \approx \ln Y_{t+h} - \ln Y_{t-1},$$
$$\frac{G_{t+h} - G_{t-1}}{Y_{t-1}} \approx (\ln G_{t+h} - \ln G_{t-1}) \frac{G_{t-1}}{Y_{t-1}}.$$

We note that both the output and government spending changes are converted to the same units before estimation to calculate the output multiplier.[4]

Our interest is whether the output multiplier in the ZLB period is greater than one, greater than zero, and larger than in the normal period. We define the output multiplier at each horizon h as the integral of the output response divided by the integral of the government spending response. The output multiplier measures the cumulative output gain relative to government spending during a given period. We follow Mountford and Uhlig (2009) and Ramey and Zubairy (2014) and choose this definition of multiplier as it has several advantages over other definitions used in the literature. We calculate the output multiplier M_h at each horizon h as follows:

$$M_h = \frac{\sum_{s=0}^{h} \beta_s^Y}{\sum_{s=0}^{h} \beta_s^G},$$

where β_s^Y and β_s^G are the impulse responses of output and government spending at horizon s, respectively. We obtain the standard errors for M_h by estimating all of the regressions jointly as one panel regression and using the Driscoll and Kraay (1998) standard errors to account for autocorrelated errors.[5]

3 Data

We use Japanese quarterly data between 1980Q1 and 2014Q1 in the baseline estimation. There are several benefits using Japanese data over other countries including the U.S. to examine the effects of government spending on the economy in the ZLB period. First, Japan has more information about the ZLB period than other countries. As plotted in Figure 1, nominal interest rate in Japan has stayed around zero ever since the fourth quarter of 1995, so there are about 20 years of data for study. Since the length of the ZLB sample can matter for estimation as well as for the effectiveness

[4]We can also convert government spending change by potential output. We discuss the results using this alternative normalization in Section 7.

[5]We thank Valerie Ramey and Sarah Zubairy for their advice on the implementation.

of government spending, Japanese data provide important evidence on the multipliers in the ZLB. Second, we can exploit a dataset that includes not only standard variables but also quarterly forecast data, which is important for our identification.

Furthermore, within the ZLB period, Japan has experienced both recessions and booms, so we can potentially tell if the estimated multiplier is driven by the nonlinear effects of government spending in different states of the business cycle. We plot in Figure 1 output per capita growth rate in Japan, taken from the National Accounts, along with the recession dates classified by the Cabinet Office. There are four business cycles after 1995 while there are three in the period between 1980 and 1995. This feature makes Japan an important case to study as other countries including the United States often have the zero lower bound period coinciding with recessions, making it difficult to distinguish the effects of government spending in the zero lower bound period from those in recession.

We exploit a rich quarterly forecast dataset that includes forecast about government spending. Unlike the United States, Japan has short surveys of professional forecasters which contain little to no information about government spending. Therefore, previous studies on Japan such as Auerbach and Gorodnichenko (2014) rely on semiannual forecast from the OECD starting in 1985 and the IMF starting in 2003 to infer about unexpected changes in government spending. An important difference in our paper is that we exploit quarterly forecast data published by the Japan Center for Economic Research (JCER) for many macroeconomic variables including government spending, output and the GDP deflator. This dataset starts in 1967Q1 and contains several forecast horizons, ranging from nowcast to eight quarters ahead although forecast horizons longer than four quarters are not published regularly. Furthermore, the JCER data also contain the initial release and up to seven subsequent revisions of realized data. The JCER publishes this dataset in the middle of the quarter. In some years, the forecast is released three out of four quarters.[6] In the quarters without updated forecast data, we assume that there is no revision in forecasts: the one-quarter ahead forecast is replaced by the two-quarter ahead forecast published in the previous quarter, i.e.: $F_{t-1}\Delta \ln G_t \equiv F_{t-2}\Delta \ln G_t = F_{t-2}\left[\ln G_t - \ln G_{t-1}\right]$, where $F_{t-j}\Delta \ln G_t$ denotes forecast of quarterly growth rate of per capita government spending at horizon j.[7] We plot in Figure 2 our one-quarter ahead forecast of the four quarter growth rate of government spending, $F_{t-1}\Delta \ln G_{t-4,t}$, along with

[6]The periods with three forecasts a year are: from 1972 to 1999, from 1995 to 2002, and from 2004 to 2006.

[7]An alternative way to fill in the missing data by nowcast or an average of nowcast $F_t\Delta \ln G_t$ and two-quarter ahead forecast $F_{t-2}\Delta \ln G_t$. We find that using these alternative series for forecast yields the same results as the baseline.

the realized government spending, $\Delta \ln G_{t-4,t}$.[8] Although forecast misses some of the fluctuations such as those in the early 2000s, the one-quarter ahead forecast tracks the actual data relatively well. This suggests that the realized government spending may have some predictable components and including these forecast data in the estimation can help us obtain a purer measure of unexpected government spending shocks. We show in Section 6.1 that these forecast data are indeed important to control for the timing of the spending and can affect the estimated multipliers.

Consistent with previous literature on the fiscal multipliers, we construct data for government spending (or government purchases) as the sum of adjusted government consumption and public investment. Adjusted government consumption is calculated as total government consumption excluding transfer of goods.[9] As plotted in Figure 1, government spending in Japan is volatile over the entire period between 1980Q2 and 2014Q1. Tax data, taken from the National Accounts starting in 1980Q1, are the sum of direct and indirect taxes less subsidies.[10] All variables are per capita and deflated by the GDP deflator.

We define the normal period to be between 1980Q1 and 1995Q3 and the zero lower bound period to be between 1995Q4 and 2014Q1. Although the earliest start date for our data with forecast is 1967Q1, we choose the start of the normal period to be 1980Q1 for three reasons. First, the definition of government spending data changes in 1980. Second, although we adjust our government spending series and extend the data to before 1980, there is a break in the monetary policy regime when Japan switched from the fixed nominal exchange rate regime to the floating exchange rate regime in 1973. According to Ilzetzki et al. (2013), the fiscal multipliers in a fixed exchange rate regime are higher than those in a flexible exchange rate regime. Since we focus on periods with homogeneous monetary policy, we exclude the fixed exchange rate regime period before 1973. Third, the 1973 oil price crisis creates a large change in the price level and affects real government spending, which can bias the estimates of the multipliers in a small sample.[11] Therefore,

[8] Note that we construct the one-quarter ahead forecast of the four quarter growth rate of government spending using real-time data, i.e. forecasters do not know the final release of government spending in $t-4$ when making forecast at time $t-1$.

[9] After 1980, the total government consumption includes both transfers (payment to households on medical services is an example) and consumption (payment for textbooks is an example). Therefore, we construct the "adjusted government consumption" by excluding transfers from total government consumption from 1980. Prior to 1980, Japan adopted System of National Account 1968, which has a different definition of government consumption. Our adjusted government consumption series is similar to the data of government spending prior to 1980. Japan also has data for "actual final" consumption of government spending after 1980. The definition of this series is the most narrow and it accounts for less than 8% of output. We show in Section 7 that the estimates using actual final government spending or the unadjusted measure of government consumption are similar to the baseline results.

[10] This series is almost identical to the series constructed by adding taxes on production and imports and taxes on income and wealth etc. less subsidies from Doi et al. (2011).

[11] To the extent that government spending is determined in nominal terms, a large unexpected change in the current

we restrict our attention of the normal period to 1980Q1-1995Q3. We note that the baseline result presented below does not change if the normal period starts after the oil price shocks in 1975Q1. The zero lower bound period starts when the short-term nominal interest rate goes down to 0.25% in 1995Q4. Since then, the short-term nominal interest rate in Japan has been low, staying under 0.6%. We then estimate equation (2) for both normal and ZLB periods.

4 Baseline Results

This section presents the main result of our empirical analysis using the local projection method to estimate the baseline model with Japanese data during normal and ZLB periods. We analyze the effect of an increase in government spending on output, private consumption and investment, inflation, the unemployment rate, nominal interest rates and expected inflation.

4.1 Output

We first consider the responses of government spending and output to an increase in government spending by one percent of output in period 0. As plotted in Figure 3, output increases on impact and up to two years in the ZLB period, while it increases slightly on impact then decreases significantly in the normal period. The one standard deviation confidence interval bands for these estimates overlap with each other in some horizons. At the same time, the response of government spending is more persistent in the normal period than in the ZLB period.

Since the government spending path in the normal period is different from that in the ZLB period, we convert the impulse responses to output multipliers. Figure 3 plots the output multipliers and their confidence bands in both normal and ZLB periods. Overall, the output multiplier in the ZLB period is significantly larger than zero. It is also substantially larger than one and larger than that in the normal period. The output multiplier in the normal period is 0.7 on impact. This estimate is in line with previous estimates for the United States and other countries. The output multiplier in the ZLB period is larger: it is 1.5 on impact. This multiplier is larger than that documented in the baseline estimate of Ramey and Zubairy (2014), but it is similar to their estimate when they exclude the WWII period. Both multipliers are significantly larger than zero.

price level can bias the identification of government spending shocks in a small sample using nominal government spending deflated by the current price level. We find that the estimated multiplier for the normal period starting in 1973Q1 is slightly higher than the baseline estimates in longer horizons. However, when we control for this change by deflating nominal government spending by a smoothed measure of inflation or one quarter lagged inflation, the estimate for the multiplier is similar to that in the baseline.

The difference between the multipliers in the normal period and in the ZLB period are pronounced at longer horizons. While the output multiplier in the normal period turns significantly negative after the first two quarters, the output multiplier in the ZLB period increases to about 2 after one year. As reported in Table 1, the output multiplier in the normal period is -1.08 and significantly smaller than zero in the two year horizon. In contrast, the output multiplier in the ZLB period increases to 2.38 in the one year horizon and stays well above two in the two year horizon. The confidence band of the multipliers do not overlap each other much.

To formally test if the multipliers in two periods are statistically significantly different from each other, we estimate the following specification:

$$x_{t+h} = I_{t-1}^{ZLB} \times (\alpha_{A,h} + \beta_{A,h} shock_t + \gamma_{A,h} F_{t-1} \Delta \ln G_t + \psi_A(L) y_{t-1})$$
$$+ \left(1 - I_{t-1}^{ZLB}\right) \times (\alpha_{B,h} + \beta_{B,h} shock_t + \gamma_{B,h} F_{t-1} \Delta \ln G_t + \psi_B(L) y_{t-1})) + \epsilon_{t+h}^{x} \text{ for } h = 1, 2, ...,$$

where I_t is one if the economy is in ZLB in period t.[12] We then calculate the difference between the multiplier in the ZLB period, M_h^{ZLB}, and that in the normal period, M_h^{normal}. Table 1 reports the differences of the multipliers, their standard errors and the corresponding p-value over different horizons. We also plot in Figure 3 the difference between M_h^{ZLB} and M_h^{normal} for all horizons between zero and ten quarters and the confidence bands. Although the 90% confidence interval includes zero, the difference is more significant at shorter horizons. The difference is significant at the 11% significance level one quarter after the shock and at the 13% significance level one year after the shock. This result suggests that there is some evidence that the output multiplier in the ZLB period is larger than that in the normal period.

4.2 Private Consumption and Investment

We next examine the effects of government spending on private consumption and investment. We modify equation (2) and estimate the effects of government spending on consumption using the following two equations:

$$\frac{C_{t+h} - C_{t-1}}{C_{t-1}} = \alpha_h^C + \beta_h^C shock_t + \psi^C(L) y_{t-1} + \epsilon_{t+h}^C$$
$$\frac{G_{t+h} - G_{t-1}}{C_{t-1}} = \alpha_h^{G,C} + \beta_h^{G,C} shock_t + \psi^{G,C}(L) y_{t-1} + \epsilon_{t+h}^{G,C} \text{ for } h = 0, 1, 2, ..$$

[12] Ramey and Zubairy (2014) also use this specification to estimate their state-dependent multipliers. If we, instead, use the indicator for current period, I_t, instead, the results do not change.

where the control vector, $\psi^{G,C}(L)y_{t-1}$, includes four lags of both the standard controls and consumption. The impulse response of consumption to an increase in government spending by one percent of consumption is β_h^C and the consumption multiplier is defined as $M_h^C = \frac{\sum_{s=1}^h \beta_s^C}{\sum_{s=1}^h \beta_s^{G,C}}$. The responses of private investment and its multiplier are estimated and defined in the same manner.[13]

The impulse responses of private consumption and investment to an increase in government spending of one percent of consumption and investment, respectively, are plotted in the upper panel of Figure 4. In the normal period, both consumption and investment decline after an increase in government spending, i.e. government spending crowds out private spending. Consumption initially increases on impact but the increase is small. In contrast, in the ZLB period, government spending crowds in private consumption and investment: the peak responses of consumption and investment are about 1.5% at the one year horizon. Figure 4 also plots the cumulative multiplier of consumption and investment to government spending at all horizons. The multiplier for consumption is significantly positive in the ZLB period whereas it is indistinguishable from zero or significantly negative in the normal period for all horizons except on impact. The investment multiplier in the ZLB period is also positive and higher than that in the normal period in most horizons other than on impact. We formally test and report in Table 1 the differences between the consumption and investment multipliers in the normal period and in the ZLB period. We find that the consumption multiplier is significantly larger in the ZLB period than in the normal period, at the 4% significance level after four quarters. The difference in the investment multipliers is less significant as the p-value is about 0.17 after four and eight quarters.[14]

4.3 Unemployment

We examine the responses of the labor market to a government spending shock by estimating the following specification for the unemployment rate:

$$U_{t+h} - U_{t-1} = \alpha_h^U + \beta_h^U shock_t + \psi^U(L)y_{t-1} + \epsilon_{t+h}^U \text{ for } h = 0, 1, 2, ..,$$

and the controls include four lags of all the standard controls and the unemployment rate. We plot the responses of the unemployment rate in Figure 4. During the normal period, the unemployment

[13] Private consumption is the final consumption data including transfer from the government. Private investment is the sum of residential and nonresidential investment. The results are the same if we use the final consumption data without transfer from the government.

[14] We also estimate the multipliers for components of consumption and investment including durable, nondurable, semi-durable, service consumption and residential and non-residential investment using the same specification. The results are reported in the Appendix Figure A3.

rate decreases in response to an increase in government spending by one percent of GDP. However, the decrease in the unemployment rate is small and insignificant. In contrast, in the ZLB period, the unemployment rate decreases significantly by 0.1 percentage point on impact and further to 0.5 percentage point a year after an increase in spending by one percent of GDP, as shown in Table 2. The drop in the unemployment rate in the ZLB period is significantly different from zero for seven quarters. Furthermore, the confidence interval of the impulse responses of the unemployment rate in the ZLB period does not overlap with that in the normal period, suggesting that the labor market responses to the government spending shocks are substantially different between the ZLB period and the normal period.[15]

4.4 Tax rates

We estimate the responses of average tax rates in the normal period and in the ZLB period to a government spending shock. We define the average tax rate as a ratio of tax revenue to GDP. The impulse response functions and the cumulative multipliers of the average tax rate are plotted in the last panel of Figure 4. We find that in response to an increase in government spending by 1% of output, average tax rate increases in both the normal period and the ZLB period. The increase in tax rate is larger in the ZLB period than in the normal period. For example, the cumulative response of the average tax rate is 0.5 percentage points in the ZLB period after two quarters while it is near zero in the normal period. This result suggests that to the extent that tax is contractionary, a different response of tax rates in the two periods do not explain the difference in the output multiplier that we observe.

4.5 Inflation, Expected Inflation and Nominal Interest rates

We next investigate the channel through which government spending shocks can affect the economy. Denoting P_t to be price level at time t and $\pi_t = \ln(P_t/P_{t-1})$ to be inflation, we estimate the responses of inflation to government spending shocks using the following version of the baseline specification (2):

$$\pi_{t+h} = \alpha_h^{\pi} + \beta_h^{\pi} shock_t + \psi^{\pi}(L) y_{t-1} + \epsilon_{t+h}^{\pi} \text{ for } h = 0, 1, 2, \ldots$$

[15] We also calculate the unemployment rate multipliers, defined as the cumulative percentage point changes in unemployment rate in response to a change in government spending by one percent of GDP at each horizon, in the ZLB period and in the normal period. We find that the difference in the unemployment rate multipliers, is significant at 0.05% level one to eight quarters after the shock as the p-values are less than 0.05.

where we include four lags of the standard controls as above and the five-year nominal interest rate.[16] We estimate the responses of both GDP deflator inflation and CPI inflation.

We find that there is mixed evidence on the response of inflation to unexpected government spending shocks: while the responses of inflation from the GDP deflator are mild and insignificant in both the normal period and the ZLB period, the responses of CPI inflation are more significantly positive in the ZLB period than those in the normal period. Figure 5 plots the responses of these two measures of inflation in both normal and ZLB periods. Inflation calculated from the GDP deflator responds little to a positive government spending shock in both periods. As tabulated in Table 2, an increase in government spending by 1% of GDP leads to a 0.07 percentage point increase in inflation in the normal period and 0.14 percentage point in the ZLB period on impact. Inflation increases about 0.2 percentage point in the one-year horizon in both periods. Overall, the responses of inflation is mild in both periods and the confidence intervals include zero. The responses of CPI inflation are different from those of inflation calculated from the GDP deflator in the ZLB period. In particular, CPI inflation in the ZLB period responds more positively and is significantly larger than zero on impact: an increase in government spending by 1% of GDP leads to a 0.5 percentage point increase in CPI inflation in the ZLB period on impact. The response of CPI inflation in the normal period is insignificantly different from zero.

The effects of government spending on one quarter ahead expected inflation, denoted by $F_t\pi_{t+1}$, are estimated using the following version of the baseline specification (2):

$$F_{t+h}\pi_{t+h+1} = \alpha_h^f + \beta_h^f shock_t + \psi^f(L)y_{t-1} + \epsilon_{t+h}^f \text{ for } h = 0, 1, 2, \ldots$$

where the control includes four lags of both the standard controls as above, the five-year nominal interest rate, and expected inflation. Figure 5 plots the impulse responses of one-quarter ahead inflation expectation calculated from both forecast of the GDP deflator and CPI to an increase in government spending by one percent of output. Inflation expectation calculated from the GDP deflator increases on impact in both the normal period and the ZLB period. This measure of inflation expectation responds slightly more strongly in the ZLB period than in the normal period although not significantly. As reported in Table 2, the one-quarter ahead inflation expectation increases by 0.85% after four quarters in the ZLB period while it is -0.17 in the normal period.

[16] Due to the limited availability of 10-year nominal interest rate, we use the five-year nominal interest rate. The results do not change if we use other nominal interest rates or the yield of the 10-year bond holders. The results do not change if we do not include interest rate in the specification.

The on-impact responses of the CPI inflation expectation are not significantly different from zero in both periods. Nevertheless, the responses of the CPI inflation expectation are more positive and significantly different from zero in the ZLB period in the longer horizons while they are negative in the normal period.

The last panel of Figure 5 plots the impulse responses of the short-term (overnight) interest rate and the five-year interest rate to an increase in government spending by 1% of output, respectively. These responses are estimated using the following specification:

$$i_{t+h} = \alpha^i_h + \beta^i_h shock_t + \psi^i(L)y_{t-1} + \zeta^i_h z_t + \gamma^i_h trend_t + \epsilon^i_{t+h} \text{ for } h = 0, 1, 2, \ldots,$$

where i_t is the short-term (or five-year) nominal interest rate, the control vector $\psi^i(L)y_{t-1}$ includes four lags of not only the standard controls but also inflation and interest rate i_t, z_t is a vector containing the contemporaneous inflation and output, and $trend_t$ is the trend.[17] We include the trend variable to control for the declining nominal interest rate over time. We report here the result estimated with a quadratic trend, but the results do not change if we include a linear trend. In the normal period, the short term interest rate increases to nearly 1 percentage point in the one year horizon in response to an increase in government spending by one percent of output. The response of the five-year nominal interest rate is less significant and only increases after 10 quarters. In the ZLB period, both short and long term interest rates do not react to the government spending shocks, consistent with the idea that the central bank is not responsive to government spending shocks during the ZLB period. These results together with the response of expected inflation suggest that the real interest rate increases more in the normal period than in the ZLB period.

To sum up, using Japanese data between 1980Q1 and 2014Q1, we find that:

1. The output multiplier in the ZLB period is larger than one and larger than that in the normal period.
2. Government spending crowds in private consumption and investment in the ZLB, but it crowds out in the normal period.
3. Unemployment rate decreases in the ZLB significantly more than in the normal period.
4. The evidence for a significantly positive inflation response in the ZLB is mixed depending on the inflation measure.

[17] The results do not change if we omit the contemporaneous inflation and output from the controls.

5. Expected inflation responses are mild in both periods.

6. Nominal interest rate does not increase much in the ZLB period relative to the normal period.

5 Output Multipliers in the ZLB period and in Recessions

Recent papers by Auerbach and Gorodnichenko (2012a,b) find that the output multiplier is larger than one in recessions while it is smaller than one in expansions using U.S. and OECD data. As the ZLB period often coincides with recessions, it is important to differentiate evidence from the ZLB period and evidence from recessions. This section shows that our estimated multiplier in the ZLB period may not be attributed to the large effects of government spending in recessions.

We first estimate the multipliers during booms and recessions in Japan between 1980Q1 and 2014Q1 by estimating a state-dependent version of the baseline specification, similarly to Ramey and Zubairy (2014):

$$\begin{aligned} x_{t+h} =& I_{t-1}^{Recession} \times \left[\alpha_{A,h} + \beta_{A,h} \cdot shock_t + \psi^A(L)y_{t-1}\right] \\ &+ \left(1 - I_{t-1}^{Recession}\right) \times \left[\alpha_{B,h} + \beta_{B,h} \cdot shock_t + \psi^B(L)y_{t-1}\right] + \epsilon_{t+h} \text{ for } h = 1, 2, ..., \end{aligned}$$

where $I_{t-1}^{Recession}$ is one if the economy is in recession in period $t-1$ and zero otherwise. The recession indicator is based on the Cabinet Office of Japan classification of trough periods.[18] Figure 6 plots the output multipliers in recessions and expansions and the difference between the two multipliers. The output multiplier on impact in recessions is as large as 2.3, while it is 0.8 in expansions. The difference between the multipliers in recessions and in expansions are smaller at horizons longer than three quarters. The difference between the multipliers in recessions and in expansions is not significant at longer horizons, as reported in Table 6. This result for Japan is qualitatively similar to that for the U.S. in Auerbach and Gorodnichenko (2012a) but weaker in significance.

Since the multiplier in recessions is larger than that in booms, to explain the larger multiplier in the ZLB period, we would need more recessions in the ZLB than in the normal period. However, that is not the case. Japan is not in a recession for the whole ZLB period between 1995Q4 and 2014Q1, as can be seen in Figure 1. The number of quarters in recession are slightly higher in the normal period than in the ZLB period: 45% of the quarters in the normal period is recession

[18] In the Cabinet Office, individual members classify recession in a similar manner to procedure used by the NBER. They then agree on the classification collectively. More information can be found at http://www.esri.cao.go.jp/jp/stat/di/150724hiduke.html. We show in Appendix Figure A2 that the results in this section do not change if we use the peak-to-trough classification by the OECD.

while it is only 30% in the ZLB period. This implies that the multiplier during the ZLB period should be smaller than the multiplier during the normal period if the only fundamental difference is between the values of the multiplier in recessions and booms.[19] We note, however, that we do not rule out the possibility that persistent aggregate demand decline that coincides with the ZLB period explains our results.

6 Discussion of Identification Issues

This section discusses the issues related to our identification strategy. First, we show the importance of controlling for expectations in the identification of government spending shocks. Our analysis further suggests that the JCER forecast captures the real-time information. We then analyze how the estimated multipliers change when government spending reacts to current and expected future output conditions.

6.1 Anticipated Government Spending Shocks

The identification of government spending shocks without forecast data in the standard VAR, as in Blanchard and Perotti (2002), assumes that the innovations in spending not predicted with all the controls constitute unexpected spending innovation. However, if government spending is announced in advance, i.e. there is implementation lag, the innovation estimated without forecast data may not be an unexpected shock. Theoretically, agents respond immediately to anticipated spending shocks, so we may only capture part of the impulse responses, which can bias the results significantly. Therefore, we include forecast data in our baseline estimation.

We now show the importance of forecast data to the estimation by examining the forecastability of the government spending shocks identified without forecast data. To implement this, 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

[19] It is probably possible that the multiplier is bigger in deeper recessions. However, it is not the case that Japan has experienced more severe recessions during the ZLB period than in the normal period.

that some of the government spending shocks identified without forecast data are predictable. The scatter plots of these two residuals along with the correlations in the whole sample, in the normal period and in the ZLB period, are shown in Figure 7. For the entire sample between 1980Q1-2014Q1, the correlation between the two residuals is 0.34 and statistically significant, suggesting that there is some forecastability of the government spending shocks $e^g_{1,t}$ identified without forecast data. This correlation is 0.39 in the normal period but it is only 0.11 for the ZLB period between 1995Q4 and 2014Q1. This result suggests that the government spending shocks are less predictable in the ZLB period than in the normal period.

We then compare the baseline estimates of the output multipliers in the normal period and in the ZLB period with those estimated without forecast data. Specifically, in the case without forecast data, $shock_t$ in the baseline specification (2) is proxied by $\widehat{\epsilon}^g_{1,t}$. We plot the estimated multiplier without forecast data along with the baseline in Figure 8. Controlling for the information that agents have about future government spending tends to make the output multipliers larger in the normal period and to a lesser extent in the ZLB period. This result is similar with the findings for the U.S., reported in Auerbach and Gorodnichenko (2012a). Consistent with the predictability analysis above, forecast data do not change the multiplier in the ZLB period as much as in the normal period as reported in Table 4. The confidence interval is larger in our baseline estimation than in the case without forecast data. These results suggest that forecast data change the estimated multipliers in a non-trivial way and it is important to control for the expectational effects.

6.2 JCER and Other Forecast

Another important issue about identification is whether the JCER forecast captures the real-time information. We first examine the movements of JCER against other forecast data in lower frequencies such as the OECD and the Japanese Government forecast. In particular, the OECD Economic Outlook releases annual forecasts for government spending in May and November every year since 1983.[20] We plot in the left panel of Figure 9 the actual cumulative growth rate of government spending along with its one-quarter ahead JCER and the OECD forecast. This plot suggests that the JCER and the OECD forecast track the actual government spending well before 2000 but less so after 2000. Notably, the JCER overestimates the growth rate of government spending around 2005 while the OECD underestimates in this same period. Overall, there is no strong reason to support the JCER or the OECD forecast over one another.

[20]We thank Yuriy Gorodnichenko for providing us the OECD and IMF data.

Another source of forecast is the Japanese Government Outlook, which publishes government spending forecast once a year in December. We plot the Government Outlook one quarter ahead forecast and the JCER forecast along with the actual cumulative growth rate of spending in the right panel of Figure 9. In general, the JCER forecast tracks the movement of government spending relatively well compared to the Government Outlook, especially before 2000. These examples suggest that the JCER forecast provides reasonable expectations about government spending.

To further demonstrate that the JCER forecast helps to estimate a good measure of unexpected government spending shocks in the baseline, we add into equation (1) other variables that may contain prior information about government spending to back out another proxy for $shock_t$ and re-estimate the output multiplier. To that end, we add a government spending component of the fiscal packages approved by the Japanese government into our first step.[21] Finally, we include the one-quarter ahead semiannual OECD forecast starting in 1983, the quarterly IMF forecast starting in 2003 and the annual Japanese Government Outlook starting in 1980, in addition to the baseline JCER forecast in the first step to identify unexpected government spending shocks.[22]

The first panel of Figure 10 plots the estimated multipliers in these cases together with those in the baseline. We also report the multipliers in different horizons in the first two panels of Table 5. The multipliers in the normal periods 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 difference between the multipliers in the ZLB period and in the normal period is signifiant in the short horizons. Overall, the results are in line with the baseline estimation, i.e. the multiplier is substantially larger than one in the ZLB period and smaller than one in the normal period.

6.3 Other Sources of Real-time Information

Since government spending can also respond to future expected states of the economy which may not be predicted with the controls in the estimation, we include measures for other real-time information that agents have about the future states. First, we add a one-year ahead forecast of annual government spending growth rate to our first step to control for the possibility that the fiscal year budget is announced a year in advance. Second, we add one- to four-quarter ahead forecast of

[21] Japanese government implements some fiscal packages from time to time. This package often contains several measures such as tax cut, spending, special transfer. We use the spending component of these packages when these fiscal packages are implemented. More information is available upon request.

[22] We include a dummy in periods that these forecasts are available in order to extract additional information from these forecast.

the quarterly government spending growth rate. Third, we include one-quarter ahead forecast of output as a variable that can summarize the real-time information on business cycles. Fourth, we include four-quarter ahead forecast of output when identifying unexpected government spending shocks. The information contained in four-quarter ahead forecast of output can include expected future changes that government spending shocks today may respond to. In other words, adding the long term forecast can mitigate the possibility that government spending shocks respond to anticipated shocks.[23]

We plot in Figure 10 the estimated multipliers in these cases together with those in the baseline. The exact multipliers in different horizons are tabulated in Table 5. The output multipliers in both the normal period and the ZLB period estimated with additional real-time information are similar to those in the baseline. For example, the multiplier on impact in the normal period is about 0.7 and that in the ZLB period is 1.5. Moreover, the confidence intervals for the multipliers within one year in the normal period do not overlap with the confidence intervals of the multipliers in the ZLB periods. For example, when we add a one-year ahead forecast of annual government spending growth rate or use the information from the fiscal packages, the estimates for the multipliers in the ZLB period are significantly larger than those in the normal period. These results suggest that the one-quarter ahead forecast of government spending in the baseline is informative about real-time information. Furthermore, these results provide more evidence that the output multiplier in the ZLB period is substantially different from that in the normal period.

Finally, we add four lags of unemployment rate to the baseline estimation as unemployment rate can provide information on the slackness of the economies. As plotted in the last row of Figure 10, the estimated multipliers for both the normal period and the ZLB period are similar to that of the baseline. Furthermore, the confidence intervals for the multipliers in the two periods do not overlap in the first eight quarters after the shocks, suggesting that there is a significant difference in the multipliers between the two periods.[24]

[23] We also run several other robustness exercises in which we add the lags of public work orders, public construction orders, excess returns of construction sector stock prices, real exchange rates and leading indicators. The results remain similar to the baseline estimates.

[24] We formally test the difference in the multipliers when we include the lags of unemployment as controls and find that the difference in the multipliers is statistically significant at 0.05 significance level for horizons shorter than two years.

6.4 Automatic Stabilizer

In the baseline, we assume that output does not automatically increase government spending, i.e. the elasticity of government spending with respect to current output change $\eta_{G,Y}$ is zero. The reason is that, as Blanchard and Perotti (2002) and Caldara and Kamps (2012) discuss, there is no consensus about the magnitude or the sign of this elasticity. For robustness, we examine how our results change if we assume different elasticities based on Caldara and Kamps (2012). In particular, we assume that in the first step,

$$\Delta \ln G_t = \alpha + \eta_{G,Y} \Delta \ln Y_t + \gamma F_{t-1} \Delta \ln G_t + \psi(L) y_{t-1} + \epsilon_t,$$

and assume $\eta_{G,Y} = \{-0.1, 0.1\}$. Consistent with their analyses, we find that the on-impact multiplier is lower than the baseline when $\eta_{G,Y} = 0.1$. The on-impact multiplier in the ZLB and normal periods are 1.4 and 0.6, respectively. The on impact multiplier is higher than the baseline when the elasticity, $\eta_{G,Y}$ is -0.1: they are 1.8 in the ZLB period and 0.8 in the normal period, respectively. However, the difference between the multipliers in the normal period and in the ZLB period is quite stable. Therefore, only when we assume substantially different elasticities in the ZLB period and in the normal period can the automatic stabilizer alone explain the difference between the multipliers.

6.5 Permanent Recession

Our empirical strategy, namely the estimation of responses of macro variables after fiscal shocks in the two subperiods of our dataset, do not rule out the possibility that the whole ZLB period coincides with a long period of elevated slack. Figure 14 plots unemployment rate in Japan from 1980 to 2014. Unemployment rate was between 2% and 3.5% in 1980-1995, and it varied between 3.5% and 5.5% during the ZLB period. Higher unemployment rate in the second subperiod may signal a permanently higher level of slack in the economy.

Recent theoretical literature emphasizes that the amount of slack in the economy affects the size of fiscal multipliers. For example, Michaillat (2014) shows that the public-employment multiplier is larger when labor market tightness is lower: an additional worker hired by the government crowds out only a few private sector workers. Our measure of public spending includes both purchases of privately produced goods as well as goods produced in public sector. So, it is reasonable to expect that the fiscal multiplier that we measure should change with the tightness of the labor market.

Despite higher average unemployment during the ZLB period, Japan does not seem to exhibit a structural break in labor market tightness. Figure 15 plots labor market tightness, defined as the ratio of job openings to applicants, in Japan.[25] There is a large increase in labor market tightness in 1986-1990 that could lead to a smaller estimated fiscal multipliers in the normal period. However, there is also a sizable increase in labor market tightness between 2002 and 2007, and after 2009 that could also lower estimated multipliers during the ZLB period. As a result, it is not obvious that the difference in labor market tightness in the two periods can explain the difference in the fiscal multipliers that we estimate.

7 Variations of the Baseline Empirical Model

In this section, we show that the baseline result that the output multiplier is larger in the ZLB period holds in other estimation specifications. We highlight that inflation responds positively and more significantly when we use other inflation data series than in the baseline results.

First, we estimate a version of specification (2) with a quadratic trend since time series estimates can be sensitive to trends. Table 6 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 in longer horizons than in the baseline.

Second, we perform an alternative transformation of government spending by potential output to calculate the multipliers, similar to Gordon and Krenn (2010). The motivation for this approach is as follows: In our baseline estimation, we convert government spending from the percent changes to dollar changes using the value of the government spending-output ratio at each point in time, rather than using sample averages. A potential problem of the baseline transformation is that the cyclicality of output can bias the estimated multiplier.[26] The multipliers estimated in this case reported in Table 6 are essentially the same as our baseline.

Third, one potential concern with our implementation of identifying the effects of unexpected government spending shocks 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 in equation (1). Although Wieland (2013) shows that using the residuals orthogonal to the information in the first stage does not create the generated regressor problem, we address this concern and implement a one-step estimation of

[25] The data on the Japanese labor tightness comes from Ministry of Internal Affairs and Communications: https://www.e-stat.go.jp/SG1/estat/eStatTopPortalE.do.

[26] This point was raised by Yuriy Gorodnichenko in his discussion for Ramey and Zubairy (2014) in the NBER.

the effects of unexpected government spending on output, i.e.

$$x_{t+h} = \alpha_h + \beta_h^x \Delta \ln G_t + \gamma_h^x F_{t-1} \Delta \ln G_t + \psi_h^x(L) y_{t-1} + \epsilon_{t+h}^x \text{ for } h = 0, 1, 2, ...$$

The multipliers from this estimation are also shown in Table 6. The multipliers are virtually identical to our baseline estimates. Furthermore, the standard errors of the one-step estimation and the baseline are almost identical. These results show that our two-step estimation approach correctly identifies the unexpected government spending shocks as the one-step estimation.

Fourth, as noted in the Data section, we adjust the government spending data for transfers in the baseline estimates. However, previous literature such as Auerbach and Gorodnichenko (2014) use unadjusted government spending; and the Japanese Cabinet office also includes actual final government spending data from 1980. We show that our results remain robust to using these different data series. The estimated output multipliers using unadjusted and actual final government spending data are shown in Table 6. The multipliers are within the confidence interval of the baseline. In fact, using actual final government spending leads to an even higher multiplier in the ZLB period. These results suggest that our results are robust to using different government spending data.

Fifth, we extend the baseline specification to estimate output multipliers with a rolling window of 15 years between 1967Q1 and 2014Q1. Figure 11 plots the multiplier in different horizons. The multiplier is time-varying. For the 15 years windows between 1967 and 1984, the cumulative output multiplier is about 1.2 on impact and increases to about 3 in the two year horizon. This result suggests that the multiplier may be larger than one in the 1960s and 1970s when the Japanese economy is under the fixed exchange rate regime. After the collapse of the fixed exchange rate regime, the multiplier is below unity for all periods up to 1997. This result is consistent with the finding in Ilzetzki et al. (2013) that the multiplier is larger in the fixed exchange rate regime than in the flexible regime. The multiplier becomes higher than unity for rolling windows starting in 1995. This rolling multiplier result is consistent with our baseline estimates and suggests that the multiplier is larger in the ZLB period than in the periods up to 1995.

Finally, to examine the robustness of the mild response of inflation in the normal period and in the ZLB period, we estimate the inflation response using different series for inflation. We examine the responses of inflation calculated from both total CPI and core CPI. Furthermore, since both total CPI and core CPI are affected by the consumption tax hikes in 1989 and 1997, we consider the responses of inflation adjusted for these consumption tax changes following Hayashi and Koeda (2014).[27] The responses of inflation calculated from these two series, together with the baseline result in the normal period and in the ZLB period, are plotted in Figure 12. The inflation responses using either tax-adjusted inflation or the CPI are similar to the baseline: the responses are mild. Different from the baseline, both CPI inflation and tax-adjusted CPI inflation responses are positive and significant on impact in the ZLB period. When taking out food and energy, core CPI inflation response is also positive and significant in the ZLB period on impact. This result suggests that there are some evidence of inflation in the ZLB period.

8 A Model of Government Spending

Our empirics provide evidence of a larger multiplier in the ZLB period than that in the normal period but with a mild inflation response. This section shows that a standard New Keynesian model calibrated with Japanese data can be consistent with these results.[28] In addition, we show that the model can also qualitatively match the empirical results if we use the estimated process of government spending response to a fiscal shock.

In this model, there is a continuum of household types, each of which consumes and supplies a differentiated labor input. The model features monopolistic competition and Calvo-style sticky prices. There is no capital investment. The government finances spending through lump-sum taxes. Since the model is standard, we describe the full model in Appendix Section A.1.[29] The model equilibrium conditions log-linearized around a zero inflation steady state can be summarized by the IS and the Phillips curves:

$$\widehat{y}_t - \widehat{g}_t = \mathbb{E}_t \left(\widehat{y}_{t+1} - \widehat{g}_{t+1}\right) - \widetilde{\sigma} \left(i_t - \mathbb{E}_t \pi_{t+1} - \overline{r}\right), \tag{3}$$

$$\pi_t = \beta \mathbb{E} \pi_{t+1} + \kappa \left(\widehat{y}_t - \Gamma \widehat{g}_t\right), \tag{4}$$

where $\widehat{y}_t$ denotes the log deviation of output from its steady state, $\widehat{g}_t$ denotes government spend-

[27] The inflation rate calculated from CPI and core CPI along with tax-adjusted inflation rate are plotted in Appendix Figure A4. 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. See Hayashi and Koeda (2014) for a detailed explanation of the tax adjustment for CPI.

[28] We only consider the standard New Keynesian model. Rendahl (2014) shows that a New Keynesian model with frictional labor market can also generate large output multiplier with a limited effect on expected inflation. The key mechanism driving this result is a persistent response of unemployment to changes in fiscal spending. We do not consider this feature in the current paper.

[29] We follow treatment in Woodford (2010), Eggertsson (2011), and Christiano et al. (2011).

ing deviation from its steady state over steady state output, π_t is inflation, i_t is a continuously compounded one-period riskless nominal interest rate, and $\overline{r}$ is the value of this rate in a steady state with zero inflation. The constant κ is the slope of the Phillips curve, Γ is the fiscal multiplier under flexible prices, and $\widetilde{\sigma}$ is the "effective" intertemporal elasticity of substitution.[30] Government spending $\widehat{g}_t$ follows an AR(1) process with persistence ρ. Monetary policy is represented by the following Taylor rule:

$$i_t = \max\left\{0, \overline{r} + \phi_\pi \pi_t + \phi_y \widehat{y}_t\right\}, \tag{5}$$

where $\phi_\pi > 1, \phi_y > 0$ are the response coefficients.

We define multipliers of variables of interest as in the empirical part of the paper. In the case of $AR(1)$ process of government spending, output multiplier is $\gamma_y = \widehat{y}_t/\widehat{g}_t$, inflation multiplier is $\gamma_\pi = \pi_t/\widehat{g}_t$, and they do not depend on t because the model does not have endogenous state variables. Because the longer horizon multipliers are identical to on-impact multipliers in this case, we compare the multipliers defined in the model to on-impact multipliers estimated in the empirical part. In section 8.3, we consider a richer dynamics of exogenous government spending process and compute, for example, output multiplier as $M_h = \sum_{t=0}^{h} \widehat{y}_t / \sum_{t=0}^{h} \widehat{g}_t$.

8.1 Calibration

We set the values of the parameters unrelated to policy choices as in Table 8. The Frisch elasticity of labor supply ν is 1, which is the standard value used in the macroeconomics literature. The elasticity of intertemporal substitution (IES) σ is set to 1.1, which is within the wide range of the IES values used in the literature. The subjective discount factor β is 0.99. The elasticity of substitution across varieties θ is set to 5 which equals the estimate in Burstein and Hellwig (2007). The production function is $f(L_t(i)) = A_t L_t(i)^a$, with $a = 2/3$. The probability of price adjustment $1 - \alpha$ is 0.25. The steady state ratio of government spending over output is 0.18. This number corresponds to the mean of government spending over GDP in Japan during 1980Q1-2014Q1. We set the persistence of government spending disturbances ρ to 0.8. This corresponds to the persistence of government spending shocks in our sample in Japan. This persistence has a half-life of three quarters.

[30] All of the variables are expressed through the model structural parameters in Appendix.

8.2 Theoretical Multipliers

We now examine the theoretical multipliers in the ZLB period and in the normal period. We consider two monetary policy specifications: a "Taylor rule policy" and a "fixed nominal-rate policy." The fixed nominal-rate policy regime assumes that the government does not react to the effects of fiscal policy changes. However, it reacts to any other disturbances in the economy according to the Taylor rule. The fixed nominal-rate policy captures the essence of the reaction of the economy to government spending disturbances under the zero lower bound constraint on the nominal interest rate: the rate does not respond to changes in fiscal policy.[31] The Taylor rule policy corresponds to the monetary policy in the normal period when the central bank reacts to changes in output and inflation. As reported in Table 8, our benchmark calibration sets $\phi_\pi = 1.5$ and $\phi_y = 0.05$.[32] We solve the model by log-linearizing the equilibrium conditions around the targeted zero inflation steady state. The derivation is in Appendix A.

We report in Table 9 the multipliers predicted by the calibrated model in the normal period, "Taylor rule policy," and in the ZLB period, "fixed nominal-rate policy," when $\rho = 0.8$. The theoretical multipliers are similar to their empirical counterparts. Under the Taylor rule policy, the output multiplier is 0.71, i.e. an increase in government spending by one percent of output leads to an increase in output by 0.71%. The consumption multiplier is -0.29. Private consumption falls as the central bank increases its policy rate.[33] The theoretical inflation response is mild and positive: an increase in government spending by one percent of output leads to an increase in inflation by 0.041 percentage points. When monetary policy does not react to government spending shocks, the multipliers are substantially larger. The output multiplier is 1.47, the consumption multiplier is 0.47. The inflation response is positive and small: an increase in government spending by one percent of output increases inflation by 0.13 percentage points.

We note that this model can generate a substantially large output multiplier without a large increase in inflation. The key is the flat Phillips curve, i.e. a small κ obtained from the heteroge-

[31] See Farhi and Werning (2012) and Nakamura and Steinsson (2014) for the discussion of this interpretation. It is important to note that the response of the economy to government spending shocks under the fixed nominal-rate policy can be equivalent to the response of the economy under liquidity trap when it is caused by fundamental shocks.

[32] Aruoba et al. (2013) estimate the Taylor rule with the interest rate smoothing term of the form $i_t = \max\{0, (1-\rho_i)(\bar{r} + \phi_\pi \pi_t + \phi_y \widehat{y}_t) + \rho_i i_{t-1}\}$. Using Japanese data, they found $\rho_i = 0.6, \phi_\pi = 1.5, \phi_y = 0.3$. To avoid introducing a state variable i_{t-1} in our analysis, we set $\rho_i = 0$. To approximate their estimates, we set ϕ_y to a lower value of 0.05 to capture a mild response of interest rate to output gap when $i_t > 0$. We set ϕ_π to 1.5 to be consistent with the Taylor principle. Alternative values of ϕ_π lead to only small variation in the multipliers in the normal period.

[33] The empirical consumption multiplier on impact is positive. However, the consumption multiplier turns negative after one quarter and it becomes significantly negative after four quarters.

neous labor market assumption. This assumption increases the degree of complementarity between different firms' optimal price choices relative to a model with a homogeneous labor market, which leads to a smaller response of inflation as the firms who currently set prices choose to set prices closer to those firms who do not reset prices. Thus, a large change in real variables such as output requires small changes in inflation. In fact, when we relax the heterogeneous labor market assumption, the model would imply an inflation response three times as large as our model in order to generate an output multiplier of 1.47 as our empirics.[34]

8.3 Empirical Path of Government Spending

There is notable difference in the response of government spending to a fiscal shock in the normal and the ZLB periods. One can see this in figure 3. In this section, we compute fiscal multipliers using the New Keynesian model presented above and feeding the point estimate of the government spending response to a fiscal shock. We show that using the empirical paths of government spending does not qualitatively alter the predictions of the model: the output multipliers are larger than one during the ZLB period and smaller than one during normal period under the chosen parameter values. Moreover, the model multipliers qualitatively capture some aspects of the dynamics of estimated multipliers. Specifically, output multipliers decline for several initial horizons both in the model and in our estimation during the normal period; output multipliers exhibit hump-shaped pattern with horizon during the ZLB period.

To compute fiscal multipliers we need to know the law of motion of the whole future government spending path. We only estimate government spending response for the first sixteen quarters. Although we can extend our estimation to further horizons, it is not possible to estimate the whole future path of government spending response. To compute fiscal multipliers, we instead assume particular government spending paths for $t > 15$ quarters.

In the normal period, we assume that the government response decays geometrically to zero. Formally, we assume that $\widehat{g}_t = \widehat{g}_{15} \cdot \rho^{t-15}$, that is, the following period after the last estimated response, government spending is fraction ρ of its value a period before. We allow ρ to take on three values $\{0; 0.8; 1\}$ and compute output multipliers for each of the three values. The model output multipliers along with the empirical point estimate are presented in the left panel of figure

[34] A derivation of this result is also reported in the Appendix. Another assumption that can flatten Phillips curve is a high value of elasticity of substitution θ. Woodford (2003) discusses the heterogeneous labor supply assumption and other assumptions that can lead to a higher degree of complementarity between firms optimal prices.

16.[35] All three model output multipliers are below one at any horizon, they are decreasing for the first several horizons, and for some values of ρ multipliers turn negative. These features are similar to the behavior of empirically estimated output multiplier, which is represented by a black bold curve on the figure. After five quarters, the model multipliers become increasing with horizon, while the empirical multiplier continue to decline. The last difference between empirical and model multipliers can potentially be reconciled by adding distortionary taxes.

In the ZLB scenario, we need to make assumptions about the behavior of government spending in the long run both during the ZLB period and after the economy exits ZLB period. We assume that government spending decays geometrically to zero, i.e., $\widehat{g}_t = \widehat{g}_{15} \cdot \rho_{ZLB}^{t-15}$, after the last estimated response, i.e., for $t > 15$, while at the ZLB. We let ρ_{ZLB} to take on three values $\{0; 0.8; 1\}$. Once the economy exits the ZLB period, we assume that government spending decays geometrically to zero with persistence parameter $\rho = 0.8$ from its last value in the ZLB period. The right panel of figure 16 presents the three model multipliers along with the empirically estimated multiplier for the ZLB period.[36] All three theoretical multipliers are above one, they first increase and then decline with horizon. These features are similar to the behavior of empirically estimated output multiplier, the solid black line on the figure. The value of model multipliers are closer the lower is the persistence of government spending outside of the ZLB period ρ (not shown on the figure).

9 Conclusion

We exploit the rich information about the ZLB period in Japan to estimate the effects of government spending changes on output. We control for the expected government spending to extract its unexpected changes. Our point estimate of the output multiplier is larger than one in the ZLB period, and this output multiplier is larger than that in the normal period. On impact, the output multiplier is 1.47 in the ZLB period and it is 0.70 in the normal period. The difference in the multipliers between the two periods are larger over longer horizons: while the multiplier increases

[35] One can observe that model multipliers are not monotonic in persistence ρ for a fixed horizon in the left panel of figure 16. In addition, the model multipliers for $\rho = 1$ and $\rho = 0$ cross each other. This is because the wealth effect associated with higher tax burden due to more persistent government spending has two opposing effects on the economy. First, more persistent government spending in the future leads to a lower consumption in the future and initially. Second, more persistent government spending in the future makes households work more reducing marginal costs of production. This results in lower inflation, and for some parameter values in deflation, in the future and initially. In case of deflation, the central bank responds by lowering the policy rate that stimulates consumption in the future and initially. The strength of these two opposing effects varies with horizon and persistence parameter ρ leading to observed non-monotonic behavior of multipliers with ρ.

[36] The model multipliers are monotonic in persistence parameter ρ_{ZLB} for a fixed horizon. This is because the monetary policy does not change with government spending persistence during the ZLB.

to over two in the ZLB period, it becomes negative in the normal period. Furthermore, government spending crowds in private consumption and investment in the ZLB period, in contrast with the crowding out effects in the normal period. We estimate a mild response of inflation in both periods with a more positive response in the ZLB period depending on the measure of inflation. Additionally, the ex-ante real interest rate decreases by more in the ZLB period relative to the normal period.

We relate our empirical findings to a standard New Keynesian model in which the zero lower bound is caused by fundamental shocks. We find that the empirical evidence for Japan can be consistent with the prediction of this model when the Phillips Curve is sufficiently flat and government spending stays elevated only within the ZLB duration.

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Appendices

A Model Solution

A.1 Baseline Model of Government Spending

Households. The economy is populated by a continuum of households. Different households supply different types of labor indexed by i and there are an equal number of households supplying each type of labor. This is the heterogeneous labor supply assumption. A household supplying labor of type i maximizes their utility given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma^{-1}}}{1-\sigma^{-1}} - \chi \frac{L_t(i)^{1+\nu^{-1}}}{1+\nu^{-1}} \right), \tag{A.1}$$

where C_t is an index of the household's consumption, $L_t(i)$ is the quantity of labor of type i supplied, β denotes the subjective discount factor, ν is the Frisch elasticity of labor supply, and σ is the elasticity of intertemporal substitution.

Consumption C_t is an index given by

$$C_t = \left[\int_0^1 C_t(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}},$$

where $C_t(j)$ denotes consumption of variety j, $\theta > 1$ is the elasticity of substitution between varieties. There is a continuum of measure one of varieties. We denote $P_t(j)$ the price of variety j, and

$$P_t = \left[\int_0^1 P_t(j)^{1-\theta} dj \right]^{\frac{1}{1-\theta}}$$

is the corresponding price index.

Household of type i maximizes its utility subject to a flow budget constraint given by

$$\int_0^1 P_t(j)C_t(j)di + \mathbb{E}_t \left[Q_{t,t+1} B_{t+1}(i) \right] + T_t \leq B_t(i) + W_t(i)L_t(i) + \int_0^1 \Pi_t(j)dj, \tag{A.2}$$

together with a no-Ponzi condition. In this equation, $B_{t+1}(i)$ is a state-contingent payoff at the beginning of period $t+1$ of the financial portfolio of household i, $Q_{t,t+1}$ is the price of Arrow-Debreu securities divided by the conditional probability of the corresponding state, which equals the unique stochastic discount factor in equilibrium, $W_t(i)$ is the nominal wage received by labor type i in period t, $\Pi_t(j)$ is the nominal profit of the firm that produces variety j in period t, T_t is lump sum taxes.

Government. There is a government that conducts fiscal and monetary policy. Fiscal policy is represented by a government spending G_t and lump sum taxes T_t. The government spending follows an AR(1) process:

$$\log \left(G_t / \overline{G} \right) = \rho_g \log \left(G_{t-1} / \overline{G} \right) + \epsilon_{g,t},$$

where $\overline{G}$ is the steady state value of government spending, ρ_g is the persistence, and $\epsilon_{g,t}$ is an i.i.d., zero-mean random variable, representing unexpected changes to fiscal policy. Because the Ricardian equivalence holds, the timing of taxes is irrelevant. Government spending G_t has the same CES form as the index of household's consumption:

$$G_t = \left[\int_0^1 G_t(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}},$$

where $G_t(j)$ is government consumption of variety j. The government splits its expenditure $\int_0^1 P_t(j)G_t(j)di$ across varieties to maximize government spending.

Monetary policy is represented by the following Taylor rule:

$$i_t = \max\left\{0, \bar{r} + \phi_\pi \pi_t + \phi_y \widehat{y}_t\right\}, \tag{A.3}$$

where hatted variables denote percentage deviations from steady state, the policy instrument i_t is a one-period riskless nominal interest rate, and $\bar{r} = -\log\beta$ is the value of this rate in a steady state with zero inflation, and $\phi_\pi > 1, \phi_y > 0$ are the response coefficients.

Firms. There is a continuum of firms, each of which specializes in the production of differentiated good j out of labor using the technology given by

$$Y_t(j) = A_t f\left(L_t(j)\right),$$

where A_t is the aggregate productivity, $f(\cdot)$ is increasing and concave. We follow Woodford (2003) and assume that firm j sets monopolistic price $P_t(j)$ for its output but acts as a price-taker on the market for labor of type j.[37] We assume that firms pay a constant employment tax $1+\tau^L$ so that the nominal total cost of production is $(1+\tau^L)W_t(j)f^{-1}\left(Y_t(j)/A_t\right)$.

Firm j can re-optimize its price with probability $1-\alpha$. The firm maximizes its value,

$$\mathbb{E}_t \sum_{n=0}^{\infty} Q_{t,t+n}\alpha^j \left[P_t(j)Y_{t+n|t}(j) - (1+\tau^L)W_t(j)f^{-1}\left(\frac{Y_{t+n|t}(j)}{A_t}\right)\right],$$

where $Y_{t+n|t}(j) = (C_{t+n} + G_{t+n})\left(\frac{P_t(j)}{P_{t+n}}\right)^{-\theta}$, taking the sequences of $C_t, G_t, P_t, W_t(j), Q_{t,t+n}$ as given.

[37] More specifically, firms belong to industries. There is a large number of firms in every industry. Each firm in industry x employs labor of type x. In addition, all firms in a particular industry reset their prices at the same time.

A.2 Equilibrium Conditions

Household's optimal choice of consumption, labor supply and securities holdings leads to

$$\frac{u_L\left(C_t, L_t(i)\right)}{u_C\left(C_t, L_t(i)\right)} = \frac{W_t(i)}{P_t}, \tag{A.4}$$

$$\beta^n \frac{u_C\left(C_{t+n}, L_{t+n}(i)\right)}{u_C\left(C_t, L_t(i)\right)} = \frac{P_{t+n}}{P_t} Q_{t,t+n}, \tag{A.5}$$

$$C_t(j) = C_t \left(\frac{P_t(j)}{P_t}\right)^{-\theta}, \tag{A.6}$$

where $u_C\left(C_t, L_t(i)\right) = C_t^{-\sigma^{-1}}$ and $u_L\left(C_t, L_t(i)\right) = -\chi L_t(i)^{\nu^{-1}}$ are the derivatives of instantaneous utility function with respect to consumption and labor. Equation (A.4) represents the household labor supply, equation (A.5) is the consumption Euler equation, and equation (A.6) is the optimal choice of variety j.

Government demand for variety j is

$$G_t(j) = G_t \left(\frac{P_t(j)}{P_t}\right)^{-\theta}.$$

Firm j optimal price is

$$P_t(j) = \mathbb{E}_t \sum_{n=0}^{\infty} \frac{\alpha^n Q_{t,t+n} Y_{t+n|t}(j)}{\mathbb{E}_t \sum_{n=0}^{\infty} \alpha^n Q_{t,t+n} Y_{t+n|t}(j)} S_{t+n|n}(j),$$

where $S_{t+n|n}(j) = W_{t+n}(i) / \left(A_{t+n} f'\left(f^{-1}\left(Y_{t+n|t}(j)/A_{t+n}\right)\right)\right)$ is the nominal marginal cost.

The log-linearized equilibrium conditions can be summarized by the New-Keynesian IS and the Phillips curves

$$\widehat{y}_t - \widehat{g}_t = \mathbb{E}_t\left(\widehat{y}_{t+1} - \widehat{g}_{t+1}\right) - \widetilde{\sigma}\left(i_t - \mathbb{E}_t \pi_{t+1} - \overline{r}\right), \tag{A.7}$$

$$\pi_t = \beta \mathbb{E} \pi_{t+1} + \kappa\left(\widehat{y}_t - \Gamma \widehat{g}_t\right), \tag{A.8}$$

where $\widetilde{\sigma} = \sigma\left(1 - \overline{G}/\overline{Y}\right)$ is the "effective" intertemporal elasticity of substitution, $\kappa = (1-\alpha)(1-\alpha\beta)/\alpha \cdot \left(\widetilde{\sigma}^{-1} + \psi_\nu\right)/\left(1 + \theta\psi_\nu\right)$ is the slope of the Phillips curve with $\psi_\nu = \left(1 - a + \nu^{-1}\right)/a$ being the elasticity of real marginal costs with respect to output, $\Gamma = \widetilde{\sigma}^{-1}/\left(\widetilde{\sigma}^{-1} + \psi_\nu\right) \in (0,1)$ is the fiscal multiplier under flexible prices. Observe that the results do not depend on disutility of labor parameter χ.

A.3 Definition of Model Multipliers

We define the output multiplier as the impact response of output to a government spending shock as follows

$$\gamma_y \equiv \frac{\log\left(Y_0/Y_{-1}\right)}{\frac{G_{-1}}{Y_{-1}}\log\left(G_0/G_{-1}\right)} = \frac{\widehat{y}_0 - \widehat{y}_{-1}}{\frac{G_{-1}}{Y_{-1}}\cdot\frac{\overline{Y}}{\overline{G}}\left(\widehat{g}_0 - \widehat{g}_{-1}\right)}.$$

Assuming that in period $t = -1$, the economy rests in the steady state, the output multiplier is $\gamma_y = \widehat{y}_0/\widehat{g}_0$. γ_y indicates the units of currency (yens or dollars) output changes when government spending increases by one unit of currency. This definition of the output multiplier in the model is identical to the definition of on-impact output multiplier in our empirical part.[38]

We also define consumption and inflation multipliers as follows

$$\gamma_c \equiv \frac{\log\left(C_0/C_{-1}\right)}{\frac{G_{-1}}{C_{-1}}\log\left(G_0/G_{-1}\right)} = \frac{\widehat{c}_0 - \widehat{c}_{-1}}{\frac{G_{-1}}{C_{-1}}\cdot\frac{\overline{Y}}{\overline{G}}\left(\widehat{g}_0 - \widehat{g}_{-1}\right)} = \frac{\overline{C}}{\overline{Y}}\cdot\frac{\widehat{c}_0}{\widehat{g}_0},$$

$$\gamma_\pi \equiv \frac{\log\left(P_0/P_{-1}\right)}{\frac{G_{-1}}{Y_{-1}}\log\left(G_0/G_{-1}\right)} = \frac{\pi_0}{\frac{G_{-1}}{Y_{-1}}\cdot\frac{\overline{Y}}{\overline{G}}\left(\widehat{g}_0 - \widehat{g}_{-1}\right)} = \frac{\pi_0}{\widehat{g}_0},$$

where the last equalities on both of the last lines use the fact that in $t = -1$ the economy is in the steady state.

A.4 Solution

Under the Taylor rule policy, we can find the solution by using the method of undetermined coefficients. We conjecture a solution of the form $\widehat{y}_t = \gamma^y \widehat{g}_t, \widehat{c}_t = \gamma^c \widehat{g}_t, \widehat{\pi}_t = \gamma^\pi \widehat{g}_t, i_t = \overline{r} + \gamma^i \widehat{g}_t$. Solving the model we get

$$\gamma^y = \frac{1-\rho+(\widetilde{\psi}-\widetilde{\sigma}\phi_y)\Gamma}{1-\rho+\widetilde{\psi}} \in (0,1) \tag{A.9}$$

$$\gamma^c = \left(\gamma_y - 1\right)\frac{\overline{Y}}{\overline{C}} = -\frac{\widetilde{\psi}\left(1-\Gamma\right)+\widetilde{\sigma}\phi_y\Gamma}{1-\rho+\widetilde{\psi}}\cdot\frac{\overline{Y}}{\overline{C}} < 0,$$

$$\gamma^\pi = \frac{\kappa}{1-\beta\rho}\cdot\frac{\left(1-\rho\right)\left(1-\Gamma\right)-\widetilde{\sigma}\phi_y\Gamma}{1-\rho+\widetilde{\psi}} \lesseqgtr 0, \tag{A.10}$$

where $\widetilde{\psi} \equiv \widetilde{\sigma}\left(\phi_y + \left(\phi_\pi - \rho\right)\frac{\kappa}{1-\beta\rho}\right)$.

[38] Because we do not have endogenous state variables in this simple model and the model is solved by log-linearization, the longer horizon multipliers would be similar to on-impact multipliers. This is why we compare the multipliers defined in the model to on-impact multipliers estimated in the empirical part.

Under the fixed nominal-rate rule, the multipliers are

$$\gamma^y_{ZLB} = \frac{(1-\rho)(1-\beta\rho) - \widetilde{\sigma}\kappa\rho\Gamma}{(1-\rho)(1-\beta\rho) - \widetilde{\sigma}\kappa\rho} > 1, \tag{A.11}$$

$$\gamma^c_{ZLB} = (\gamma_y - 1)\,\frac{\overline{Y}}{\overline{C}} = \frac{\widetilde{\sigma}\kappa\rho\,(1-\Gamma)}{(1-\rho)(1-\beta\rho) - \widetilde{\sigma}\kappa\rho} \cdot \frac{\overline{Y}}{\overline{C}} > 0,$$

$$\gamma^\pi_{ZLB} = \frac{\kappa}{1-\beta\rho} \cdot \frac{(1-\rho)(1-\beta\rho)\,(1-\Gamma)}{(1-\rho)(1-\beta\rho) - \widetilde{\sigma}\kappa\rho} > 0. \tag{A.12}$$

For the unique bounded solution to exist it must be that $(1-\rho)(1-\beta\rho) - \widetilde{\sigma}\kappa\rho > 0$, otherwise the economy "explodes" (this can be shown by solving forward equations (A.7) and (A.8)). This condition ensures the inequilities in (A.11)-(A.12).

Heterogeneous vs. Homogeneous labor market. These two assumptions correspond to different value of κ where

$$\kappa = \frac{(1-\alpha)\,(1-\alpha\beta)}{\alpha}\,\frac{\frac{1}{\widetilde{\sigma}} + \psi_v}{1+\theta\psi_v}$$

for heterogenous labor market assumption and

$$\kappa_{homogeneous} = \frac{(1-\alpha)\,(1-\alpha\beta)}{\alpha}\,\frac{\frac{1}{\widetilde{\sigma}} + \psi_v}{1+\theta\frac{1-a}{a}} > \kappa$$

for homogenous labor market assumption and

$$\psi_v = \frac{1-a+\frac{1}{v}}{a}.$$

Our benchmark calibration implies $\kappa = 0.02$ and an output multiplier of 1.47 in the fixed nominal rate regime while in the homogeneous labor market case, $\kappa = 0.08$ and an output multiplier of 3.59 in the fixed nominal rate regime.

A.5 Model Multipliers with Empirical Empirical Path of Government Spending

This section details the computation of model output multipliers using the estimated government spending response.

Normal period. To compute fiscal multipliers after a period $t = 0$ fiscal shock, we assume that government spending $\{\widehat{g}_t\}_{t=0}^{\infty}$ is such that $\widehat{g}_t = \widehat{g}_t^{Est\,Norm}, t \in [0, 15]$ and $\widehat{g}_t = \widehat{g}_{15} \cdot \rho^{t-15}, t > 15$, where $\widehat{g}_t^{Est\,Norm}$ is the point estimate of the response of government spending to a fiscal shock at horizon t in the normal period. We earlier computed the output and inflation multipliers in the normal period when a fiscal shock decays geometrically, see formulas (A.9) and (A.10). We can express output and inflation as $\widehat{y}_t = \gamma_y \widehat{g}_t, \pi_t = \gamma_\pi \widehat{g}_t$ for $t > 15$, where γ_y, γ_π are fiscal multipliers in the normal period given by formulas (A.9), (A.10). To compute output and inflation for the first sixteen quarters we solve the Euler and Phillips curve equations (A.7), (A.8) backwards period by period starting from $t = 15$ and finishing at $t = 0$. This gives us output gap for all of the periods. Finally, we compute cumulative output multiplier employing a formula used in the empirical part

$$M_h = \frac{\sum_{t=0}^{h} \widehat{y}_t}{\sum_{t=0}^{h} \widehat{g}_t}.$$

ZLB period. To compute fiscal multipliers after a period $t = 0$ fiscal shock, we assume that government spending path $\{\widehat{g}_t\}_{t=0}^{\infty}$ is such that $\widehat{g}_t = \widehat{g}_t^{Est\,ZLB}, t \in [0, 15]$ and the economy is till in the ZLB, $\widehat{g}_t = \widehat{g}_{15} \cdot \rho_{ZLB}^{t-15}, t > 15$ and the economy is still in the ZLB, $\widehat{g}_t = \widehat{g}_T \cdot \rho^{t-T}, t > T$ and the economy exited ZLB after period T. Note that T can be any period, $\widehat{g}_t^{Est\,ZLB}$ is the point estimate of the response of government spending to a fiscal shock at horizon t in the ZLB period.

We solve for output and inflation backwards. Once the economy exited the ZLB period, output and inflation can be expressed as $\widehat{y}_t = \gamma_y \widehat{g}_t, \pi_t = \gamma_\pi \widehat{g}_t$, where γ_y and γ_π are the normal times multipliers. When the economy is still in the ZLB, and more than sixteen quarters have passed since the fiscal shock, i.e., $t > 15$, output and inflation solve the following Euler and Phillips equations

$$\begin{aligned}
\widehat{y}_t - \widehat{g}_t &= \mu \left(\widehat{y}_{t+1} - \rho_{ZLB} \widehat{g}_t\right) + (1-\mu)\left(\gamma_y - 1\right)\rho \widehat{g}_t + \widetilde{\sigma}\left(\mu \pi_{t+1} + (1-\mu)\gamma_\pi \rho \widehat{g}_t + r_L\right), \\
\pi_t &= \beta\left(\mu \pi_{t+1} + (1-\mu)\gamma_\pi \rho \widehat{g}_t\right) + \kappa\left(\widehat{y}_t - \Gamma \widehat{g}_t\right).
\end{aligned}$$

We solve this system by the method of undetermined coefficients, that is, we assume that $\pi_t = \overline{\pi} + \gamma_\pi^{ZLB} \widehat{g}_t$ and $y_t = \overline{y} + \gamma_y^{ZLB} \widehat{g}_t$ and solve for $\overline{\pi}, \gamma_\pi^{ZLB}, \overline{y}, \gamma_y^{ZLB}$. We find that

$$\begin{aligned}
\overline{y} &= \frac{\widetilde{\sigma}\left(1 - \beta\mu\right)}{(1-\mu)(1-\beta\mu) - \widetilde{\sigma}\mu\kappa} r_L, \\
\overline{\pi} &= \frac{\kappa}{1-\beta\mu}\overline{y}, \\
\gamma_y^{ZLB} &= \frac{\left[1 - \mu\rho_{ZLB} + (1-\mu)\rho\left(\gamma_y - 1 + \widetilde{\sigma}\gamma_\pi\right)\right]\left(1 - \beta\mu\rho_{ZLB}\right) + \widetilde{\sigma}\mu\rho_{ZLB}\left[\beta(1-\mu)\gamma_\pi\rho - \kappa\Gamma\right]}{(1-\mu\rho_{ZLB})(1-\beta\mu\rho_{ZLB}) - \widetilde{\sigma}\mu\kappa\rho_{ZLB}}, \\
\gamma_\pi^{ZLB} &= \frac{\beta(1-\mu)\gamma_\pi\rho + \kappa(\gamma_y^{ZLB} - \Gamma)}{1 - \beta\mu\rho_{ZLB}}.
\end{aligned}$$

Having solved the model in the ZLB period for $t > 15$, we can find output and inflation in the ZLB period for $t \in [0, 15]$ by solving the following equations backwards

$$
\begin{aligned}
\widehat{y}_t - \widehat{g}_t &= \mu \left(\widehat{y}_{t+1} - \widehat{g}_{t+1}\right) + (1-\mu)\left(\gamma_y - 1\right)\rho\widehat{g}_t + \widetilde{\sigma}\left(\mu\pi_{t+1} + (1-\mu)\gamma_\pi\rho\widehat{g}_t + r_L\right), \\
\pi_t &= \beta\left(\mu\pi_{t+1} + (1-\mu)\gamma_\pi\rho\widehat{g}_t\right) + \kappa\left(\widehat{y}_t - \Gamma\widehat{g}_t\right).
\end{aligned}
$$

The model output multiplier during the ZLB period is given by

$$
M_h = \frac{\sum_{t=0}^{h}(\widehat{y}_t - \overline{y})}{\sum_{t=0}^{h}\widehat{g}_t}.
$$

Note that in the denominator we subtracted $\overline{y}$ which is the level of the ZLB output gap without government spending shocks.

Tables and Figures

Table 1: Multipliers

	Normal	ZLB	Difference	p-value
Output				
On impact	0.71	1.48	0.77	0.18
	(0.42)	(0.55)	(0.60)	
1 quarter	0.45	1.74	1.29	0.11
	(0.38)	(0.72)	(0.82)	
4 quarter	0.00	2.37	2.37	0.13
	(0.94)	(1.60)	(1.81)	
8 quarter	-1.08	1.99	3.07	0.23
	(1.04)	(2.27)	(2.71)	
Consumption				
On impact	0.24	0.69	0.45	0.12
	(0.20)	(0.32)	(0.36)	
4 quarter	-0.10	1.54	1.64	0.04
	(0.45)	(0.76)	(0.84)	
8 quarter	-0.44	1.33	1.77	0.17
	(0.44)	(1.05)	(1.20)	
Investment				
On impact	-0.07	-0.20	-0.13	0.65
	(0.23)	(0.22)	(0.29)	
4 quarter	-0.50	0.77	1.27	0.17
	(0.64)	(0.73)	(0.90)	
8 quarter	-1.26	0.77	2.03	0.17
	(0.89)	(1.08)	(1.41)	
Unemployment				
On impact	-0.03	-0.09	-0.06	0.26
	(0.04)	(0.05)	(0.06)	
4 quarter	-0.05	-0.50	-0.45	0.03
	(0.10)	(0.13)	(0.25)	
8 quarter	-0.03	-0.31	-0.28	
	(0.13)	(0.27)	(0.35)	0.05

Notes: The table reports the results of the multipliers on impact and over four- and eight- quarter horizons in the normal period (Normal column) and in the ZLB period (ZLB column). The output multiplier is calculated as the cumulative change of output over the cumulative change of government spending over each horizon. The consumption, investment and unemployment rate multipliers are defined analogously. The difference between the multiplier in the normal period and that in the ZLB period is reported in "Difference" column with the corresponding p-value in "p-value" column. All numbers in parentheses are the standard errors.

Table 2: Impulse Responses

	On impact	Horizon 4	Horizon 8
GDP deflator Inflation			
Normal	0.07	0.20	-0.20
	(0.15)	(0.16)	(0.22)
ZLB	0.14	0.20	-0.05
	(0.23)	(0.21)	(0.17)
Inflation			
Normal	-0.08	-0.08	-0.11
	(0.23)	(0.23)	(0.28)
ZLB	0.52	0,07	0.04
	(0.16)	(0.17)	(0.16)
GDP deflator Inflation expectation			
Normal	0.18	-0.17	-0.40
	(0.24)	(0.21)	(0.32)
ZLB	0.33	0.61	0.30
	(0.22)	(0.25)	(0.29)
CPI Inflation expectation			
Normal	-0.18	-0.29	-0.24
	(0.18)	(0.13)	(0.17)
ZLB	0.27	0.34	0.34
	(0.24)	(0.44)	(0.68)
Short-term interest rate			
Normal	0.06	0.35	-0.44
	(0.29)	(0.64)	(1.17)
ZLB	-0.04	-0.01	0.03
	(0.02)	(0.09)	(0.08)
Long-term interest rate			
Normal	-0.40	-0.14	-0.77
	(0.23)	(0.48)	(0.86)
ZLB	-0.07	-0.03	-0.22
	(0.09)	(0.18)	(0.20)

Notes: This table reports the impulse responses of inflation, inflation expectation, short-term and long-term nominal interest rates and unemployment rate to an increase in government spending by 1% of output. All numbers in parentheses are the standard errors.

Table 3: The Multipliers of Components of Consumption and Investment

	On impact	4 quarter	8 quarter
Durable consumption			
Normal	0.05	-0.02	-0.09
	(0.05)	(0.12)	(0.17)
ZLB	0.16	0.25	0.21
	(0.05)	(0.13)	(0.15)
Non-durable consumption			
Normal	0.06	0.04	0.06
	(0.08)	(0.12)	(0.10)
ZLB	0.22	0.47	0.54
	(0.07)	(0.15)	(0.19)
Semi-durable consumption			
Normal	-0.01	0.03	0.04
	(0.03)	(0.04	(0.04)
ZLB	0.01	0.07	0.06
	(0.02)	(0.05)	(0.08)
Services			
Normal	0.14	-0.07	-0.29
	(0.11)	(0.22)	(0.22)
ZLB	0.06	0.19	-0.04
	(0.14)	(0.30)	(0.41)
Residential Investment			
Normal	0.01	0.03	0.13
	(0.07)	(0.20)	(0.33)
ZLB	0.01	0.38	0.40
	(0.06)	(0.16)	(0.24)
Nonresidential investment			
Normal	-0.05	-0.27	-0.82
	(0.25)	(0.80)	(1.06)
ZLB	-0.17	0.23	0.04
	(0.20)	(0.48)	(0.68)

Notes: This table reports the multipliers for components of consumption and investment over several horizons. All numbers in parentheses are the standard errors.

Table 4: Output Multipliers: Importance of Forecast

	On impact	4 quarter	8 quarter
No Forecast Data			
Normal	0.47	-0.29	-1.02
	(0.35)	(0.84)	(0.96)
ZLB	1.44	2.18	1.97
	(0.55)	(1.47)	(1.98)

Notes: This table reports the output multipliers over several horizons considering the importance of forecast data. "No forecast Data" reports the multiplier when there is no forecast data in identifying government spending shocks. All numbers in parentheses are the standard errors.

Table 5: Output Multipliers: Adding other sources of real-time information

	On impact	4 quarter	8 quarter
Add fiscal packages			
Normal	0.77	0.15	-1.07
	(0.45))	(1.13)	(1.17)
ZLB	1.74	2.80	1.98
	(0.58)	(1.65)	(3.07)
Add OECD, IMF and Government Outlook forecast			
Normal	0.59	-0.05	-1.13
	(0.39)	(0.99)	(1.03)
ZLB	1.59	2.74	2.02
	(0.62)	(2.08)	(3.85)
Add one-quarter ahead output forecast			
Normal	0.47	0.02	-0.69
	(0.55)	(1.19)	(1.34)
ZLB	1.50	2.98	3.11
	(0.63)	(2.19)	(3.38)
Add one to four quarter ahead of G			
Normal	0.73	-.06	-1.19
	(0.42)	(0.92)	(1.01)
ZLB	1.49	2.33	1.91
	(0.56)	(1.62)	(2.30)
Add four quarter ahead cumulative forecast of G			
Normal	0.60	-0.41	-1.73
	(0.42)	(0.93)	(1.04)
ZLB	1.47	2.36	2.03
	(0.54)	(1.57)	(2.21)
Add four-quarter ahead cumulative forecast of GDP			
Normal	0.65	-1.07	-2.34
	(0.400	(1.12)	(1.64)
ZLB	1.30	1.43	0.75
	(0.59)	(1.37)	(1.42)

Notes: "No forecast Data" reports the multiplier when there is no forecast data in identifying government spending shocks."Add output forecast" reports the results when we add one quarter ahead forecast of output growth rate to identify spending shocks. "Add cumulative forecast of G" reports the case when we add four quarter ahead forecast of annual growth rate of spending into the estimation. "Add one to four quarter ahead of G" reports when forecasts of government spending from horizon one to four quarter ahead are included. "Add fiscal packages" reports the results when we add the public investment component of the fiscal packages approved in Japan into the estimation. "Add OECD, IMF and Government Outlook"reports when we include one quarter ahead forecast of different sources into the estimation. All numbers in parentheses are the standard errors.

Table 6: Output Multipliers in Different Specifications

	On impact	4 quarter	8 quarter
Slackness			
Expansion	0.87	1.44	1.47
	(0.34)	(0.72)	(1.05)
Recession	2.28	3.00	2.37
	(0.68)	(1.86)	(2.73)
Difference	1.41	1.56	0.90
	(0.77)	(1.96)	(2.90)
Quadratic trend			
Normal	0.65	-0.06	-0.13
	(0.44)	(1.03)	(1.14)
ZLB	1.51	2.99	2.71
	(0.63)	(2.35)	(3.41)
Normalized by potential output			
Normal	0.71	0.00	-1.08
	(0.42)	(0.93)	(1.01)
ZLB	1.49	2.38	1.97
	(0.55)	(1.61)	(2.30)
One step estimation			
Normal	0.71	-0.01	-1.08
	(0.41)	(0.93)	(1.05)
ZLB	1.48	2.33	2.03
	(0.56)	(1.63)	(2.16)
Unadjusted government spending			
Normal	0.77	-0.19	-1.30
	(0.44)	(0.91)	(0.99)
ZLB	1.35	2.09	1.75
	(0.49)	(1.21)	(1.58)
Actual final government spending			
Normal	0.68	-0.05	-1.14
	(0.46)	(0.95)	(1.01)
ZLB	1.59	2.66	2.60
	(0.56)	(1.62)	(2.46)

Notes: This table reports the output multipliers over several horizons in alternative specifications. "Slackness" reports the multipliers in two regimes: recession and expansion, which is classified based on the Japanese Cabinet Office, and the difference in multipliers."Quadratic trend" reports the estimates when we add quadratic trend to the baseline specification. "Normalized by potential output" reports the estimates when the RHS variables in the baseline specification are converted to the same unit by dividing by potential output. "One step estimation" estimates the output multiplier in one regression by adding one-quarter ahead forecast of government spending to the control variables. "Unadjusted government spending" reports the multiplier when we use the published government spending data that include transfer of goods and services to estimate the baseline specification. "Actual final government spending" reports the multiplier when we use the published government spending data that exclude all transfer of goods and services to estimate the baseline specification. All numbers in parentheses are the standard errors.

Table 7: The Responses of Different Inflation Measures

	On impact	4 quarter	8 quarter
CPI			
Normal	0.00	-0.11	-0.27
	(0.23)	(0.23)	(0.28)
ZLB	0.67	-0.02	0.19
	(0.21)	(0.25)	(0.28)
Tax-adjusted CPI			
Normal	0.06	-0.13	-0.33
	(0.21)	(0.20)	(0.27)
ZLB	0.52	-0.09	0.12
	(0.19)	(0.20)	(0.22)
Core CPI			
Normal	-0.05	-0.19	-0.17
	(0.14)	(0.13)	(0.18)
ZLB	0.23	0.26	-0.15
	(0.06)	(0.12)	(0.13)
Tax-adjusted core CPI			
Normal	-0.14	-0.22	-0.31
	(0.10)	(0.13)	(0.13)
ZLB	0.03	0.04	-0.20
	(0.16)	(0.16)	(0.16)
CPI excluding food			
Normal	-0.07	-0.10	-0.08
	(0.15)	(0.11)	(0.19)
ZLB	0.26	0.27	-0.02
	(0.11)	(0.25)	(0.22)
Tax-adjusted CPI excluding food			
Normal	0.06	-0.09	-0.10
	(0.10)	(0.11)	(0.17)
ZLB	0.21	0.18	-0.05
	(0.10)	(0.24)	(0.20)

Notes: This table reports the responses of CPI, core CPI (without food and energy), CPI without food and their tax-adjusted counterparts. The tax-adjusted data adjust the original series for consumption taxes in 1989 and 1997. All numbers in parentheses are the standard errors.

Table 8: Parameter Values

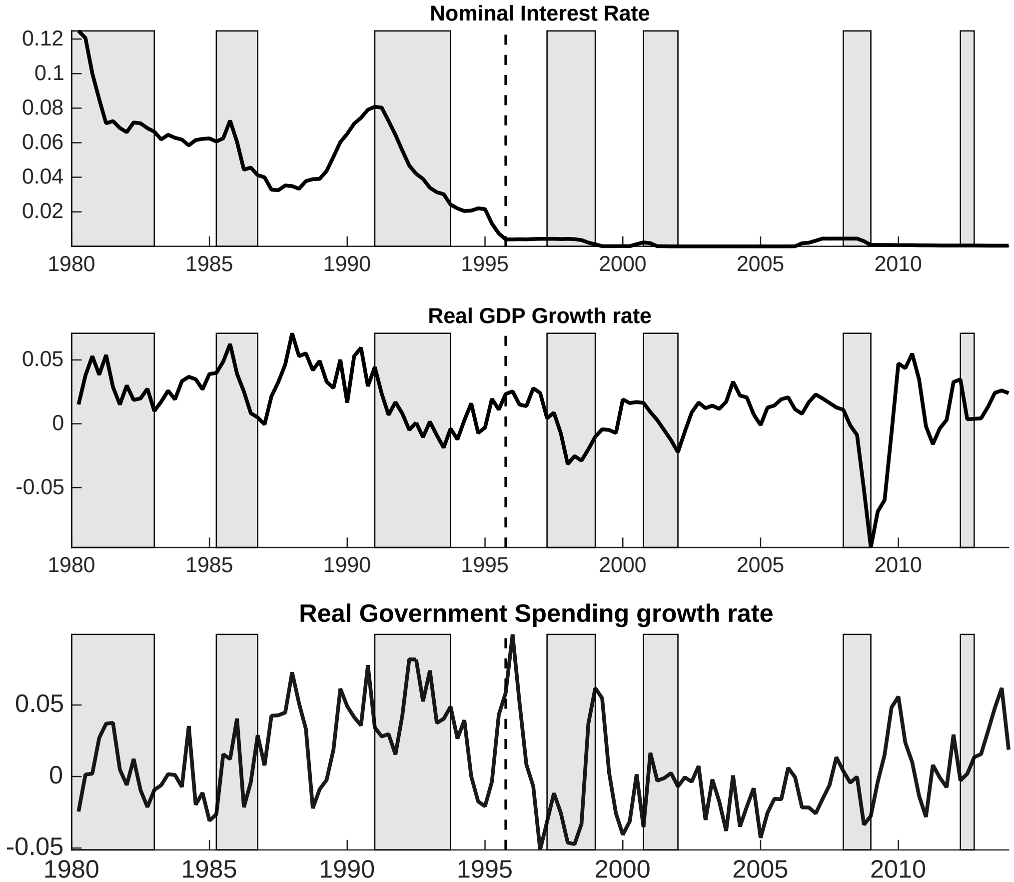
Benchmark Calibration	
Discount factor	$\beta = 0.99$
Elasticity of intertemporal substitution	$\sigma = 1.1$
Elasticity of substitution	$\theta = 5$
Frisch elasticity of labor supply	$\nu = 1$
Steady state spending-GDP ratio	$\frac{G}{Y} = 0.18$
Capital share	$a = \frac{2}{3}$
Probability of price adjustment	$1 - \alpha = 0.25$
Taylor rule parameters	$\phi_\pi = 1.5, \phi_y = 0.05$
Composite parameters	$\kappa = 0.02$
Persistence of G	$\rho_g = 0.8$

Table 9: Model Multipliers

	Output Multiplier	Consumption Multiplier	Inflation Multiplier
Taylor Rule	0.71	-0.29	0.04
Fixed Nominal Rate	1.47	0.47	0.13

Notes: The table reports output, consumption and inflation fiscal multipliers under two monetary policy specifications. The first row (Taylor Rule) corresponds to active monetary policy response to inflation and output gap. The second row (Fixed Nominal Rate) corresponds to monetary policy that does not respond to government spending shocks.

Figure 1: Japan's Nominal Interest rate and Real GDP and Government Spending growth rates between 1980Q2 and 2014Q1



Notes: The shaded areas are Cabinet Office recession dates.

Figure 2: Government Spending Annual Growth Rate: Actual and Forecast

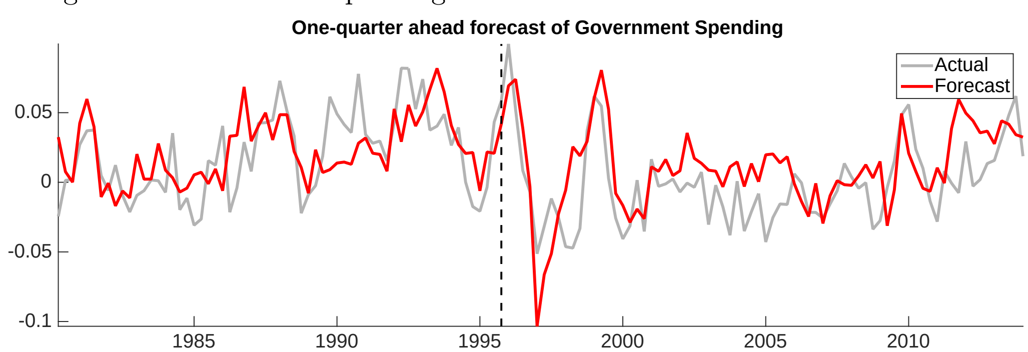
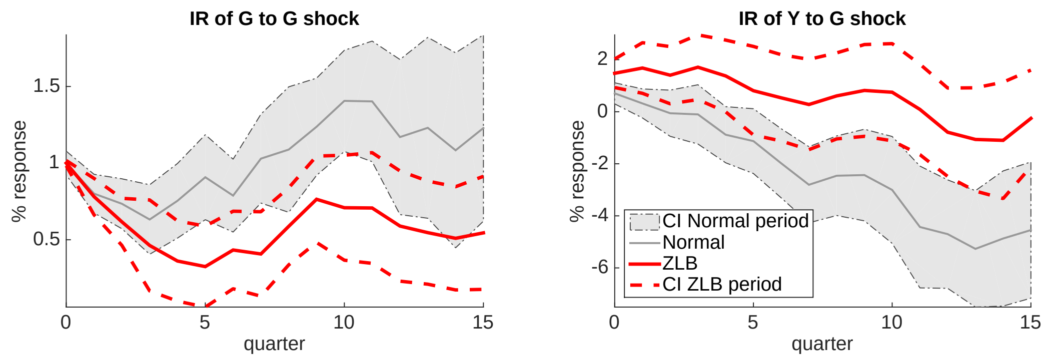
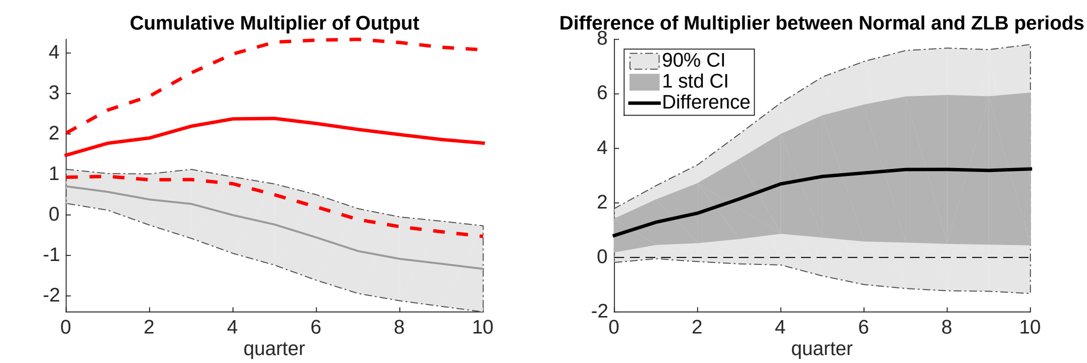


Figure 3: The effects of government spending on output in the normal period and the ZLB period

(a) Impulse Responses of Output and Government Spending

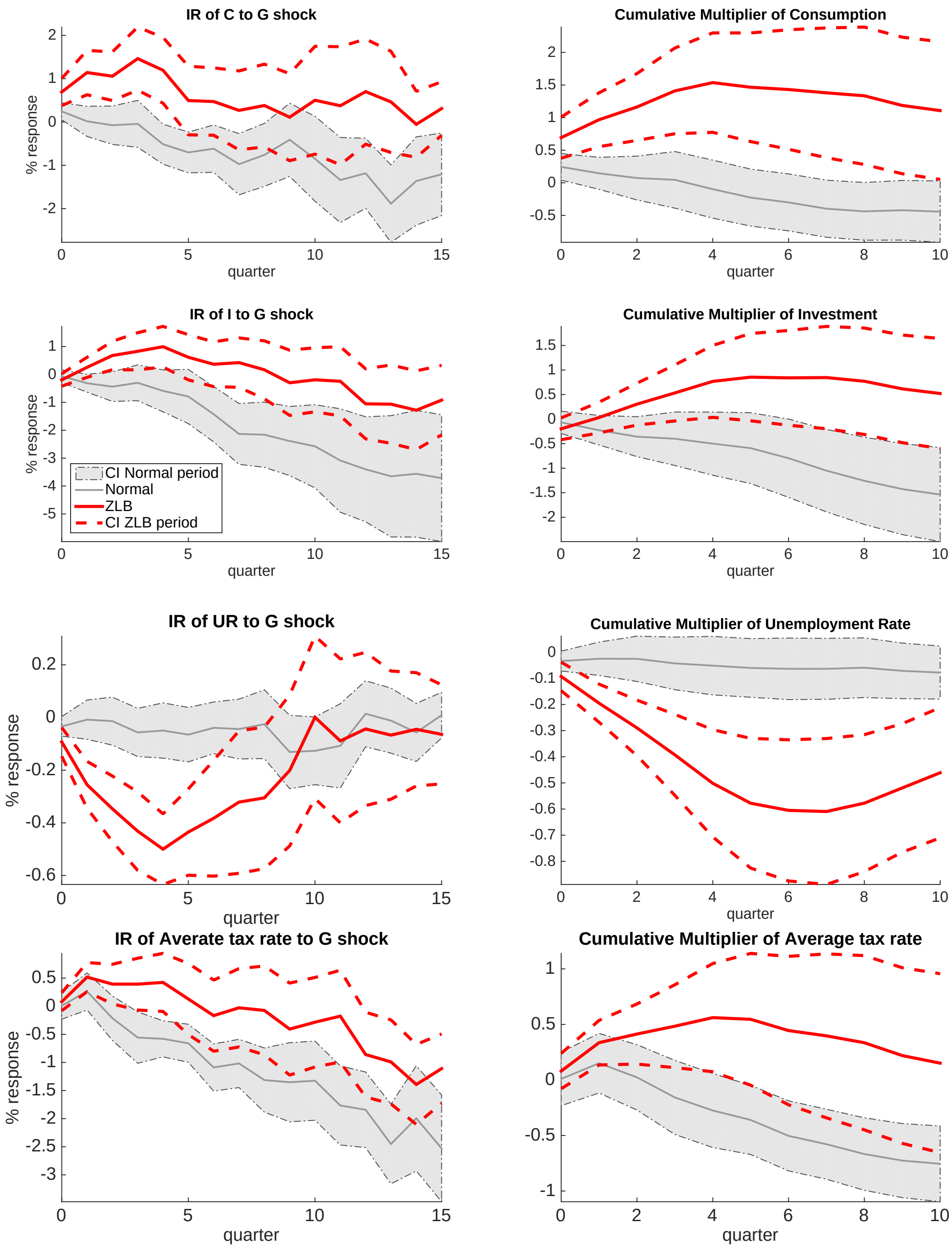


(b) Output Multipliers and the Difference of the Multipliers



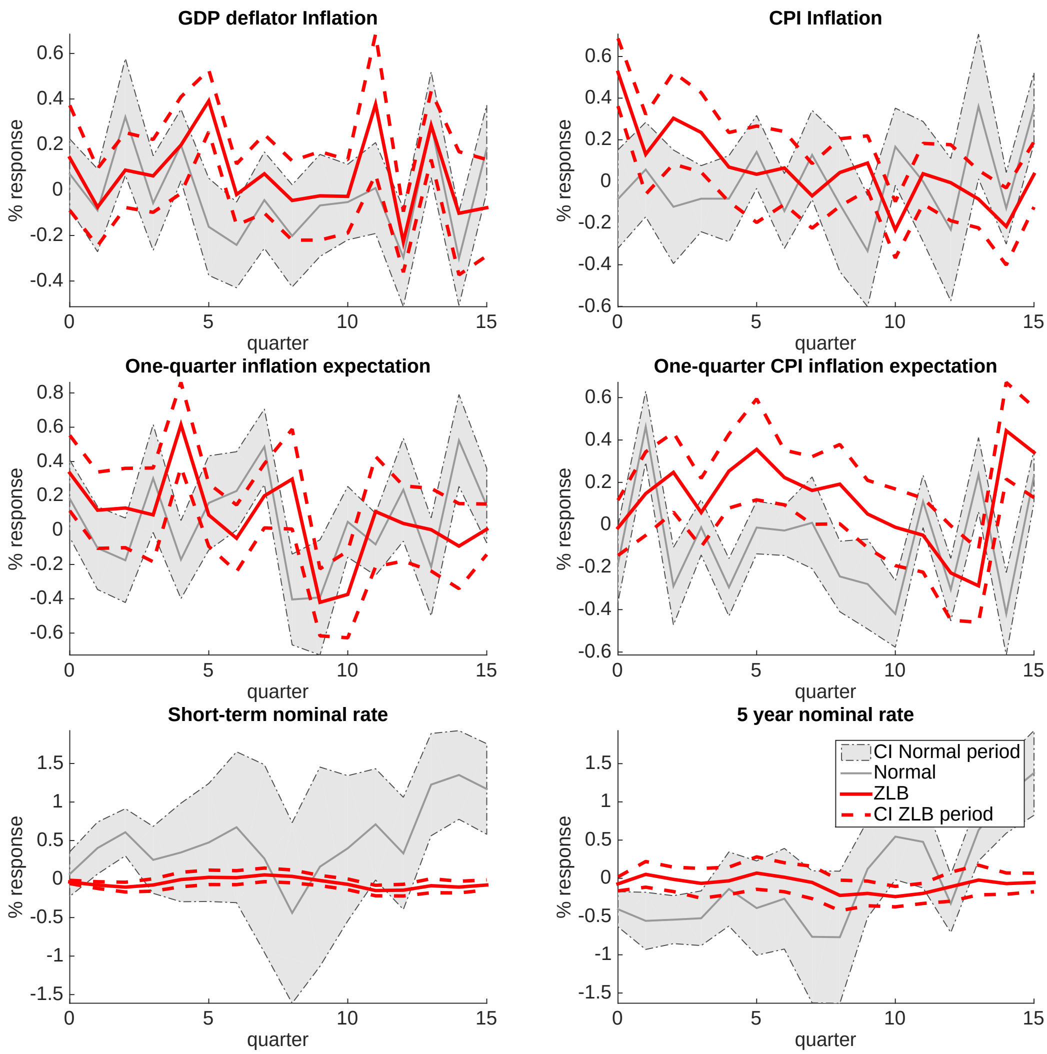
Notes: Impulse responses of output and government spending to an unexpected increase in government spending by 1% of output during normal and ZLB periods.

Figure 4: Impulse Responses and Multipliers for Consumption, Investment and Unemployment Rate



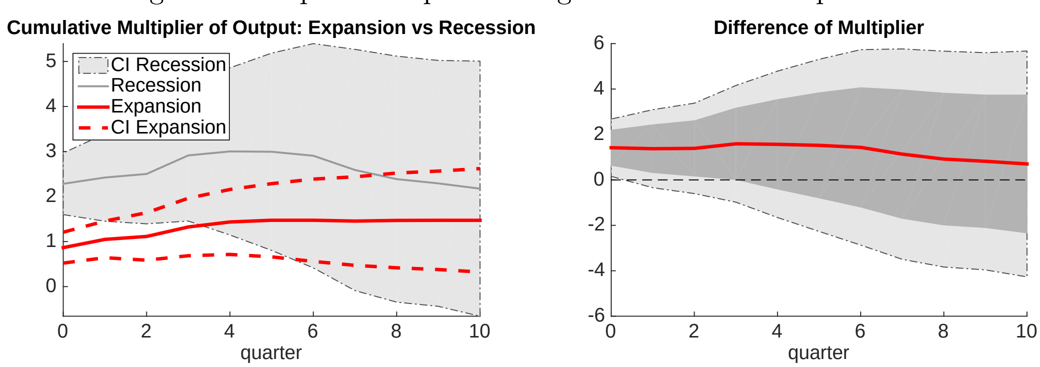
Notes: This figure presents the impulse responses of Consumption, Investment, Unemployment Rate, Average tax rate to an increase in government spending along with the Cumulative Multipliers of Consumption, Investment and Unemployment Rate and Average tax rate in the normal period and in the ZLB period.

Figure 5: Impulse Responses of Other Variables



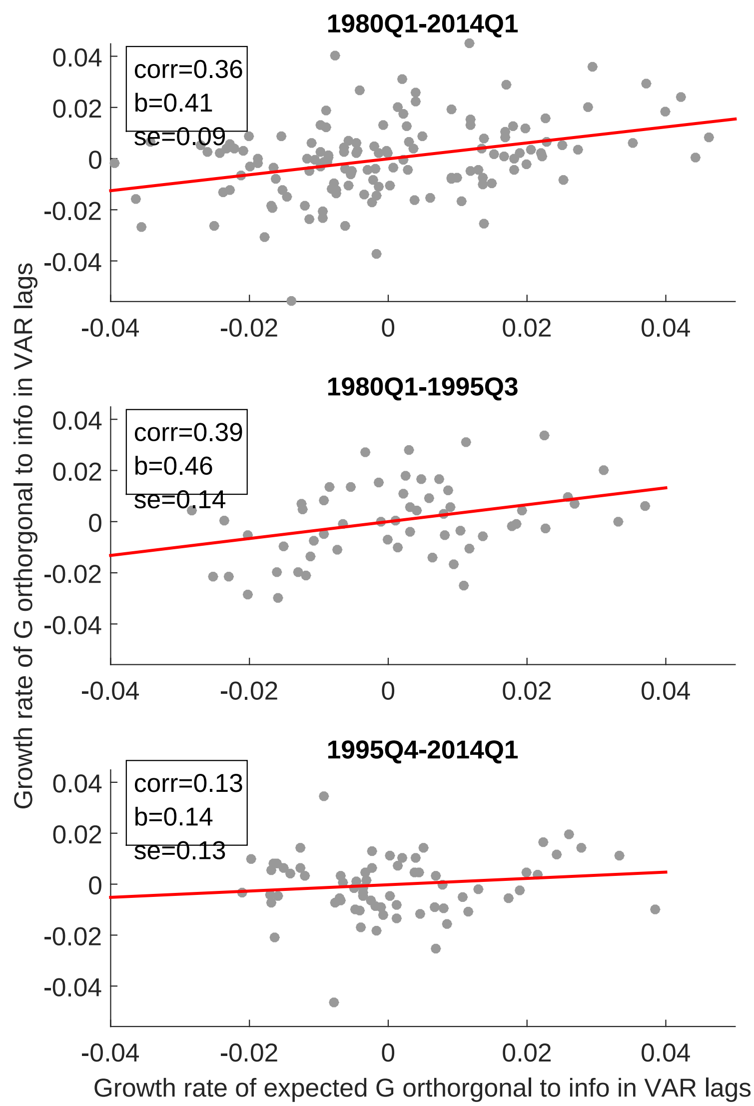
Notes: This figure plots impulse responses to an increase in government spending by 1% of output in normal and ZLB periods. "One-quarter inflation expectation" is the inflation expectation from GDP deflator forecast, $F_{t-1}\pi_t$, and "One-quarter CPI inflation expectation" is the inflation expectation from CPI forecast, $F_{t-1}\pi_t^{CPI}$.

Figure 6: Output Multiplier during Recessions and Expansions



Notes: Recessions are defined by the Japanese Cabinet Office.

Figure 7: Predictability of Government Spending Shocks without Controlling for Expectations



Notes: The Figure plots residuals from projection of the growth rate of government spending predicted in JCER forecast (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.

Figure 8: Output Multipliers with and without Forecast Data

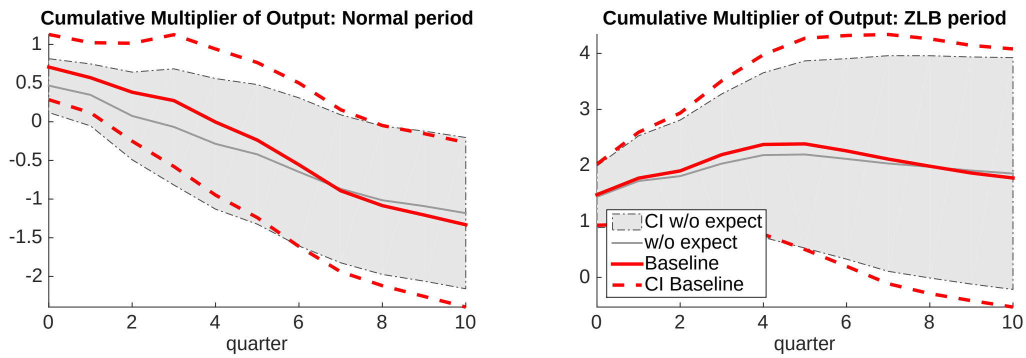


Figure 9: Other Annual Forecasts of Government Spending

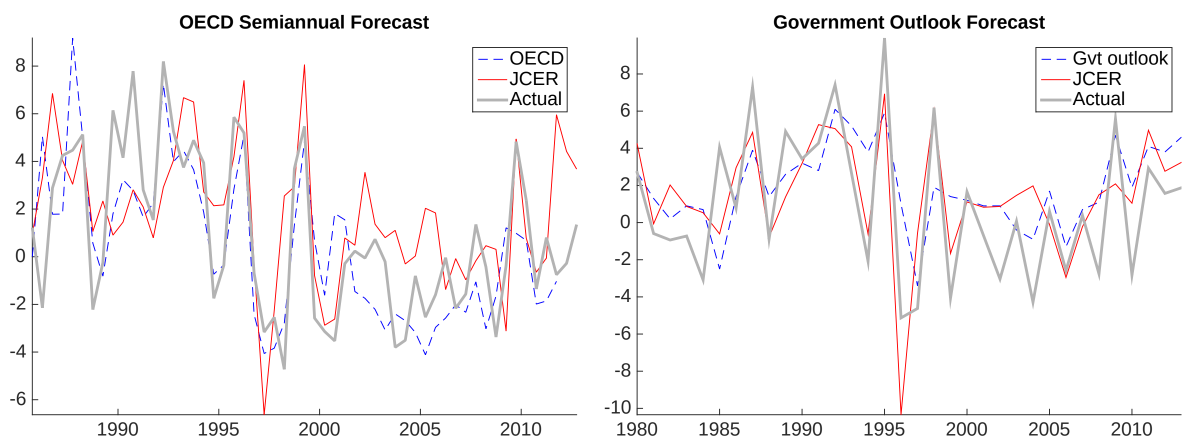
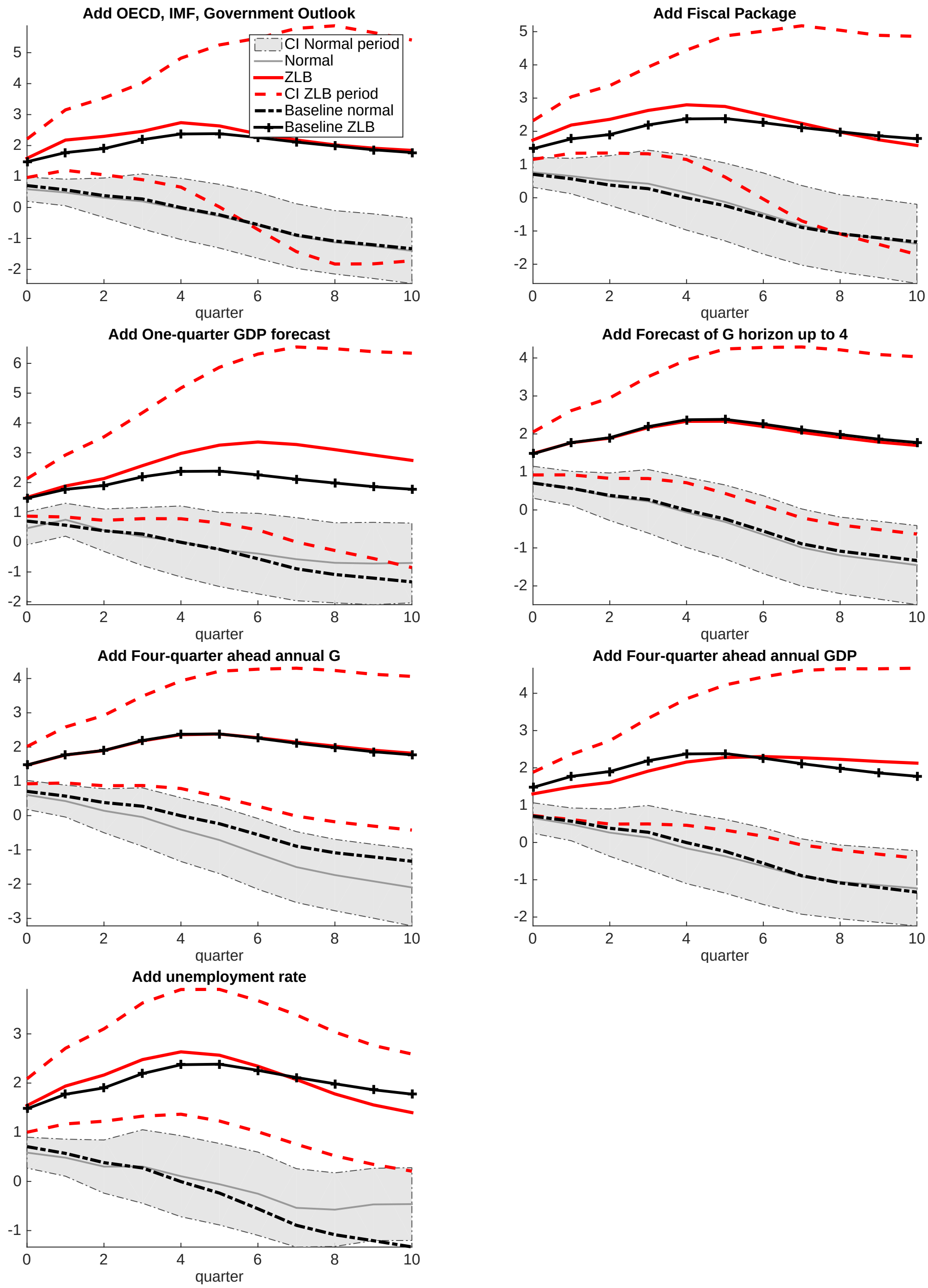
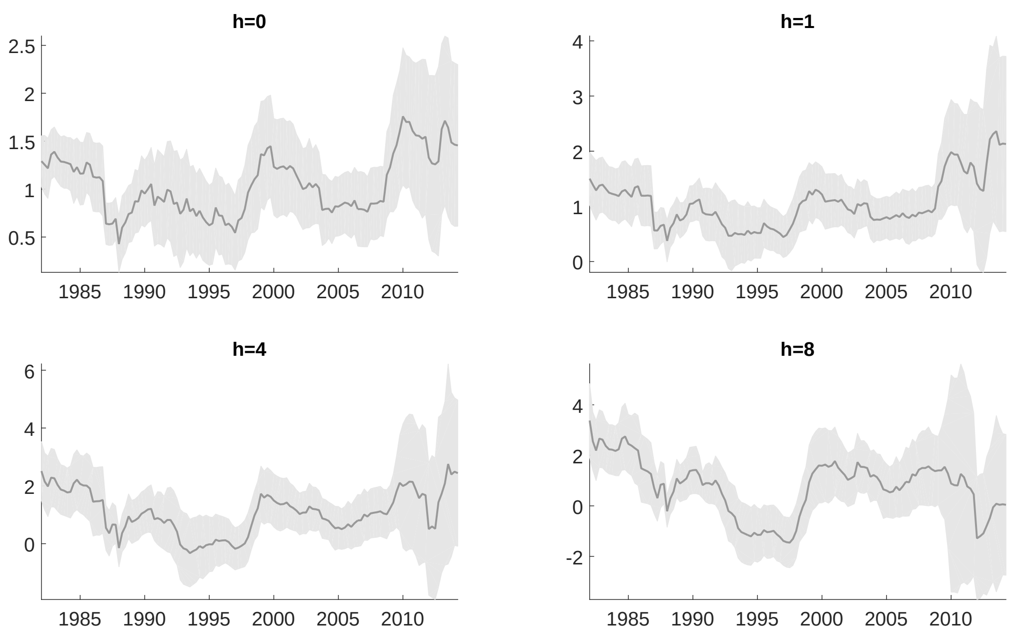


Figure 10: Output Multipliers: Adding Other Sources of Real-time Information



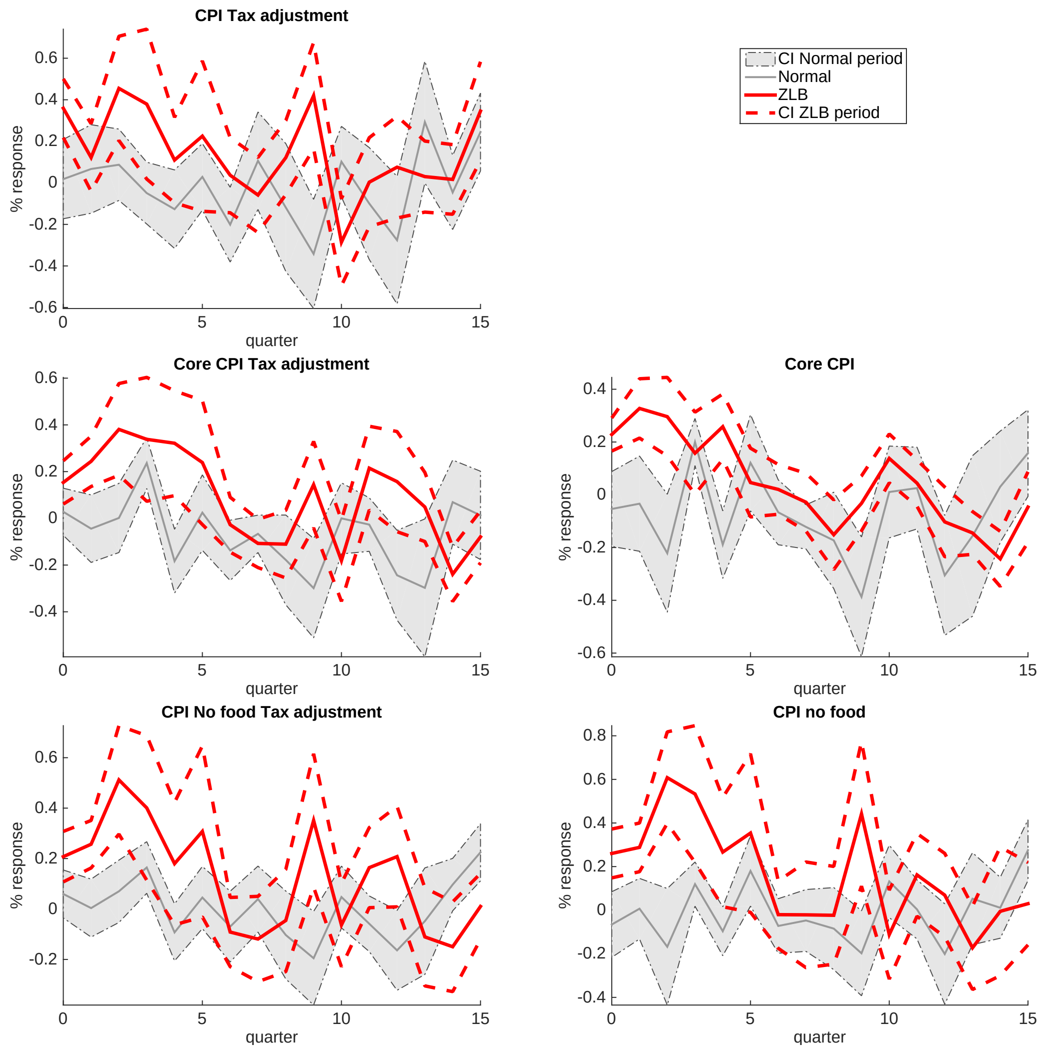
Notes: This figure plots the output multiplier when we add several data in the controls. The black lines are the estimates in the ZLB (with plus signs) and in the normal period (dotted) in the baseline.

Figure 11: Output Multiplier: Rolling Estimation



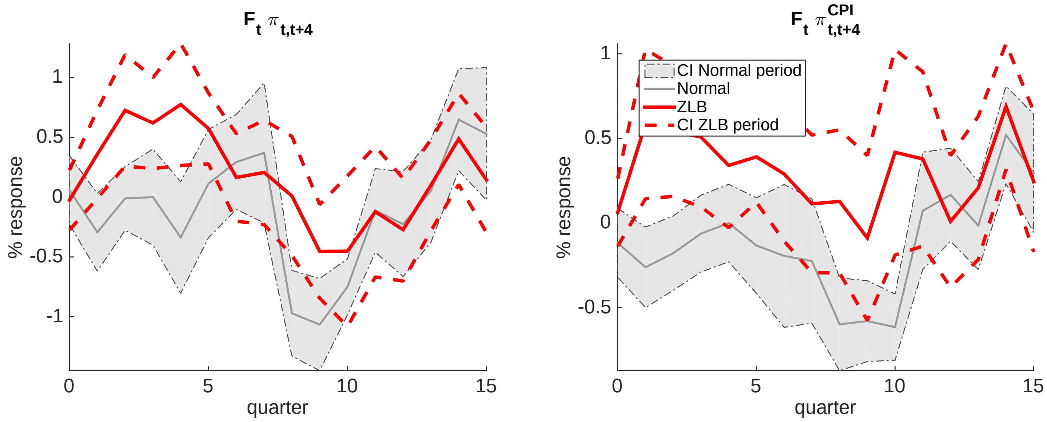
Notes: The year of a reported multiplier corresponds to the last year of the 60 quarter window; for example, a multiplier reported for 1990Q1 is estimated over 1975Q1-1990Q1.

Figure 12: Different Inflation Data



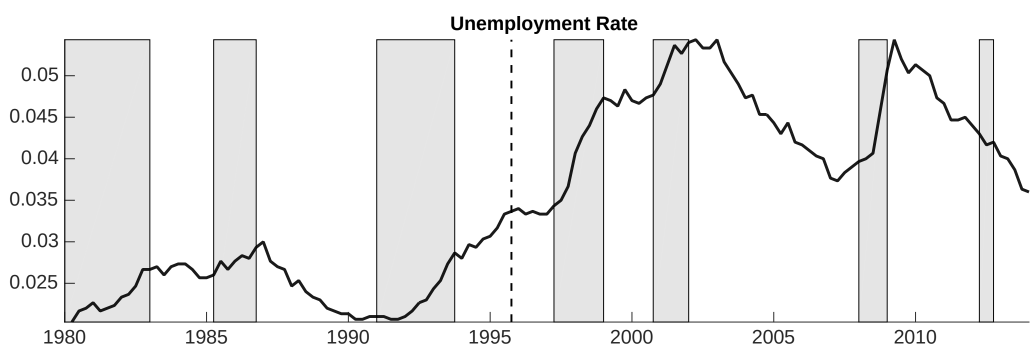
Notes: This figure plots the impulse responses of the inflation rate and expected inflation calculated from GDP deflator (baseline inflation), CPI, core CPI (excluding food and energy) and CPI no food (excluding fresh food) along with the measures of CPI inflation adjusted for consumption tax changes.

Figure 13: Longer horizon Inflation expectation responses



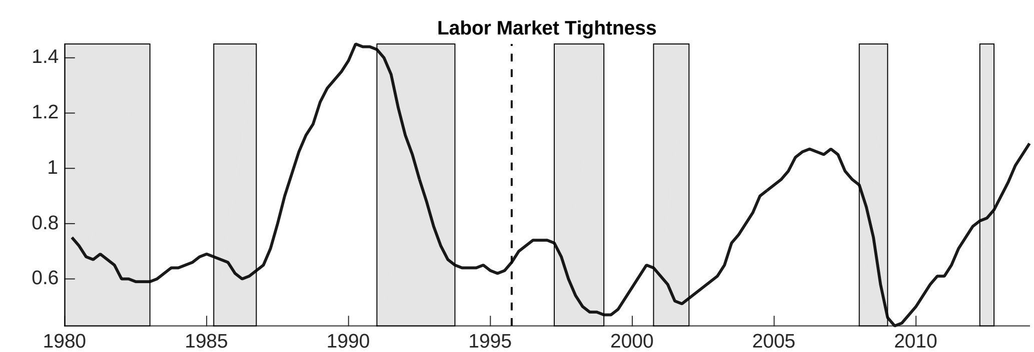
Notes: "Four-quarter ahead annual inflation expectation" denotes the annual inflation expectation calculated from GDP deflator forecast, $F_t\pi_{t,t+4}$. "Four-quarter ahead annual CPI inflation expectation" denotes the annual inflation expectation calculated from CPI forecast,$F_t\pi^{CPI}_{t,t+4}$.

Figure 14: Unemployment Rate in Japan



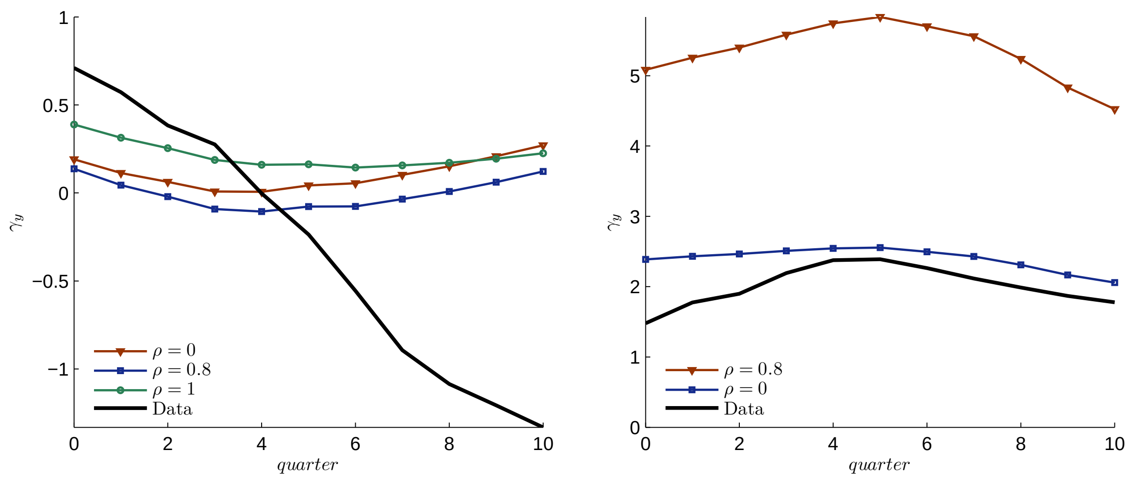
Notes: The shaded areas are Cabinet Office recession dates.

Figure 15: Labor Market Tightness in Japan



Notes: The shaded areas are Cabinet Office recession dates.

Figure 16: Estimated and Model Output Multipliers



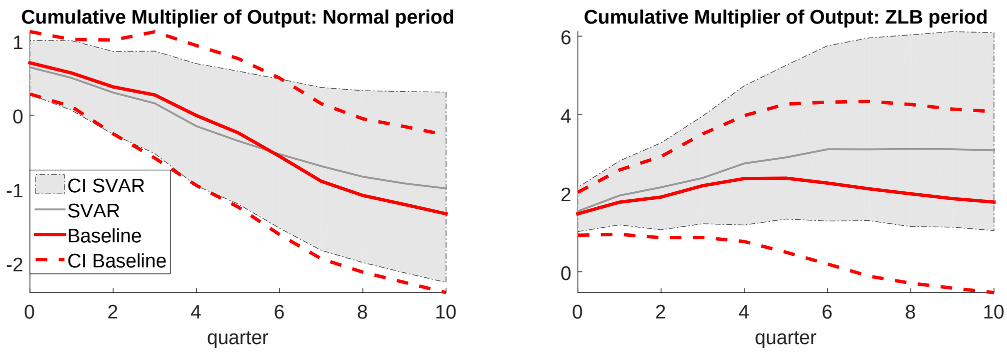
(a) Normal period

(b) Fixed nominal interest rate period

Notes: This figure plots model and empirically estimated output multipliers in the normal period (left panel) and the ZLB period (right panel). The model multipliers are computed assuming that during first sixteen quarters government spending equals the estimated path of government spending after a government spending shock. ρ is the normal period persistence of government spending after the estimated government spending path (left panel) and after the ZLB period stopped binding (right panel). ρ_{ZLB} is the ZLB period persistence of government spending after the estimated government spending path.

Additional Results - Not for Publication

Figure A1: Cumulative Multipliers for Output: Baseline vs SVAR



Notes: This figure plots the output multipliers in the normal period (left) and in the ZLB period (right) in the baseline estimation compared with the SVAR estimation.

Figure A2: Output Multiplier during Recessions and Expansion

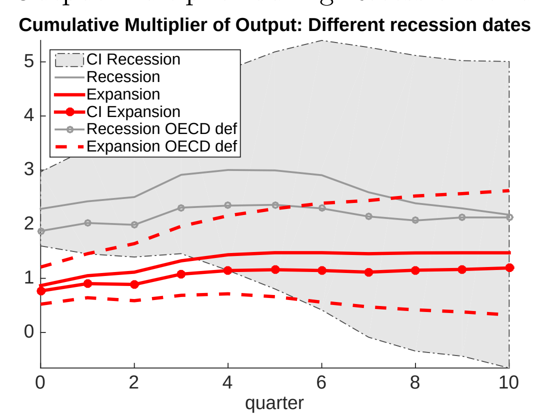


Figure A3: Cumulative Multipliers for Consumption and Investment Components

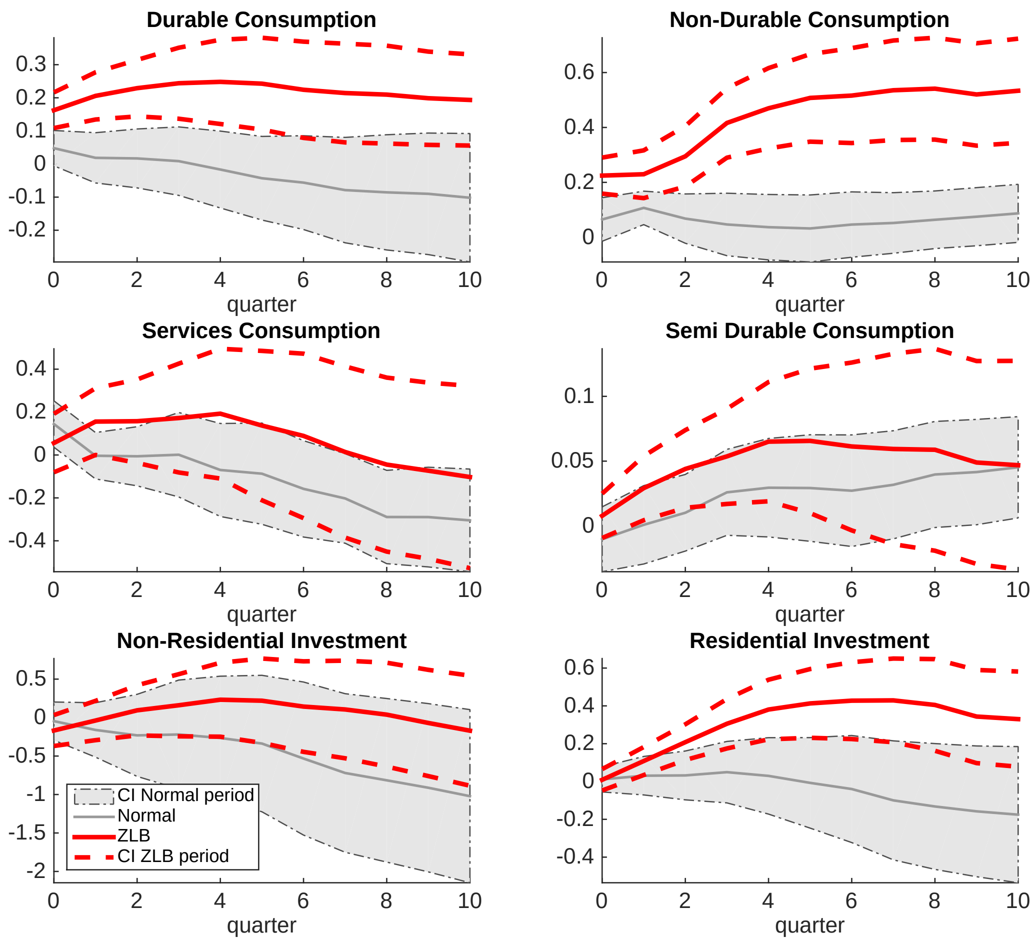


Figure A4: CPI Inflation in Japan: Original and Tax-adjusted