Stock Market Response to Public Investment under the Zero Lower Bound: Cross-industry Evidence from Japan ♦

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This research examines the effects of public investment on stock returns using Japanese cross-industry data. 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 impulse responses for the non-manufacturing industries are larger than those of the manufacturing industries. Our results imply that the government should increase public investment under the zero-interest bound to prop up the stock market but cut back once the economy is no longer in a liquidity trap.

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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. (Eichengreen 2016)[1]

1. Introduction

Since the global financial crisis (GFC), several 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, many economists, including Eichengreen (2016), underscore the effectiveness of public investment to spur private sector investment, arguing that crowding out effects are not likely to occur given extremely low interest rates. However, the reality is that public investment has a positive impact on the stock market first.

[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.

Afterward, it improves firm balance sheets, enabling firms to embark on further investments. That is why the stock market, whose participants are forward looking, immediately responds to the announcement or implementation of public investment projects, even though the productivity effect of public capital appears in the future. Therefore, the relationship between public investment and stock market response is worth investigating, not just the direct effect of public investment on private investment. To the best of our knowledge, however, the relationship between public investment and the stock market during the ZLB period remains underexplored.[2]

The purpose of this study is to examine the effect of public investment on the stock market between the non-ZLB and ZLB periods using Japanese sectoral panel data. To do this, we calculate impulse response functions (IRFs) using the local projection method developed by Jordà (2005) and Stock and Watson (2007). Studies in Japan have two advantages over those

[2] As stated later, 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 of this paper summarizes their theoretical foundation. When it comes to the research using Dynamic Stochastic General Equilibrium (DSGE) model, for instance, Mumtaz and Theodoridis (2017) investigate the effects of fiscal policies on stock prices in the US; however, while Mumtaz and Theodoridis (2017) address the changes in the policy stance from passive to active (and vice versa), they do not compare the policy effects between the ZLB periods and others.

in other countries. First, there is ample data on the ZLB period in Japan because the nominal interest rate has been near the ZLB since the late 1990s. Second, the Japanese government has used public investment in a bid to bolster the sluggish stock market even before the short-term interest rate became close to zero.

We use a quarterly panel of returns on common stocks (hereafter, stock returns) on 27 industries.[3] We adopt the former because stock return is usually considered stationary whereas stock price/index is not. We use sectoral panel data for two reasons. First, policy effects may be different among sectors. For example, the manufacturing industry benefits substantially from the production of infrastructures such as roads, water and sewer systems, etc. However, the services and banking sectors do not seem to benefit much. Second, we can avoid the problem of reverse causality running from the stock price index to public investment policies, which can occur in an analysis that uses aggregate data. In general, the government decides public investment policies based on a representative stock price index such as the Nikkei 225 or the S&P 500. We mitigate concerns for reverse causality using

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[3] This is calculated by the equation $\left(\frac{Income\ gain_t + Capital\ gain_t}{Stock\ Price_{t-1}}\right) \times 100$ (%). Note that our stock return data covers common stocks (or stocks other than preferred stocks).

sectoral panel data.

Our main findings are as follows. First, public investment (public capital) shocks have a stimulating effect on stock returns in the ZLB period, but not outside. Second, the estimated impulse response for the manufacturing industry is a little bit larger than that of non-manufacturing industries during the ZLB period. We check the robustness of our findings under alternative model specifications; changing the lag length of public investment shocks, using a second indicator to calculate public investment shocks, and adding the dummy variable that takes the value of 1 during the asset bubble periods yield similar findings. By comparing policy effects between the manufacturing and non-manufacturing industries, we were able to confirm that the manufacturing industry responded positively to public investment shocks regardless of how the model was specified under the ZLB environment. However, the effects on non-manufacturing industries are not robust. The principal implication of our results is that, whereas public investment should be included in economic stimulus packages in the ZLB period to achieve stock market resurgence, it would be favorable for the government to curtail it once the economy has escaped the ZLB.

This paper is related to two bodies of literature. The first deals with fiscal policy effectiveness under ZLB. There have been a multitude of theoretical and empirical works on the fiscal policy effectiveness under the ZLB: Christiano et al. (2011), Eggertsson (2011), Woodford (2011), Ramey (2011), Auerbach and Gorodnichenko (2013), Dupor and Li (2015), Bouakez et al. (2017), Bilbiie et al. (2018), Miyamoto et al. (2018), Ramey and Zubairy (2018), and Bouakez et al. (2019), etc. Above all, a recent paper by Bouakez et al. (2017) 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 the effect on the stock market, which public investment affects first as we mentioned earlier. In this regard, our contribution to this field is to fill the gap between the extant studies and the realistic transmission path of public investment that leads the way to economic recovery.

Second, our paper is also related to the literature regarding the effects of public investment on firm activities such as: Aschauer (1989), Pereira and Roca-Sagales (2001), Boscá et al. (2002), Pereira and Andraz (2003), Annala et al. (2008), Afonso and Aubyn (2009), Hatano (2010), Hunt (2012), Belo and Yu (2013), Fujii et al. (2013), Miyazaki (2018), and Wu et al. (2019). Much work examines how the positive externality of public capital stimulates the private enterprise capital formation. But surprisingly little work explores how it can energize the stock market; a paper by Belo and Yu (2013) is the only exception, which examines the effects of public investment on stock returns in different sectors. However, they did not compare the effects between the ZLB period and others. Hence, we can differentiate ourselves by utilizing the long ZLB experience in Japan.

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")[4], 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.[5]

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:

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[4] For details on the "construction state," see *the Economist* (2008, https://www.economist.com/asia/2008/07/23/this-is-japan).

[5] 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.

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).[6] 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 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.[7] By issuing construction bonds, the government used public infrastructure

[6] 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.

[7] As a matter of fact, the Japanese government has issued bonds to fill the gap between revenues and

investment to stimulate the economy.

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. The stock price is indeed an important indicator for Japanese economic policy in terms of the effects on company's financial statements, the activities 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.

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.

Finally, as mentioned in Fukuda and Yamada (2011), Japanese politicians are pressured by their constituents, some of whom 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

3.1. Outline and the procedure to extract policy shocks

To examine the impact of public investment, first we calculate public investment shocks using factor-augmented VAR (FAVAR) estimation. Then, we calculate IRFs using the local projection method. Local projection has several 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.

We use the public capital data rather than investment data to extract policy shocks.[8] 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 through 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 also call this shock "public investment shock."

We calculate public investment shocks using FAVAR estimation developed by Bernanke et al (2005). Appendix 1 offers the details on our FAVAR estimation and how to extract public investment shocks. FAVAR has the advantage of being able to identify the public investment shocks because it enables us to extract the policy shocks by applying principal component

[8] Whereas we basically use aggregate public capital data, we also examine the effects of infrastructure capital to check the robustness of the results in Section 4.3. This is why infrastructure such as roads, airports, and port facilities have direct effect on firms' economic activities. However, while the sectoral data is available within the Japanese public capital data, public investment (government capital formation) data of the Systems of National Account, which has been frequently used, does not offer each item of the government investment. In this sense, it is also favorable to use the public capital data.

analysis to the VAR model while considering various potential factors as either slow-moving or fast-moving. We calculate the standard error of the estimated coefficients used to calculate our IRFs by bootstrap replications to address the problem of generated regressor.

To extract the shocks, we estimate using quarterly macroeconomic time series data for public capital, tax revenues, total factor productivity (TFP), and aggregate (sector average) and sectoral stock returns. TFP is added to control for the supply-side factors of the stock market, and we account for intertemporal government budget constraints by including tax revenues following Owyang and Zubairy (2013). We also include the stock return of 27 industries that we would like to focus on our paper. We do this in order to extract common factors across industries.[9] The industries considered here are shown in Table 1.

Stock returns are in levels, while we take the logarithm difference of TFP, tax revenues, and public capital because these three variables follow an I (1) process. Slow-moving variables in FAVAR estimation are those predetermined in the current period, such as

[9] We could also utilize other macroeconomic variables such as GDP, exchange rate, interest rate, and the factors related with labor market as in Hiraga et al. (2018). 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. (2018).

output and employment. Following this, the slow-moving variables are TFP, tax revenues, and public capital. Although we also use these variables as the observable economic variables for our FAVAR estimation, they are employed as part of the slow-moving variables in FAVAR estimation like Bernanke et al. (2005), Shibamoto (2007), and Fujii et al. (2013).[10] Fast-moving variables are those sensitive to contemporaneous economic news or shocks, such as asset prices. In this regard, aggregate and sectoral stock returns are used as our fast-moving variables.[11] As mentioned in Morita (2014), Shioji and Morita (2015), Shioji (2017), and Kanazawa (2018), 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. Therefore, we exclude the construction industry in isolating common factor across industries and calculating IRFs.

Regarding policy shocks, we could also use the method based on Fischer and Peters (2010) or Miyamoto et al. (2018). Since we use sectoral data unlike the two studies, it is favorable

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[10] As discussed later, we also check the robustness of the results by adding the sectoral firm investment per unit of capital stock and sectoral deflators to the group of slow-moving variables. The results are shown in Appendix 4 of this paper. The main results and implications remain to be the same, although the IRFs become a little bit smaller than that of our basic specification.

[11] Note that TFP is aggregate-level data because sectoral TFP data is not available on a quarterly basis.

for us to utilize the information of as many industries as possible. The method developed by Fischer and Peters (2010) uses the stock returns of related industries; Shioji and Morita (2014), Shioji (2017), and Kanazawa (2018) apply this method to examine the effectiveness of Japanese fiscal policy using information on construction companies. However, unlike the method developed by Fischer and Peters (2010), which focuses on one or two industries directly affected by a public expenditure, our strategy enables us to capitalize information on a broad range of industries.[12] In this respect, our method is better suited to extract policy shocks in sectoral panel estimation.

We can also employ variables such as sectoral investment or the deflators among industries as common factors. However, the Japan Securities Research Institute, which provided the stock returns data, only offers data on sectoral stock returns. Although there are other institutions that have data on sectoral investments and deflators, their classification of industries is different from that used by the Japan Securities Research Institute. This

[12] We also estimate the model by using the shock calculated by Kanazawa (2018), which utilizes news shocks from the excess return of road pavement firms; whereas the implications drawing from the results are unchanged, the estimated IRFs are not as stable as our basic specification. The detailed results are shown in Appendix 5 of this paper.

makes it harder for us to use these data with the stock return data with full confidence.[13]

3.2. Estimation equation of impulse response functions

Using the public investment shocks, we first estimate Equation (1) for each future period k following Miyamoto et al. (2018) and Ramey and Zubairy (2018):

$$R_{i,t+k} = I_t^{ZLB} \times (\alpha_{A,i}^k + \beta_{A,k} Gshock_t + \sum_{j=1}^{l} \gamma_{A,j}^k R_{i,t-j} + \varphi_A(L) y_{t-1})$$
$$+ (1 - I_t^{ZLB}) \times (\alpha_{B,i}^k + \beta_{B,k} Gshock_t + \sum_{j=1}^{l} \gamma_{B,j}^k R_{i,t-j} + \varphi_B(L) y_{t-1}) + \varepsilon_{i,t}^k, \qquad (1)$$

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. (2018).

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[13] As a robustness check, we also estimate the model that has these variables included in the common factors as mentioned before.

[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.

An industry fixed effect in each forecasting horizon k is expressed as α_{Ai}^{k} or α_{Bi}^{k}, $Gshock_t$ is the public investment shock, and y_{t-1} is a vector of controls with a lag operator $\varphi_A(L)$ or $\varphi_B(L)$. $Gshock_t$ is the structural public investment shock, which is calculated using the Cholesky decomposition as shown in Appendix 2. 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).[15] Meanwhile, as said, since a problem of generated regressor may be worried, we calculate the standard error by 2000 bootstrap replications. Further, we add three control variables: TFP shock, the first difference of GDP (Y_t), the first difference of real effective exchange rate (e_t), the first difference of unemployment rate (E), and the level of long-term interest rate (r_t). Since $R_{i,t+k}$ 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. Also, r_t is stationary in a level specification. To be consistent with these variables, we also take the first difference for Y_t, e, and E_t, which are non-stationary in a level specification. The TFP

[15] This prevents us from adding time dummy variables. Furthermore, since $R_{i,t+k}$ is stationary, we avoid adding time trend to our estimation equation.

shock encompasses the productivity shocks that are common across industries. GDP, real effective exchange rate, and unemployment rate are used to capture macroeconomic fluctuations. Since government bonds are assumed to be an alternative to stock assets, the long-term interest rate controls for the effects of alternative assets. Lag lengths for the lagged dependent variable and five control variables are set to four, following many previous studies using local projection method such as Miyamoto et al. (2018), Ramey and Zubairy (2018), etc. We also add seasonal dummy variables to control for seasonality.

Meanwhile, it would be an option to add some variables that capture sectoral determinants of stock returns. However, as mentioned in Section 3.1, regarding the data collected by other organizations, the classification of industries is different from the stock return data, preventing us from using these variables as independent variables in Equation (1). Instead, we add these variables as factors in our FAVAR estimation as shown in Appendix 4.

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. Note that all coefficients in Equation (1) are separately estimated for each horizon k. We directly estimate

Equation (1), and as in the case of Tenreyro and Thwaites (2016), the cumulative IRFs are computed using the estimated $\beta_{A,k}$ and $\beta_{B,k}$ for k=0, ... ,8, with confidence bands computed using the standard errors of estimated coefficients $\beta_{A,k}$ and $\beta_{B,k}$.

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). However, following the strategies used in many previous studies, since the length of the time dimension (T=104) mitigates this concern, we proceed with the LSDV estimator.

4. Empirical results and discussion

4.1. Dataset

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 Bank of Japan (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 for stock returns. 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 potential GDP and TFP following Kamada and Masuda's (2001) procedure.[16]

Public capital data, which is used to calculate public investment shocks, and the data on GDP came from the Cabinet Office of Japan. Official Cabinet Office data are annual and are

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[16] Further details are shown in Appendix 3 of this paper.

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.[17] 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.

Data on the real effective exchange rate, tax revenues (=tax and stamp revenues of the central government), and long-term interest rate (the yield of 10-year government bonds) come from the BOJ's website. Unemployment rate refers to the total unemployment ratio (= $(Nunber\ of\ unemployed)/(Total\ labor\ force)$, U3), which comes from the Labor Force Survey by the Statistics Bureau, Ministry of Internal Affairs and Communication.

The sample period is from 1983 Q1 to 2008 Q4 in quarterly data. One might consider adding the data from 2009 to 2014 like Miyamoto et al. (2018) to take advantage of the fact that

[17] For more details, please see Kitasaka (1999).

Japan experienced the ZLB for a longer time than the US or the euro area. However, we cannot do this for two reasons. First, to be consistent with the base year of the PPI, which is used for putting the data of stock returns into real terms, it would be favorable to use data expressed in 2005 terms. The public capital data expressed in 2005 terms goes until 2009. Second, the data on the stock price earnings ratio is only available up to 2013. Therefore, our sample period is different from that of Miyamoto et al. (2018).

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). The IRFs are the cumulative sum of stock returns, where the horizontal axis measures quarter. We also report the 95 % confidence intervals based on a parametric bootstrap procedure with 2,000 repetitions.

Figure 3a shows that for non-ZLB periods, stock returns react negatively for 6 quarters. Note that confidence intervals contain 0 after period 2. Figure 3b reports that public investment shocks have a positive effect on stock returns in the ZLB period.

Figure 3b also shows stock return initially rises by 1.82%, with a peak response of about 5% 4 quarters after the shock. The possible explanation of this hump-shaped response is as follows; the future profit via the positive production externality of future public capital is expected to be sufficiently larger than current profit, which brings the incremental increase in stock returns. However, the returns peter out after a year as the future profit becomes smaller.

When it comes to the non-ZLB period, we initially observe negative responses, and IRFs gradually increase though statistically insignificant. The initial negative response can be explained by the findings of Ardagna (2009), who reports that fiscal expansion driven by the rise in government debt aggravates stock prices in OECD countries. As explained in Section 2, the Japanese government often issues construction bonds to procure funds for public investments. Generally speaking, stock market participants ask for a higher premium on government bonds in accordance with the rise in government debt, which raises the interest rate paid on government bonds. The rise in the interest rate by deficit-financed public investment crowds out private demand and consumption, which has a negative impact on the stock market. This is especially plausible outside of the ZLB period because central banks do not purposely suppress interest rates. This path explains the reason why we initially observe negative responses in Figure 3a. However, since stock returns increase because of the externality of future public capital, negative effects are gradually offset as shown in this figure.

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).

The results are shown in Figures 4a to 5b. Regarding the policy effects during the ZLB period, positive responses of stock returns are observed for both industry groups. Further, the IRF of the manufacturing group does not include zero for 6 quarters and is slightly larger than that of the non-manufacturing group. In contrast, negative responses are still dominant for both industries outside of the ZLB period, and confidence intervals do not include zero in the short run (< 2 periods ahead) for the manufacturing industry group.

4.3. Robustness issues

To check the robustness of our results, we calculate IRFs under alternative model specifications. First, we use the data on infrastructure capital instead of aggregate public capital to extract the public capital (investment) shock. Second, we add the first four lags of $Gshock_t$ in Equation (1), following Teulings and Zubanov (2014). Finally, we re-estimate Equation (1) by adding the dummy variable indicating the so-called asset price bubble period, D_t^b; this dummy variable takes the value of 1 from 1986 Q1 to 1991 Q1 and 0 otherwise.[18] We do this in order to address the business cycle fluctuations during the asset bubble period. D_t^b is added as an intercept dummy variable. We also multiply this by the industry fixed effects for both regimes so that we have the variables $D_t^b * \alpha_{A,i}^k$ and $D_t^b * \alpha_{B,i}^k$.

The results are reported in Tables 2 to 4 for each case.[19] Overall, in spite of these alternative specifications, we confirm positive responses in the ZLB period. In particular, when we add four-periods lag of $Gshock_t$ to Equation (1), the size of the IRFs is larger than

[18] The Cabinet Office of Japan defines the asset price bubble period from December 1986 to January 1991. However, since stock prices in Japan began to surge in the early 1986 following the Plaza Accord in the late 1985, we set 1986 Q1 as the initial period.

[19] 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.

our basic specification during the ZLB periods on the manufacturing industry group.

When it comes to the manufacturing industry group, regardless of the alternative specifications, the IRFs are estimated to be positive and significant for at least four quarters.

On the other hand, regarding the non-manufacturing industry group, the IRFs in the ZLB periods are found to be statistically insignificant on impact (horizon 0) when we add four-periods lag of $Gshock_t$ as shown in Table 4. More than that, the IRFs include zero 4 quarters after the shock except the case that we add the dummy variable specifying the asset price bubble period. Based upon these results, we cannot strongly support the positive responses with respect to the non-manufacturing industry group even when the nominal interest rate is stuck at zero.

4.4. Discussion of the results

Our results suggest that public investment has a positive and statistically significant impact on stock returns when the economy is in a liquidity trap. Thanks to the extremely low interest rate environment, the crowding out effects mentioned in Section 4.2 are not likely to happen in the ZLB periods.[20] We observe the positive responses for about a year in most cases, which is consistent with the results on output by Miyamoto et al. (2018). In this respect, we confirm the results of Miyamoto et al. (2018) regarding stock market responses in Japan.

In terms of quantitative evaluation, our IRFs under the ZLB environment are well over 1. Some notable studies mentioned in Section 1 such as Christiano et al. (2011), Eggertsson (2011), and Woodford (2011) report that fiscal multiplier at the ZLB is more than 1 using standard New Keynesian models; so do Miyamoto et al. (2018) in Japan. Our empirical results support the findings of these studies on stock returns.

It is also notable that positive responses in the ZLB period are robust for the manufacturing industry. There are two explanations for this. First, as stated in Section 1, the manufacturing industry benefit more from public capital than non-manufacturing industries do. Second, the artificially suppressed interest rate policy depreciates the value of the yen, from which the manufacturing industry substantially benefit. This will also boost

[20] For example, please also see the website for this point: http://larrysummers.com/2016/02/17/the-age-of-secular-stagnation/.

the future productivity of the manufacturing industry under the ZLB environment. From these two reasons, once public sector increases its investment, the enhancement of future productivity is expected to be larger on firms classified into the manufacturing industry, which leads to an increase in stock returns of manufacturing enterprises during the ZLB periods.

5. Conclusion

This study examines the effects of public investment on stock returns using Japanese sectoral panel data. 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 show that, while public investment (public capital) shocks have positive and persistent effects on stock returns in the ZLB period, this is not the case outside of the ZLB. This is especially true of the industry group consisting of machine, electrical equipment, transportation machine, etc.

Our findings imply that, whereas public investment contributes to the resurgence of the stock market when the nominal interest rate is stuck at zero, policy makers should cut back once the economy has escaped the liquidity trap. This perspective is also 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 a matter of fact, the share of public investment within economic stimulus packages was smaller in the ZLB period than out of the ZLB in Japan. Furthermore, the Japanese government has curtailed public investment since 2001 as a part of fiscal adjustments. In these regards, fiscal expansion before the ZLB period in Japan might "reduce the 'fiscal space' for responding to the next crisis" (Krugman 2018). We warn policy makers not to make the same mistake as the Japanese government in trying to invigorate the stock market through public investment.

This study's analysis could be fruitfully extended in three ways. First, whereas we focus on empirical analyses, it would be needed to construct theoretical model to support our results. Second, we could 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:

$$Y_t = e^{x_t}(GK_t)^{\alpha}K_t, \quad \text{(A.1)}$$

where Y is output, GK is public sector physical capital, K is private capital x_t is profitability shock (or productivity shock). Seminal parameter α 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):

$$K_{t+1} = (1-\delta)K_t + I_t, \tag{A.2}$$

$$GK_{t+1} = (1-\delta)GK_t + GIK_t, \tag{A.3}$$

where $GIK_t \equiv GI_t/\widetilde{GK}_t$ is the public sector investment rate, GI_t is the total investment in public sector capital, $\widetilde{GK}_t$ is the total stock of public sector capital and δ^{GK} is the depreciation rate. The specification of Eq. (A.3) guarantees that the stock of effective public sector capital is stationary[21], the adjustment cost of private capital

[21] Assumption of stationary is necessary condition to derive the empirical predictions as effective stock of

$$g(I_t, K_t) = \frac{c}{2}(IK_t)^2 K_t, \tag{A.4}$$

where $IK_t \equiv I_t/K_t$ 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:

$$D_t = e^{x_t}(GK_t)^{\alpha} K_t - I_t - \frac{c}{2}(IK_t)^2 K_t. \tag{A.5}$$

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

$$V^{CUM}(s_t) = \max_{I_{t+j}, K_{t+j}} \left\{E_t\left[\sum_{j=0}^{\infty} M_{t,t+j} D_{t+j}\right]\right\}, \tag{A.6}$$

public sector capital is equal to detrended stock of total public capital.

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 $M_{t,t+j}$ 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:

$$q_t = 1 + c \cdot IK_t, \tag{A.7}$$

$$q_t = E_t\left[M_{t,t+1}\left(e^{x_{t+1}}(GK_{t+1})^{\alpha} + \frac{c}{2}(IK_t)^2 + (1-\delta)(1 + c \cdot IK_t)\right)\right]. \tag{A.8}$$

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

R^{l}_{t+1} as follows:

$$R^{l}_{t+1} = \frac{e^{x_{t+1}}\left((1-\delta^{GK})GK_t + GIK_t\right)^{\alpha} + c/2(IK_{t+1})^2 + (1-\delta)(1+c\cdot IK_{t+1})}{1+c\cdot IK_t}. \tag{A.9}$$

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

Appendix 2. Explanation of the FAVAR model

Here we explain the econometric framework of the FAVAR model.[22] Let Y_t be an $M\times1$ vector of observable economic variables. Although the lags of Y_t are used as explanatory variables in a standard VAR, they alone may not provide sufficient economic information. We therefore assume that a $K\times1$ vector of unobserved factors, where K is small, provides

[22] This section follows Bernanke et al. (2005).

the remaining information. We set K =3 as the number of factors drawn by the dynamic factor model of Bernanke et al (2005) and Fujii et al. (2013). The joint dynamics of (F_t, Y_t) are given by

$$\begin{bmatrix} F_t \\ Y_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_{t-1} \\ Y_{t-1} \end{bmatrix} + u_t, \qquad \text{(A.10)}$$

where $\Phi(L)$ is a matrix of polynomials of finite order d and the error term u_t has mean 0 with covariance matrix Σ. The equation is in reduced form, and contains a recursive restriction that the unobservable factors (F_t) do not respond to the public investment (public capital) shock contemporaneously. This reflects the fact that the fiscal authority does not immediately respond to the state of the industry sectors as shown in Section 1. Thus, we use a six-variable system, where the ordering of the variables is F_t (which contains three factors), public capital, tax revenue, then TFP.[23] We take first differences for public capital, tax revenue, and TFP as mentioned in Section 3.1.

[23] We check the robustness of the results by changing the order between tax revenue and TFP while keeping the order between F_t and public capital. The results are not substantially changed from our basic specification.

We use the two-step approach of Bernanke et al. (2005): after identifying F_t using principal component analysis, we estimate Equation (A.10) and compute the structural shocks using Cholesky decomposition as done in Bernanke et al (2005), Shibamoto (2007), and Fujii et al. (2013).[24]

Equation (A.10) 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.10). This assumption allows us to infer the unobservable factors from observable economic time series variables. Let X_t be an $N \times 1$ vector of informational time series, where N is large such that $K + M \ll N$.[25] We also assume that the informational time series X_t are related to the unobservable factors F_t and the observable variables Y_t as follows:

$$X_t = \Lambda^f F_t + \Lambda^y Y_t + e_t, \tag{A.11}$$

[24] 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.

[25] As Bernanke et al. (2005) point out, it is acceptable for N to be greater than T.

where Λ^f is an $N \times K$ matrix of factor loadings, Λ^y is $N \times M$, and e_t is an $N \times 1$ vector of the error terms, which is weakly correlated with mean 0.

We perform the following procedure as the first step. Initially, the common components, C_t, are estimated using the first $K + M$ principal components of X_t. After that, following Bernanke et al. (2005), the variables are classified as slow-moving or fast-moving. The slow-moving variables are TFP, tax revenues, and public capital. As the fast-moving variables, we use the stock returns of the 27 industries shown in Table 1 and aggregate stock returns (average of the 27 industries). Finally, after a principal component analysis is applied to the slow-moving variables to derive a vector of slow-moving factors, F_t^S. Finally, the following regression is estimated:

$$\hat{C}_t = b_{F^S}\hat{F}_t^S + b_Y Y_t + e_t, \tag{A.12}$$

where the estimated factors, $\hat{F}_t$, are obtained from $\hat{C}_t - b_Y Y_t$.

As the second step, we estimate Equation (1) by replacing F_t with $\hat{F}_t^S$, which is a vector of estimated slow-moving factors. We can also calculate the structural shock $u_t = \Psi^{-1}\varepsilon_t$, where Ψ^{-1} is the inverse of the coefficient matrix in the related structural model. We assume that $\Psi = I - \Psi_0$ (I is a 6×6 identity matrix) so that $u_t = \Psi^{-1}\varepsilon_t$ can be written as $u_t = \Psi_0 u_t + \varepsilon_t$. The recursive identification procedure implies that Ψ_0 becomes lower triangular, and the ordering in the VAR determines the degree of exogeneity of the variables. Here public capital is placed after F_t as mentioned earlier. Innovations in public capital are public investment (public capital) shocks, which is equivalent to $Gshock_t$ of Equation (1).

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 × working hours) as L_t, Solow residual as A_t, operating ratio of capital as λ, and the coefficient labor input as α. The parameter α is defined as (Compensation of employees)/ (total income) assuming perfect competition. The production function is then

$$\ln Y_t = \ln \overline{A}_t + (1-\alpha)\ln \lambda K_t + \alpha \ln L_t. \qquad \text{(A.13)}$$

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 $\ln \lambda K_t$ can be written as

$$\ln \lambda K_t = \ln(\lambda_m K_{mt} + \lambda_{nm} K_{nmt}) \qquad \text{(A.14)}$$

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 λ_{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.[26] We set the peak of BSI as 100% of the operation ratio.

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

$$\ln \overline{A}_t = \ln Y_t - (1-\alpha)\ln \lambda K_t - \alpha \ln L_t \tag{A.15}$$

Here, we regard the Solow residual as the TFP.

Appendix 4. Alternative framework using policy shocks with sectoral investment

[26] In Kamada and Masuda (2001), the consumption of electric power is also considered in calculating the rate of operation.

or deflators included in factors

We extract the policy shock by adding sectoral I/K or sectoral deflator as a factor to our FAVAR model.

When it comes to I/K, we construct flow investment data (I_t) following the equation:

$$I_t = K_t^E - K_t^B + Dep_t, \tag{A.16}$$

where K_t^E is the tangible fixed asset at the end of period t, and K_t^B is initial tangible fixed asset (or the one at the end of period t-1). Land is excluded and construction-in-progress accounts are included. Dep_t is depreciation and I_t is the flow of investment in period t.

We obtain the data from the Seasonal Company Statistics Report by the Ministry of Finance, Japan; however, since this data is revised at the end of every fiscal year to address bankruptcy and opening of firms, some companies are dropped or added between the 1st and the 2nd quarters.[27] We modify the flow investment variable to deal with this following

[27] Following the UK, the Japanese fiscal year is from April to the following March.

Ogawa (2003). First, we calculate the change in the number of firms from the 1st quarter to the 2nd quarter for every year, and assume that the calculated change is equal to the change in the number of firms in each of the quarters from the previous fiscal year. Then, we multiply the calculated change with per capita flow, and add it to the total flow in each quarter.

Second, we re-calculate the data series of capital stock (K_t) following the perpetual inventory method. Using the flow data, we calculate capital stock as follows:

$$K_t = K_t^B + I_t - Dep_t \tag{A.17}$$

Using Equation (A.16) and (A.17), we calculate sectoral I/K.

As for sectoral deflators, we use the monthly sectoral consumer price index in Japan (2015 base), which is available from the Ministry of Internal Affairs and Communication in Japan.

Estimation results are reported in Tables A2 and A3. Overall, these results reaffirm our main conclusions. The IRFs are estimated to be positive and statistically significant in the ZLB periods for all industries. Further, we show negative and statistically significant results outside the ZLB periods for up to a year in some cases. Although the size of the IRFs reported in Table A3 is smaller than that of our basic specification during the ZLB periods, we have positive and significant response for all industries and the manufacturing industry group when the short-term nominal interest rate is close to the zero-lower bound.

Appendix 5. Estimation using the policy shock calculated by Kanazawa (2018)

Kanazawa (2018) extracts policy shocks using the excess return of road pavement firms as a news shock about future public investment following Fisher and Peters (2010). We also estimate Equation (1) by replacing our original shock with the shock of Kanazawa (2018).

We reported the results in Figures A1 and A2. We confirm the positive response for one year in the ZLB periods, though the confidence intervals include zero in the 2nd period. On the other hand, the IRF is estimated to be negative and significant at first. In this respect, we can confirm our implication as well as basic results even when we use another shock.

Meanwhile, the estimated IRFs are larger. Further, they are not as stable as our specification. These may be ascribed to the fact that the shock calculated using the information of quite a few industries may lead to some biases in panel data estimation. In this respect, it is favorable for us to make use of policy shocks extracted based upon the data of various industries.

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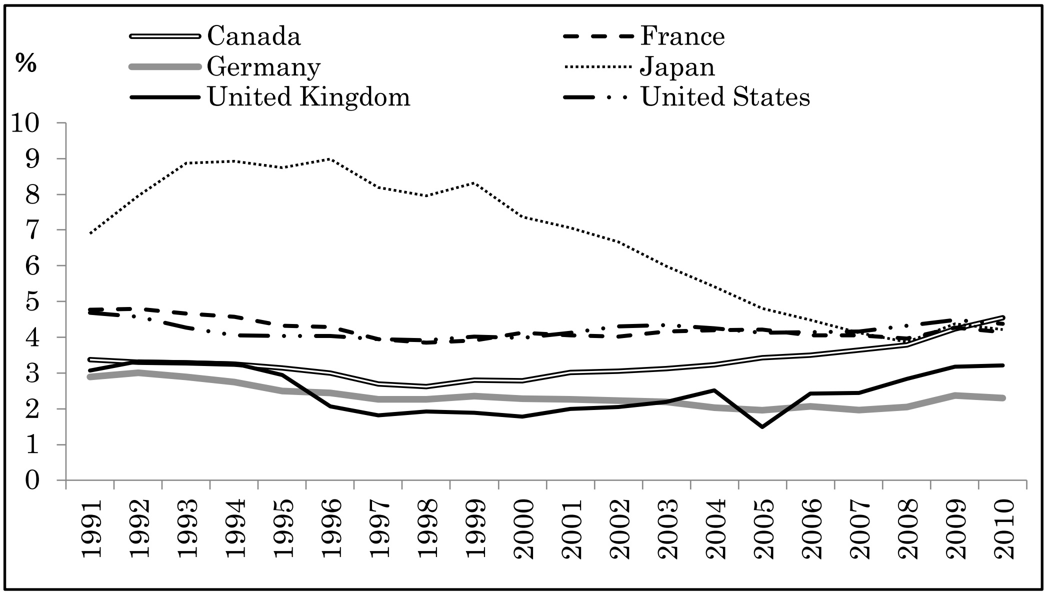
Figure 1. Government gross capital formation per GDP among some developed countries



Source: OECD Economic Outlook

Figure 2a. The content of fiscal stimulus packages in the former half of the 1990s

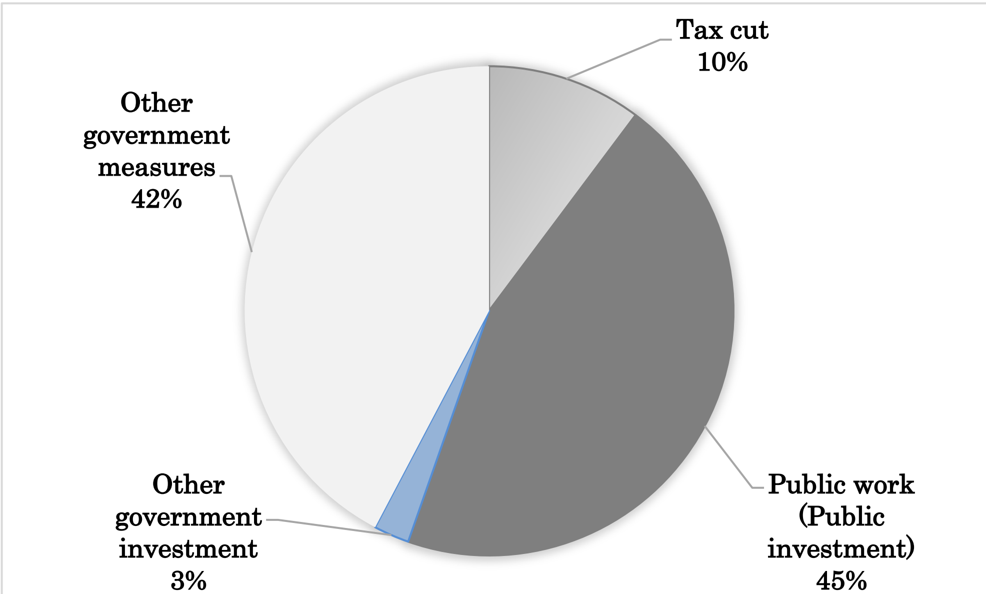
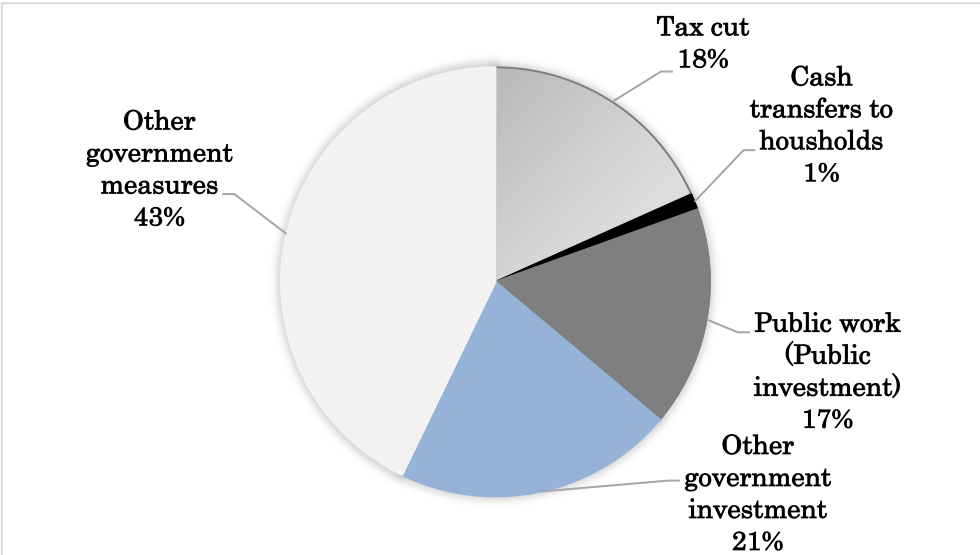
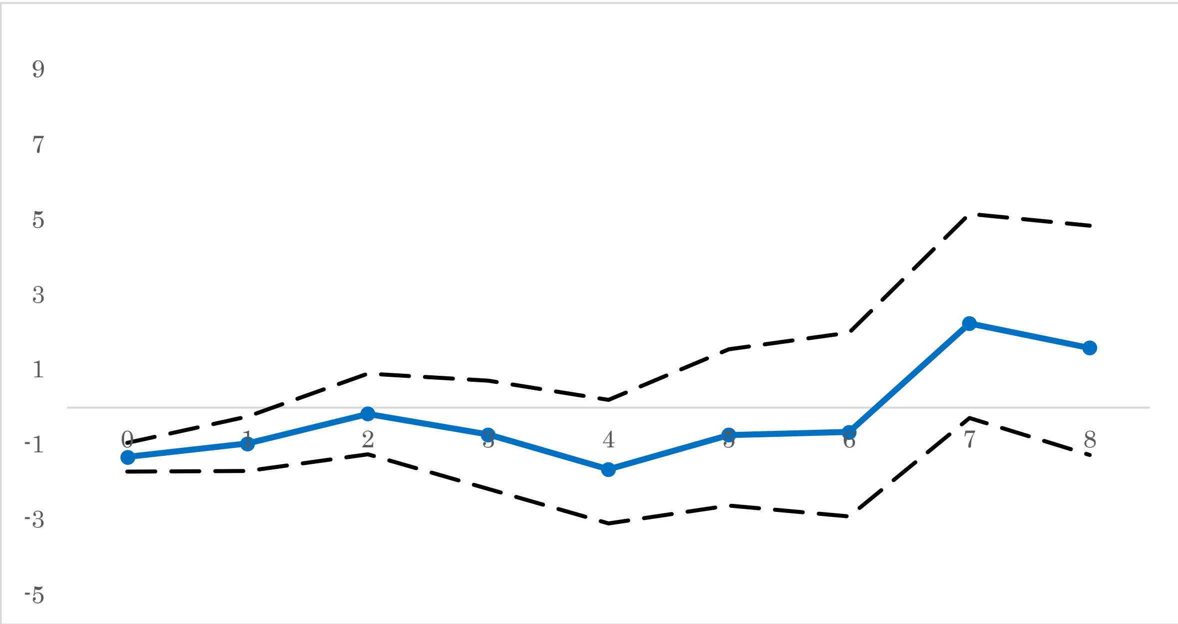


Figure 2b. The content of fiscal stimulus packages in the latter half of the 1990s



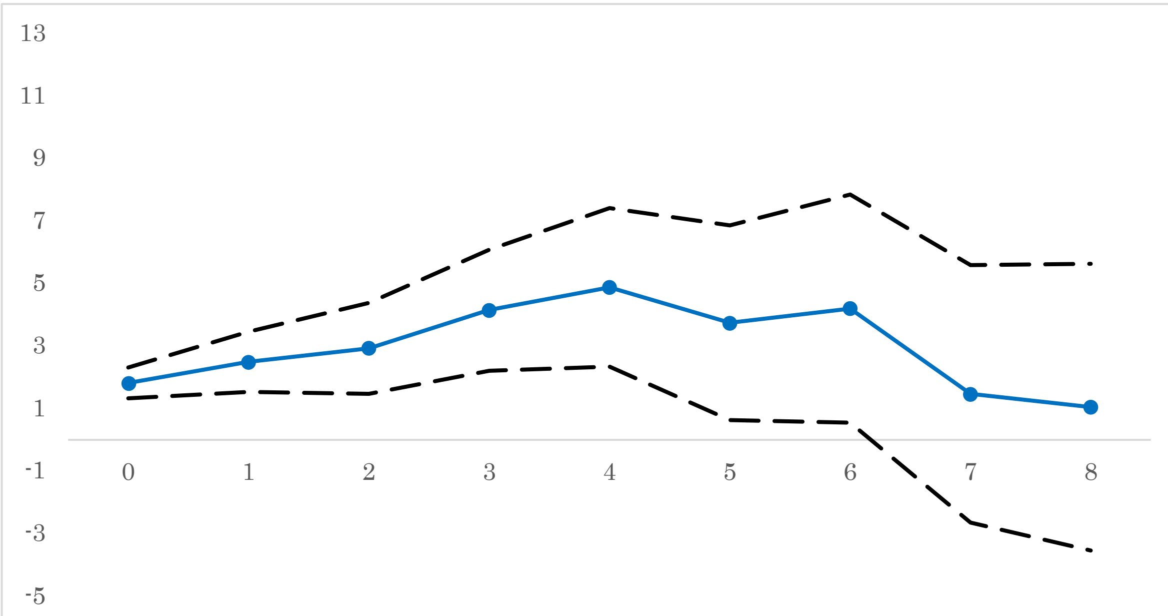
Note: The source of numbers for both figures come from Brückner and Tuladhar (2014). The "Other government investment" category includes investment in fields such as science and technology, education and social welfare, alternative energy and the environment, and natural disaster relief. Further, we 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 (All industries, unit=%)



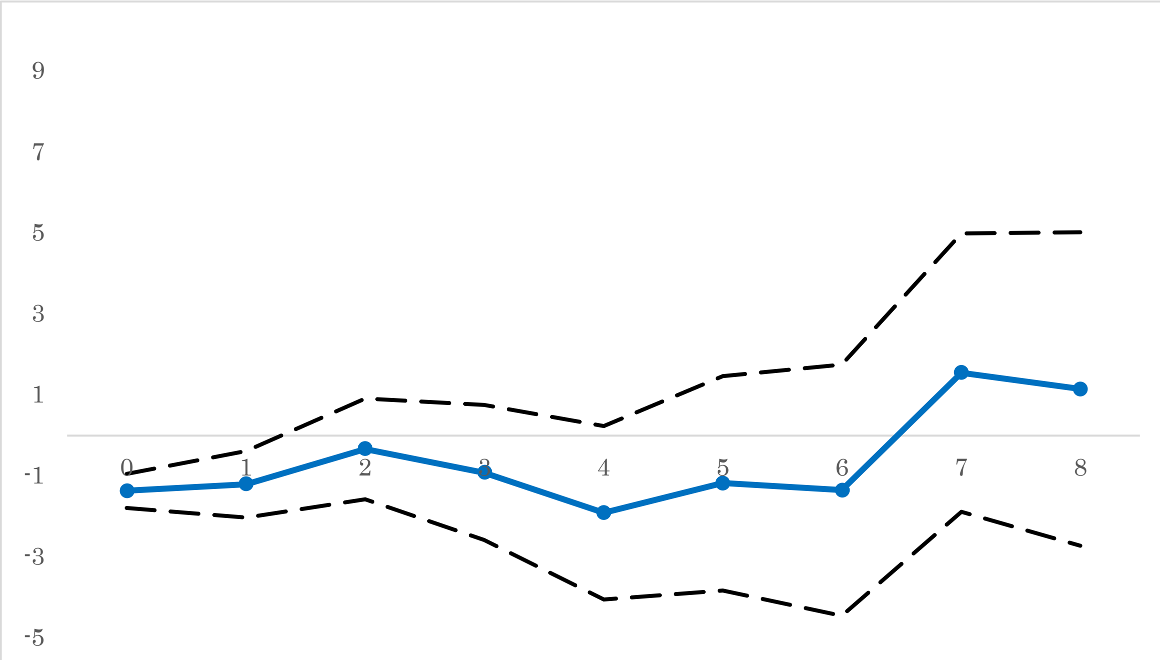
Note: The solid line indicates the cumulative impulse response, and the dotted lines represent the 95 % confidence intervals based on a parametric bootstrap procedure with 2,000 repetitions.

Figure 3b: IRF of stock returns with respect to public investment (public capital) shock in the ZLB period (All industries, unit=%)



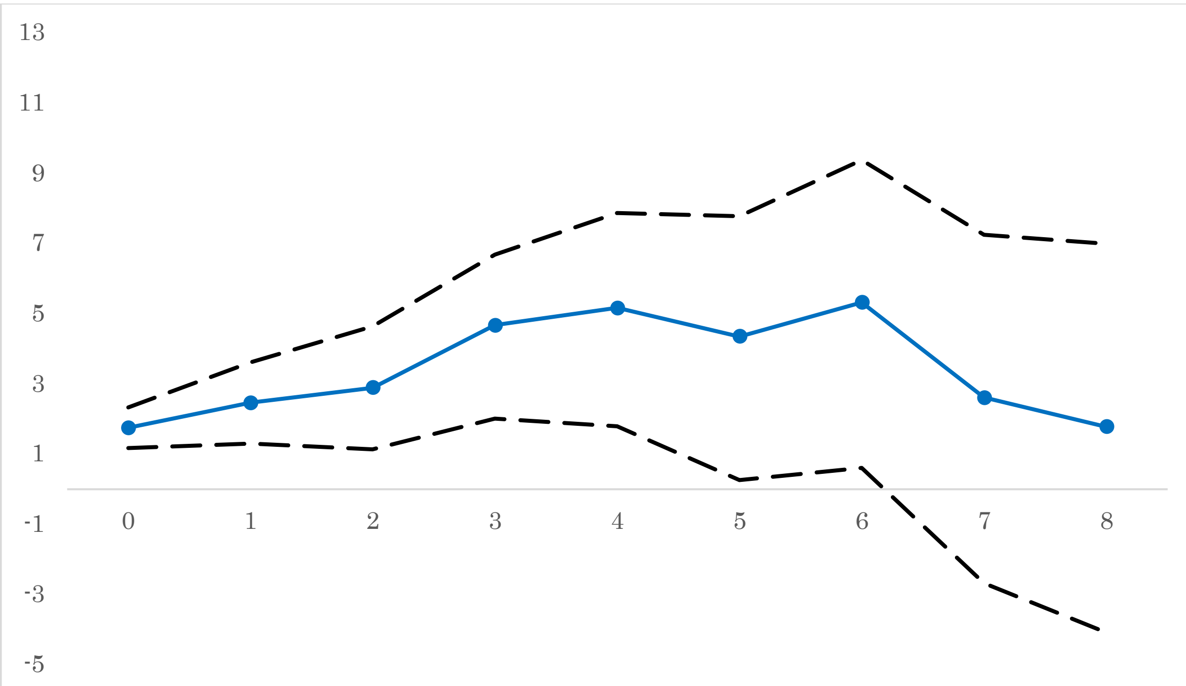
Note: The solid line indicates the cumulative impulse response, and the dotted lines represent the 95 % confidence intervals based on a parametric bootstrap procedure with 2,000 repetitions.

Figure 4a: IRF of stock returns with respect to public investment (public capital) shock outside of the ZLB period (Manufacturing industry group, unit=%)



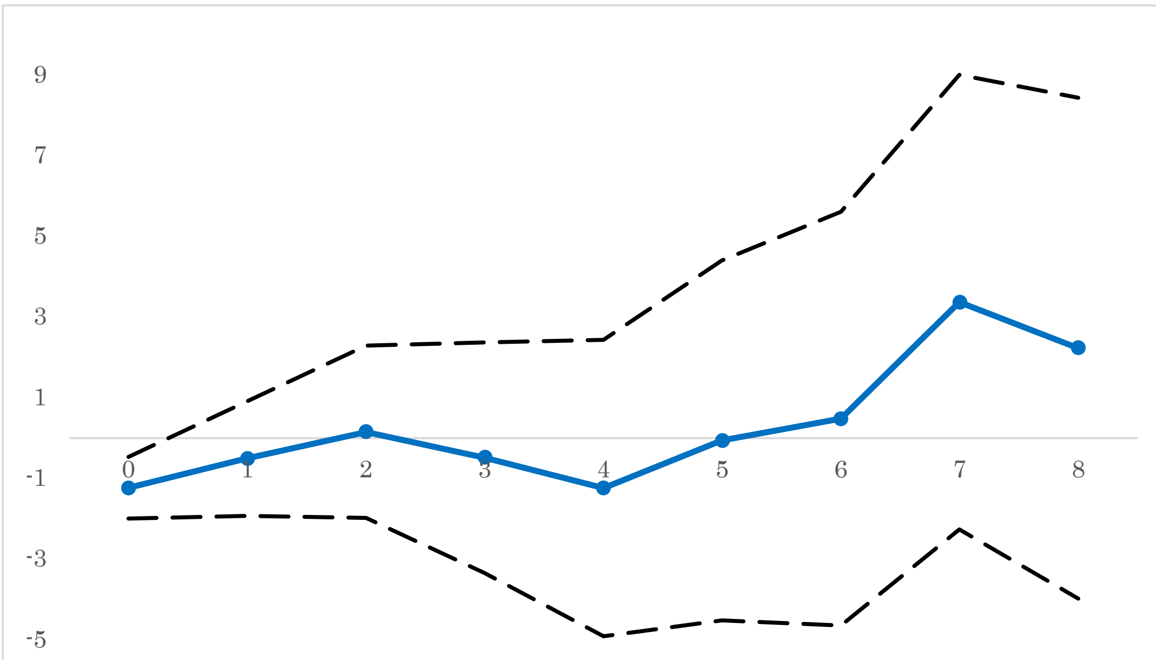
Note: The solid line indicates the cumulative impulse response, and the dotted lines represent the 95 % confidence intervals based on a parametric bootstrap procedure with 2,000 repetitions.

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



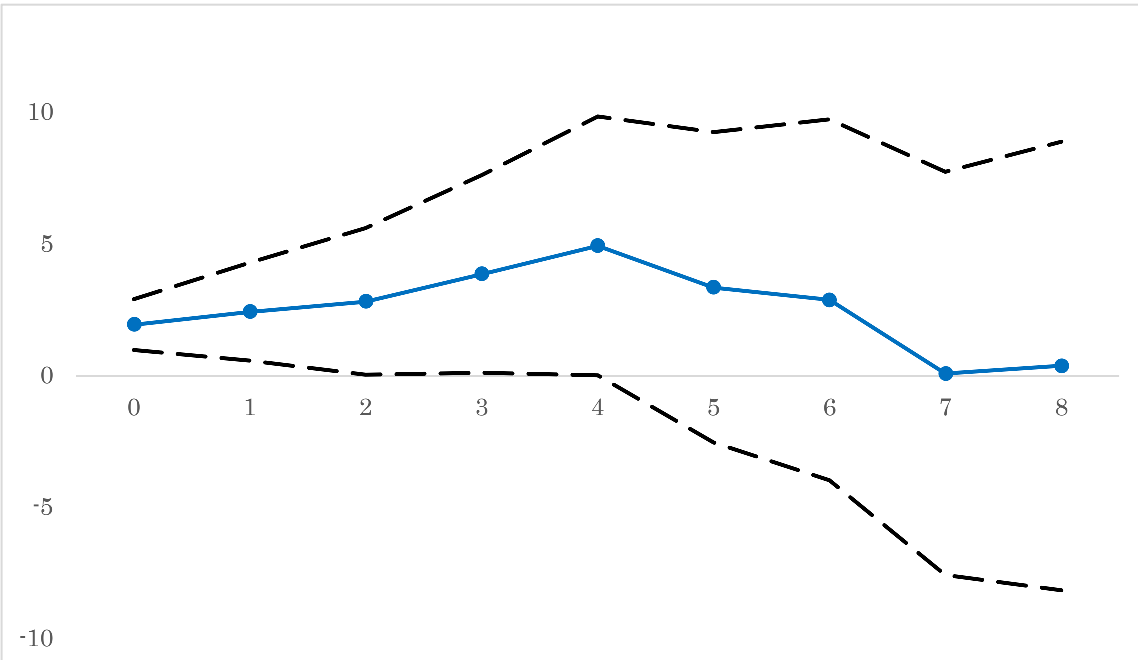
Note: The solid line indicates the cumulative impulse response, and the dotted lines represent the 95 % confidence intervals based on a parametric bootstrap procedure with 2,000 repetitions.

Figure 5a: IRF of stock returns with respect to public investment (public capital) shock outside of the ZLB period (Non-manufacturing industry group, unit=%)



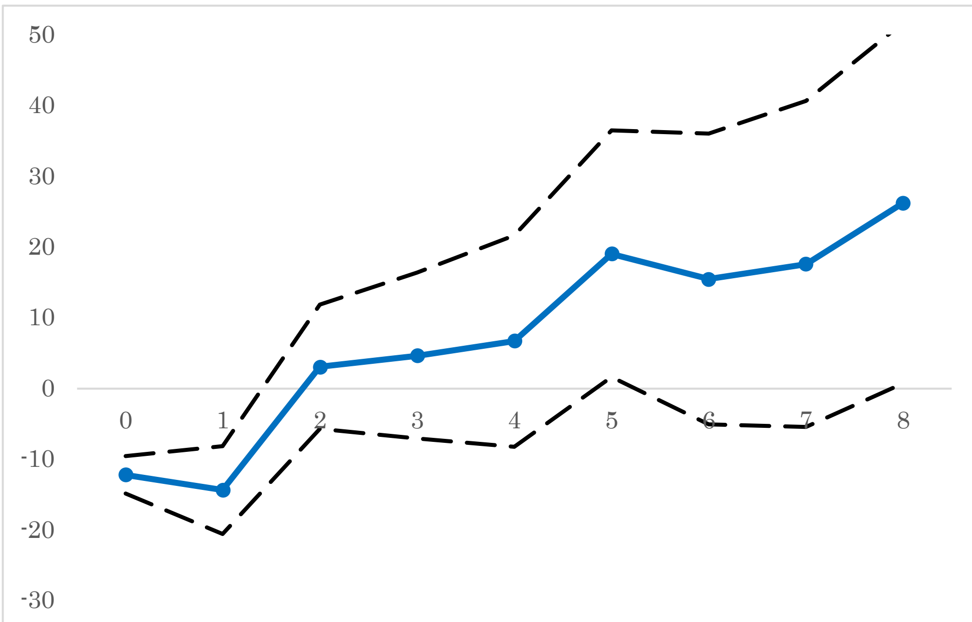
Note: The solid line indicates the cumulative impulse response, and the dotted lines represent the 95 % confidence intervals based on a parametric bootstrap procedure with 2,000 repetitions.

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



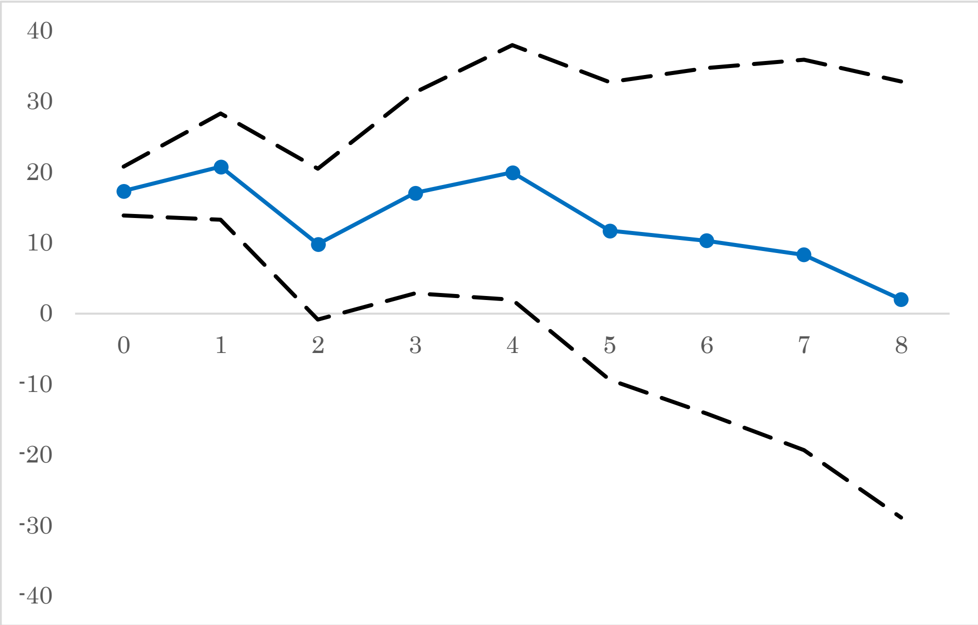
Note: The solid line indicates the cumulative impulse response, and the dotted lines represent the 95 % confidence intervals based on a parametric bootstrap procedure with 2,000 repetitions.

Figure A1: IRF of stock returns with respect to public investment (public capital) shock outside of the ZLB period (All industries, calculated using the shock of Kanazawa (2008))



Note: The solid line indicates the cumulative impulse response, and the dotted lines represent the 95 % confidence intervals based on a parametric bootstrap procedure with 2,000 repetitions.

Figure A2: IRF of stock returns with respect to public investment (public capital) shock <u>in the ZLB period</u> (All industries, calculated using the shock of Kanazawa (2008))



Note: The solid line indicates the cumulative impulse response, and the dotted lines represent the 95 % confidence intervals based on a parametric bootstrap procedure with 2,000 repetitions.

Table 1. Details about the industries

Broad category	Small classification
Fishery and agriculture	
Mining	
Manufacturing (15 industries)	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
Non-manufacturing (10 industries)	Land transport, shipping, air transport, warehousing, information and communication, wholesale and retail, finance, real estate, electrical and gas, and services

Note: The number of industries is in the parentheses.

Table 2. IRF of the robustness check (All industries, unit=%)

	On impact (Horizon 0)	Horizon 4	Horizon 8
G=infrastructure			
Non-ZLB	-1.359*	-1.721	1.587
ZLB	1.860*	4.654*	0.154
lag=4 for X			
Non-ZLB	-0.476	-0.837	0.993
ZLB	1.159*	5.917*	3.406
Adding bubble dummy			
Non-ZLB	-1.199*	-1.622	1.698
ZLB	1.711*	4.864*	0.961

Note: A^{*} indicates that 0 is outside the region between the 95 % confidence intervals based on a parametric bootstrap procedure with 2,000 repetitions. "ZLB" refers to the period during which the short-term nominal interest rate is close to the zero-lower bound, and "non-ZLB" indicates the outside of the ZLB period. "G=infrastructure" reports the case when we use infrastructure instead of all public capital data. "Lag 4 for $Gshock_t$" reports the cumulative IRF when we also add four-periods lags of $Gshock_t$ in Equation (1). "Adding bubble dummy" is the case where we add the dummy variables that takes 1 during the asset price bubble periods.

Table 3. IRF of the robustness check (Manufacturing industry group, unit=%)

	On impact (Horizon 0)	Horizon 4	Horizon 8
G=infrastructure			
Non-ZLB	-1.382*	-1.746	1.368
ZLB	1.76*	4.516*	0.402
lag=4 for X			
Non-ZLB	-0.731*	-1.955	0.355
ZLB	1.074*	6.696*	4.256
Adding bubble dummy			
Non-ZLB	-1.208*	-1.771	1.321
ZLB	1.617*	4.720*	1.312

Note: A^* indicates that 0 is outside the region between the 95% confidence intervals based on a parametric bootstrap procedure with 2,000 repetitions. "ZLB" refers to the period during which the short-term nominal interest rate is close to the zero-lower bound, and "non-ZLB" indicates the outside of the ZLB period. "G=infrastructure" reports the case when we use infrastructure instead of all public capital data. "Lag 4 for $Gshock_t$" reports the cumulative IRF when we also add four-periods lags of $Gshock_t$ in Equation (1). "Adding bubble dummy" is the case where we add the dummy variables that takes 1 during the asset price bubble periods.

Table 4. IRF of the robustness check (Non-manufacturing industry group, unit=%)

	On impact (Horizon 0)	Horizon 4	Horizon 8
G=infrastructure			
Non-ZLB	-1.297*	-1.359	2.194
ZLB	2.03*	4.833	-0.330
lag=4 for X			
Non-ZLB	-0.141	0.503	1.641
ZLB	1.280	5.123	2.370
Adding bubble dummy			
Non-ZLB	-1.156*	-1.415	2.174
ZLB	1.878*	5.105*	0.434

Note: A^{*} indicates that 0 is outside the region between the 90% confidence intervals based on a parametric bootstrap procedure with 2,000 repetitions. "ZLB" refers to the period during which the short-term nominal interest rate is close to the zero-lower bound, and "non-ZLB" indicates the outside of the ZLB period. "G=infrastructure" reports the case when we use infrastructure instead of all public capital data. "Lag 4 for $Gshock_t$" reports the cumulative IRF when we also add four-periods lags of $Gshock_t$ in Equation (1). "Adding bubble dummy" is the case where we add the dummy variables that takes 1 during the asset price bubble periods.

Table A1. Source of the data on TFP

Data	Source
Real GDP (chained), Compensation of Employees, and Total Income	National Account (93SNA, seasonally adjusted and reference year 2000) in the Annual Report on National Account, Cabinet Office
Capital Stock	Capital Stock on Private Sector (93SNA) with adjustment for privatization, Cabinet Office
Working Population	Labor Force Survey (for all industries), Ministry of Internal Affairs and Communication
Working Hours	Monthly Labor Survey (All Industries, companies with more than 30 employees), Ministry of Health, Labor and Welfare
Business Survey Index	Business Survey Index for Capital Investment (Large Company, Non-manufacturing), Ministry of Finance
Operating Ratio of Capital	Indices of Operating Ratio of Manufacturing (1995=100), Ministry of Economics, Trade and Industry
Maximum Working Population	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 trend of the working population to the peak of original data for each category, and we total these two adjusted linear trends.
Maximum Working Hours	(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 calculate the linear trend and adjust it to the peak of the original data. (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 linear trend.

Table A2. IRF when private sectoral investments per capital stock (I/K) are included as factors in FAVAR estimation (Unit=%).

	On impact (Horizon 0)	Horizon 4	Horizon 8
All Industries			
Non-ZLB	-1.470*	-2.649*	0.131
ZLB	1.328*	4.888*	2.636
Manufacturing Industry group			
Non-ZLB	-1.573*	-2.989*	-0.458
ZLB	1.438*	4.808*	3.297
Non-Manufacturing Industry group			
Non-ZLB	-1.290*	-2.130	0.950
ZLB	1.171*	4.907*	1.653

Note: An asterisk (*) indicates that 0 is outside of the 95 % confidence interval based on a parametric bootstrap procedure with 2,000 repetitions. "ZLB" refers to the period during which the short-term nominal interest rate is close to the zero-lower bound, and "non-ZLB" indicates the outside of the ZLB period.

Table A3. IRF when sectoral deflators are included as factors in FAVAR estimation (Unit=%).

	On impact (Horizon 0)	Horizon 4	Horizon 8
All Industries			
Non-ZLB	-1.152*	-2.516*	0.305
ZLB	1.174*	3.952*	0.997
Manufacturing Industry group			
Non-ZLB	-1.245*	-2.686*	-0.221
ZLB	1.161*	3.697*	1.399
Non-Manufacturing Industry group			
Non-ZLB	-0.982*	-2.287	1.137
ZLB	1.152*	4.247	0.222

Note: A^* indicates that 0 is outside the region between the 95 % confidence intervals based on a parametric bootstrap procedure with 2,000 repetitions. "ZLB" refers to the period during which the short-term nominal interest rate is close to the zero-lower bound, and "non-ZLB" indicates the outside of the ZLB period.