This research examines the effects of public investment on stock returns using Japanese cross-industry data. We calculate impulse response functions using the local projection method. The empirical results show that public investment shocks have strong and stimulating effects on stock returns when the nominal interest rate is at the zero lower bound (ZLB) while negative responses dominate outside of the ZLB period. Furthermore, the estimated impulse responses for the non-manufacturing industry group are larger than those of the manufacturing industry group. Our results imply that the government should increase public investment when nominal interest rates are near zero to prop up the stock market and cut back once the economy is no longer in a liquidity trap.

**JEL classification:** E44, G12, H54

**Keywords:** Public investment; Stock returns; Local projection method; Zero lower bound.
1. Introduction

Since the global financial crisis (GFC), certain developed countries have been plagued by a protracted recession that keeps the short-term nominal interest rate close to the zero lower bound (ZLB). In the wake of this recession, several economists underscore the effectiveness of public investment to spur private sector investment. For example, Eichengreen (2016) writes as follows.

The solution is straightforward. It is to fix the problem of deficient demand not by attempting to further loosen monetary conditions, but by boosting public spending... Productive public investment would also enhance the returns on private investment, encouraging firms to undertake additional projects.1

When the nominal interest rate is stuck at the ZLB, firm financial conditions deteriorate, leading to the decrease in the asset value of collateral used in bank lending. This makes it difficult for firms to embark on further projects. However, if public investment can bolster the stock market, it contributes to the improvement of balance sheets, which enables firms to initiate new projects. Eichengreen (2016)'s idea

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1 For more details, please see https://www.socialeurope.eu/why-the-world-economy-needs-fiscal-policy-to-overcome-stagnation.

We define public investment as investment in public infrastructure such as livelihood social capital, soil and water conservation, agricultural use, as well as production use. We exclude investments in science and technology, education and social welfare, alternative energy, the environment, and natural disaster relief. Therefore, our definition for public investment is slightly different from that of Eichengreen (2016), who also includes investment for research and education.
reflects the path mentioned above because there is a positive link between public investment and stock returns by virtue of a positive externality of public capital. In light of this, it is worthwhile investigating the effect of public investment on the stock market during the ZLB period. To the best of our knowledge, however, this relationship between public investment and the stock market during the ZLB period remains unexplored.

The purpose of this study is to examine the relationship between public investment and the stock market using Japanese sectoral panel data from 1984 Q2 to 2008 Q4. Studies in Japan have several advantages over those in other countries. First, as illustrated by the expression “the lost decades,” Japan has experienced a long-term stagnation since the early 1990s. Especially, as mentioned in Miyamoto et al. (2017), the nominal interest rate has been near the ZLB since 1995 Q4. Furthermore, the government included public investment measures in its economic stimulus packages even before the nominal interest rate neared zero, which enables us to compare its effects between the non-ZLB and ZLB periods. Second, as discussed in Section 2, the

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2 Belo and Yu (2013) demonstrate this point using both theoretical and empirical models, without dividing the situation between the ZLB and non-ZLB periods. Appendix 1 summarizes their theoretical framework.

3 Public capital data, which is used to calculate public investment shocks, is not available 2010 onward. Therefore, our sample period is different from that of Miyamoto et al. (2017). We also considered limiting the sample period to after 1991, the year in which the asset price bubble collapsed, and found that our results do not change qualitatively. The results are reported in Appendix 4.
Japanese government has used public investment in a bid to bolster the sluggish stock market.

We use a quarterly panel of returns of investment on stock (hereafter, stock returns)\(^4\) on 27 industries. Since stock return is usually considered stationary whereas stock price/index is not, we adopt the former. We conduct an empirical study using sectoral panel data for two reasons. First, since the stock market consists of various sectors, policy effects may be different between sectors. Second, we can avoid the problem of reverse causality running from the stock price index to public investment policies that could occur in an estimation using macro data. As a rule, the government decides on how to implement public investment policies based on a representative stock price index such as the Nikkei 225 or the S&P 500. Thus, in estimating the effects of public investment on stock returns, we must account for the problem of reverse causality from stock price to public investment.

We calculate impulse response functions (IRFs) using the local projection method developed by Jordà (2005) and Stock and Watson (2007). Local projection has several

\(^4\) This is calculated by the equation \(\frac{\text{Income gain} + \text{Capital gain}}{\text{Stock Price}_{t-1}}\).
advantages for IRF estimation. First, this approach is relatively robust to misspecifications of the data generating process. Second, we can economize on the number of estimated parameters compared to the panel vector autoregression model as mentioned in Sekine and Tsuruga (2018).

Our main findings are as follows. First, we observe that public investment (public capital) shocks have a strong, stimulating effect on stock returns in the ZLB period. In contrast, outside of the ZLB period, negative and statistically significant responses are observed after three quarter. These results are robust to misspecification: adding other control variables, changing the lag length of public investment (public capital) shocks, and using an alternative variable for public investment yields qualitatively similar findings. This implies that, although public investment contributes to the resurgence of the stock market when the nominal interest rate is stuck at zero, it has negative impacts on the stock market in non-ZLB periods. Second, we find that the estimated impulse responses for the non-manufacturing industries are larger than those of the manufacturing industries during the ZLB period. Impulse responses are especially large for a group which is composed of banking and finance, whole sale and retail, real estate,
This paper is related to two bodies of literature, the first of which is comprised of studies on the fiscal policy effectiveness under the ZLB. There have been a multitude of works regarding this topic: Ramey (2011), Ramey and Zubairy (2014), Morita (2015), Dupor and Li (2015), Bouakez et al. (2017), and Miyamoto et al. (2017), etc. Our paper is most closely related to Bouakez et al. (2017), which examines the effects of public investment on inflation, interest rate, GDP, and its components in a ZLB environment. However, none of these papers take into account stock market response, though some of them show that an increase in public investment induces an increase in private sector investment under the ZLB. When it comes to its effects on private investment, the reality may be that public investment has a positive impact on the stock market, which improves firm balance sheets, thereby enabling firms to undertake new projects. Therefore, we should examine the relationship between public investment and stock market response rather than the direct effects of public investment on firm’s investment. Our contribution to this field are the following: first, we show that public investment paves the way for the stock market to recover in the ZLB period, which is
indispensable to the aforementioned transmission path. Second, we demonstrate that public investment is detrimental to the stock market outside of the ZLB period. This comes in contrast with most previous works that find positive fiscal multipliers even in non-ZLB periods. From a theoretical perspective, negative hump-shaped responses to public investment shocks can be explained by the relationship between debt (and tax) policy rules and consumption externalities (habits), which induce the delayed behavior of stock returns as shown in Ravn et al. (2006) and Zubairy (2014). The results outside of the ZLB period can be explained by these works.

Our results imply that, whereas public investment should be included in economic stimulus packages in the ZLB period, it would be favorable for the government to curtail it once the economy has escaped the ZLB. This is supported by Glazer (2013), who states that the government should delay fiscal consolidation in a recession but pursue it in a boom from the viewpoint of economic welfare. However, as shown in Section 2, the reality is that the size of public stimulus investment was larger in non-ZLB periods in Japan. In this regard, fiscal expansion before the ZLB period in Japan might “reduce the ‘fiscal space’ for responding to the next crisis” (Krugman (2018)) such
as the ZLB economy.

Second, our paper is also related to studies that compare the effects of public investment on stock returns in different sectors. A recent work by Belo and Yu (2013) is a representative literature of this topic. They find a stronger impact for industries for which public capital is a relatively important input in the firm’s production technology. Contrary to their finding, our IRF's are larger for the non-manufacturing industries than for the manufacturing industries in the ZLB period. Our results are supported by two facts on the Japanese economy. First, goods and services in certain non-manufacturing industries such as advertising, transportation, information/communication, and entertainment/leisure tend to fluctuate in accordance with macroeconomic conditions (the Bank of Japan (BOJ), 1998). This implies that the non-manufacturing sector is more strongly affected by the expectation of an economic recovery than the manufacturing sector. Second, Miyagawa et al. (2013) show that the positive externality in the manufacturing industry is not as large as that of the non-manufacturing industry using Japanese data, which may lead to our empirical results.

The rest of this paper is organized as follows. Section 2 describes public investment and
stock price target policies in Japan. Section 3 presents the study’s empirical framework. Section 4 reports the estimation results. Section 5 concludes.

2. Background: Public infrastructure investment and stock target policy in Japan

2.1. Public investment and macro stabilization policy in Japan

As demonstrated by the word *doken-kokka* (“construction state”)\textsuperscript{5}, the Japanese government has injected a huge amount of money into public infrastructure. Figure 1 shows the movement of public investment (public capital formation) per GDP for six developed countries. This figure shows that Japan’s public investment to GDP ratio was the highest among said six countries until the mid-2000s. Although the government has been curtailing public investment since 2001, Japan is still among the top countries.\textsuperscript{6}

\textsuperscript{5} For details on the “construction state,” see [http://www.economist.com/node/11779435](http://www.economist.com/node/11779435).

\textsuperscript{6} Junichiro Koizumi’s cabinet (2001–2006) initiated public investment cutbacks as part of the so-called “structural reform of the government,” a fiscal consolidation achieved by decreasing government expenditures and privatizing public corporations. Further, the Democratic party-led coalition government (2009–2012) reduced public investment while attempting to increase welfare expenditures under the slogan “from construction to people.”
In Japan, public investment is often used as a tool for macroeconomic stabilization.

Unlike in most developed countries, fiscal policy has often been employed as a tool for macroeconomic stabilization in Japan even before the GFC. The government deployed fiscal stimulus packages as a supplementary budget (extra budget) almost every year in the 1990s: five times during the so-called “first Heisei recession” (1992-1995) following the burst of the asset price bubble and three times after Japan’s financial crisis (1997-1999). As shown in Figures 2a and 2b, public works (which is equivalent to public investment as defined in this study) comprised as much as 46% of total stimulus packages implemented in the former half of the 1990s. Though the share fell to less than 20% after Japan’s financial crisis, public investments were still included in the stimulus packages in the 1990s.

Public investment has been used as a stabilization policy tool for two reasons. First, as mentioned by Ishi (2000), most of Japan’s macroeconomics specialists and bureaucrats in charge of economic policy are so-called traditional Keynesians. Second, the Japanese

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7 For more details, please see also Miyazaki (2010) and Asako (2012).
8 We exclude the supplementary budget of April 1995 because its purpose was not to stimulate the economy but to aid relief efforts following the Great Hanshin-Awaji earthquake.
9 Since the government increased the funds for use in credit crunch measure in November 1998 and 1999 supplementary budget, the share of public investment was reduced in the latter half of the 1990s package.
government follows the “golden rule for public finance,” which allows the government to issue construction bonds. Article IV of the Public Finance Act approves bond issuance in the General Account (the Japanese central government’s budget) so as to finance public investments, but prohibits the government from issuing bonds to finance a deficiency of the budget. By issuing construction bonds, the government used public infrastructure investment to stimulate the economy in the 1990s.

2.2. Public stimulus investment and stock price targeting

The Japanese government has made use of economic stimulus packages not only to pump up the macroeconomy but also to reinvigorate the stock market since the 1990s. For example, Fukuda and Yamada (2011) argue that the stock price was used as an indicator for macroeconomic policy decisions, thus becoming a target for Japanese macro stabilization policy in the 1990s and the 2000s.

The stock price (or stock return) is indeed an important indicator for Japanese economic policy in terms of the effects on company’s financial statements, the activities

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10 As a matter of fact, the Japanese government has issued bonds to fill the gap between revenues and expenditures as well. This is called “special deficit-financing bonds,” which must be approved by the National Diet along with a law effective only for a year whenever the government seeks to issue.
of both financial and non-financial sectors, and shareholders. First, changes in the
stock price affect corporate performance: they directly influence a company’s balance
sheet and profit-loss statement because Japan uses current-value accounting. Second,
Japanese banks often hold the stocks of various companies regardless of industry type.
Needless to say, the changes in stock price affect banks’ lending behaviors, which also
leads to impact on business activities of non-financial corporations and hence
propagates business cycles. Finally, as mentioned in Fukuda and Yamada (2011),
Japanese politicians are pressured by their constituents, some of who are also
shareholders, to implement expansionary policies so as to halt the fall in asset prices.
These facts tell us that economic stimulus packages in Japan have been used for the
purpose of stock market resurgence. What is more, public investment shared a part of
these stimulus packages. In light of these factors, it is worthwhile investigating the
relationship between public investment and stock market response in Japan.
3. Empirical framework

To estimate the impact of public investment, first we calculate public investment shocks using Factor-Augmented VAR (FAVAR) estimation developed by Bernanke et al. (2005). Then, we estimate IRFs using the local projection method.

FAVAR enables us to extract the public investment shocks by applying principal component analysis to the VAR model while considering potential omitted variables as either slow-moving or fast-moving.\(^{11}\) We estimate factors (public capital, total factor productivity [TFP], and stock return of each industry) from a dataset containing quarterly macroeconomic time series for 27 industries used in Hiraga et al. (2017). We do this in order to extract common factors across industries.\(^{12}\) The industries considered here are shown in Table 1. Meanwhile, as mentioned in Morita (2014) and Shioji and Morita (2015), since stock prices in the construction industry tend to reflect current news on public investment expansion, this industry suffers from the endogeneity bias caused by the reverse causality mentioned in Section 1. Therefore, we

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11 Appendix 2 offers the details on our FAVAR estimation.

12 We could also utilize other macroeconomic variables such as money supply, exchange rate, interest rate, and tax revenues as in Hiraga et al. (2017). However, these macroeconomic variables should be added to the equation that calculates IRFs as independent variables in our estimation. Therefore, we do not use the procedure employed in Hiraga et al. (2017).
exclude the construction industry in isolating common factor across industries and calculating IRFs.

Following Bernanke et al. (2005), stock returns are the levels, while we take a logarithm difference of TFP and public capital because these two variables follow an I (1) process. TFP is our slow-moving variable and sectoral stock returns are our fast-moving variables. If public investment has a positive impact on stock returns, it may be explained by the path of public capital rather than that of public investment: public capital stock increases the marginal productivity of private enterprises via the channel of positive production externality, thereby raising stock returns. This would best be captured using public capital data. On the other hand, now that it is similar to public investments because we take first differences, we can call this shock “public investment shock.”

In light of these, using the public investment shocks, we estimate IRFs for each future period \( k \) with the following equation:

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13 TFP is aggregate-level data because sectoral TFP data is not available on a quarterly basis.
\[ R_{i,t+k} = a_i^k + \text{trend}^k + I_{t}^{ZLB} \times (\beta_{A,k} G\text{shock}_t + \sum_{j=1}^{t} \gamma_{A,j} R_{i,t-j} + \varphi_A(L)y_{t-1}) \]
\[ + (1 - I_{t}^{ZLB}) \times (\beta_{B,k} G\text{shock}_t + \sum_{j=1}^{t} \gamma_{B,j} R_{i,t-j} + \varphi_B(L)y_{t-1}) + \epsilon_{i,t}^k, \quad (1) \]

where \( R_{i,t} \) represents stock returns for industry \( i \) in period \( t \) (quarterly).\(^{14}\) \( I_{t}^{ZLB} \) is the dummy variable which takes 1 if the economy is in the ZLB at period \( t \) and 0 otherwise. We define the ZLB period to be after 1995 Q4, following Miyamoto et al. (2017). We use the indicator for current period, \( I_{t}^{ZLB} \), to capture the effects of the ZLB period. As long as public investment shocks are exogenous and we take the lagged values for other independent variables in Equation (1), there is no need to use the indicator for the former period (although Miyamoto et al. (2017) use \( I_{t-1}^{ZLB} \) following Ramey and Zubairy (2014), they also mention the results do not change even if \( I_{t}^{ZLB} \) is used). Therefore, we employ \( I_{t}^{ZLB} \) to address the effects of the ZLB period.\(^{15}\)

\(^{14}\) Equation (1) implicitly assumes stock markets are not efficient, suggesting that the efficient market hypothesis (EMH) is not valid and people can obtain extra profit from the market. Nagayasu (2003) showed that the EMH is not confirmed in the Japanese equity market. He also pointed out that, although the sample period (from January 1, 1990 to August 8, 2002) includes financial deregulation in Japan, there are inefficiencies in the Japanese equity market due to corporate cross-shareholding, price keeping operation policy by the Japanese government, and the restrictions on short-selling. Furthermore, some points do not contradict the arguments on the Japanese stock market in Section 2.2., and therefore our specification is plausible.

\(^{15}\) Ramey and Zubairy (2014) and Miyamoto et al. (2017) also added the ZLB dummy as an intercept dummy variable. We multiply \( I_{t}^{ZLB} \) by an industry fixed effect and make the variable \( a_i^k \times I_{t}^{ZLB} \), and estimate Equation (1) by adding \( I_{t}^{ZLB} \) as an intercept dummy and \( a_i^k \times I_{t}^{ZLB} \). The results do not change substantially (see Section 4.2). For more details, please see Appendix 4.
An industry fixed effect in each forecasting horizon $k$ is expressed as $\alpha_t^k$, $trend^k$ is a time trend, $Gshock_t$ is the public investment (public capital) shock, and $y_{t-1}$ is a vector of controls with a lag operator $\varphi_A(L)$ or $\varphi_B(L)$. In our specification, public investment (public capital) shock is plugged into the estimation equation as a “common shock” across the sectors as in the case of Belo and Yu (2013). Further, we add three control variables: TFP shock, the first difference of logarithm of monetary base ($M_t$), and the first difference of long-term interest rate ($r_t$). Since $R_{t+k}$ is stationary and both public investment and TFP shocks are derived by taking the first differences of public capital and TFP to make these two variables stationary, we also take the first difference for $M_t$ and $r_t$, which are non-stationary in a level specification. TFP shock addresses the productivity shocks that commonly affect all industries. Monetary base is used to capture the effects of monetary policy. Since government bonds are assumed to be an alternative to stock assets, the long-term interest rate controls for the effects of alternative assets. To check the robustness of the results, we also estimate the model

16 This prevent us from adding time dummy variables. Instead, we plug into time trend. We also estimate the model by adding $\alpha_t^* \times trend^k$ instead of common time trend so as to address the time trend specific to each industry. The results do not substantially change. The results can be shown in Appendix 4, which remains our conclusion and implications basically unchanged.
by adding net export and the logarithm of real effective exchange rate in Section 4.3.

Lag lengths for the dependent variable and three control variables are set to four, although the results are not substantially different using shorter or longer lag lengths.\(^\text{17}\) We also add seasonal dummy variables to control for seasonality.

The key parameters in Equation (1) are \(\beta_{A,k}\) and \(\beta_{B,k}\), representing the response of \(k\)-period-ahead stock returns with respect to a current public investment shock. We directly estimate Equation (1), and IRFs are obtained by plotting the estimated \(\beta_{A,k}\) and \(\beta_{B,k}\) for \(k=0, \ldots, 8\), with confidence bands computed using the standard deviations of estimated coefficients \(\beta_{A,k}\) and \(\beta_{B,k}\). Note that all coefficients in Equation (1) are separately estimated for each horizon \(k\).

In a standard local projection estimation, Equation (1) is estimated using least squares dummy variable (LSDV) with White (1980)'s robust standard errors. The presence of a lagged dependent variable and industry fixed effects may lead to a severe bias when the serial correlation of the dependent variables is high and the time-series dimension of the data is short (Nickell, 1981). Although the length of the time

\(^{17}\) We also check the robustness of the lag length by assuming the case with 3 or 5 periods lags. For more details, please refer to Appendix 4.
dimension (T=104) mitigates this concern, we also conduct a system GMM estimation
developed by Arellano and Bover (1995) and Blundell and Bond (1998) to check the
robustness in Appendix 5.

4. Empirical Results

4.1. Dataset

The sample period is from 1983 Q1 to 2008 Q4 in quarterly data. Data on stock
returns \((R)\) are drawn from the data of stock price earnings ratio provided by the
Japan Securities Research Institute. The original data on the stock price earnings ratio
is in the monthly rate. The number of industries is 27. All data are put into real terms
using the producer price index (PPI, base year=2005) provided by the BOJ. The
procedures are as follows. First, we calculate the annual rate of change of the PPI,
which is converted into quarterly data (the period average). We define this as our
inflation rate. Second, we calculate a quarterly average for the stock price earnings
ratio and annualize them. Finally, we deflate the annualized price earnings ratio using
the PPI inflation rate that we calculated before. We calculate TFP following Kamada and Masuda’s (2001) procedure, and details are shown in Appendix 3.

Public capital data came from the Cabinet Office in Japan (accessed last May 21, 2016). Official Cabinet Office data are annual and are expressed in 2005 terms. Therefore, we converted the original annual capital stock data into quarterly (initial value) data following the procedure employed by Kitasaka (1999) using the weight for each quarter calculated by the real general government gross capital formation data.\(^{18}\)

There are four ways to account for depreciation in public capital stock: the straight-line method, declining-balance method, and the two types of depreciation shown in the OECD’s (2009) method. We report the results using the data calculated by the straight-line method.\(^{19}\)

Monetary base (non-seasonally adjusted and average amounts outstanding, reserve requirement rate change-adjusted) and long-term interest rate (the yield of 10-year government bonds) data come from the BOJ’s website. Monetary base is expressed in real terms using the aforementioned monthly inflation rate based on the PPI.

\(^{18}\) For more details, please see Kitasaka (1999).

\(^{19}\) The results are not substantially changed using the data estimated by the rest of three methods.
4.2. Estimation results

Figures 3a and 3b plot the estimated IRFs of stock returns with respect to a public investment shock from periods 0 to 8 based on Equation (1). We also report the one standard error bands (dotted lines), where the horizontal axis measures quarter. The IRFs are the cumulative sum of stock returns.

Figures 3b shows that public investment shocks have a positive and stimulating effect on stock returns in the ZLB period. Figure 3a shows that for non-ZLB periods, stock returns react positively to public investment shocks in the short-run (< 3 periods ahead) but negatively in the long run (3+ periods ahead). Note that standard error bands do not contain 0 in periods 3 through 6.

We also compare effects between two industry groups as shown in Table 1: mining and manufacturing industries (number of cross sections=16) and non-manufacturing industries (number of cross sections =10). We further divide our non-manufacturing industry group into (a) transportation and communication group, consisting of land transport, shipping, air transport, warehousing, and information and communication,
and (b) the non-transportation and communication group, composed of wholesale and retail, finance, real estate, electrical and gas, and services. We do this because public capital may be more important an input in the production technology of companies classified into the transportation and communication group.

The results are shown in Figures 4a to 7b. Regarding the policy effects during the ZLB period, positive responses of stock returns are observed for all cases, and 0 is outside the region between the one-standard error bands from periods 0 to 6 for the non-manufacturing group. Further, the cumulative IRF of the non-manufacturing group is larger than that of the manufacturing group. In this regard, public investment is more effective at boosting stock returns in the non-manufacturing industry group than in the manufacturing industry group under the ZLB environment. In contrast, negative responses are still observed after period 3 for all industries outside of the ZLB period. That is, public investment has harmful effects on the stock market when the nominal interest rate is not near zero regardless of industry.

Our results suggest that public investment has a positive impact on stock returns in the ZLB period. The positive effects reflect the arguments of Belo and Yu (2013).
However, when it comes to outside of the ZLB period, we observe positive responses initially in some cases but negative responses dominate in all industries. Although it seems to be counterintuitive at first glance, this is consistent with the findings of some earlier empirical works on the relationship between fiscal policy and the stock market.\textsuperscript{20} In addition, as mentioned in Section 1, negative hump-shaped responses are consistent with the theoretical model developed by Ravn et al. (2006) and Zubairy (2014).

4.3. Robustness issues

To check the robustness of our results, we calculate IRFs under alternative frameworks. We report the results by focusing on their differences from those described in Section 4.2.\textsuperscript{21} The results are reported in Tables 2 to 4.

First, we re-estimate Equation (1) by adding the first difference of net exports and the first-differenced real effective exchange rate to address the effects of foreign factors.\textsuperscript{22}

\textsuperscript{20} Indeed, Afonso and Sousa (2009) demonstrate that public expenditure shocks have a negative impact on stock prices. Further, Ardagna (2009) shows that fiscal expansion driven by the rise in government debt aggravates stock prices.

\textsuperscript{21} Since our estimation reports massive number of figures of impulse response functions, we omit these figures for the sake of brevity. Instead, we present the results in tables. Graphs of the impulse response functions can be obtained from the author upon request.

\textsuperscript{22} Data on these variables were downloaded from the BOJ’s website.
The results are shown in Table 2. Unlike the results reported in Section 4.2, we confirm the negative and statistically significant response of stock returns with respect to public investment in non-ZLB periods. However, except for the transportation and communication industry group, we confirm positive and statistically significant responses until period 4 in the ZLB period.

Second, we add four-periods lag of $Gshock_t$ in Equation (1), following Teuling and Zubanov (2014). Table 3 shows that while we also confirm negative and significant results for all cases in the periods other than the ZLB, positive and statistically significant effects are observed until period 4 in the ZLB period in any case.

Finally, we recalculate $Gshock_t$ by focusing on infrastructure such as roads, airports, and port facilities instead of the aggregate public capital. We use aggregate public capital data because public capital can plausibly be considered a public good, as it is a non-excludable good that can affect the economic activities of industries. However, as infrastructure supports businesses, we also estimate its effects. According to Table 4, the results basically replicate the ones shown in Figures 3a to 7b.
5. Conclusion

This study examines the effects of public investment on stock returns using Japanese sectoral panel data covering 1983 Q2 to 2008 Q4, which includes the ZLB period. Japan's nominal interest rate has been in the ZLB for a long time and its government has used public investment with the aim to reinvigorate the stock market. These facts make Japan a suitable case for an examination of the relationship between public investment and the stock market in the ZLB economy. Our results using the local projection method show that, while public investment (public capital) shocks have positive and persistent effects on stock returns in the ZLB period, negative effects on stock returns dominate outside of the ZLB. This is especially true of the industry group consisting of services, financial institutions, wholesalers, and retailers, etc.

Policy implication drawing from our results between the ZLB period and others is that Japan’s fiscal policy was inappropriate for stock market resurgence. In Japan, the share of public investment within economic stimulus packages was smaller in the ZLB period than out of the ZLB as shown in Section 2. Furthermore, the Japanese
government has reduced public investment since 2001. On the other hand, stock prices rose from 2004 to 2008 in spite of public investment cuts even during the ZLB period. However, following our results, it may be fair to say that had the government not curtailed public investments in those periods, stock prices might have gone up further.

This study's analysis could be fruitfully extended in three ways. First, while we focus on the effects of public investment, it would also be possible to compare the effects with those of alternative policies to determine whether the public investment multiplier is greater. Second, we could also examine the effects of using firm-level data so as to compare the effects among more disaggregated industries like Nekarda and Ramey (2011). Finally, a recent paper by Ozdagli and Weber (2017) examine the stock market reaction with respect to monetary policy considering network effects or spillover effects. It is also possible to apply their framework to public investment as a fiscal stimulus.
Appendix 1. Theoretical explanation of supply-side effect of public capital on stock return

This appendix introduces public sector physical capital into the neoclassical q-theory model of investment following Belo and Yu (2013).

A.1. The setups

Firm technology is shown as follows:

\[ Y_t = e^{x_t}(GK_t)^{\alpha}K_t, \]  \hspace{1cm} (A.1)

where \( Y \) is output, \( GK \) is public sector physical capital, \( K \) is private capital, \( x_t \) is profitability shock (or productivity shock). Seminal parameter \( \alpha \) is the productivity (profitability) of public sector capital.

The accumulation processes of private and effective public capital are shown as Eq. (A.2) and (A.3):
\[ G_{t+1} = (1 - \delta)G_t + I_t, \]  
\[ GK_{t+1} = (1 - \delta)GK_t + GIK_t, \]

where \( GI_K \equiv GI_t / \bar{G}_K \) is the public sector investment rate, \( GI_t \) is the total investment in public sector capital, \( \bar{G}_K \) is the total stock of public sector capital and \( \delta^{GK} \) is the depreciation rate. The specification of Eq. (A.3) guarantees that the stock of effective public sector capital is stationary \(^{23}\), the adjustment cost of private capital

\[ g(I_t, K_t) = c \left( I_t / K_t \right)^2 K_t, \]

where \( I_K \equiv I_t / K_t \) is the private sector investment rate.

A.2. The firm’s maximization problem

Suppose that the firm is all-equity financed. Dividends \( D_t \) distributed by the firm to the shareholders are given by:

\(^{23}\) Assumption of stationary is necessary condition to derive the empirical predictions as effective stock of public sector capital is equal to detrended stock of total public capital.
\[ D_t = e^{x_t(GK_t)^\alpha K_t - l_t - \frac{c}{2} (IK_t)^2 K_t}. \]  

(A.5)

The cumulative dividend market value \( V^{\text{CUM}}(s_t) \) is shown as follows:

\[ V^{\text{CUM}}(s_t) = \max_{l_{t+j}, K_{t+j}} \{ E_t[\sum_{j=0}^{\infty} M_{t+j}^r D_{t+j}] \}. \]  

(A.6)

Subject to Eq. (A.2) and (A.3) for all dates \( t \). \( s_t = (K_t, GK_t, GIK_t, x_t) \) is the vector of state variables and \( M_{t+j}^r \) is a market–determined stochastic discount factor at period \( t \), which is used to value the cash flows arriving in period \( t+j \).

A.3. First-order conditions

We solve the maximization problem of Eq. (A.6). First order conditions with respect to \( l_t \) and \( K_{t+1} \) are as follows:

\[ q_t = 1 + c \cdot IK_t, \]  

(A.7)
\[ q_t = E_t \left[ M_{t,t+1} \left( e^{x_{t+1}}(GK_{t+1})^a + \frac{c}{2} (IK_t)^2 + (1 - \delta)(1 + c \cdot IK_t^2) \right) \right] . \]  

(A.8)

Combining Eq. (A.2), (A.3), (A.7), (A.8) and the standard asset pricing equation
\[ E_t[M_{t,t+1}R_{t+1}^l] = 1, \]
in which \( R_{t+1}^l \) is the private sector investment return, we obtain \( R_{t+1}^l \) as follows:

\[ R_{t+1}^l = \frac{e^{x_{t+1}}(GK_{t+1})^a + \frac{c}{2} (IK_t)^2 + (1 - \delta)(1 + c \cdot IK_t^2)}{1 + c \cdot IK_t} . \]  

(A.9)

Equation (A.9) explains the supply-side effect of public capital shown in the first term of the numerator. If \( \alpha \) is positive, stock return increases by a channel of positive production externality of public capital.

Appendix 2. Explanation of the FAVAR Model

Appendix 2 explains the econometric framework for the FAVAR model.\(^{24}\) Let \( Y_t \) be an \( M \times 1 \) vector of observable economic variables, where \( M \) is small. Although \( Y_t \) is used in

\(^{24}\) This section follows Bernanke et al. (2005).
a standard VAR, $Y_t$ alone does not provide sufficient economic information. We therefore assume that a $K \times 1$ vector of unobserved factors, where $K$ is small, provides this information. The joint dynamics of $(F_t, Y_t)$ are given by

$$
\begin{bmatrix}
F_t \\
Y_t
\end{bmatrix} = \Phi(L) \begin{bmatrix}
F_{t-1} \\
Y_{t-1}
\end{bmatrix} + u_t,
$$

(A.10)

where $\Phi(L)$ is a matrix of polynomials of finite order $d$ and the error term $u_t$ is the mean 0 with covariance matrix $\Sigma$.

There is apparently little difference between a standard VAR and the FAVAR. However, Equation (A.10), which is a FAVAR, cannot be estimated because the factors are unobservable. We must therefore assume that the factors affect a large number of variables to estimate Equation (A.11). This assumption allows us to infer the unobservable factors from these economic time series variables. Let $X_t$ be an $N \times 1$ vector of informational economic variables, where $N$ is large, such that $K + M << N$.\footnote{As Bernanke et al. (2005) point out, it is acceptable for $N$ to be greater than $T$.} We also assume that $X_t$ is related to both the unobservable factors vector $F_t$ and the observable variables...
factors vector $Y_t$, given as follows:

$$X_t = \Lambda^F F_t + \Lambda^Y Y_t + e_t,$$  \hspace{1cm} (A.11)

where $\Lambda^F$ and $\Lambda^Y$ are the $N \times K$ and $N \times M$ matrices of factor loadings, respectively, and $e_t$ is an $N \times 1$ vector of the error terms, which is weakly correlated with the mean 0.

For the estimation, we follow the two-step approach of Bernanke et al. (2005).\textsuperscript{26} This means we identify $F_t$ in the first step and estimate Equation (A.10) in the second. Specifically, we perform the following procedures in the first step. Initially, the common components, $C_t$, are estimated using the first $K + M$ principal components of $X_t$. In the second step, following Bernanke et al. (2005), the variables are classified as slow-moving or fast-moving. Slow-moving variables are those predetermined in the current period, such as output and employment. Fast-moving variables are those sensitive to contemporaneous economic news or shocks, such as asset prices. Next, a principal

\textsuperscript{26} Although Bernanke et al. (2005) estimate the FAVAR using the two-step approach and a Bayesian method based on Gibbs sampling, they suggest that the two-step approach tends to produce more plausible responses.
component analysis is applied to the slow-moving variables to derive a vector of slow-moving factors, $F_S^t$. Finally, the following regression is estimated:

$$\hat{C}_t = b_F s \hat{F}_t^S + b_Y Y_t + e_t, \quad (A.12)$$

where the estimated factors, $\hat{F}_t$, are obtained from $\hat{C}_t - b_Y Y_t$. In the second stage, we estimate the VAR in $\hat{F}_t^S$, which is a vector of estimated moving factors and $Y_t$, and compute the impulse response function using a Choleski decomposition.

**Appendix 3. Calculation of potential GDP**

In order to obtain the total factor productivity (TFP) in Japan, we have to calculate the Solow residual without measurement error. In this study, we employ the production function approach. The Economic Planning Agency (2000), Miyao (2001) and Kamada and Masuda (2001) utilize the method of calculation based on the Solow residual derived from Cobb–Douglas-type production functions. Here, we follow the methods
proposed in Kamada and Masuda (2001). Table A.1. presents the source of the data.

First, we denote real GDP as \( Y_t \), capital stock as \( K_t \), total labor hours (working population \( \times \) working hours) as \( L_t \), Solow residual as \( A_t \), operating ratio of capital as \( \hat{\lambda} \), and the coefficient labor input as \( \alpha \). The parameter \( \alpha \) is defined as \((\text{Compensation of employees})/(\text{total income})\) assuming perfect competition. The production function is then

\[
\ln Y_t = \ln \hat{A}_t + (1 - \alpha) \ln \hat{\lambda} K_t + \alpha \ln L_t . \tag{A.13}
\]

The real GDP and capital stock are 93 SNA in the Annual Report on National Accounts. The industry consists of manufacturing and non-manufacturing sectors, and \( \ln \hat{\lambda} K_t \) can be written as

\[
\ln \hat{\lambda} K_t = \ln (\hat{\lambda}_{m} K_{m} + \hat{\lambda}_{nm} K_{nm}) \tag{A.14}
\]

Here, \( m \) indicates the manufacturing industry and \( nm \) the non-manufacturing
industry. The data of operating ratio of capital in manufacturing industries can be utilized, and we standardize the highest value as 100%. However, we must consider the \( \lambda_{nm} \) because we cannot obtain this kind of data in Japan. Although some previous studies assumed that the operating ratio in non-manufacturing industries is always 100%, this is indefensible. In order to calculate the operating ratio of non-manufacturing industries, Miyao (2001) uses the Business Survey Index (BSI) as a simplified method.\(^{27}\) We set the peak of BSI as 100% of the operation ratio.

Then, the Solow residual (\( \ln \bar{A}_t \)) is calculated as follows:

\[
\ln \bar{A}_t = \ln Y_t - (1 - \alpha) \ln \lambda K_t - \alpha \ln L_t
\]  
(A.15)

Here, we regard the Solow residual as the TFP.

**Appendix 4. Additional estimation for Equation (1)**

In addition to the robustness check shown in Section 4.3, we estimate Equation (1)

\(^{27}\) In Kamada and Masuda (2001), the consumption of electric power is also considered in calculating the rate of operation.
using alternative frameworks further.\textsuperscript{28}

First, we estimate Equation (1) by changing the lag length as 3 or 5. Second, we also estimate the model by adding $\alpha_t^k \cdot trend^k$ instead of common time trend so as to address the time trend specific to each industry. Third, we multiply $I_t^{ZLB}$ by an industry fixed effect and make the variable $\alpha_t^k \cdot I_t^{ZLB}$, and estimate Equation (1) by adding $I_t^{ZLB}$ as an intercept dummy and $\alpha_t^k \cdot I_t^{ZLB}$. This is done because Ramey and Zubairy (2014) and Miyamoto et al. (2017) also added the ZLB dummy as an intercept dummy variable. Finally, we reestimate Equation (1) by limiting the sample periods after the 1991. This is done in order to remove the effects of asset price bubble periods from the late 1980s to the early 1990s, when the volatility of stock returns was large.

The results are shown in Table A2. As reported in this table, while the responses of stock return with respect to public investment shock are positive in the ZLB period, they are estimated to be negative and significant outside of the ZLB as shown in Figures 3a and 3b. Therefore, our basic conclusion is supported.

\textsuperscript{28} We report the results of the case that all 27 industries are used for cross section sample. The results of categorizing these industries into several groups can be available from the author upon request.
Appendix 5. System GMM estimation

To address potential bias due to the serial correlation of the dependent variables mentioned in Section 3, we also estimate Equation (1) using system GMM estimation. Basically, system GMM estimation should be conducted by the level specification. Further, the null hypothesis of serial correlation test is rejected when the lag length is set as 4 and we conduct our estimation shown in Equation (1). Therefore, when we implement system GMM estimation, we do not multiply ZLB dummy except $G_{shock_t}$. Thus, the estimation equation in GMM estimation is as follows.

$$
R_{i,t+k} = \alpha_i^k + trend^k + \beta_k \cdot G_{shock_t} + \beta'_k \cdot D_t^{ZLB} \cdot G_{shock_t} + \sum_{j=1}^{l} y_j^k \cdot R_{i,t-j} \\
+ \sum_{j=1}^{l} \delta_j^k \cdot TFP_{shock,t-j} + \sum_{j=1}^{l} \theta_j^k \cdot M_{t-j} + \sum_{j=1}^{l} \varphi_j^k \cdot R_{t-j} + \epsilon_{i,t}^k
$$ (A.16)

The results are shown in Table A3. Regarding non-manufacturing industry, we confirm a positive and significant response of stock return for on impact, period 4, and period 8 in the ZLB period. In addition to this industry group, the IRFs are estimated to be positive and significant until period 4 when the nominal interest rate has been close to
zero. In this regard, we can confirm the results by LSDV with regard to the policy effects in the ZLB. On the other hand, although negative responses of stock return with respect to public investment shock are basically observed outside of the ZLB, public investment shock has positive and statistically significant effect on stock return on impact as for transportation and communication industry group.

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Fiscal News for Japan.” Papers presented at EEA 30th Annual Congress.
Forecast?” *Journal of Money, Credit and Banking* 39:1, 3-33.


Direct Test for Heteroskedasticity.” *Econometrica* 48:4, 817-838.

Zubairy, S. (2014)” On Fiscal Multipliers: Estimates from a Medium Scale DSGE
Figure 1. Government gross capital formation per GDP among some developed countries

Source: OECD Economic Outlook
Figure 2a. The Content of Fiscal Stimulus Packages in the Former Half of the 1990s

Note: The source of numbers for both figures come from Brückner and Tuladhar (2014). The “Other government investment” category includes investment in fields such as science and technology, education and social welfare, alternative energy and the environment, and natural disaster relief. Further, we exclude the supplementary budget in April 1995 to be compatible with the arguments in Section 2.1.
Figure 3a: IRF of stock returns with respect to public investment (public capital) shock outside of the ZLB period

Note: The solid line indicates the estimated response, and the dotted lines represent the one standard error bands.

Figure 3b: IRF of stock returns with respect to public investment (public capital) shock in the ZLB period

Note: The solid line indicates the estimated response, and the dotted lines represent the one standard error bands.
Figure 4a: IRF of stock returns with respect to public investment (public capital) shock outside of the ZLB period (Manufacturing industry group)

Note: The solid line indicates the estimated response, and the dotted lines represent the one standard error bands.

Figure 4b: IRF of stock returns with respect to public investment (public capital) shock in the ZLB period (Manufacturing industry group)

Note: The solid line indicates the estimated response, and the dotted lines represent the one standard error bands.
Figure 5a: IRF of stock returns with respect to public investment (public capital) shock outside of the ZLB period (Non-manufacturing industry group)

Note: The solid line indicates the estimated response, and the dotted lines represent the one standard error bands.

Figure 5b: IRF of stock returns with respect to public investment (public capital) shock in the ZLB period (Non-manufacturing industry group)

Note: The solid line indicates the estimated response, and the dotted lines represent the one standard error bands.
Figure 6a: IRF of stock returns with respect to public investment (public capital) shock outside of the ZLB period (Transportation and communication group)

Note: The solid line indicates the estimated response, and the dotted lines represent the one standard error bands.

Figure 6b: IRF of stock returns with respect to public investment (public capital) shock in the ZLB period (Transportation and communication group)

Note: The solid line indicates the estimated response, and the dotted lines represent the one standard error bands.
Figure 7a: IRF of stock returns with respect to public investment (public capital) shock outside of the ZLB period (Non-transportation and communication group)

Figure 7b: IRF of stock returns with respect to public investment (public capital) shock in the ZLB period (Non-transportation and communication group)

Note: The solid line indicates the estimated response, and the dotted lines represent the one standard error bands.
Table 1. Details about the industries

<table>
<thead>
<tr>
<th>Broad category</th>
<th>Small classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishery and agriculture</td>
<td></td>
</tr>
<tr>
<td>Mining</td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Food, fiber, pulp and paper (paper), chemical, petro-coal (petro), rubber, glass, steel, non-steel, metal, machine, electrical equipment, transportation machine, precision mechanical, and other machines</td>
</tr>
<tr>
<td>Non-manufacturing</td>
<td>a. Transportation and communication group = land transport, shipping, air transport, warehousing, information and communication.</td>
</tr>
<tr>
<td></td>
<td>b. Non-transportation and communication group = wholesale and retail, finance, real estate, electrical and gas, and services</td>
</tr>
</tbody>
</table>

Note: The number of industries is in the parentheses.
Table 2. IRF of the case adding two variables related to foreign factors

<table>
<thead>
<tr>
<th></th>
<th>On impact (Horizon 0)</th>
<th>Horizon 4</th>
<th>Horizon 8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.237 *</td>
<td>-0.232 *</td>
<td>0.070</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.368 *</td>
<td>0.582 *</td>
<td>-0.028</td>
</tr>
<tr>
<td><strong>Manufacturing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.233 *</td>
<td>-0.275 *</td>
<td>0.097</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.328 *</td>
<td>0.477 *</td>
<td>-0.079</td>
</tr>
<tr>
<td><strong>Non-manufacturing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.226 *</td>
<td>-0.185 *</td>
<td>-0.025</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.424 *</td>
<td>0.702 *</td>
<td>0.057</td>
</tr>
<tr>
<td><strong>Transportation &amp; communication</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.184 *</td>
<td>-0.177 *</td>
<td>-0.038</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.356 *</td>
<td>0.678</td>
<td>0.155</td>
</tr>
<tr>
<td><strong>Non-transportation &amp; communication</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.268 *</td>
<td>-0.186 *</td>
<td>-0.015</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.500 *</td>
<td>0.724 *</td>
<td>-0.386</td>
</tr>
</tbody>
</table>

* indicates that 0 is outside the region between the one-standard error bands. “Non-ZLB” indicates the outside of the ZLB period, and “ZLB” means when the short-term nominal interest rate has been stuck at the ZLB.
Table 3. IRF of the case that the lag length of $Gshock_t$ is also set as 4

<table>
<thead>
<tr>
<th></th>
<th>On impact (Horizon 0)</th>
<th>Horizon 4</th>
<th>Horizon 8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.136 *</td>
<td>-0.426 *</td>
<td>-0.384 *</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.191 *</td>
<td>0.898 *</td>
<td>0.092</td>
</tr>
<tr>
<td><strong>Manufacturing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.120 *</td>
<td>-0.379 *</td>
<td>-0.258</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.092 *</td>
<td>0.741 *</td>
<td>-0.070</td>
</tr>
<tr>
<td><strong>Non-manufacturing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.158 *</td>
<td>-0.510 *</td>
<td>-0.603</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.345 *</td>
<td>1.180 *</td>
<td>0.300</td>
</tr>
<tr>
<td><strong>Transportation &amp; communication</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.160 *</td>
<td>-0.462 *</td>
<td>-0.542</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.224 *</td>
<td>1.088 *</td>
<td>0.460</td>
</tr>
<tr>
<td><strong>Non-transportation &amp; communication</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.155 *</td>
<td>-0.567 *</td>
<td>-0.686</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.479 *</td>
<td>1.324 *</td>
<td>0.109</td>
</tr>
</tbody>
</table>

*Note: A* indicates that 0 is outside the region between the one-standard error bands. “Non-ZLB” indicates the outside of the ZLB period, and “ZLB” means when the short-term nominal interest rate has been stuck at the ZLB.
Table 4. IRF of the case when G is limited to infrastructures

<table>
<thead>
<tr>
<th>All</th>
<th>On impact (Horizon 0)</th>
<th>Horizon 4</th>
<th>Horizon 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-ZLB</td>
<td>-0.105 *</td>
<td>-0.664 *</td>
<td>-0.472 *</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.131 *</td>
<td>1.007 *</td>
<td>0.570 *</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Manufacturing</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-ZLB</td>
<td>-0.066 *</td>
<td>-0.621 *</td>
<td>-0.377</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.049</td>
<td>0.816 *</td>
<td>0.417</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-manufacturing</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-ZLB</td>
<td>-0.152 *</td>
<td>-0.753 *</td>
<td>-0.651 *</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.247 *</td>
<td>1.140 *</td>
<td>0.637</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transportation &amp; communication</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-ZLB</td>
<td>-0.140 *</td>
<td>-0.731 *</td>
<td>-0.639</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.199 *</td>
<td>1.181 *</td>
<td>0.819</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-transportation &amp; communication</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-ZLB</td>
<td>-0.155 *</td>
<td>-0.770 *</td>
<td>-0.669</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.294 *</td>
<td>1.396 *</td>
<td>0.729</td>
</tr>
</tbody>
</table>

Note: * indicates that 0 is outside the region between the one-standard error bands. “Non-ZLB” indicates the outside of the ZLB period, and “ZLB” means when the short-term nominal interest rate has been stuck at the ZLB.
Table A1. Source of the data on TFP

<table>
<thead>
<tr>
<th>Data</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>of Employees, and Total Income</td>
<td></td>
</tr>
<tr>
<td>Capital Stock</td>
<td>Capital Stock on Private Sector (93SNA) with adjustment for privatization, Cabinet Office</td>
</tr>
<tr>
<td>Working Population</td>
<td>Labor Force Survey (for all industries), Ministry of Internal Affairs and Communication</td>
</tr>
<tr>
<td>Working Hours</td>
<td>Monthly Labor Survey (All Industries, companies with more than 30 employees), Ministry of Health, Labor and Welfare</td>
</tr>
<tr>
<td>Business Survey Index</td>
<td>Business Survey Index for Capital Investment (Large Company, Non-manufacturing), Ministry of Finance</td>
</tr>
<tr>
<td>Operating Ratio of Capital</td>
<td>Indices of Operating Ratio of Manufacturing (1995= 100), Ministry of Economics, Trade and Industry</td>
</tr>
<tr>
<td>Maximum Working Population</td>
<td>We separate the population into two categories: (1) from 15 to 64 years old and (2) more than 65 years old. Then, we adjust the linear</td>
</tr>
<tr>
<td></td>
<td>trend of the working population to the peak of original data for each category, and we total these two adjusted linear trends.</td>
</tr>
<tr>
<td>Maximum Working Hours</td>
<td>(In designed hours) We separate three samples: (1)1978 Q1–1987 Q4 (2)1988 Q1–1993 Q4 (3)1994 Q1–1997 Q3. And for each sample, we</td>
</tr>
<tr>
<td></td>
<td>calculate the linear trend and adjust it to the peak of the original data.</td>
</tr>
<tr>
<td></td>
<td>(Out of designed hours) We adjust the linear trend of working hours to the peak of the original data. Then we total these two adjusted</td>
</tr>
<tr>
<td></td>
<td>linear trend.</td>
</tr>
</tbody>
</table>

55
Table A2. IRF based on some additional estimations for Equation (1)

<table>
<thead>
<tr>
<th></th>
<th>On impact (Horizon 0)</th>
<th>Horizon 4</th>
<th>Horizon 8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>lag=3 for X</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.086 *</td>
<td>-0.525 *</td>
<td>-0.353 *</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.101 *</td>
<td>0.855 *</td>
<td>0.517 *</td>
</tr>
<tr>
<td><strong>lag=5 for X</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.117 *</td>
<td>-0.657 *</td>
<td>-0.267 *</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.158 *</td>
<td>0.936 *</td>
<td>0.304</td>
</tr>
<tr>
<td><strong>trend*Fixed</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.107 *</td>
<td>-0.641 *</td>
<td>-0.434 *</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.140 *</td>
<td>1.010 *</td>
<td>0.575</td>
</tr>
<tr>
<td>*<em>I_{ZLB}<em>Fixed</em></em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.110 *</td>
<td>-0.638 *</td>
<td>-0.422 *</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.159 *</td>
<td>0.982 *</td>
<td>0.496 *</td>
</tr>
<tr>
<td><strong>After the 1990s</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.150 *</td>
<td>-0.692 *</td>
<td>0.018</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.152 *</td>
<td>0.951 *</td>
<td>0.025</td>
</tr>
</tbody>
</table>

*Notes: Number of cross section is all 28 industries. A * indicates that 0 is outside the region between the one-standard error bands. “Normal” indicates the outside of the ZLB period, and “ZLB” means when the short-term nominal interest rate has been stuck at the ZLB.*
Table A3. IRF based on GMM estimation

<table>
<thead>
<tr>
<th></th>
<th>On impact (Horizon 0)</th>
<th>Horizon 4</th>
<th>Horizon 8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.021</td>
<td>-0.291 *</td>
<td>-0.032</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.118 *</td>
<td>0.434 *</td>
<td>0.266</td>
</tr>
<tr>
<td><strong>Manufacturing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.014</td>
<td>-0.255 *</td>
<td>-0.055</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.158 *</td>
<td>0.936 *</td>
<td>0.304</td>
</tr>
<tr>
<td><strong>Non-manufacturing</strong></td>
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<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.064 *</td>
<td>-0.379 *</td>
<td>-0.207</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.206 *</td>
<td>0.741 *</td>
<td>0.652 *</td>
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<td><strong>Transportation &amp; communication</strong></td>
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<td></td>
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<tr>
<td>Non-ZLB</td>
<td>0.102 *</td>
<td>-0.202</td>
<td>0.032</td>
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<tr>
<td>ZLB</td>
<td>0.125 *</td>
<td>0.583 *</td>
<td>0.374</td>
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<td><strong>Non-transportation</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Non-ZLB</td>
<td>-0.022</td>
<td>-0.248 *</td>
<td>-0.142</td>
</tr>
<tr>
<td>ZLB</td>
<td>0.171 *</td>
<td>0.516 *</td>
<td>0.464</td>
</tr>
</tbody>
</table>

*Note:* *A* indicates that 0 is outside the region between the one-standard error bands. “Normal” indicates the outside of the ZLB period, and “ZLB” means when the short-term nominal interest rate has been stuck at the ZLB.