Public Investment Multipliers: Evidence from Stock Returns of the Road Pavement Industry in Japan

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September 17, 2020

Abstract

This paper contributes empirical evidence of the macroeconomic impacts of public investment. I extract public investment news shocks from the excess returns of narrowly defined road pavement firms and use them as an instrument for future public investment spending. Using Japanese data for the period between 1980 and 2014, I find that when the news shock is followed by a persistent increase in public investment and a weak real interest rate response, the cumulative multiplier can be as large as 6.10 four years after the shock. Additionally, I report a substantial improvement in aggregate labor productivity associated with a rise in public investment spending.

Keywords: Fiscal multiplier; Stock returns; Public Investment; Infrastructure Investment; News shock.

JEL Classification: E32;E62;H54.

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1 Introduction

What is the public investment multiplier, defined as the percentage increase in GDP caused by an increase in public investment spending by one percent of GDP? Understanding the macroeconomic impact of public investment is critical given that public investment typically constitutes a large part of countercyclical fiscal packages. For example, approximately 40% of non-transfer spending in the American Recovery and Reinvestment Act (ARRA) of 2009 was allocated to public infrastructure investment. Yet, it remains an open question whether public investment has a larger or smaller multiplier. Leduc and Wilson (2013) and Ilzetzki et al. (2013) have provided some evidence that public *investment* has larger multipliers while Boehm (2019) has suggested that public *consumption* has larger multipliers. This paper contributes empirical evidence of the dynamic macroeconomic effect of public investment by exploiting the news shocks extracted from the excess returns of road pavement firms in Japan.

Estimating public investment multipliers is challenging because of the long implementation lag associated with public investment projects. As emphasized by Leeper et al. (2013), failure to control for public expectation about future government spending can lead to incorrect inference. To address this concern, I use the excess returns of Japan's road pavement firms to identify surprise components of the changes in public expectations about future public investment, following Fisher and Peters (2010). If the profitability of the selected road pavement firms depends heavily on public road investments, the shocks to their excess returns can be interpreted as a surprise news about future public road investment spending.

I regress the excess return on a number of contemporaneous and lagged economic and financial variables. The residuals from the regression are my measure of extracted news shocks.[1] To verify that the extracted news measure is orthogonal to the current state of the economy, I conduct a series of robustness checks.

I employ the local projection-IV method using the extracted news shocks as an instrumental variable to estimate the public investment multiplier. My identification strategy relies on two crucial assumptions: the instrumental variable 1) captures news about future public investment (relevance condition) and 2) affects output only through public investment spending (exclusion restriction). The relevance condition is directly testable. I show that the extracted news shocks predict future public investment at longer horizons in a statistically significant manner. The exclusion restriction is dealt with by regressing the excess return on current and lagged macroeconomic/financial variables, as described above.

I find that the cumulative public investment multiplier is approximately 1.98 a year after the shock and as large as 6.10 after four years. The estimated multipliers at shorter horizons are not precisely estimated due to the small relevance of the instrument. However, the multipliers at longer horizons are precisely estimated. The estimated multipliers are considerably larger than conventional estimates of fiscal multipliers. However, these results are in line with Leduc and Wilson (2013), who estimated cumulative public investment multipliers of 1.4 on impact and 6.6 at peak using state-level US data.[2] The estimated results are robust to different specifications. Additionally, I find that public investment crowds in

[1] This is the same as placing the excess return behind all macro/financial variables in the causal ordering of VAR.

[2] Leduc and Wilson (2013) do not report the cumulative multipliers, but Chodorow-Reich (2019) calculates the cumulative multipliers based on the most conservative estimates of Leduc and Wilson (2013).

consumption and investment and that both multipliers are larger than the multipliers found in previous studies, which used different government spending shocks.

Finally, I empirically explore factors that could explain the large public investment multipliers. As suggested by Ramey (2011), the size of fiscal multiplier depends on: 1) the tax rate response, 2) the real interest rate response, 3) the persistence of government spending, and 4) the type of government spending. Investigating whether any of these factors contribute to the large public investment multiplier, I conclude that the combination of a productive nature of the public investment, a weak real interest rate response, and a high persistence of public investment spending played key roles. Put differently, when these conditions are met, public investment can be an effective tool for stimulating the aggregate economy over the medium term.

1.1 Related Literature

This paper contributes to a vast literature that estimates the macroeconomic impacts of government spending (e.g., Ramey and Shapiro (1998), Blanchard and Perotti (2002), and Ramey (2011)). The literature tends to focus on estimating the effects of military spending or of total government spending. However, according to Fernald (1999) public investment such as road investment differs from other types of government spending in that road investment is more productive. Thus, it is expected that public investment multiplier is different from other types of fiscal spending multipliers. Some recent studies provided aggregate evidence on the economic impact of public investment. Ilzetzki et al. (2013) found public investment multipliers ranging between 0.4 in the short run and 1.6 in the long run in their panel

of countries.[3] Using Cholesky decompositions and after controlling for forecasts, Boehm (2019) estimated the public investment multipliers for a panel of OECD countries and found that the public investment multipliers are smaller than public consumption multipliers and attributed the smaller multipliers of public investment to a high intertemporal elasticity of substitution for investment demand. Ramey (2019) summarized recent related literature and concluded that infrastructure investment is not effective in stimulating the economy in the short run but is likely effective in the long run. This study contributes new evidence of the aggregate public investment multiplier by reporting large public investment multipliers a few years after the news shock when the increase in public investment is highly persistent.

This study is also related to Leduc and Wilson (2013), who estimated the local road investment multipliers in the US by identifying highway spending news shocks at the state level. The authors' estimates of the cumulative fiscal multiplier are considerably greater than conventional estimates: 1.4 on impact and 6.6 at its peak. Chandra and Thompson (2000), Leigh and Neill (2011), and Acconcia et al. (2014) also exploited variation in public investment at the state and city levels in the US and Australia and found large local public investment multipliers.[4] However, as argued by Ramey (2016) and Nakamura and Steinsson (2014), establishing a direct link between local fiscal multipliers and aggregate multipliers can be difficult, because factors such as spillover effects and national tax or interest rate

[3] Additionally, Ellahie and Ricco (2017), who used a Bayesian VAR and US macroeconomic data, reported that public investment has larger multipliers than public consumption well in excess of one. Examining variation in the World Bank disbursements to developing countries, Kraay (2012) found small public investment multipliers. Using US macroeconomic data from 1956 to 1997, Pereira (2000) found a highway spending multiplier of about 2. However, his estimates are probably contaminated by anticipation effects because the study does not control for changes in expectations.

[4] Garin (2019) and Buchheim and Watzinger (2017) also explored the local effects of public investment spending in the US and Germany, respectively.

responses, are absent in local multipliers.

The theoretical literature offers a wide range for the public investment multiplier. Using a neoclassical growth model, Baxter and King (1993) showed that over the long run, public investment multipliers can be between 4 and 13. Leduc and Wilson (2013) built an open economy, monetary union model to study the effects of public investment. Their model produced an on-impact multiplier of 0.3 and a peak multiplier of 2. The authors also reported that a highly persistent spending shock can produce a peak multiplier of 7. Boehm (2019) used a general macroeconomic model to show that a short-lived public investment spending shock has a small multiplier because of a high intertemporal elasticity of substitution for investment demand. However, the authors also noted that when the spending shocks are long-lived, the multipliers can be greater because, in such a case, the intertemporal elasticity of substitution becomes smaller.[5] Overall, the cumulative public investment multipliers of 2 to 7 do not necessarily contradict the multipliers implied by existing macroeconomic models, particularly when investment spending is highly persistent.[6]

The remainder of this paper is organized as follows: Section 2 reviews public investment in Japan. Section 3 explains the empirical strategy, and Section 4 explains the data. Section 5 presents the baseline results, and Section 6 explores factors that might have contributed to the findings. Finally, Section 7 concludes.

[5]Additionally, Leeper et al. (2010) showed that the size of multipliers depends on the implementation lag and that a substantial delay produces a negative multiplier. Coenen et al. (2013), Albertini et al. (2014), and Bouakez et al. (2017) considered models with nominal rigidities and showed that the public investment multipliers can exceed one, but they also noted that their results depend on the response of monetary policy, the substitutability of the spending, and the implementation lag.

[6]Literature reviews of the related methodology and of the estimates of fiscal multipliers using Japanese data are available in Appendix 8.4.

2 Road Construction and Public Investment in Japan

The choice of road pavement firms as an indicator of public investment spending is motivated by the following two facts. First, road construction constitutes the largest fraction of total infrastructure investment. Between 1970 and 2013, road construction was the single-largest component of infrastructure investment in Japan ranging from 20% to 35% of total public infrastructure investment.[7] As it accounts for the largest fraction of overall infrastructure investment, changes in road investment should reflect in the overall changes in public investment.

Second, road construction is almost exclusively initiated by government-related agencies. The survey results from the 50 largest construction firms in Japan reveal that since 1985, the annual share of road investment orders issued by government-related agencies has almost always exceeded 90%.[8] The dominance of government-related agencies in the issuance of road construction orders suggests that the firms that specialize in road construction are heavily government-dependent. If that is the case, changes in public investment policies should be priced into the market valuations of road pavement firms. In Appendix 8.5, I show the high correlation between the short-run variations of sales of road pavement firms and public investment spending.

I conduct a preliminary analysis to check whether the stock prices of the road pavement firms can be a credible indicator of future public investment spending. I plot in Figure 1 the detrended (third polynomial) log of real public investment spending and the detrended log

[7] Displayed in Panel (a) of Figure 8 in Appendix 8.5.
[8] Displayed in Panel (b) of Figure 8 in Appendix 8.5.

of real sales between 1980 and 2014. In Panel (a) of Figure 1, the blue dotted line shows the average sales of the five *road pavement firms* and the red solid line shows public investment spending.[9] The sales of the road pavement firms line up well with public investment spending during all periods, yielding the contemporaneous correlation of 0.717. For comparison, in Panel (b), I plot the average real sales of the top four *construction* firms (red line).[10] The sales of the top construction firms align closely with public investment spending until the bubble collapse of the early 1990s. Immediately after the bubble burst, the sales of the top construction firms plummeted, although public investment spending was still increasing. Since then, the dynamics of the sales of the top four construction firms and public investment spending have diverged, yielding the contemporaneous correlation of only 0.028.[11] The initial preliminary test suggests that sales of the selected road pavement firms depend significantly on public investment spending.

3 Empirical models

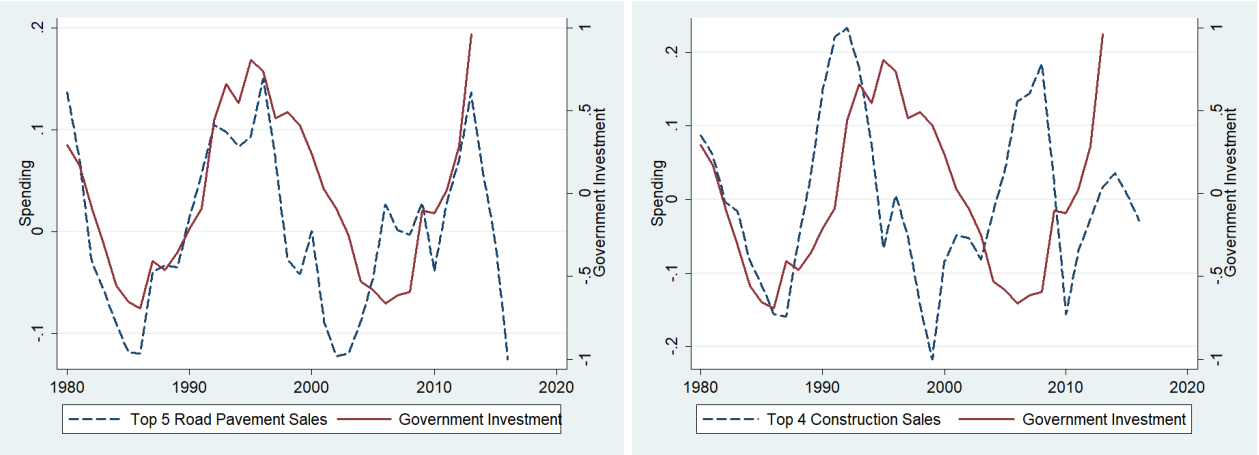
This section outlines the empirical strategy of the study. I first discuss the excess returns of the road pavement firms. I then discuss the local projection IV estimation.

[9] Selection criterion for the road pavement firms is described in Section 4.

[10] Japan's well recognized top four construction firms, known as super general contractors, are: Taisei Corporation, Obayashi Corporation, Shimizu Corporation, and Kashima.

[11] Additionally, to see if the public investment spending and sales are correlated in the medium run, I conduct the same exercise using the linear and second polynomial trend for detrending. The contemporaneous correlation between the sales of *road pavement* firms and public investment spending with linear and second polynomial-detrending are 0.82 and 0.67, respectively. In contrast, the correlation between the sales of the *top four construction* firms and public investment spending with linear and second polynomial-detrending are 0.56 and 0.13, respectively. In each case, the correlation between the sales of road pavement firms and public investment spending is substantially higher.

Figure 1: Sales and public investment



(a) Sales of five road pavement firms
Corr(Sales$_t$, Pub.Inv$_t$) = 0.717

(b) Sales of top four construction firms
Corr(Sales$_t$, Pub.Inv$_t$) = 0.028

Notes. This figure shows the detrended log of real public investment spending and the detrended log of real sales of road pavement firms (Panel (a)) and top four construction firms (Panel (b)). The road pavement firms are Nippo, Toa Road Corporation, Maeda Road, Nippon Road, and Seiki-Tokyu Kogyo. The top four construction firms are Taisei Corporation, Obayashi Corporation, Shimizu Corporation, and Kashima. Data are from the annual financial reports.

3.1 Excess returns of road pavement firms

I define excess returns as the difference between the average stock price of the road pavement firms and the average stock price for the market:

$$ER_t^{\text{Road}} = log(\text{Stock Price}_t^{\text{Road}}) - log(\text{Stock Price}_t^{\text{Market}}), \tag{1}$$

where Stock Price$_t^{\text{Road}}$ is the road pavement firms' average stock price and Stock Price$_t^{\text{Market}}$ is the average Nikkei stock price index. I use the simple average for the baseline result because the Nikkei stock price index uses the simple average of selected stock prices.[12] Obviously, ER_t^{Road} is endogenous because road investment was frequently used for stimulus purposes

[12]I also calculate the excess returns using the geometric average of road pavement firms' stock price as a robustness check and find that the baseline results remain the same. Another candidate is the weighted average using the market capitalization as weights. However, data on market capitalization of individual firms are available only from 1986. Thus, I do not employ the market capitalization approach.

and because it reflects the overall economic conditions. To avoid this issue, I regress ER_t^{Road} on the current and past macroeconomic and financial variables and use the orthogonalized residuals as instruments for public investment.

Following Fieldhouse et al. (2017), I define excess return shocks as the residual from the following regression:

$$ER_t^{\text{Road}} = \widehat{\alpha} + \widehat{\xi} W_t + \widehat{\phi}(L) V_{t-1} + er_t^{\text{Road}}, \tag{2}$$

where W_t includes the log of output, public investment, tax income, and the unemployment rate and the GDP deflator.[13] V_{t-1} includes four lags of all the variables in W_t and the four lags of financial variables, which are ER_t^{Road}, the one-year and five-year Japanese Government bond rates, and the log change in real exchange rates.[14] The residual from the regression, er_t^{Road}, is my measure of public investment news shocks that should be orthogonal to the current and past state of the macroeconomy.

3.2 Measuring multipliers

I estimate the public investment multiplier by employing the local projection IV method (Jordà (2005) and Ramey and Zubairy (2018)) using the extracted measure of public investment news shocks as an IV. The local projection method estimates impulse response functions directly by regressing a variable of interest h-periods ahead on shocks and lagged control variables. The local projection IV method is the same as the local projection method

[13] The unemployment rate is included in the control variables because Barro (1981) and Barro and Redlick (2011) argued that the unemployment rate contains extra information about the business cycle that might not be captured in output data.

[14] The baseline model does not include the contemporaneous financial variables as controls because it might be too restrictive to assume that ER_t^{Road} does not affect the financial variables contemporaneously. I show a version of the result that includes current financial variables as the controls in the robustness check and show that the results are unaffected.

except that it uses the shocks as instruments for an endogenous variable to uncover the causal impacts of the endogenous variable. One advantage of the local projection method is that it does not require imposing linear restrictions on the estimated dynamic responses.

To take into account the dynamic aspect of responses in output and public investment, I calculate the cumulative output multiplier, following Ramey and Zubairy (2018):

$$\sum_{j=0}^{h} \frac{Y_{t+j} - Y_{t-1}}{Y_{t-1}} = \beta_h + M_h \sum_{j=0}^{h} \frac{G_{t+j} - G_{t-1}}{Y_{t-1}} + \xi_h W_t + \phi_h(L) V_{t-1} + u_{t+h}, \tag{3}$$

where $\sum_{j=0}^{h} \frac{Y_{t+j}-Y_{t-1}}{Y_{t-1}}$ is the sum of the differences in output between $t+j$ and $t-1$ normalized by the output in period $t-1$, G_t is public investment spending in periods t. Because both the dependent variable and public investment spending are normalized by the output, M_h has the direct interpretation as the cumulative output multiplier. I estimate the multiplier coefficient M_h using ER_t^{Road} as the instrumental variable. Because equation 3 includes the same control variables as equation 2, instrumenting with ER_t^{Road} is the same as using er_t^{Road} as the instrumental variable. However, instrumenting with ER_t^{Road} makes calculating the correct standard errors and thus avoiding the problem of the generated regressor straightforward. I calculate 90% confidence bands using heteroskedasticity and autocorrelation-consistent (HAC) standard errors. I choose automatic bandwidth selection for the estimation.

4 Data

Most of the data are identical to those provided by Miyamoto et al. (2018) and are taken from Japan's System of National Accounts (SNA). All variables are expressed in per capita

and, except for the financial variables, are deflated by the GDP deflator. Adjusted public consumption is calculated as public consumption less the transfer of goods.[15] The stock prices for road pavement firms, the average stock price of the construction industry, and the Nikkei average are from the Nikkei FinancialQuest. I use the adjusted closing price on the last day of each quarter for the stock price of the firms. I define road pavement firms according to the 2007 Japan Standard Industry Classification. Road pavement firms are firms whose main segment of activity is classified as D-0631 (pavement construction).[16] The real exchange rate between the Japanese yen and the US dollar is obtained from the BIS statistics. The producer prices of asphalt and asphalt mixture for pavement construction are taken from the Bank of Japan statistics. Tax data, obtained from the National Accounts starting in 1980Q1, are composed of the total of direct and indirect taxes minus subsidies. The dataset is quarterly and spans 1980Q2 to 2014Q1.

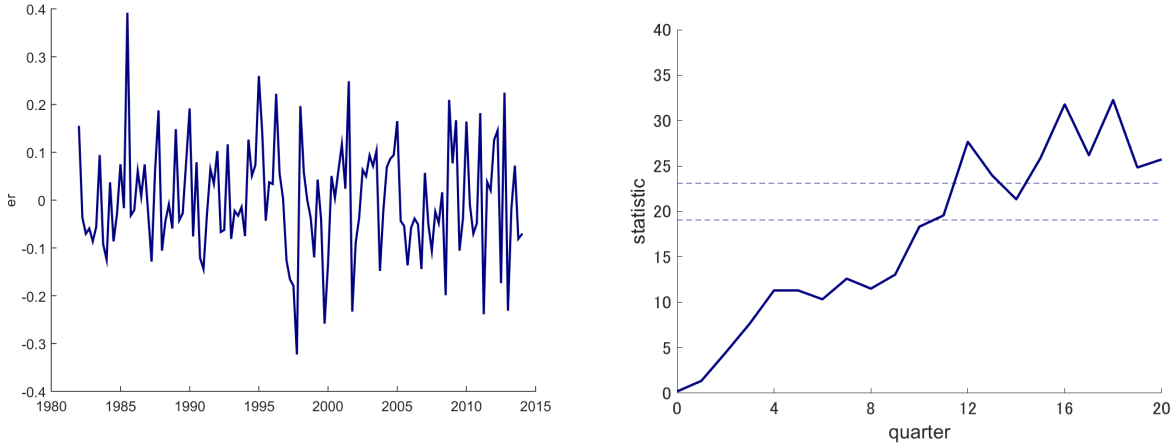
5 Results

This section presents the estimated results. I first describe the extracted news shocks and discuss their relevance as an instrumental variable for public investment spending. I then estimate the public investment multipliers of output.

[15] For a discussion of the construction of the adjusted government spending, refer to Miyamoto et al. (2018).

[16] Pavement firms that fall into this category are Nippo, Toa Road Corporation, Maeda Road, Nippon Road, Seiki-Tokyu Kogyo, Mitsui-Sumiken Road, and Sato-Watanabe. The stock prices for the first five firms are available from 1977, while stock prices for Mitsui-Sumiken Road and Sato-Watanabe are available only from 1996 and from 2013, respectively. To maintain consistency, I drop the latter two firms from the dataset.

Figure 2: Relevance condition



(a) er_t^{Road} (b) First stage robust F-statistic

Notes. The figure shows the residual, er_t^{Road}, from the regression in equation 2 (Panel (a)) and the robust F-statistics for the first-stage relevance of ER_t in equation 3 (Panel (b)). The threshold is 23.1 for one instrument for the 5% critical value for testing the null hypothesis that the two-stage least squares bias exceeds 10% of the OLS bias, and it is 19.7 for the 10% critical value.

5.1 News shock

The extracted shocks, er_t^{Road}, from equation 2 are shown in Panel (a) of Figure 2. In Appendix 8.2, I highlight some significant events that are likely to be associated with the news shocks to explain what this news shock might be capturing.

To take into account the possibility that the errors are serially correlated, I follow Ramey (2016) and apply the weak instrument tests developed by Olea and Pflueger (2013) for every horizon. Panel (b) of Figure 2 shows the robust F-statistics for the first-stage relevance of ER_t^{Road} in equation 3 together with the threshold values for the 5% and 10% critical values for testing the null hypothesis that the two-stage least squares bias is larger than 10% of the ordinary least squares (OLS) bias.[17] Although initially low, the F-statistic gradually

[17] Olea and Pflueger (2013)'s robust F-statistics and critical values are computed by the *weakivtest* stata

increases and peaks in the 18th quarter at 32.27. The F-statistics exceed the threshold values between the 12th quarter and the 20th quarter.[18] The fact that the F-statistics only peak after 18 quarters indicates that the extracted shocks capture the news element of public investment spending. In fact, the F-statistics from Ramey and Shapiro (1998) military spending news shock exhibit a similar pattern, wherein the peak comes a year after the shock.

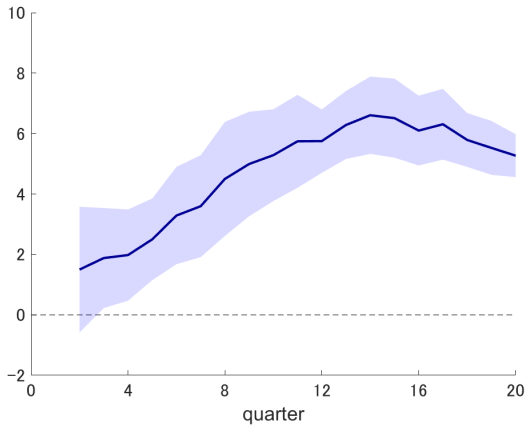
5.2 Output responses and multipliers: baseline model

Next, I use equation 3 to estimate the cumulative output multiplier, taking into account the dynamics of the public investment spending response. Figure 3 plots the output multipliers and their confidence bands. I omit the initial two quarters from the figure because the confidence bands are too wide due to the low F-statistics during these horizons. The result shows that four quarters after the shock, the cumulative output multiplier is 1.98. The multiplier steadily increases and reaches 6.10 after four years. The multiplier peaks during the 14th quarter at 6.61, and it starts to slowly decline. These estimates are substantially larger than conventional estimates of cumulative output multipliers for the US and for other countries, including Japan. However, the multiplier is in line with the local cumulative public investment multiplier reported by Leduc and Wilson (2013). The 90% confidence bands are initially large and include zero at short horizons, but they shrink as the number of horizons increases, making the multiplier statistically significant during the middle and long horizons.

command.

[18] The results contrast with the F-statistics of Fisher and Peters (2010)'s military spending shocks that are extracted from the excess returns of top military contractors. According to Ramey (2016), the F-statistics of Fisher and Peters (2010)'s shocks do not exceed 5 for all horizons. In addition, the shape of the F-statistics is different from the shapes of F-statistics using a BP method, which typically peak during the first horizon.

Figure 3: Cumulative output multipliers



Notes. This figure shows the cumulative output multipliers at each horizon as well as 90% confidence bands estimated via the local projection-IV in equation 3.

5.3 Robustness check

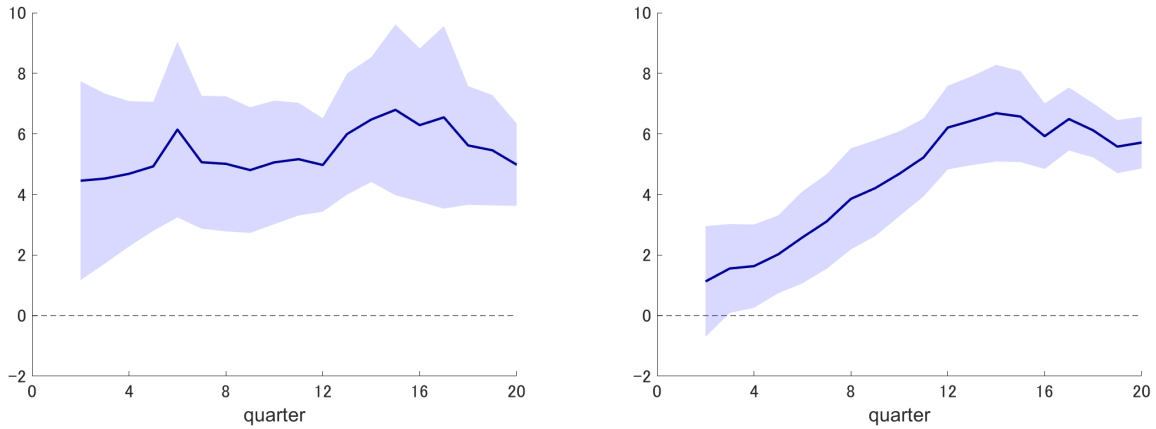
I perform several robustness checks of the baseline results. In particular, I first highlight two concerns that could invalidate the baseline results. The first concern is that my measure of excess return news shock captures economic news other than public investment that affects future output, because the construction industry is known to be a highly pro-cyclical sector of the economy. The second concern is that the excess returns are possibly affected by industry-specific shocks, such as input cost shocks.[19]

To address these two concerns, I add to the control variables the contemporaneous and four lags of 1) the construction industry's average excess returns and 2) the price of asphalt mixture for pavement construction. First, by adding the excess return of the construction

[19]The industry-specific technology shock is another factor that might be captured in the excess returns. I cannot control for the changes in road pavement technology because there is no such consistent measure. However, I suspect that the direct impact of the changes in road pavement technology on the overall economy are small, because road pavement constitutes only a fraction of the overall economic activity. Thus, I suspect that excluding road pavement technology shocks from the excess returns would not substantially affect the baseline results.

industry, I remove the industry-specific pro-cyclical components from the excess returns of road pavement firms. Panel (a) of Figure 4 shows the output multiplier when controlling for the excess returns of the construction industry. The multiplier almost doubled during the first few horizons; however, the multiplier in the middle to longer horizons, between the 12th and 20th quarters, is around 6, which aligns with the baseline results.

Figure 4: Robustness checks



(a) Construction industry excess returns

(b) Price of asphalt mixture for pavement

Notes. This figure shows the output multipliers and the 90% confidence bands estimated via the local projection-IV when the excess returns of the construction industry (Panel (a)), the price of asphalt mixture for pavement (Panel (b)) are each added to the controls.

Panel (b) of Figure 4 shows the output multipliers when the price of asphalt mixture for pavement construction is added to the control variables. Controlling for the price of asphalt, which reflects changes in the input costs of road pavement firms, is particularly important, because many other sectors of the economy also rely on asphalt.[20] As the figure shows, controlling for the proxy of input costs does not change the baseline results substantially.[21]

[20] According to the Annual Report on Road Statistics (*Douro toukei nenpou*), more than 90% of roads in Japan have been paved with asphalt since 1975.

[21] In Appendix 8.7, I show results after controlling for the public investment deflator and the price of

The output multipliers 4 quarters after the shock are about 2 and the multipliers 16 quarters after the shock are between 6 and 8.

The baseline results are robust to the inclusion of other various variables as the control variables.[22] I also examine how changing the baseline specification influences the estimates of the multipliers. In Appendix 8.7, I show that the baseline results are robust to the normalization in equation 3, using a potential output and to the inclusion of trend.

Additionally, as public investment spending is often used as part of stimulus packages, I test whether the reverse causality is a serious problem by regressing er_t^{road} on eight lags of recession indicators. If the government announces a stimulus package few quarters after the recession, er_t^{road} should be predicted by lag indicators of recession.[23] The estimated result shows that none of the eight lags of recession indicators predicts the er_t^{road}, which suggests that the influence of reverse causality is likely limited in this study.

5.4 Consumption and investment multiplier

In this section, I investigate the size of public investment multipliers for consumption and private investment. For example, I estimate the consumption multipliers using the following regression:

$$\sum_{j=0}^{h} \frac{C_{t+j} - C_{t-1}}{Y_{t-1}} = \beta_h^c + M_h^c \sum_{j=0}^{h} \frac{G_{t+j} - G_{t-1}}{Y_{t-1}} + \xi_h^c W_t + \phi_h^c(L) V_{t-1} + u_{t+h}^c, \tag{4}$$

asphalt. The baseline results are also invariant to these added controls.

[22] I conduct additional robustness checks by including contemporaneous and four lags of the public construction order, the amount of the fiscal stimulus packages and recession indicators, public works orders, and two large earthquake indicators (for the *Great Hanshin-Awaji* earthquake in January 1995 and the *Great East Japan* earthquake in March 2011). Additionally, I also conduct robustness check by including the contemporaneous financial variables, which are one-year and five-year interest rates as well as yen-dollar exchange rates. The results remain unchanged even when I control for these variables.

[23] Table 4 in Appendix 8.7 show the estimated results.

where M_h^c is the cumulative consumption multiplier estimated using the instrument, ER_t^{Road}. The controls are the same as in equation 3 plus the four lags of the dependent variable.

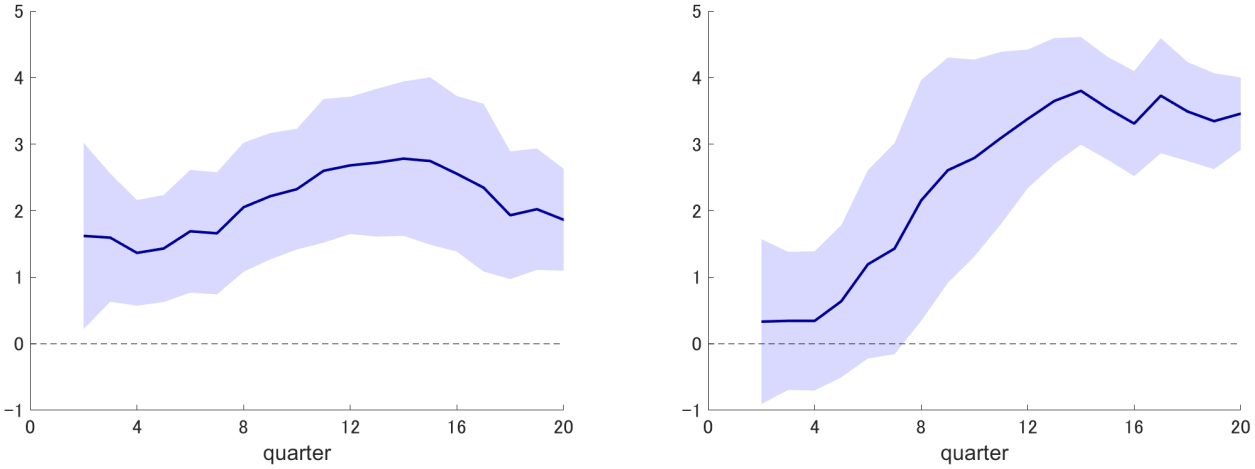
Panel (a) of Figure 5 shows the cumulative multipliers of consumption. The multipliers are above 1 starting from the second quarter, and they stay at around 2 for more than 20 quarters. The consumption multipliers are larger than the estimated Japanese consumption multiplier during the zlb periods, as reported by Miyamoto et al. (2018).

Panel (b) of Figure 5 shows the cumulative multipliers of investment. The investment multipliers are close to zero at short horizons and gradually rise to 3 by the 12th quarter. Additionally, the investment multipliers are considerably larger than the estimated investment multipliers reported by Miyamoto et al. (2018), who found that the multiplier peaks at around 1.2 even during the zlb period.[24] The result is also in contrast with Boehm (2019) who found that public investment substantially crowds out private investment when the spending shock is short-lived. These results show that public investment multipliers for consumption and investment are notably large, and the crowding-in effects are consistent with the large output multipliers found in the baseline result.[25]

[24] If one is willing to interpret the quarter when public investment spending is dispersed as the quarter in which the public investment project is completed, the response of public investment spending to a news shock (Panel (c) of Figure 6) suggests that the infrastructure projects are increasingly being completed between the second and fourth years after the shock, which partly explains why private investment starts to rise after two years. Additionally, according to Miyamoto et al (2018), who used government spending shocks that increase Japanese government spending immediately after the shock, private investment increases gradually between the first and fourth quarters during the zero lower bound (weak interest rate response) period. The gradual increase of the private investment multiplier after the shock is also observed in my estimates of private investment multipliers. However, in my paper, public investment does not immediately increase, but it increases only gradually after the news shock, which explains the a delay in the rise of public investment multipliers in my study.

[25] In Appendix 8.9, I additionally estimate the unemployment multipliers and find that the unemployment multipliers are also larger than conventional estimates.

Figure 5: Consumption and investment multipliers



(a) Consumption multipliers

(b) Investment multipliers

Notes. This figure shows the consumption multipliers (Panel (a)) and investment multipliers (Panel (b)) as well as the 90% confidence bands estimated via the local projection-IV.

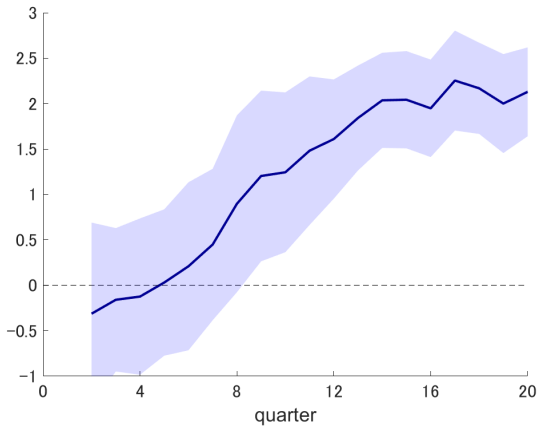
6 Discussion of the mechanism

What explains the larger public investment multipliers? Ramey (2011) explained that the government spending multipliers depend on the tax policy response, the interest rate response, the persistence of government spending, and the type of expenditure. I empirically examine which factor might explain the large public investment multipliers.

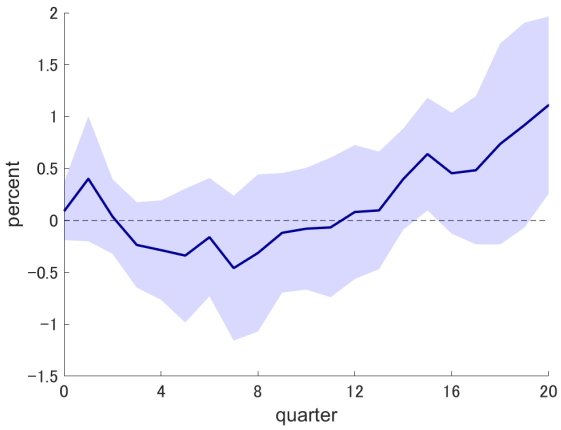
6.1 Tax multiplier

Ramey (2011) suggested that government spending multipliers are generally larger when the spending is deficit-financed. To explore this possibility, I first estimate the (cumulative) tax multipliers using equation 4. The dependent variable, the tax rate, is defined as a ratio of tax revenues to output. Panel (a) of Figure 6 shows the tax multipliers. The multiplier initially is close to zero, but it increases to 2.25 at the peak during the 17th quarter. Since

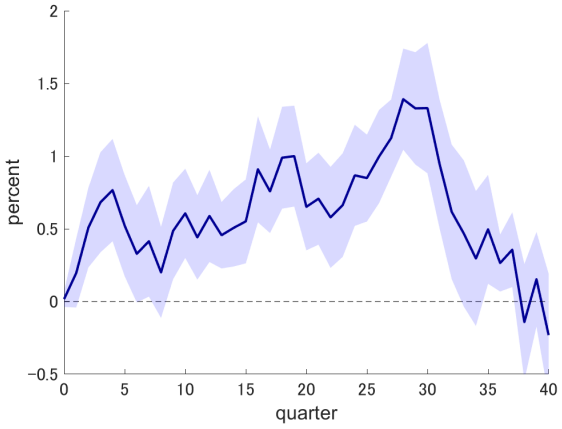
Figure 6: Tax multipliers and responses of real interest rate, public investment, and aggregate labor productivity



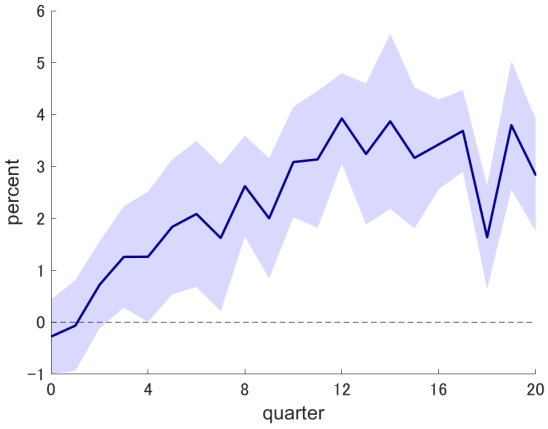
(a) Tax multipliers



(b) Short-term real interest rate responses



(c) Public investment spending responses



(d) Aggregate labor productivity responses

Notes. This figure shows the tax multipliers (Panel (a)), short-term interest rate impulse responses (Panel (b)), public investment spending impulse responses (Panel (c)), and aggregate labor productivity impulse responses (Panel (d)) as well as the 90% confidence bands. The multipliers are estimated via the local projection-IV using equation 4 and the impulse responses are estimated using equation 5. The public investment impulse responses are adjusted so that the peak response before the 20th quarter is 1 percent of the GDP in period $t-1$. The short-term interest rate responses and aggregate labor productivity responses are adjusted in such a way that they are the responses to the shock in ER_t^{Road} that causes the public investment responses shown in Panel (c).

the average tax rate responds positively to public investment spending, the tax response is unlikely to be responsible for the large public investment multiplier.

6.2 Real interest rate response

Another factor that could account for the large multiplier is the negative real interest rate response. If the real interest rate falls in response to the rise in public investment, it will have the additional effect of stimulating the economy, which contributes to a larger multiplier. To examine whether such a mechanism is at work, I estimate the short-term (*realized*) real interest rate response, which is calculated as the difference between the nominal interest rate and the inflation rate (measured in CPI). The impulse responses are estimated using equation 5, and the result is shown shown in Panel (b) of Figure 6.[26] The figure indicates that the real interest rate responses are very weak in the short horizons and gradually turn to positive 12 quarters after the news shocks. The weak real interest response during the short horizons suggests that the public investment does not crowd out private investment, which partly explains the large output and private investment multipliers.

6.3 Persistence of public investment

The third factor that could contribute to the large fiscal multiplier is the persistence of government spending. To investigate this, I calculate the impulse response of public investment spending following a shock in ER_t^{Road}. The response is adjusted so that the peak response before the 20th quarter is 1 percent of GDP. As shown in Panel (c) of Figure 6, the public investment spending response is positive and very persistent, returning to zero only about nine years after the shock.[27] When the spending shock is persistent, the intertemporal

[26] The real interest rates in the figure are in responses to the shock in ER_t^{Road} that causes the public investment responses shown in Panel (c) of Figure 6.

[27] In Appendix 8.1, I describe the history of infrastructure investment in Japan, in which long-term (5-10 years) plannings was common. The response of public investment corresponds to the span of these plans.

substitution for investment demand is mitigated. The finding is consistent with the strong crowd-in effects of private investment discussed in Section 5.4. Thus, the highly persistent public investment spending response likely induced the large output multiplier.

6.4 Aggregate labor productivity response

Finally, I examine if the increase in public investment spending raises aggregate productivity. I define aggregate labor productivity simply as the GDP over hours worked.[28] The response is calculated using equation 5, wherein the dependent variable is replaced with the aggregate labor productivity h periods ahead. Panel (d) of Figure 6 shows the aggregate labor productivity responses following a shock in ER_t^{Road} that causes the public investment responses shown in Panel (c) of Figure 6. The figure shows that labor productivity responds positively; by the sixth quarter, it increases by 2%, and by the 12th quarter, it increases by 4%. The positive productivity response suggests that public investment is productive. This particular nature of public investment probably also accounts for the large output multipliers.

7 Conclusion

In this paper, I use public investment news shocks extracted from the excess returns of road pavement firms in Japan to estimate public investment spending multipliers. The estimated multiplier is 6.10 four years after the news shock, and public investment is found to crowd in private consumption and investment. Investigating the mechanism, I find that when public investment rises persistently and simultaneously, the real interest rate responds only mildly, the public investment is substantially stimulative over the medium term.

[28] Quarterly utilization-adjusted total factor productivity data equivalent of Fernald (2014) are not available for Japan.

8 Appendix

8.1 Japanese infrastructure investment policies

The Japanese infrastructure investment policies have been affected by various factors, including the long-term goals of developing the infrastructure stock, international agreements between the US and Japan to expand Japanese domestic demand to correct large trade imbalances, and concerns regarding fiscal sustainability. The announcement of the long-term goals and agreements described above usually includes the total yen amount of planned investment for the next five to ten years, and the coverage periods of these long-term plans frequently overlap, which provides an ample source of unexpected variation in expectations for future public investment.

Of the factors listed above, the long-term plan for the construction of infrastructure has most influenced Japanese infrastructure investment policies. Two long-term plans have had an influence over infrastructure provisioning: 1) high-level comprehensive plans and 2) component-specific infrastructure plans. As highlighted by Yada (1999), four high-level comprehensive plans reflect the overall stance of the Japanese government toward the country's economic and social development: Economic Planning (EP); Comprehensive National Development Plans (CNDP); National Land Use Planning (NLUP); and the Basic Plan for Public Investment (BPPI). Of these four, the latter three have direct implications for infrastructure construction, which Table 1 summarizes. The goal of the CNDP was to reduce imbalances among different prefectures. The NLUP supplements the CNDP in that its goal is the equal

development of lands throughout Japan. Finally, the BPPI was issued after a long series of negotiations between the US and Japan; these were finally settled in 1990 when both sides agreed to correct large and long-running trade imbalances by expanding Japanese domestic demand. As their goals span many years (often more than ten), these plans do not directly aim to stimulate short-run economic outcomes.

Although the high-level comprehensive plans were useful for publicizing the government's overall stance on the future course of public investment, they were often criticized because they lacked enforcement and had a low rate of achievement. Kuroda (1996) and Koyama (2011) attributed the low achievement rate to the absence of agencies responsible for implementing the policies. In addition to the three comprehensive plans, 15 long-term plans are specifically designed for each component of public infrastructure investment (see Table 2).[29] Notably, the plans explicitly state 1) the amount of planned investment for the next five years and 2) that the plans expire and are then renewed every five years. Various government agencies design, propose, and independently execute the plans.[30] After an initial submission of the proposals, the Ministry of Finance reviews them and negotiates with each responsible government agency to determine the final amount of the planned investment.

If the component-specific plans are perfectly determined by the high-level comprehensive plans, then the announcements of new component-specific plans are perfectly anticipated. This results in some variations in beliefs about public investment policies, which come only

[29]Table 3 shows an example of plans for road investment.

[30]These include the Ministry of Transport, the Ministry of Construction, the National Land Agency, Forestry Agency, and the Ministry of Agriculture, Forestry and Fisheries. The Ministry of Transport, the Ministry of Construction, the Ministry of Land, the National Land Agency, and the Hokkaido Development Agency were integrated into the Ministry of Infrastructure, Transport and Tourism in 2001.

from revisions of the comprehensive plans.[31] The BPPI had a particularly strong influence on the component-specific plans because the BPPI was a bilateral international agreement. However, the extent to which the comprehensive plans influence component-specific plans is unclear. In fact, major newspapers usually mispredict the amount of planned investment for component-specific plans.[32] Importantly, the 15 component-specific plans were renewed in different years, and consequently, there are variations in the timing of the announcement for these 15 plans.

The comprehensive plans and the component-specific plans are both determined after a series of public and non-public discussions. This institutional setting makes it difficult to identify exactly when people's beliefs about the future course of public investment change. Thus, it could be important to consider the possibility that the release of information about future investment policy was gradual and subtle.

After the collapse of the housing bubble in the early 1990s, the Japanese government launched a series of large fiscal stimulus packages, which most often included plans for public investment and infrastructure construction. However, with public debt mounting, the public became wary of fiscal sustainability, and consequently, the long-term plans were successively terminated in the early 2000s. Since then, most of the component-specific plans have been integrated into a single "provision of the social capital" plan that does not explicitly state

[31] Nonetheless, one could argue that information about each new comprehensive plan is gradually released over time, resulting in some variation in beliefs about public investment policies.

[32] For example, on February 11, 1997, the *Yomiuri Shimbun* predicted that the planned investment for the 12th road maintenance plan would be more than 100 trillion yen. The actual amount was 78 trillion yen. On May 20, 1982, the *Yomiuri Shimbun* reported a meeting of the National Road Users Association, in which the participants demanded that the planned investment for the 9th road maintenance plans should be 50 trillion yen. The actual amount was 38.2 trillion yen.

the amount of planned investment. Starting around 1996, the share of public investment per GDP declined substantially, as shown in Figure 7.

Table 1: Comprehensive Public Investment Plans

(A) Comprehensive National Development Plan (CNDP)

	Approved on	*Coverage periods*	*Planned investment*
Comp. National Dev. Plan	1962.10.5	target year: 1970	N/A
2nd Comp. National Dev. Plan	1969.5.30	1966-1985	130-170 trillion yen
3rd Comp. National Dev. Plan	1977.11.4	1976-1989	370 trillion yen
4th Comp. National Dev. Plan	1987.6.30	1986-2000	1000 trillion yen
5th Comp. National Dev. Plan	1998.3.31	target year: 2010-2015	N/A

(B) National Land Use Planning (NLUP)

	Approved on	*Coverage periods*	*Planned road investment*
National Land Use Plan.	1976.5.18	1972-1985	210,000 ha
2nd National Land Use Plan.	1985.12.17	1982-1994	240,000 ha
3rd National Land Use Plan.	1996.2.23	1992-2005	200,000 ha
4th National Land Use Plan.	2008.7.4	2004-2017	70,000 ha

(C) Basic Plan for Public Investment (BPPI)

	Approved on	*Coverage periods*	*Planned investment*
Basic Plan for Pub. Invest.	1990.6.28	1991-2000	430 trillion yen
New Basic Plan for Pub. Invest.	1994.10.7	1995-2004(2007)	630 trillion yen

Notes. Coverage periods in fiscal years. Planned investment for second, third, and fourth CNDP are expressed in yen in 1965, 1975, and 1980, respectively. Planned investment for NLUP include various goals, including roads, farm land, forest, plain field, rivers and waterways, and housing land. The table shows the goal for road pavement only. Planned investments for BPPI are expressed in nominal values at the time of plan approval. The coverage periods for the New Basic Plan for Public Investment initially were 1995-2004 but later were expanded to 1995-2007.

8.2 Extracted news shocks and significant events

In this section, I highlight some notable events that might be associated with the movement in news shocks, as illustrated in Figure 2. First, the largest positive news shock in Figure 2 occurred during the third quarter of 1985. On August 19, 1985, the Ministry of Construction proposed a long-term plan for 21st century infrastructure construction that widely expanded

Table 2: List of Long-term Infrastructure Plans

		First plan began in	*duration*	*discontinued in*
(1)	*Fishing Harbors*	1951	5 years	2001
(2)	*Roads*	1954	5 years	2002
(3)	*Erosion and Flood Controls*	1960	5 years	2003
(4)	*Forest*	1992	5 years	2003
(5)	*Municipal Parks*	1972	5 years	2002
(6)	*Sewage System*	1963	5 years	2002
(7)	*Waste Disposal*	1963	5 years	2002
(8)	*Coastal Areas*	1970	5 years	2002
(9)	*Dock and Harbor*	1961	5 years	2002
(10)	*Airport*	1967	5 years	2002
(11)	*Traffic Safety Facilities*	1966	5 years	2002
(12)	*Housing*	1966	5 years	2000
(13)	*Coastal Fishing Ground*	1976	5 years	2001
(14)	*Land Improvement*	1965	10 years	continuing
(15)	*Steep Slope Failure Prevention*	1983	5 years	2002

Notes. in fiscal year.

Table 3: Five-year Road Investment/Maintenance Plans

	Begins in	*Ends in*	*Planned investment*
1st plan	1954	1958	0.26 trillion yen
2nd plan	1958	1962	1 trillion yen
3rd plan	1961	1965	2.1 trillion yen
4th plan	1964	1968	4.1 trillion yen
5th plan	1967	1971	6.6 trillion yen
6th plan	1970	1974	10.35 trillion yen
7th plan	1973	1977	19.5 trillion yen
8th plan	1978	1982	28.5 trillion yen
9th plan	1983	1987	38.2 trillion yen
10th plan	1988	1992	53 trillion yen
11th plan	1993	1997	76 trillion yen
12th plan	1998	2002	78 trillion yen

Notes. in fiscal year.

the infrastructure plans for the next 15 years. The proposal became the basis for the fourth Comprehensive National Development Plan as well as five component-specific long-term plans that were to be renewed the following year. Major newspapers, including Nikkei shimbun, Yomiuri shimbun, and Asahi shimbun, reported on August 20, 1985 that by 2000, the Ministry of Construction proposed spending 341 trillion yen for infrastructure and 388 trillion yen for housing. At that time, the proposal by the conservative administration, led by Prime Minister Nakasone, was viewed as aggressive. The Nakasone administration strongly promoted a conservative fiscal budget, and under Nakasone, all component-specific long-term plans, which started before he became prime minister, failed to reach their goals. Another significant event during the third quarter of 1985 was the Plaza Accord. Signed on September 22, 1985, the Plaza Accord between Japan, the US, and three other nations, aimed to depreciate the US dollar against the Japanese yen and German Deutsche Mark. Following the announcement of the accord, the Japanese yen significantly appreciated. The Plaza Accord no doubt had a considerable impact on the future course of the Japanese economy, and it might explain to some extent the magnitude of the shock that occurred during the third quarter of 1985. However, the magnitude of the shock remains largely the same even after I control for the exchange rate during this period. Thus, the large positive shock that occurred during the third quarter of 1985 cannot be explained by the Plaza Accord alone.

The magnitude of positive news shocks, on average, becomes smaller over time. Two of the larger shocks in recent years occurred during the second and the last quarters of 2012.

In June 2012, the opposition party of the Liberal Democratic Party (LDP) announced and proposed a bill called the "Basic Act for National Resilience" (or Kokudo Kyoujinka Kihon Houan), which aimed to vastly expand infrastructure investment. The bill, a response to the Great East Japan Earthquake of 2011, mandated that infrastructure investment spend a total of 200 trillion yen over the next ten years. Since the LDP was still an opposition party when the bill was proposed, the bill did not pass the Congress, but it hinted that once the LDP became the ruling party, which was expected to happen the following year, a large fiscal expansion would occur.[33] In November 2012, Prime Minister Noda and the LDP leader Abe agreed to dissolve the Diet and call for a surprise snap election. The general election took place the following month. The LDP became the ruling party and the new administration was formed under the newly-elected Prime Minister Abe in December 2012. That the new shocks reacted positively in the second and fourth quarters of 2012 suggests that the shocks picked up the surprise components of the news about the future course of infrastructure spending during these periods.

I now turn to a discussion of some negative new shocks. Starting in the first quarter of 1997 and lasting until the last quarter of 1997, a series of negative shocks occurred. During these periods, concern about fiscal sustainability became a prime issue for the Hashimoto administration, and concrete measures to suppress government spending included reducing the scale of the BPPI and other long-term infrastructure plans. A series of negative news shocks during this period appeared to coincide with the government's announcement that it

[33]The approval rating of the administration in July 2012 was 28%, according to Nikkei shimbun, and 23%, according to Mainichi shimbun, and many expected that the LDP would win the next election

would scale back its infrastructure plans.

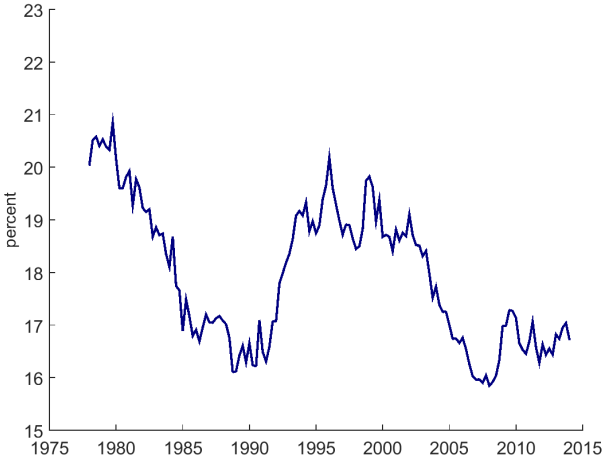
Another series of negative news shocks started during the second quarter of 2005 and continued until the fourth quarter of 2006. On August 8, 2005, the Diet dissolved and Prime Minister Koizumi called for a snap general election. The election resulted from Prime Minister Koizumi's long political struggle to privatize Japan's postal service, which he accomplished after winning the snap election. Postal privatization had important implications for future infrastructure spending because Japan's postal service was taking deposits and using them to fund road investment and other government expenses. The postal privatization meant that the government could no longer freely use those deposits for government expenses. Starting in the second quarter of 2005, the news shocks became negative for six consecutive quarters, which might reflect the negative fiscal shocks associated with postal privatization and its ramification during these periods.

8.3 Comparison of Japanese and US public investment

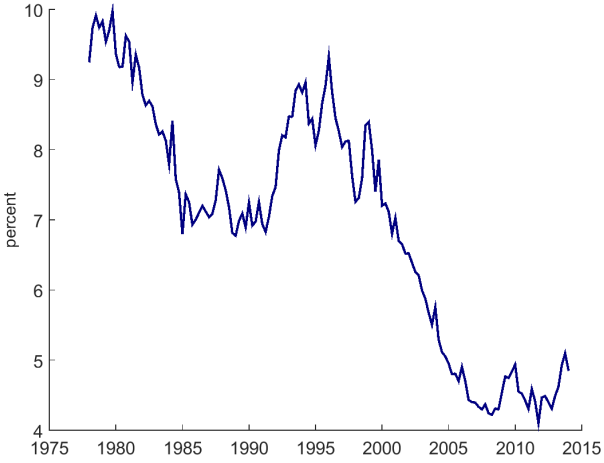
Although understanding the scale of the public investment multiplier is crucial for assessing the effectiveness of fiscal policies, its empirical investigation using macroeconomic data is challenging because of the long implementation lag associated with public investment projects. Highlighting the difficulty of controlling for the anticipation effects of public investment in the US, Ramey (2016) noted that although the highway system was a significant component of government spending between the late 1950s and the early 1970s, "most of the spending on the US highway system was anticipated once the highway bill was passed in 1956." In addition, after the highway system was completed, variation in public investment

in the US became substantially smaller, making it difficult to estimate the public investment multipliers using US aggregate data, even after the 1980s.

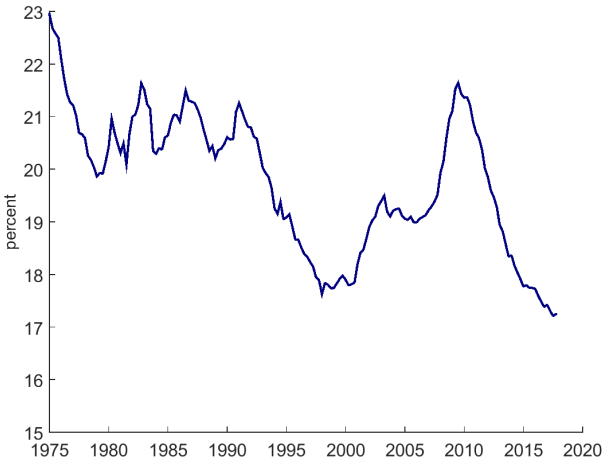
Figure 7: Government spending and public investment as a share of GDP



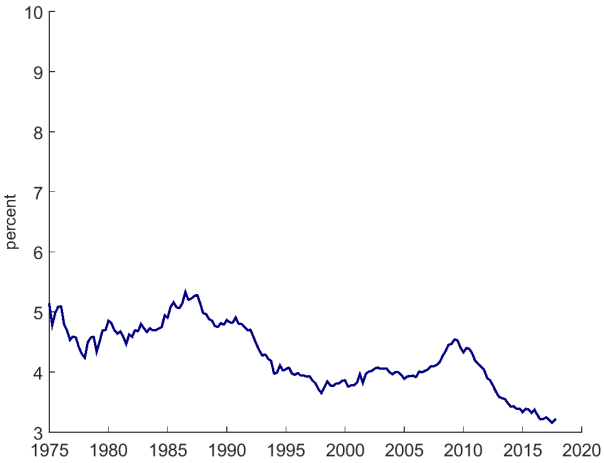
(a) Japan: Government Spending/GDP



(b) Japan: Public Investment/GDP



(c) United States: Government Spending/GDP



(d) United States: Public Investment/GDP

Notes. This figure shows Japanese government spending per GDP (Panel (a)), Japanese public investment per GDP (Panel (b)), US government spending per GDP (Panel (c)), and US public investment per GDP (Panel (d)). Data are from SNA for Japan and from NIPA for the US.

Infrastructure investment in Japan, on the other hand, has been driven by various factors

that are often irrelevant to the current state of the economy, such as the renewals of the long-term plan for developing an infrastructure stock, international agreements between the US and Japan to expand Japanese domestic demand to correct large trade imbalances, and concerns about long-term fiscal sustainability.[34] Changes in these factors provide unexpected variations in public investment that can be used to estimate the aggregate public investment multipliers.[35] Figure 7 shows Japanese government spending (upper left panel) and public investment (upper right panel) as a share of GDP as well as the government spending share and public investment share for the US (in the lower panels). Two important differences between the US and Japan emerge from the figure. First, between 1978 and 2014, public investment as a share of GDP in Japan was, on average, about twice as large as that of the US. Second, during the same periods, the share of public investment in Japan was approximately three times more volatile than in the US. The standard deviation of public investment per GDP in Japan between 1978 and 2014 was 0.0133 while the standard deviation in the US during the same period was only 0.0046. The variability of Japanese public investment helps to precisely estimate the multipliers. These features make the Japanese experience valuable for learning the macroeconomic impacts of public investment.

8.4 Additional literature review

Several researchers have estimated the fiscal multiplier in Japan. Using the BP methods and controlling for government spending forecasts, Miyamoto et al. (2018) estimated fiscal

[34]Public investment = infrastructure investment + public inventory investment. As infrastructure investment accounts for the majority of public investment, I use the terms "public investment" and "infrastructure investment" interchangeably.

[35]The details of these factors and a brief description of the history of Japanese public investment are found in Appendix 8.1.

multipliers in Japan under normal periods as well as under zero lower bound (zlb) periods. The authors found cumulative fiscal multipliers of 0.6 under normal periods and 1.5 under zlb periods. Kuttner and Posen (2002) used the BP method to find government expenditure multipliers well in excess of one in Japan. Bayoumi (2001), who also employed the BP method, reported a multiplier of 0.65. Miyazaki et al. (2018) investigated the effect of public investment on the stock market under the zero lower bound environment.[36] Using the same dataset as Miyamoto et al. (2018), I find the cumulative multiplier of 6.10 four years after public investment news shocks.

Methodologically, this study follows Fisher and Peters (2010), who used the excess returns of three top military contractors in the US as a military spending news shock. Applying the same framework, Morita (2017) used the excess returns of the construction industry and the sign-restriction VAR to estimate fiscal multipliers in Japan. Recently, Fieldhouse et al. (2017) used the excess returns of Fannie Mae and Freddie Mac to estimate the impacts of their activities on the mortgage market and the aggregate economy. This study is also related to Shioji (2017) and Shioji (2018), who combined the narrative approach and the excess return approach to identify news shocks about public investment in Japan. Shioji first identified dates when significant news concerning future public investments was released in major newspapers.[37] The author then measured the surprise component of the news shocks by comparing the movements of stock prices on those dates in highly government-dependent construction firms and in less dependent construction firms. He found that public

[36] Additionally, Fujii et al. (2013) and Miyazaki (2018) estimated the local and aggregate effects of public investment in Japan on private investment.

[37] For example, news about fiscal stimulus packages and disasters (such as large earthquakes).

investment news shocks have a positive and statistically significant impact on output. The current study differs from Shioji's in that I take into account the possibility that expectation grows gradually on days not identified as significant news days, thereby avoiding the problem inherent in the narrative approach, which is the subjectivity of date selection.

8.5 Japanese road investment statistics

Figure 8 shows Japanese road investment as a share of total government spending in Panel (a) as well as the share of road construction orders from government-related agencies based on the surveys of the 50 largest Japanese construction firms in Panel (b). The figure indicates that the road pavement spending closely reflects public investment spending.

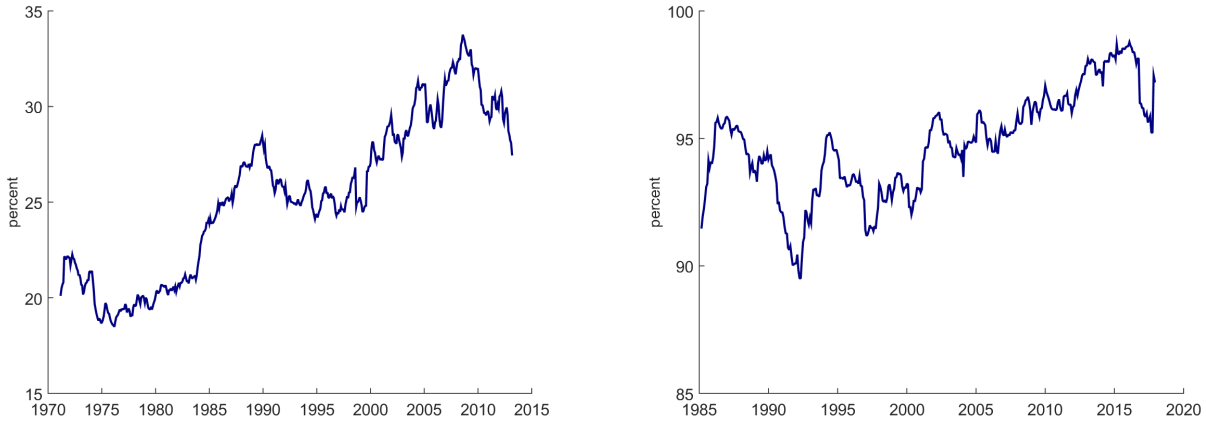
8.6 Impulse response functions

I estimate the impulse responses to a shock in ER_t^{Road} using the following regression for different horizons h:

$$z_{t+h} = \alpha_h + \gamma_h \, ER_t^{\text{Road}} + \Lambda_h W_t + \theta_h(L) V_{t-1} + \nu_{t+h}, \tag{5}$$

where z_{t+h} is the dependent variable. When the dependent variable is the public investment (Panel (c) in Figure 6), $z_{t+h} = \frac{G_{t+h} - G_{t-1}}{Y_{t-1}}$ is the growth of the public investment from period t to $t+h$ normalized by the output in period $t-1$. When the dependent variable is the real interest rate (Panel (b) in Figure 6), $z_{t+h} = r_{t+h}$, where r_{t+h} is the real interest rate in period $t+h$. Finally, when the dependent variable is the aggregate labor productivity (Panel (d) in Figure 6), $z_{t+h} = A_{t+h} - A_{t-1}$, where A_{t+h} is the aggregate labor productivity in period

Figure 8: Road investment spending



(a) Road investment as a share of total government spending

(b) Share of road construction orders from government-related agencies

Notes. This figure shows the road investment as a share of total government spending (Panel (a)) and the share of road construction orders from government-related agencies (Panel (b)). Data for Panel (a) are from the Comprehensive Statistics on Construction (Kensetsu-Sougou Toukei) conducted by the Ministry of Land, Infrastructure. The series in Panel (a) is calculated by dividing the road construction orders by total infrastructure construction orders, both in a 12-month moving average. Data for Panel (b) are from Current Survey on Orders Received for Construction, the 50 largest construction firms in Japan (A-group survey), conducted by the Ministry of Land, Infrastructure, Transport and Tourism. The series in Panel (b) is calculated by dividing the road construction orders by total infrastructure construction orders, both in a 12-month moving average.

$t + h$. The control variables are identical to the ones used for estimating the multipliers in equation 3. Additionally, the regression includes four lags of ER_t^{Road}. I include the lags of ER_t^{Road} to ensure that the results are not affected by a possible serial correlation of ER_t^{Road}.

8.7 Additional robustness checks

In this section, I perform additional robustness checks. Panels (a) and (b) of Figure 9 show the output multipliers when the public investment deflator and the price of asphalt are added to the control variables. These variables are alternative measures for the changes in the input costs of road pavement firms. As the figure shows, the baseline results are robust to inclusion

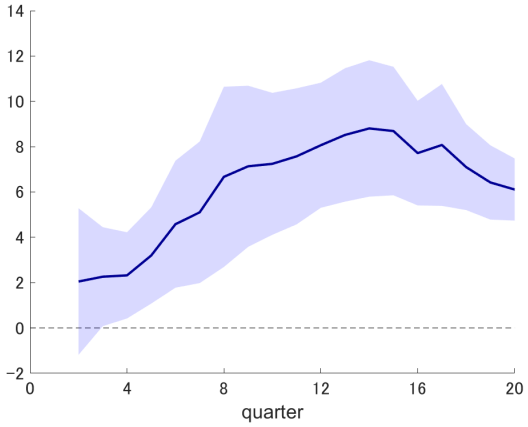
of these proxies of input costs. Additionally, Panel (c) shows the output multipliers when the public construction orders are added to the control. The public construction orders are controlled so that the residual variation in the excess return does not respond to the increase in public investment orders not yet reflected in the public investment data. Panel (d) shows the multipliers after controlling for contemporaneous financial variables, which are one-year and five-year interest rates as well as yen-dollar exchange rates. The output multipliers are invariant to these added controls.

In addition, I briefly introduce how baseline results change when using different model specifications in equation 3. First, I include a quadratic time trend (Panel (e) of Figure 9). Second, I normalize changes in public investment spending and output in equation 3 using a potential output estimated by the HP-filter (Panel (f)). With the exception of multipliers over the longer horizons in the case of the trend, the results are similar to the baseline model. When the trend is included, the cumulative multiplier exceeds 9 at the longer horizon. However, the multipliers at the shorter and middle horizons remain similar to the baseline results, even when the trend is included. Normalization with the potential output does not make any meaningful difference to the estimated results.

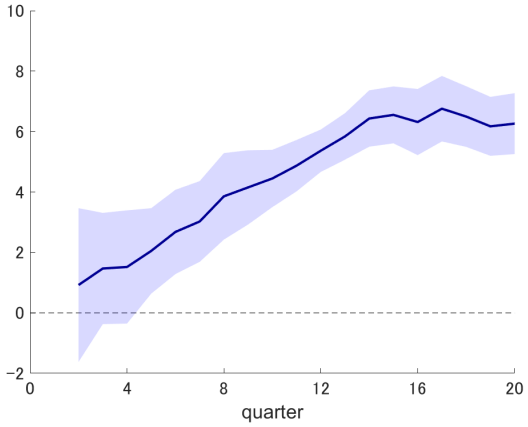
Additionally, I conduct a test for reverse causality, as described in Section 5.1. Specifically, I estimate the following regression:

$$\begin{aligned} er_t^{\text{road}} =& \alpha + \beta_0 \text{recession}_t + \beta_1 \text{recession}_{t-1} + \beta_2 \text{recession}_{t-2} + \beta_3 \text{recession}_{t-3} + \beta_4 \text{recession}_{t-4} \\ &+ \beta_5 \text{recession}_{t-5} + \beta_6 \text{recession}_{t-6} + \beta_7 \text{recession}_{t-7} + \beta_8 \text{recession}_{t-8} + \eta_t \end{aligned}$$

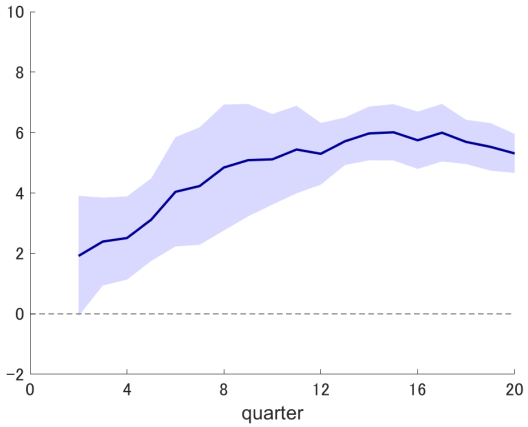
Figure 9: More robustness checks



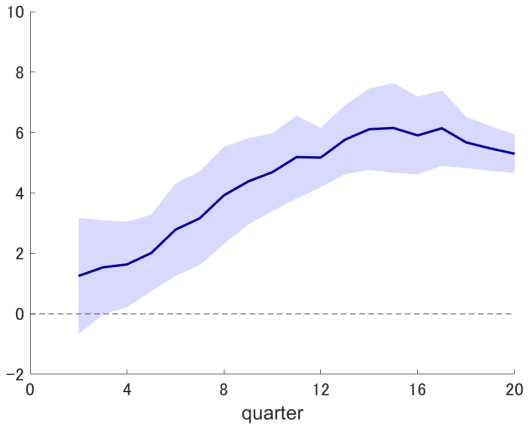
(a) Public investment deflator



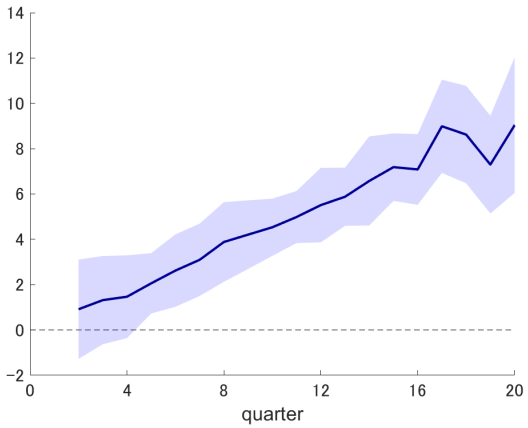
(b) Price of asphalt



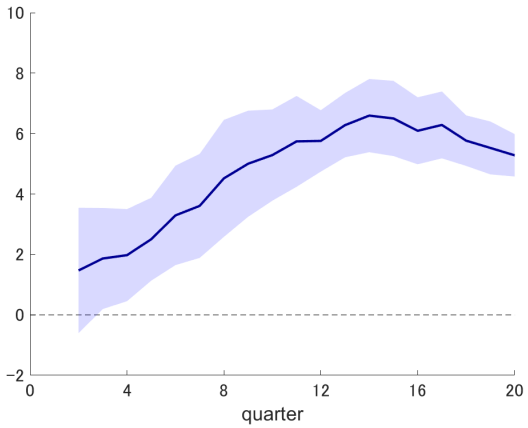
(c) Public construction order



(d) Contemporaneous financial var.



(e) With trend



(f) Using potential output

Notes. This figure shows the output multipliers and the 90% confidence bands estimated via the local projection-IV when the public investment deflator (Panel (a)), the price of asphalt (Panel (b)), the public construction order (Panel (c)), and the contemporaneous financial variables (Panel (d)) and the trend (Panel (e)) are added to the controls. Additionally, the figure shows the output multipliers when the potential output extracted by the HP-filter is used for normalization of output in equation 3 (Panel (f)).

where recession$_t$ is the recession indicator in period t. The result is shown in Table 4. None of the eight lags of recession indicators predicts the er_t^{road}, which suggests that the influence of reverse causality is likely limited in this study.

Table 4: Test for reverse causality

	coefficient	t-statistics
Recession Indicator$_t$	-0.23	-0.58
Recession Indicator$_{t-1}$	0.03	0.05
Recession Indicator$_{t-2}$	-0.25	-0.62
Recession Indicator$_{t-3}$	0.00	0.01
Recession Indicator$_{t-4}$	-0.42	-1.09
Recession Indicator$_{t-5}$	-0.14	-0.35
Recession Indicator$_{t-6}$	-0.09	-0.24
Recession Indicator$_{t-7}$	-0.12	-0.31
Recession Indicator$_{t-8}$	0.07	0.18
Observations	123	
R^2	0.0189	
p-value for F-test for joint significance	0.987	

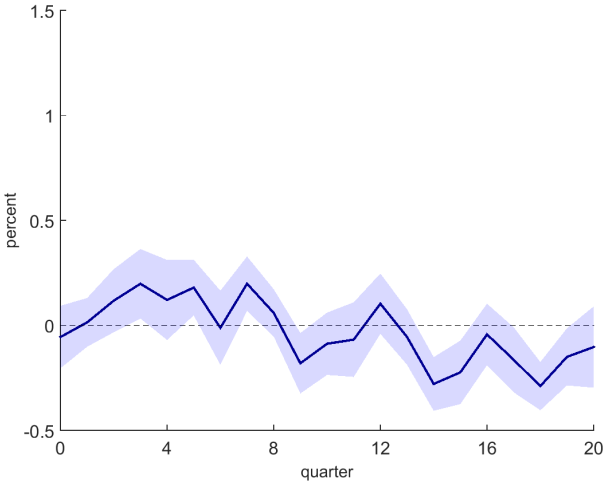
Table shows the results of the regression where the dependent variable is er_t^{Road} and the independent variables are eight lags of recession indicators. Specifically, the regression is as follows: $er_t^{\text{road}} = \alpha + \beta_0 \text{recession}_t + \beta_1 \text{recession}_{t-1} + \beta_2 \text{recession}_{t-2} + \beta_3 \text{recession}_{t-3} + \beta_4 \text{recession}_{t-4} + \beta_5 \text{recession}_{t-5} + \beta_6 \text{recession}_{t-6} + \beta_7 \text{recession}_{t-7} + \beta_8 \text{recession}_{t-8} + \eta_t$. The null hypothesis for F-test is $\beta_0 = \beta_1 = \beta_2 = \cdots = \beta_8 = 0$.

8.8 Response in public consumption

To credibly estimate the public investment multipliers, my public investment news measure should predict only the public investment spending component of government expenditure and not public consumption. Therefore, I estimate regression equation 5 using public consumption as the dependent variable.[38] Figure 10 shows the response in public consumption to a shock in my public investment news measure. The response is adjusted so that the mag-

[38]The public consumption is expressed as the change in public consumption spending normalized by output.

Figure 10: Public consumption impulse response



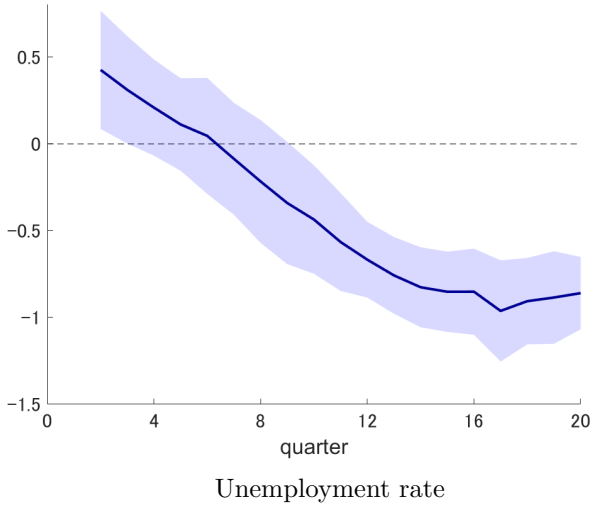
Notes. The figure shows the impulse responses of public consumption as well as the 90% confidence bands. The public consumption responses are adjusted in such a way that they are the responses to the shock in ER_t^{Road} that causes the public investment spending responses in Panel (c) in Figure 6.

nitude of the shock is the same as the shocks that increased public investment by 1% at its peak. In contrast to the response in public investment, the response in public consumption is weakly negative over longer horizons, which suggests that the public consumption is adjusted downward slightly to accommodate an increase in public investment spending. This implies that the extracted measure of news shocks captures the combined effect of both a substantial increase in public investment and a small reduction in public consumption. Given that public consumption has a positive impact on output, the effect on output estimated using the news shocks probably is a lower bound for the true effect of public investment.

8.9 Unemployment multiplier

To investigate whether public investment has a similarly large impact on the labor market, I estimate the multiplier of the unemployment rate. As with the output and other multipliers, I

Figure 11: Unemployment rate multipliers



Notes. The figure shows the unemployment rate multipliers as well as the 90% confidence bands via the local projection-IV.

estimate the multiplier of the unemployment rate as the cumulative percentage point change in the unemployment rate that occurs in response to a change in public investment spending of 1% of output. Figure 11 shows the multipliers of the unemployment rate. The multiplier is weakly positive during the first few quarters and then gradually decreases, reaching -0.96 in the 17th quarter. The positive multiplier in the short term is not statistically significant, except during the second quarter, while the negative unemployment rate multiplier over the longer term is statistically significant with the 90% confidence bands. According to Miyamoto et al. (2018), the unemployment rate multiplier is similar to the government spending multipliers during the zlb periods. Given that the sample in this study includes both normal and zlb periods, the result indicates that the public investment multiplier for the unemployment rate is also greater in magnitude than previous estimates of the government

spending multiplier.

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