An Estimation and Decomposition of the Government Investment Multiplier[a]

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Abstract

We construct a new narrative instrument for government investment shocks from official records in Germany. Using structural vector autoregressions, we document a significant crowding-in of private demand and an output multiplier of 2 on impact, which increases to 3 after five years. Then, we use a New Keynesian dynamic stochastic general equilibrium model matched to the empirical responses to decompose the multiplier into two channels. In the short run, public investment reduces private investment costs by 16%. In the long run, public investment increases the production capacity of the economy. The estimated output elasticity of public capital is 0.06.

JEL: E62, E65, H54

Keywords: Fiscal policy, public investment, structural vector autoregression, instrumental variable, general equilibrium model, Germany.

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1 Introduction

Global GDP fell by more than 3% in 2020. In response, many governments issued large fiscal spending packages to stimulate the economy. In the US, the rescue and recovery plan initially summed to more than 15% of GDP. In Europe, the NextGenerationEU package alone provides roughly 800 billon euros; this is on top of national funds. Many of the stimulus programs are intended to stabilize the economy in the short term while also, simultaneously, modernizing and transforming the public infrastructure over the medium term as aging societies and climate change call for a substantial increase in public investment (Summers, 2015; Blanchard et al., 2021).

In this paper, we estimate the macroeconomic effects of government investment. We build a novel and unique narrative instrument for public investment from historical records in Germany. We use government finance reports, legislation, and forecasts. The instrument measures the financial volume of concrete exogenous investment programs. We employ the instrument in structural vector autoregressions (SVAR) to trace out the dynamic effects of the shocks. We find a crowding-in of private demand and large output effects. Then, we build a New Keynesian dynamic stochastic general equilibrium (DSGE) to decompose the effects. We focus on two transmission channels: public investment can affect private investment adjustment costs, and public capital can be productive. We estimate the size of these effects by impulse response matching. We find that both features are relevant for understanding the empirical dynamics. The first leads to a crowding-in of private investment in the short run. The second implies a crowding-in of private investment as well as private consumption in the long run.

We contribute to a literature that uses official government documents, for example, laws or budgetary reports, to construct time series of narratively identified exogenous changes in fiscal policy. Such series can be used as instrumental variable to estimate the macroeconomic effects of fiscal policy measures. Previous studies concentrate on changes in tax rates (Romer and Romer, 2010; Mertens and Ravn, 2011; Cloyne, 2013; Mertens and Montiel Olea, 2018), total government expenditures with a focus on military spending (Ramey, 2011; Ramey and Zubairy, 2018), both (Barro and Redlick, 2011), or social security contributions (Gechert et al., 2021). We contribute to this literature by constructing and applying the first narrative instrument for government investment.

Since Aschauer (1989a,b), researchers have aimed at measuring the effects of government investment, whether it is productive, and whether private activity is crowded-in. Crowding-in can occur if public investment increases the returns for the private sector and stimulates investment activity there. An expansion of the public road network, for example, can accelerate the transport and trade of goods. This would lead to gains in the efficiency of the production process and raise the profit expectations of private companies. Firms are then potentially more willing to invest as the marginal product of private capital increases. On the contrary, crowding-out of private activity might occur if an increase in public investment raises the user costs of capital. As the government demands financial resources, private investment can become less profitable. Although this channel may be weakened in a low interest rate environment, financing public investment can still be harmful to the private sector as it leads to higher tax burdens that might depress demand.

These opposing effects are reflected in a lack of consensus in the literature about the size of government investment multipliers. Auerbach and Gorodnichenko (2012a) and Ilzetzki et al. (2013) estimate that the government investment multiplier is higher than the government consumption multiplier, while Boehm (2020) documents the opposite. Leeper et al. (2010) and Ramey (2021) analyze the macroeconomic effects of public investment in DSGE models. They find lower multipliers in the short run because of implementation delays inherent in infrastructure projects but sizable effects in the long run if government capital is productive. Moreover, multipliers are greater if the economy starts from a point below the socially optimal amount of public capital. Gechert (2015) addresses this controversy in a meta-study where he identifies about 100 relevant studies on fiscal multipliers. For public investment, he finds an average multiplier of 1.3 with a standard deviation of 0.9. The crucial parameter for the size of the medium term public investment-to-output multiplier is the output elasticity of public capital. Estimates range from slightly negative to 0.4 (Bom and Ligthart, 2014; Leeper et al., 2010; Ramey, 2021).

We contribute to this literature along two dimensions. First, we reassess the empirical question about the size of the public investment multiplier and whether there is crowding-in or crowding-out of private demand based on our novel narrative instrument. The instrument incorporates key public investment programs in Germany since 1970Q1. The primary sources for the series are the annual finance reports and historical budgetary plans in the library archive of the German Federal Ministry of Finance. These include chronological notes about the size and duration of

investment programs. While the documents are in principle publicly available, access to the archive required the consent of the Ministry, a signed project contract, and the supervision by staff. We add information on the purpose of the spending, specifically, whether it was designed to stabilize aggregate output in the short run or to increase potential output in the medium term, from legislative documents of the German Bundestag and semi-official forecasts.

The instrument addresses several challenges that arise when relying on information gathered from national account or public finance statistics. First, these sources do not cover the entire public investment activity; for example, due to outsourcing from federal budgets or definitions that exclude public investment grants. Second, they do not allow addressing reverse causality concerns, that is, if public investment is increased in the short term as a result of economic stabilization, because the statistical sources do not provide the motivation for the increase in public investment. Third, they are ambiguous regarding the types, size, and timing of investments. As a result, they capture only the economic effects that arise immediately after completion of an investment program, but not the program's impact on expected future cost and revenue changes and, hence, on private investment decisions today.

We use the narrative series as an instrument in Proxy-SVAR models to identify the causal effects of public investment, using the methodology of Stock and Watson (2012) and Mertens and Ravn (2013). We estimate a government investment to output multiplier of 2 upon impact and of 3 after five years. Furthermore, we find that an expansionary government investment shock raises both private investment and private consumption significantly. The unemployment rate falls and the real wage rises, while prices increase little. A variance decomposition shows the importance of government investment shocks for output fluctuations. At the one year horizon, the shocks explain 8% of the variability in GDP. After five years, they account for one fifth. A historical decomposition of the output gap documents a significant positive role for government investment especially after reunification. These findings complement the empirical literature that regularly relies on exclusion restrictions (Gechert, 2015; Auerbach and Gorodnichenko, 2012a; Ilzetzki et al., 2013; Boehm, 2020). Caldara and Kamps (2017) show that the government spending multiplier is sensitive to the identification strategy.

The second contribution is that we decompose the output effects of government investment shocks estimated with the new instrument. We set-up a New Keynesian DSGE model that builds

on Leeper et al. (2017). We add public investment to the model and focus on two transmission channels. First, government investment enters an otherwise standard private investment adjustment cost function. This modification reflects that empirically about one third of the investment programs in our narrative series are investment grants. The main purpose of these grants is to reduce private investment costs. The second channel is the traditional augmentation of the production function of private firms with public capital (Baxter and King, 1993). We match the impulse response functions of the DSGE model to those of the SVAR by estimating the two parameters corresponding to the two channels and determining the size of the multiplier.

The first channel is relevant for the short run. In principle, public investment can decrease or increase actual and expected private investment adjustment costs. A cost-reducing effect can arise if public investment programs contain investment grants that directly lower private investment costs. In addition, private costs may decrease if the new public infrastructure lowers trade and transaction costs. For example, a tighter transportation network could allow firms to build more quickly. Similarly, an expansion of public digital infrastructure may imply that private-sector projects will be approved with less bureaucracy and more rapidly. In contrast, a cost-increasing effect may result if public investment leads to congestion. For example, the construction of an additional freeway lane may lead to a temporary closure of existing lanes. We find that the cost-reducing effect dominates: public investment programs reduce private investment adjustment costs by 16%. Thereby, they have a positive effect on private investment activity in the short run.

The second channel is relevant for the long run. Government investment raises the public capital stock. If public capital is productive, this increases the marginal product of private inputs, generates positive wealth effects, and spurs private demand. In contrast, if public capital is unproductive, resources are wasted and private demand falls. We find that public capital is productive. The estimated output elasticity of public capital is 0.06. Hence, public investment programs have a positive effect on private demand in the long run.

2 Construction of instrument for government investment

To estimate the macroeconomic effects of public investment, we need a series that properly reflects the investment activities of the government. We construct a novel and unique public

investment data series from alternative sources available in Germany. The series incorporates key public investment programs since 1970Q1. We use four sources.[1] The main sources are two official government publications: the annual finance reports ('Finanzberichte') and the historical budgetary plans. Both documents are published annually since 1970 and exist in printed versions in the library archive of the German Federal Ministry of Finance. In principle, they are publicly available. However, before we obtained actual access to the archive, we needed to contact the Ministry, its consent to access the library, a signed project contract, and to agree to the supervision by two staff members.[2]

The raw data points are cross-checked and filled with information from two additional sources. The first is the online archive of the German Bundestag. It contains 167.000 legislative documents and reports for the period since 7th September 1949, of which 8.700 are enacted laws. We can search specifically for investment programs in the online archive with the information from the physical archive at hand, as the latter contains the calendar days of the announcement and resolution of the programs. In this way, we collect additional chronological legislative notes from the online archive about most of the investment programs, but not about all programs as some were covered by general warrants and did not require a new law. It is not possible to construct the instrument starting from the online archive, which has only a basic search function. When looking for, say, 'investment' or similar search words we obtain way too many and unrelated search results. This limitation restricts the sample to the period 1970 onward of the physical archive.

Moreover, we resort to the semi-annual reports of the Joint Economic Forecast Group to collect additional information about the size and the duration of the programs.[3] The group forecasts, among others, the fiscal budget in detail, including different types of public investments and public investment grants. The reports for the 1970-2007 period are available physically in the library archive of DIW Berlin. For 2007 onwards, they can be downloaded via `https://gemeinschaftsdiagnose.de/`.

From the four sources, we collect in total information on 25 investment programs for the period

[1] Appendix A.1 contains a detailed explanation of the data sources and investment programs.

[2] We are extremely thankful to Erik Klär and Christoph Priesmeier for their time and support to access, collect, and organize the documents and for fruitful discussions about the data. For replication purposes, the reports are also available online but only since 1995.

[3] The Joint Economic Forecast Group is an institutionalized project group of Germany's leading business cycle forecast research institutes (DIW Berlin, ifo Munich, ifw Kiel, IWH Halle, RWI Essen).

1970Q1-2018Q4. Table 1 lists the programs. For example, in 1977Q1 the German government started a 6.7 bn Euro five-year Program for Future Investments (No. 5), in which states and municipalities are involved. The Regulation Statement foregrounds the longer term, growth, and structural economic motivation for the program. Consequently, it contains mainly infrastructure investments. Business cycle stabilization and employment policy goals are not mentioned. The federal government has earmarked 4.1 bn Euro for its own share. The states and municipalities had planned to spend 1.6 bn Euro and 1 bn Euro, respectively.

Nr.	Official title	Start	End	Volume (bn Euro)	Endog.
1	Urban Development Promotion Program	1971Q1	1972Q4	0.2	Yes
2	Second Stability Program	1973Q2	1974Q4	-4.2	Yes
3	Program to Promote Employment & Growth	1974Q1	1974Q4	4.0	Yes
4	Program for Housing and other Investment	1975Q3	1976Q3	2.9	Yes
5	Program for Future Investments	1977Q1	1981Q4	6.7	
6	Program to Promote of Growth & Employment	1977Q3	1978Q4	2.7	Yes
7	Program to Promote Energy-Saving Investments	1978Q2	1982Q4, repeatedly ext.	2.2	
8	Federal Aid Program for Investments in Saarland	1984Q4	1985Q4	0.3	Yes
9	Balancing Economic Disparities Act	1989Q1	1998Q4	12.3	
10	Economic Resilience Plan	1990Q1	1990Q2	0.7	
11	German Reunification Fund	1990Q1	1995Q1	10.5 (4 bn in 1990)	
12	Extension of German Reunification Funds I	1990Q3	1990Q4	1.15	
13	Extension of German Reunification Funds II	1992Q1	1995Q1	6.9	
14	Housing Investment Program	2006Q1	2009Q4	5.9	
15	Excellence Initiative	2006Q3	ext. until 2017Q4	4.6	
16	University Package I	2007Q3	2010Q2	1.2	
17	Children Funds	2007Q4	2014Q4	4.7	
18	University Package II	2011Q1	2014Q4	5.9	
19	Stimulus Package I	2008Q4	2009Q4	8	Yes
20	Stimulus Package II	2009Q1	2010Q4	14	Yes
21	Municipal Investment Fund: Infrastructure	2015Q2	2018Q4	3.5	
22	Municipal Investment Fund: School	2015Q2	2022Q4	3.5	
23	University Package III	2016Q1	2023Q4	8.8	
24	Public Transportation Investment Program	2016Q2	2030Q4	2.5	
25	Digitalization Program	2018Q1	2023Q4	5	

Table 1: Investment Programs in Germany 1970Q1-2018Q4. *Sources:* authors own calculations based on reports and legislation of the Federal Ministry of Finance, German Bundestag, and Joint Economic Forecast Group.

Another example is the University package II (No. 18) for the years 2011-2015, by which the federal and state governments aimed at increasing the performance of universities. The federal government granted lump sum transfers to universities for the expansion of university places. It also supported teaching capacities with the Teaching Quality Pact. The federal government has earmarked 5 bn Euro for the expansion of study places (building investments) and 0.9 bn Euro for the Teaching Quality Pact (equipment investments).

Based on the information about the 25 programs, we construct an instrument that meets the following three criteria:

1. The instrument is not affected by reverse causality. The problem might arise if the government uses public investment to stabilize current, that is, within quarter output fluctuations. This would bias the estimates and distort the causal interpretation of the results. We carefully determine for each program the underlying political motivation stated in the text sources. We differentiate between exogenous and endogenous investment programs. The former are launched to meet medium and long term goals. Following Romer and Romer (2010) and Gechert et al. (2021), the motivation can be increasing the growth rate of potential GDP, budgetary consolidation tackling inherited debt unrelated to current circumstances, ideological preferences, or court rulings related to cases with long decision lags unrelated to the state of the economy. The latter programs contain short run investment funds as a reaction to macroeconomic shocks. We identify and exclude 8 programs of the second type (see final column of Table 1). This leaves us with 17 exogenous investment programs .

2. We can extract the exact start and expiration date of the program. Public funds can flow from the start date onward such that other public institutions (states or municipalities) and private firms in case of investment grants can immediately invest. The financial reports and draft laws contain both the announcement and the resolution dates. For many programs, the two are within the same quarter. For the remaining ones, we use the resolution date. Fiscal foresight is unlikely to be a main problem as investment programs in Germany are usually decided without public discussion on an ad-hoc basis by the incumbent government to strike a compromise within the coalition and, unlike tax changes, they are not deliberately pre-announced with long notice. The robustness analysis confirms this notion by showing that the results are essentially unaffected when including forward-looking variables into the model (Figure B.5). We set the expiration date according to the scheduled total duration of the program. We code positive and negative values of the same size at the start and expiration date of each program. Extensions or enlargements of existing programs are treated as new programs with potentially new expiration date.

3. We can determine the size of the program. We use the total amount that is stipulated by the government over the planing horizon. Thereby, we emphasize the information effect of new investment. The sensitivity analysis shows that results are robust to weighting the

program size by its inverse duration (Figure B.2). We normalize the program volume by nominal GDP.

The resulting instrument series is shown with bars in Figure 1. We have 24 non-zero observations. We have more positive than negative values as investment programs are often topped up and as several programs will end after the sample period. The instrument spikes in the 1970s, after re-unification in the 1990s, following the global financial crisis in the late 2000s, and with the renewed investment impetus at the end of the sample. The maximum is 1.12% of GDP in 1989Q1. The minimum is –0.69% in 1981Q4. The mean and standard deviation are 0.02 and 0.17, respectively.

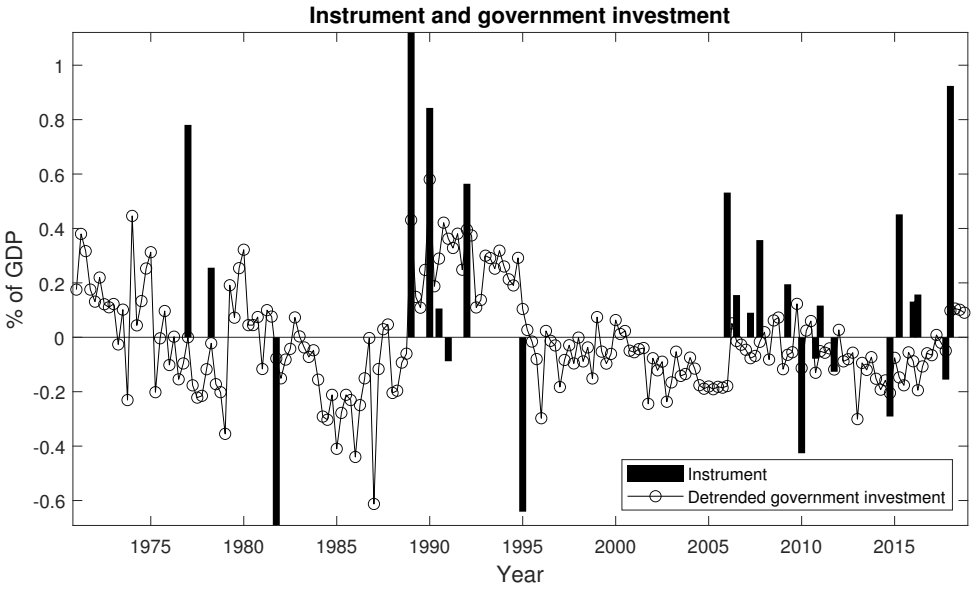

Figure 1: Instrument for government investment shocks and detrended government investment. *Notes:* A positive bar indicates additional public investment by the government. The line with circles shows detrended government investment. Investment includes public gross fixed capital formation and investment grants. The sample is from Germany for the period 1970Q1-2018Q4.

The solid line with circles shows detrended public investment. The instrument captures movements in this series. Many non-zero instrument observations coincide with large changes in the data. For example, there are spikes in public investment in 1977Q1, 1978Q2, and 1989Q1, and visible drops in 1981Q4 and 2014Q4. In some instances, the instrument precedes the actual increase in public investment, as in 2006Q2 and 2009Q4, for example.

Our instrument based on individual investment programs calculated from primary sources has several advantages over official quarterly measures of public investment. First, it is closer to an

economic definition of investment. Germany, like many advanced economies, provides two official data series on government investment: public 'gross fixed capital formation' (GFCF) from the National Account Statistics (NAS) and public 'investment expenditures' from the Government Finance Statistics (GFS). The NAS define public investment as public GFCF, which includes mainly changes in the physical capital stock of federal, state, and local governments.[4] In contrast, the GFS series includes public investment grants, which account for about one third of the program volumes in the instrument. From an economic perspective the GFS definition seems more appropriate.[5] However, the dynamics of GFS series during a year are influenced by contractual details because here the accounting of investive expenditures follows a cash-flow perspective: investment is counted if the amount is paid.

Another drawback of both official series is the treatment of outsourcing of public tasks, which affects the accounting of public highway construction, traffic services, and schools. Moreover, these series are influenced by price changes. Finally, the definition of the public capital stock has changed repeatedly in the offical data. For example, now research and development as well as weapon systems are integrated. Therefore, the National Statistic Office needs to project the historical investment series backwards to recalculate depreciation and capital stocks consistently. All these issues can lead to spurious results, which makes it less advantageous to use either the NAS or the GFS series to identify exogenous investment programs.

[4]Public GFCF consists largely of buildings and infrastructure (50%) alongside a minor part of machinery and equipment (22%) and other investments (mainly research and development). Each administrative level takes care of the investments needed to fulfill its respective tasks. The federal level provides nationwide transportation and utilities infrastructure; the state level, for example, maintains universities and research institutions as well as legal and homeland security structures. The broadest range of infrastructure investment is provided by local governments. They maintain almost all schools, as well as social facilities, theaters, and museums. However, the states must assist if a municipality does not have the funds for infrastructure investments. In Germany, this is the rule rather than the exception. In addition, in many cases the states and municipalities receive investment subsidies from the federal government. These are funds earmarked only for public investments.

[5]For example, the Deutsche Bahn and regional public transportation, airports, and harbors belong to the private sector, but the government is often the authorizing officer and general owner. Thus, federal investment grants for railway construction to the Deutsche Bahn (5 bn euro in 2015) are not counted as public GFCF but as public investment grant in the NAS. In contrast, in the GFS it is counted as investive expenditure. In 2019, total public investive expenditure (113 bn euro) and public GFCF (84 bn Euro) differ by 29 bn euro.

3 Estimation of the government investment multiplier

In this section, we first discuss the specification of the empirical model and the identification strategy, which uses the instrument of Section 2. Thereafter, we present the empirical results.

3.1 The Proxy-SVAR model

The reduced form VAR model is

$$y_t = c + A_1 y_{t-1} + \cdots + A_p y_{t-p} + \Gamma x_t + u_t \tag{1}$$

and refers to quarterly endogenous variables in the $k \times 1$ vector y_t. The vector c includes constants, the matrices A_p and Γ lag and contemporaneous coefficients, respectively, the vector x_t exogenous variables, and the vector u_t serially uncorrelated reduced form innovations with $u_t \sim \mathcal{N}(0, \Sigma)$.

In the baseline specification, y_t includes government investment, private investment, private consumption, GDP, tax revenues, and government consumption for the period 1970Q1-2018Q4. All variables are seasonally adjusted, in real terms, and per capita. Moreover, these are scaled by real per capita trend GDP, following Ramey and Zubairy (2018), using a fifth-order polynomial for computing the log-trend, and enter the model in levels. Appendix A.2 contains details on the variables, definitions, and sources.

We set $p = 4$ as is standard in SVARs with quarterly fiscal data (Ramey, 2011; Caldara and Kamps, 2017).[6] x_t includes quarter dummies and, following Gechert et al. (2021), a linear trend, a reunification dummy, and a financial crisis dummy.

The choice of the baseline variables follows the benchmark in the literature adapted to our research question. Blanchard and Perotti (2002) include government spending, tax revenues, and output. Their measure of government spending is the sum of public investment and public consumption. We break the sum up into its components as we want to estimate the effects of government investment shocks, while controlling for government consumption. Moreover, we add private investment and private consumption to determine crowding-in effects.

[6] The Ljung-Box test for autocorrelation never rejects the null hypothesis of no autocorrelation of the residuals at a significance level of 10% or lower for lags 1-4 or 1-8. White tests of the residuals reject the assumption of homoskedasticity only for one equation (government consumption, at 1%). Similarly, Engle's test never rejects the assumption of no ARCH in the residuals at lags 1 to 1-4.

We test the invertibility of the VAR using the Granger causality test proposed by Stock and Watson (2018). We add $p = 4$ lags of the instrument to each VAR equation and test whether the lags jointly predict the endogenous variable. The largest F-statistic is 1.41 for GDP and the associated p-value is 0.23. Thus, the test results indicate that there is no statistically significant evidence against the null hypothesis of invertibility. Table B.1 contains the details.

The VAR innovations are assumed to be linearly driven by a government investment shock ϵ_t^{IG}, which we aim to identify, and other structural shocks ϵ_t^*, which are of no interest for this paper. The VAR innovations u_t are related to the structural shocks ϵ_t^{IG} and ϵ_t^* as

$$u_t = b^{IG}\epsilon_t^{IG} + B^*\epsilon_t^*. \tag{2}$$

We order the government investment shock first. This is without loss of generality as identification will not rely on a Choleski decomposition. The $k \times 1$ vector b^{IG} captures the impulse vector to a government investment shock of size 1. We normalize the variances of the structural shocks to unity such that b^{IG} captures the responses to a one standard deviation shock, which allows measuring the efficacy of public investment.

For identification, we follow the external instrument approach for SVARs developed by Stock and Watson (2012) and Mertens and Ravn (2013). We assume that the instrumental variable m_t constructed in Section 2 is correlated with the latent government investment shock and uncorrelated with the other structural shocks. Hence, it fulfills

$$E(m_t\epsilon_t^{IG}) \neq 0, \tag{3}$$

$$E(m_t\epsilon_t^*) = 0. \tag{4}$$

(3) is usually called the relevance condition and (4) the exogeneity condition. If both hold, the instrument is valid.

We use m_t to consistently estimate b^{IG} and identify ϵ_t^{IG}. In the first step, we estimate the relative impulse vector. It is defined as $\tilde{b}^{IG} = b^{IG}/b_1^{IG} = (1, b_2^{IG}/b_1^{IG}, \ldots, b_k^{IG}/b_1^{IG})'$. It captures the responses of the last $k-1$ variables relative to the first variable, which is government

investment. We estimate $\tilde{b}^{IG}$ as $(1, \hat{\beta}_2/\hat{\beta}_1, \ldots, \hat{\beta}_k/\hat{\beta}_1)'$ through the regressions

$$\hat{u}_{it} = \alpha_i + \beta_i m_t + \eta_{it},\ i = 1, \ldots, k, \tag{5}$$

where $\hat{u}_{it}$ are the estimated VAR innovations of equation i of model (1) and $\hat{\beta}_i$ is an estimate of β_i. The consistency of the estimate for $\tilde{b}^{IG}$ follows from the fact that $E(u_t m_t) = b^{IG}\phi$ with $\phi = E(m_t \epsilon_t^{IG})$, due to (2)-(4). In the second step, we combine the estimate of $\tilde{b}^{IG}$ with the covariance restrictions $\Sigma = BB'$ with $B = [b^{IG}, B^*]$ to obtain the absolute impulse vector b^{IG}. Inference is based on a standard fixed-design residual wild bootstrap with 1000 replications.

One main advantage of the instrumental variable strategy is that it does not rely on exclusion restrictions. It allows for the possibility that the fiscal authority responds to business cycle fluctuations contemporaneously. Technically, it does not impose a recursive structure on the impact matrix B with government spending ordered first. Such an ordering is usually justified by legislative decision lags that prevent policy makers from responding within quarter (Blanchard and Perotti, 2002). However, the assumption is debatable given that fiscal policy may sometimes adapt spending in response to the state of the economy. For example, many countries issued large stimulus packages during the global financial crisis and the Covid-19 pandemic in 2008Q4 and 2020Q1-Q2. Caldara and Kamps (2017) show that already a small contemporaneous response of government spending to output can have a large effect on the estimated government spending multiplier. Moreover, in our context a recursive structure is particularly difficult to justify as it is unclear whether government investment or government consumption should be ordered first.

Another important advantage of the instrumental variable approach is that it accounts for potential measurement error in the proxy series. While we construct the instrument with great care, coding the exact amount of additional public investment from the legislative documents is prone to measuremnt error given the forecast errors and political bias in these documents. Stock and Watson (2012) and Mertens and Ravn (2013) show that the Proxy-SVAR accounts for such problems provided that the instrument is valid.

To assess the validity of the instrument, we perform several tests. First, we determine whether it is autocorrelated or predictable. We regress it on 1 up to 1-4 lags of itself and of the endogenous variables and test whether the lags of the instrument are jointly significant or whether all predictors

are jointly significant. The p-values of all tests exceed 0.1 and the F-statistics of the regressions never exceed 1 for all lag combinations. This suggests that the instrument is neither autocorrelated nor predictable. Table B.2 contains the details.

Table 2 evaluates the relevance of the instrument. We compute the F-statistic of the null hypothesis that $\beta_1 = 0$ (see 5). It is 16.00 with p-value of 0.00. Alternatively, we compute a Huber/White robust and a HAC F-statistic.These statistics are 24.69 and 24.72 with p-values of 0.00. Finally, we compute the reliability measure suggested by Mertens and Ravn (2013) by regressing the identified structural government investment shocks on the non-zero instrument observations. The R^2 of the regression is as high as 0.65 and the p-value on the coefficient of the instrument is 0.00, suggesting a high explanatory power of the instrument for the shocks. Overall, we conclude that the instrument is not autocorrelated or predictable and that it is strong.

	F-test OLS	F-test robust	F-test HAC	Reliability	
F-statistic	16.00	24.69	24.72	$R^2(\epsilon_t^{IG}, m_t^{\neq 0})$	0.65
p-value	0.00	0.00	0.00	p-value β_m	0.00

Table 2: Tests for instrument strength. *Notes:* The table shows OLS, Huber/White and HAC (with 1 lag) F-statistics and corresponding p-values testing the null hypothesis that the coefficient on the instrument for government investment shocks is zero in a regression of the residual of the government investment equation on the instrument. It also contains the R^2 of a regression of the structural government investment shocks on the non-zero instrument observations and the p-value of the coefficient for the instrument.

3.2 The macroeconomic effects of government investment shocks

Now, we present the main empirical results.

3.2.1 The dynamic effects of government investment shocks

Figure 2 shows the responses of the baseline variables to a positive government investment shock of one standard deviation for 20 quarters. The shaded areas are one and two standard error confidence bands. The shock size implies that government investment increases by 0.14% of trend GDP. After the large impact effect, it drops quickly back to 0.05% within the first year, but then stays significantly above trend until the end of the response horizon. Private investment increases by 0.21% upon impact, drops back, and then shows a hump-shaped pattern. It remains significantly elevated for three years and returns to the pre-shock level after five years. The

response of private consumption is more sluggish and smaller. It does not respond much for the first two quarters. Then, it rises significantly above trend (judged by the one standard error band) and peaks at 0.02% in quarter 5. Afterwards, it returns to the level where it would have been without the shock, which it also reaches after five years.

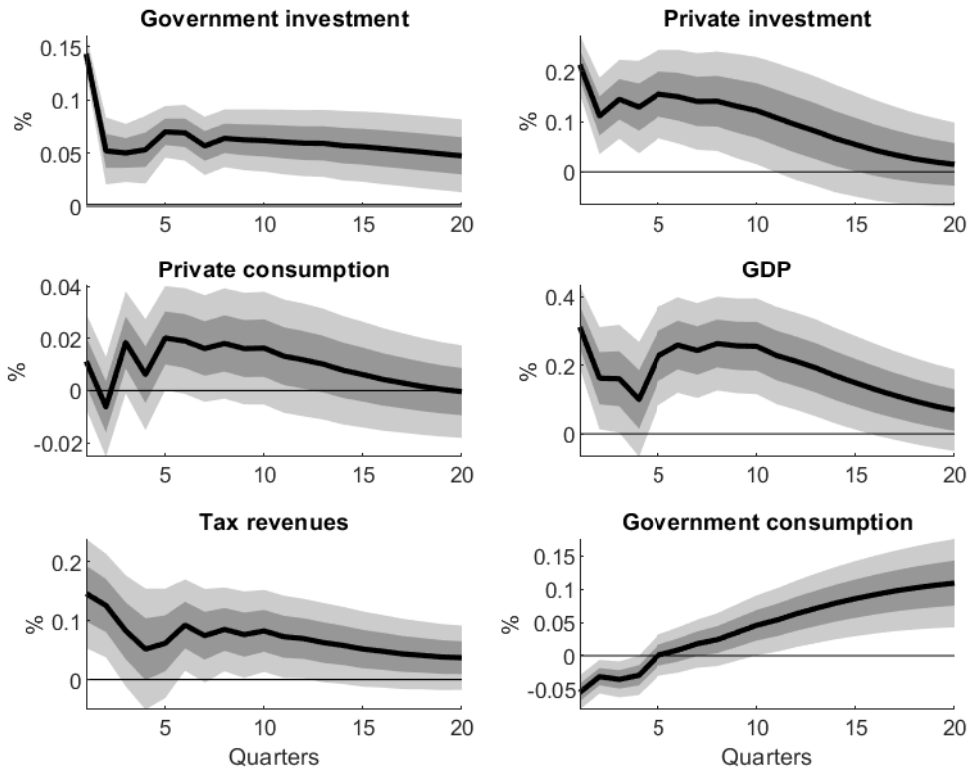

Figure 2: Dynamic effects of government investment shocks. *Notes:* The figure shows the responses of the baseline variables to a positive government investment shock of one standard deviation identified with an external instrument over 20 quarters. The shaded areas are 1 and 2 standard error confidence bands based on 1000 bootstrap replications. All variables are expressed relative to trend GDP.

Reflecting the crowding-in of both private demand components, GDP rises for five years as well, and significantly so for four years. The impact response is 0.31% and seems to be largely driven by the two investment components, given the muted initial reaction of private consumption. Thereafter, output drops to 0.10% in quarter 4, probably reflecting the sharp fall in public investment, before increasing private investment and successively higher private consumption induce a hump-shaped response. Consistent with the increase in GDP, taxes rise significantly over the full response horizon. Finally, government consumption drops upon impact and stays below trend for the first year, suggesting a substitution between the two government spending

categories. From the second year onward, government consumption rises persistently above trend, likely mirroring a higher public wage bill and additional demand for intermediate goods, given a higher public capital stock following the strong and persistent increase in government investment.

Based on the impulse responses, we estimate the output multiplier. We compute the ratio of the cumulative sum of output to the cumulative sum of public investment to obtain the euro-per-euro effect of exogenously higher public investment on GDP. Given that the variables are already divided by trend GDP, we do not need to scale the ratio by the inverse of the public investment share in GDP in the sample. Figure 3 shows the multiplier for 20 quarters. The multiplier is significantly positive and larger than one (according to the 1 standard error bands) over the full horizon. It is 2.2 upon impact. Then, it increases to 2.5 in the first year. It slowly rises further to about 3.3 for years two and three, before falling slowly back. The long run multiplier after ten years (not shown in the figure) is 2.

The estimated multiplier of 2-3 for the medium to long term is within the typical range (Ramey, 2021). The estimated short run multiplier of 2 is at the upper end of the range of empirical estimates. It is similar to the value of Auerbach and Gorodnichenko (2012a), but about 1 point larger than that documented by Ilzetzki et al. (2013) and 2 points larger than that found by Boehm (2020). It is also larger than the multipliers obtained from calibrated DSGE models (Leeper et al., 2010; Ramey, 2021), which are mostly between 0 and 1. In his meta study, Gechert (2015) documents an average multiplier of 1.4 with a standard deviation of 0.9, roughly covering these values. He also documents a negative publication bias whereby multipliers are higher for more precise studies.

The relatively large short run multiplier may, to some extent, reflect economic conditions that are specific to Germany and the sample period. First, the public capital stock was relatively low in East Germany before reunification. A lower initial public capital stock typically implies higher output multipliers. Second, Germany was in a currency union for about half of the sample. The European Central Bank may not have counteracted business cycle fluctuations in Germany as much as the Bundesbank. Moreover, risk premia and interest rates are low and stable in Germany, which also prevents a worsening of public financing conditions. Third, there was an important labor market reform in 2005 that led to many years of extreme wage moderation. This potentially tempered real wage increases and crowding-out effects.

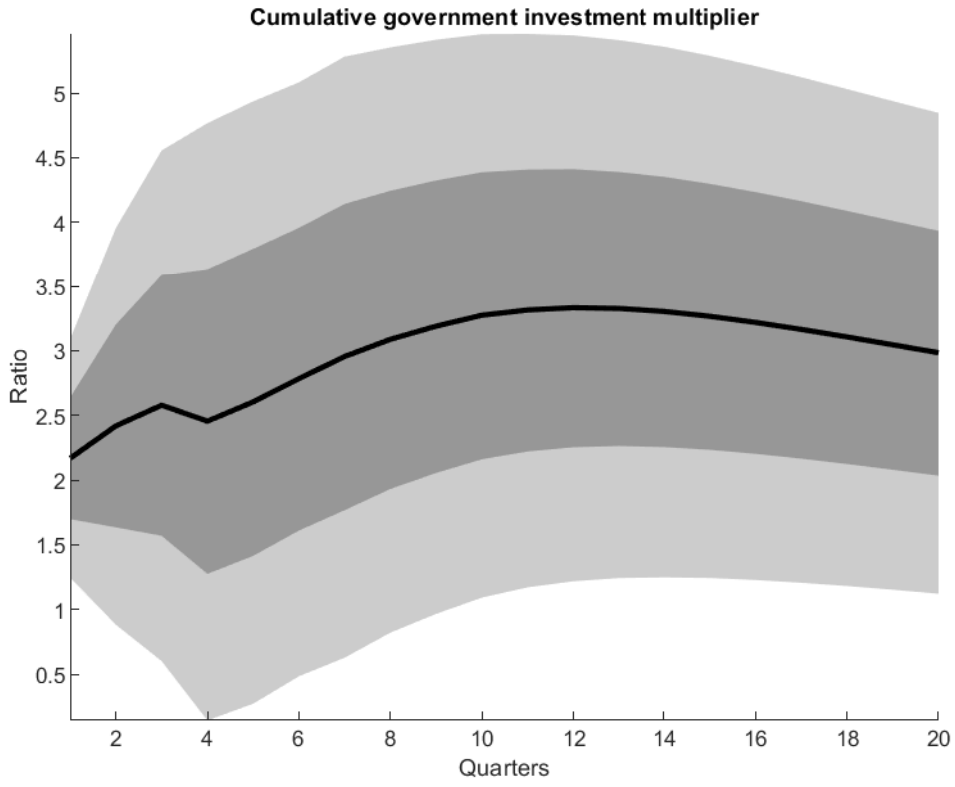

Figure 3: Cumulative government investment multiplier. *Notes:* The figure shows the cumulative government investment to output multiplier following a positive government investment shock identified with an external instrument over 20 quarters. The shaded areas are 1 and 2 standard error confidence intervals based on 1000 bootstrap replications. The multiplier is computed as the cumulative sum of the output response divided by the cumulative sum of the government investment response shown in Figure 2.

3.2.2 The importance of government investment shocks

Next, we measure the average economic importance of government investment shocks for macroeconomic fluctuations. Table 3 shows the forecast error variance decomposition. It gives the percentage contribution of the government investment shocks to the unexpected variation of the endogenous variables at forecast horizon of 4, 8, 20, and 100 quarters, respectively, where the last value approximates the unconditional variance decomposition. At the one-year horizon, the shocks explain 7-8% of the variation in private investment and GDP but only 2% of private consumption. Thereafter, their importance increases up to a horizon of five years. Here, they explain 8-18% of the variance of these variables. In the long run, they account for roughly 10%, 22%, and 21% of the variability in private investment, private consumption, and GDP, respectively. The shocks are also important for understanding the long run unexpected variation in government consumption.

The explanatory power is 44%.

Horizon	Gov. inv.	Priv. inv.	Priv. cons.	GDP	Taxes	Gov. cons.
4	92.9	7.0	2.4	7.6	5.7	2.6
8	87.7	7.5	4.0	11.1	6.0	13.1
20	71.1	7.9	5.1	18.4	11.3	34.2
100	59.3	10.4	22.0	20.5	14.0	43.6

Table 3: Percentage variance contribution of government investment shocks. *Notes:* The table shows the percent contribution of the government investment shocks to the forecast error variance of the endogenous variables in y_t over horizons of 4, 8, 20, and 100 quarters ahead.

Overall, these numbers seem consistent with the size of the estimated output multiplier. Furthermore, they imply that government investment shocks account for a large portion of the fluctuations in the data. This is a solid basis for the impulse response matching below, which estimates the model only on this component of the variation in the data.

Now, we investigate whether the identified public investment shocks and their effects on GDP square with the economic narrative of Germany in the sample and the selected episodes that the instrument captures. The upper panel of Figure 4 shows the cumulative shocks. The sample can roughly be divided into three phases. First, there are relatively large swings in the first twenty years, reflecting a large welfare state in the 1970s that was starved in the 1980s. Second, there is a reunification boom in the 1990s. Third, there is a long sequence of predominantly negative shocks since 2000, corresponding to a successive cutback of public investment after the boom, which only ends toward the end of the sample, when the attrition of the public infrastructure became unmissable.

The bottom panel of Figure 4 shows detrended GDP (solid line) and a historical decomposition of it (dotted line), where the contribution of government investment shocks to GDP is eliminated. The comparison allows gauging the importance of the shocks to output fluctuations during specific episodes of the sample. It also gives a rough idea about whether the shocks identified with the instrument correspond to the underlying investment programs. Consistent with the cumulative shocks, public investment shifts increased output at the end of the 1970s and lowered it during the phase of market liberalization in the 1980s. The strongest contribution to GDP is after reunification. In 1991, government investment shocks doubled the output gap from 2% to 4%. The long shadow of the boom was a mostly negative contribution from the end of the 1990s until

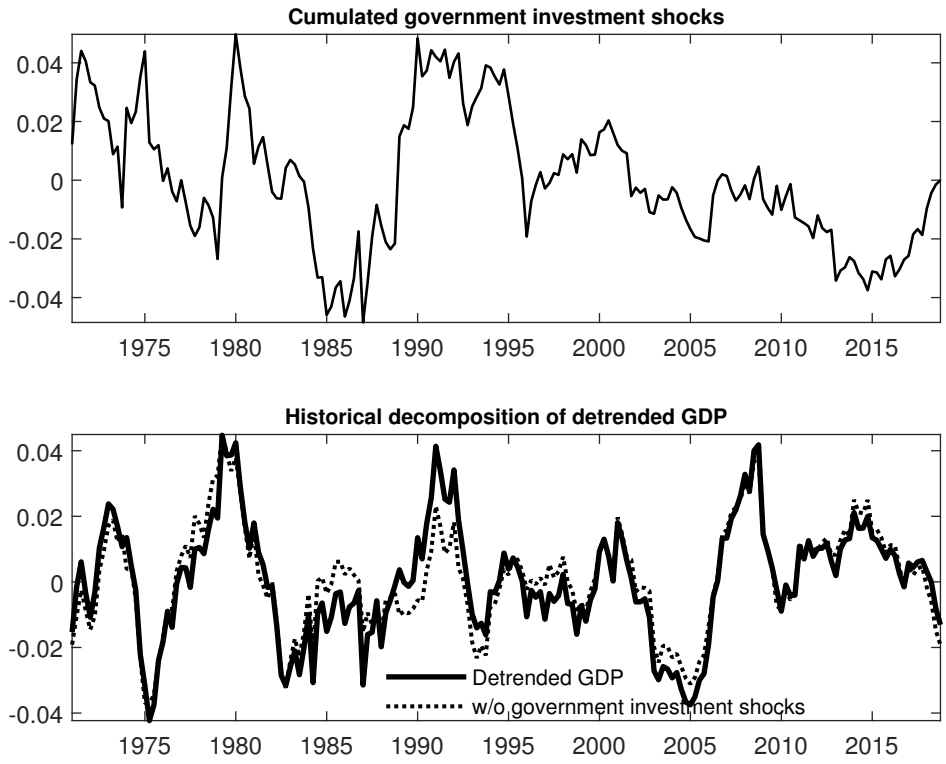

Figure 4: Estimated shocks and historical decomposition. *Notes:* The upper panel shows the identified cumulative government investment shocks. The lower panel shows detrended GDP and detrended GDP without the contribution of government investment shocks, obtained from a historical decomposition. In the lower panel, both series neglect the base, or transients, due to the initial conditions.

the mid-2000s. Overall, the estimated shocks and their contribution to GDP correspond to the narrative about public investment in Germany during the sample and to the investment programs identified by the instrument.

3.2.3 Shock propagation through the economy

We add variables to the model one-by-one to assess in detail how the output effects come to pass. This approach follows Ramey (2011) and is a particularly flexible. It does not require a Bayesian perspective, a panel VAR, or factor structure to deal with the curse of dimensionality, given that the baseline model already contains $k(kp+1)+\frac{k(k-1)}{2}=165$ parameters. In all augmented models, the instrument is strong. The F-statistics are between 12.1 and 28.5.

Figure 5 collects the responses of a first set of additional variables. The first panels look at the financing side of the additional public outlays. The budget balance/GDP ratio increases shortly and then undershoots slightly, but the response is mostly insignificant. The one-year and ten-year

government bond rate both increase significantly upon impact and remain elevated for roughly two years. As the GDP deflator first remains constant and then slightly rises, the ex-post real interest rate spikes shortly, but then falls persistently below trend. The fiscal stimulus seems to be self-financing, given the strong rise in output and the associated increase in public revenues, as well as the moderate reaction of the real interest rate.

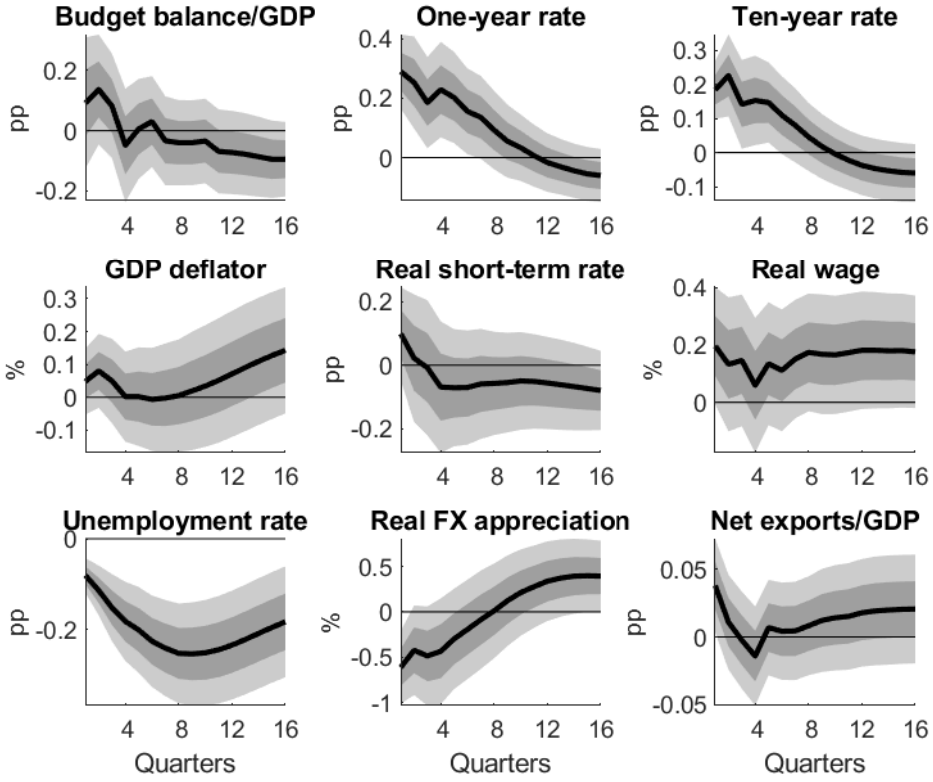

Figure 5: Economy-wide effects of government investment shock. *Notes:* The figure shows the responses of macroeconomic variables following a positive government investment shock of one standard deviation identified with an external instrument over 16 quarters. The shaded areas are 1 and 2 standard error confidence intervals based on 1000 bootstrap replications. The variables are added, one at a time, to the baseline SVAR.

The next two panels show the real wage and the unemployment rate. The responses of the labor market variables are important for distinguishing labor demand and supply effects and thereby real business cycle (RBC) from New Keynesian (NK) effects. RBC models typically predict a fall in the real wage because the government extracts resources from the private sector, which implies a negative wealth effect. Households lower consumption and leisure and increase labor supply, leading to a fall in the real wage. In contrast, NK models with labor market frictions imply that output and labor are demand determined such that the real wage rises. We find an increase in

the real wage by 0.2% and a strong and persistent decline in the unemployment rate by up to 0.3pp. These patterns are consistent with NK models in which demand dominate supply effects in the short run. The final two panels look at the external sector of the economy. The real effective exchange rate depreciates shortly, and then overshoots after two years. Consistently with the initial dip, the net export/GDP ratio rises, but largely insignificantly.

Figure 6 looks in detail at specific investment components. In all underlying augmented models, the instrument is strong with an F-statistic between 10.5 and 30.2. The top three panels show the responses of the three subcomponents of public investment: construction, equipment, and other investment. Government construction investment—consisting of new infrastructure as well as residential and nonresidential buildings—reacts most. It increases by nearly the same amount as total government investment and with a similar shape subsequently (compare Figure 2). There is an initially strong increase, a quick fall back to about one third of the impact reaction, but then a high persistence. Government equipment investment—comprising machines, equipment, and vehicles—also rises significantly for the full response horizon, but less. In contrast, other government investment—like research and development or expenses for software and patents—tends to fall, although largely insignificantly. Overall, the detailed analysis suggests that the identified aggregate government investment shock reflects higher public construction outlays and some additional investment in equipment.

The middle three panels summarize the reaction of the three analogue private investment categories. The responses of private construction and equipment investment mirror those of the public components closely. Private other investment increases as well such that all three private investment categories are crowded-in. The bottom panels indicate why private investment is not crowded-out. Both the corporate bond rate and the bank bond rate increase only mildly. They rise by essentially the same amount as the one-year government bond rate as the response of the credit spread shows, which is computed as the differences between the corporate bond yield and the one-year rate. Hence, real interest rates relevant for firms financing decisions remain roughly constant given the increase in the GDP deflator (compare Figure 5).

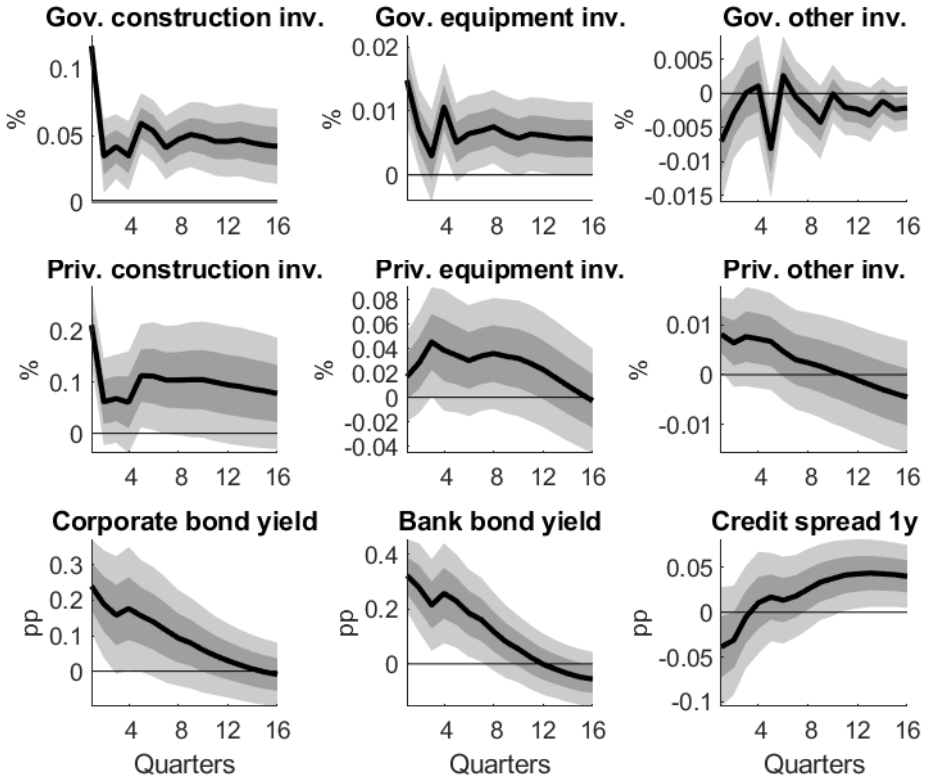

Figure 6: Investment responses to government investment shock. *Notes:* The figure shows the responses of public and private investment components as well as of interest rates following a positive government investment shock of one standard deviation identified with an external instrument over 20 quarters. The shaded areas are 1 and 2 standard error confidence intervals based on 1000 bootstrap replications. The variables are added, one at a time, to the baseline SVAR.

3.3 Sensitivity analysis

We conduct an extensive sensitivity analysis, which we summarize here. Online Appendix B.2 contains the details. First, we show that the main results hold when we use alternative versions of the instrument. Specifically, we either construct the instrument from the information of the annual finance reports only to increase internal consistency. Or, we scale the programs inversely by the duration (Figure B.2). Moreover, the results are robust to dealing with outliers by Winsorizing the non-zero instrument observations at the 90th or 80th percentile (Figure B.3). Finally, they hold when excluding one non-zero instrument observation at a time, suggesting that no single investment program drives the results (Figure B.4).

Next, we account for fiscal foresight (Figure B.5). This can arise when households and firms react to news about impending future government investment plans. Then, we might not be able

to recover the unexpected spending shock because the information sets of agents in the sample and us are misaligned (Leeper et al., 2013). The literature has proposed different solutions for this problem. First, we add stock prices as endogenous variable because they are forward looking and incorporate expectations about future policy actions (Beetsma and Giuliodori, 2011). Second, we include two factors: one financial factor computed as the first principal component of a large set of financial variables and one real factor. Third, we include a series of government investment forecasts to the model, following Auerbach and Gorodnichenko (2012b).

Finally, we perform a large number of specification tests. We add endogenous variables to the model (Figure B.6), change the lag length to $p = 3,5,6,7,8$ (Figure B.7), change the trend assumption (Figure B.8), use aggregate instead of per capita variables and employ log-levels instead of ratios (Figure B.9), compute trend GDP with slightly lower order polynomials (Figure B.10), exclude the reunification dummy and the crisis dummy (Figure B.11), start the sample after the Fall of the Wall (Figure B.12), or construct Efron's and Hall's confidence bands for the responses of the variables (Figures B.13, B.15) and the multiplier (Figures B.14, B.16).

Overall, the estimated one-year multiplier is relatively stable. It mostly lies between 2-3 around the baseline estimate. The multiplier after 2-5 years is a bit more sensitive. It is particularly affected by the trend assumption.

4 Decomposition of the government investment multiplier

In this section, we build a DSGE model that aims to capture the crowding-in of private investment and private consumption documented above. Hence, the model is of the New Keynesian type. It includes a fiscal and monetary authority, rule-of-thumb consumers, physical capital, as well as nominal rigidities and real frictions. Given the limited empirical role of the external sector, we assume a closed economy.

4.1 Public investment in a New Keynesian DSGE model

The model builds on Leeper et al. (2017). It has a rich fiscal sector that includes consumption taxes, labor taxes, capital taxes, transfers, government consumption, long-term government debt, and substitutability/ complementarity between private and government consumption. We add

government investment, which has two main effects. The first is standard in the literature since Baxter and King (1993). Intermediate good producer i uses public capital K_t^G together with private physical capital $K_t(i)$ and employment $L_t(i)$ to produce output $Y_t(i)$:

$$Y_t(i) = \exp(e_{a,t})\, K_t(i)^{\alpha}\, L_t(i)^{1-\alpha} (K_t^G)^{\alpha^{kg}} - \bar{O}, \tag{6}$$

where α^{kg} and α is the production elasticity of public and private physical capital, respectively. $e_{a,t}$ is deterministically growing total factor productivity and $\bar{O}$ are fixed costs to production. This specification assumes constant returns to private inputs. α^{kg} determines the productivity of public capital. If $\alpha^{kg} > 0$, public capital is productive. If $\alpha^{kg} \leq 0$, it is unproductive because there is congestion or waste. The parameter is crucial for the medium and long run effects of public investment but there is considerable uncertainty in the literature about its size (Bom and Ligthart, 2014). Thus, a main goal of the subsequent analysis is the estimation of this parameter.

To that standard effect of public investment, we add a short run effect to account for the immediate crowding-in of private investment found in the data. Specifically, we assume that public investment affects private investment adjustment costs $\Phi_t(j)$ of household j who is the owner of private physical capital:

$$\Phi_t(j) = 1 - \frac{\kappa^k}{2}\left(1 - \kappa^g - \frac{I_t(j)}{I_{t-1}(j)} + \kappa^g \frac{I_t^G}{I_{t-1}^G}\right)^2, \tag{7}$$

where $I_t(j)$ is private investment, I_t^G public investment, and the parameters κ^k and κ^g measure the sensitivity of the adjustment costs to changes in these investment components. Hence, κ^g affects the short run dynamics. If $\kappa^g > 0$, public investment reduces private investment adjustment costs. $\kappa^g \times 100$ can be interpreted as the percentage reduction in private costs.

The mechanism captures the economic definition of public capital: an enlargement of public digital or transportation infrastructure, investment into schooling and child care, as well as investment grants reduce the costs of installing new capital in the private sector. For example, the building or re-opening of roads, telephone lines, and highways that connected West and East Germany after reunification lowered private transportation time and trade costs of equipment and machinery. Similarly, public infrastructure provision spurred private construction investment.

Moreover, the modernization and enlargement of public universities as well as child-care in schools and playschool in the late 2000s may have increased labor supply and thereby spurred private investment. In addition, public investment programs typically include investment grants, which allow firms to partially and temporary deduct their investment costs. This may stimulate private investment. Conversely, if $\kappa^g < 0$ there is congestion. Hence, our second central goal is estimating the value of this parameter.

The dynamics are also determined by the persistence of the public investment shocks. We assume that the shocks follow an exogenous AR(1) process

$$log(I_t^G) = constant + \rho^{ig} log(I_{t-1}^G) + u_t^{ig}, \tag{8}$$

where ρ^{ig} is the autocorrelation and u_t^{ig} are iid innovations. The size of ρ^{ig} is important for the two wealth effects of the shocks and, hence, for the output multiplier. The first wealth effect implies a positive relation between ρ^{ig} and the output multiplier. The more persistent the shocks, the more persistent are the appropriations needed to finance them. This makes households poorer and induces them to work and produce more. The second effect works in the opposite direction. More persistent public investment enhances the production capacity of the economy for longer and makes households richer. Which effect dominates is *a priori* unclear and depends on the size of ρ^{ig} as well as the horizon considered and the other parameters of the model. Accordingly, ρ^{ig} is the third crucial parameter that we want to estimate.

Now, we outline the other blocks of the model. Appendix C.1 contains the details.

Private households A continuum of households is defined over the interval $[0,1]$, consisting of a fraction n of non-saving households (indexed by N) and a fraction $1-n$ of saving households (indexed by S). A saving household j obtains utility through composite consumption $C_t^S(j)$ and suffers utility losses due to hours worked $L_t^S(j)$. Total composite consumption $C_t^S(j)$ consists of private and public consumption $C_t^S(j) = C_t^{S,P}(j) + \alpha^g G_t$, where α^g describes the degree of substitutability between both consumption types. Furthermore, utility obtained by composite consumption depends on the relative comparison between one's own consumption and the consumption of all saving households in the previous period, with the relative importance of the

other savers' consumption determined by h:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\log(C_t^S(j) - hC_{t-1}^S) - \chi \frac{(L_t^S(j))^{1+\psi}}{1+\psi} \right). \tag{9}$$

The budget constraint of saving households is

$$\begin{aligned}(1+\tau_t^c)P_t C_t^S(j) + P_t I_t(j) + P_t^B B_t(j) + R_t^{-1} B_{s,t}(j) = (1+\rho P_t^B)B_{t-1}(j) + B_{s,t-1}(j) \\ + (1-\tau_t^W)\int_0^1 W_t(l) L_t^S(j,l)dl + (1-\tau_t^K)R_t^k \nu_t(j)\tilde{K}_{t-1}^S(j) - \psi(\nu_t)\tilde{K}_{t-1}^S + P_t Z_t^S(j) + \Pi_t(j),\end{aligned} \tag{10}$$

where nominal consumption expenditures $P_t C_t^S(j)$ include value added taxes $\tau_t^c P_t C_t^S(j)$. Nominal investments are divided among the physical capital stock $P_t I_t(j)$, one-period private discount bonds $R_t^{-1} B_{s,t}(j)$ which are in zero net-supply, and long-term government bonds $P_t^B B_t(j)$ with decay rate ρ. Expenditures are financed through after tax labor income $(1-\tau_t^W)\int_0^1 W_t(l) L_t^S(j,l)dl$, interest payments from bond holding $(1+\rho P_t^B)B_{t-1}(j) + R_{t-1}B_{s,t-1}(j)$, profits $\Pi_t(j)$, and effective capital income $(1-\tau_t^K)R_t^k \nu_t(j)\tilde{K}_{t-1}^S(j) - \psi(\nu_t)\tilde{K}_{t-1}^S$, as well as from government transfers $P_t Z_t^S(j)$. The effective private capital stock $K_t^S(j)$ is determined by the private capital stock and the utilization rate $K_t^S(j) = \nu_t(j)\tilde{K}_{t-1}^S(j)$. The utilization involves unit costs of $\Psi(\nu_t)$, which are zero in steady state where private capital is fully used. The effective private capital stock evolves according to $\tilde{K}_t^S(j) = (1-\delta)\,\tilde{K}_{t-1}^S(j) + I_t(j)\Phi_t(j)$, where $\Phi_t(j)$ is given by (7).

The nominal consumption of liquidity-constrained household j is defined by the budget constraint:

$$(1+\tau_t^c)P_t C_t^N(j) = \left(1-\tau_t^W\right)\int_0^1 W_t(l) L_t^N(j,l)dl + P_t Z_t^N(j), \tag{11}$$

We assume that tax rates for saving and non-saving households are identical.

Each household supplies a continuum of differentiated labor services indexed by l. These services are supplied by both saving and non-saving households. A competitive labor agency combines the differentiated services into a homogeneous sector-specific labor input that is sold to the intermediate firms. The labor demand function for different labor types is $L_t(l) = L_t\left(W_t(l)/W_t\right)^{-(1+\eta^w)/\eta^w}$, where L_t is the demand for composite labor services and W_t is the aggregate nominal wage that

satisfies $W_t = \left(\int_0^1 W_t(l)^{1/\eta^w} dl \right)^{\eta^w}$. Solving the optimization problem of both households yields in the symmetric equilibrium the marginal utility of consumption, the intertemporal Euler equation, the price relation between long-term and short-term bonds, the relative price of private capital, and the nominal wage setting equation.

Production In each sector, there exists a continuum of intermediate firms indexed by $i \in [0,1]$. Each firm i produces an intermediate good according to (6). Cost minimization under an identical production technology implies that firms have identical marginal costs per unit of output:

$$MC_t = (1-\tilde{\alpha})^{\tilde{\alpha}-1} \, \tilde{\alpha}^{-\tilde{\alpha}} \, {W_t}^{1-\tilde{\alpha}} \, {R_t^k}^{\tilde{\alpha}} (K_t^G)^{\frac{\alpha^{kg}}{\alpha^{kg}-1}} \tag{12}$$

with $\tilde{\alpha} = \frac{\alpha}{1-\alpha^{kg}}$. The prices are set according to Calvo (1983). Firms have the chance to reoptimize their price each period with the probability $(1-\theta_p)$. They maximize profits according to

$$E_t \sum_{s=0}^{\infty} (\beta\theta_p)^s \frac{\lambda_{t+s}}{\lambda_t} \left[\left(\Pi_{k=1}^s (\pi_{t+k-1}^H)^{\chi_p} (\overline{\pi}^H)^{1-\chi_p} \right) P_t(i) Y_{t+s}(i) - MC_{t+s} Y_{t+s}(i) \right], \tag{13}$$

where firms that cannot reset their price partially index to past inflation. The final goods producer uses the basket of intermediate goods to produce the final good according to $Y_t = \left(\int_0^1 Y_t^{(\epsilon_p-1)/\epsilon_p}(i) di \right)^{\epsilon_p/(\epsilon_p-1)}$. Thus, the demand for intermediate firm i's output is given by $Y_t(i) = (P_t(i)/P_t)^{-\epsilon_p} Y_t$, where Y_t is the final demand and P_t the producer price.

Fiscal Policy In each period t, the government collects tax revenues from labor income $\tau_t^W W_t L_t$, capital income $\tau_t^k R_t^k K_t$, and value added $\tau_t^c P_t C_t$ and issues bonds in order to finance interest rate payments and expenditures; that is, public consumption G_t, public investment I_t^G, and transfers $P_t Z_t$. Therefore, government nominal debt evolves according to:

$$P_t^B B_t = P_t Z_t + P_t G_t + P_t I_t^G + (1 + P_t^B \rho) B_{t-1} - \tau_t^k R_t^k K_t - \tau_t^W W_t L_t - \tau_t^c P_t C_t, \tag{14}$$

where transfers are identical across households $Z_t = \int_0^1 Z_t(j) dj = Z_t^S = Z_t^N$. The public capital stock evolves according to $K_t^G = \left(1-\delta^G\right) K_{t-1}^G + I_t^G$ where δ^G is the public depreciation rate.

We assume that the government follows a non-distortionary transfer rule in order to consolidate:

$$Z_t = (Z_{t-1})^{\phi_\tau} \left((S_{t-1} - \bar{S})^{\gamma_S}\right)^{1-\phi_\tau} \tag{15}$$

where $S_t = \frac{P_t^B B_t}{P_t Y_t}$ is the debt-to-GDP ratio. According to the fiscal rule, the government reduces transfers if the ratio is above its steady state, where γ_S measures the debt elasticity.

Monetary Policy The central bank sets the short-term nominal interest rate R_t and follows a Taylor (1993)-Rule:

$$R_t = {R_{t-1}}^{\phi^R} \left[\frac{1}{\beta}\left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi^\pi}\left(\frac{y_t}{\bar{y}}\right)^{\phi^y}\right]^{1-\phi^R}. \tag{16}$$

Thus, the nominal interest rate follows its lagged value and responds to current inflation and to deviations of output from its trend.

Aggregation Consumption, employment, and transfers $X_t(j) = \{C_t(j), L_t(j), Z_t(j)\}$ are aggregated according to $X_t = \int_0^1 X_t(j)$ and can be decomposed into household-specific components via the share of non-saving households n: $X_t = (1-n)X_t^S + nX_t^N$. Because only the saver households have access to capital markets, the aggregation for $T_t(j) = \{K_t(j), B_t(j), B_{s,t}(j), \Pi_t(j)\}$ is $T_t = \int_0^1 T_t^{(1-n)}(j)$. Finally, goods market clearing provides the aggregate resource constraint: $Y_t = C_t + I_t + I_t^G + G_t$.

4.2 Parameterization and estimation approach

We estimate the three parameters that are central to the effects of government investment shocks: the persistence of the shocks ρ^{ig}, the parameter governing the short run effects of government investment on private investment adjustment costs κ^g, and the output elasticity of public capital α^{kg}. The estimates for these parameters depend on the structure of the model and the values of the other parameters, given that the model contains many cross-equation restrictions. We are particularly interested in α^{kg} as it is a crucial parameter in the literature on public capital but at the same time surrounded by large estimation uncertainty so far (Bom and Ligthart, 2014). We parameterize all other parameters.

This estimation strategy serves two purposes. First, it sharpens inference on the three core parameters. Second, it conditions the estimation of these on values of the other parameters that can either be directly observed in the data or for which the literature agrees upon reasonable values. The sensitivity analysis in Section C.3 shows that the estimates for the core parameters do not depend much on the values of the calibrated parameters.[7]

Table 4 lists the calibrated parameters. We set them to values within the range typically considered in the literature on estimated or calibrated DSGE models of fiscal policy (Leeper et al., 2010, 2017; Ramey, 2021). Regarding households, we set the time discount factor $\beta = 0.996$ to match a steady-state annualized real interest rate of 1.5 percent. The degree of substitutability of private and public consumption in utility is $\alpha^g = -0.24$, implying weak complementarity. The inverse Frish labor supply elasticity is $\psi = 0.5$. The strength of external habits in consumption is $h = 0.7$. The share of non-saving households is $n = 0.1$

The second block consists of parameters that determine the dynamics of production and prices. The capital share $\alpha = 0.33$ corresponds to the average capital-to-output ratio in Germany. The quarterly depreciation rate for private and public investment is $\delta = 0.02$ and $\delta^G = 0.015$ to match annualized depreciation rates of 8% and 6%, respectively. The private capital adjustment costs parameter is $\kappa^k = 12.4$. The Calvo parameter for price and wage adjustments is $\theta^p = 2/3$ and $\theta^w = 3/4$, respectively, following Christiano et al. (2005). The degrees of indexation are $\chi_p = \chi_w = 0.5$. The elasticity of substitution between different types of goods or labor is $\epsilon_p = \epsilon_w = 6$.

The third block contains long run ratios and policy parameters. The shares of government consumption, government investment, and transfers in GDP match their empirical counterparts: $G/Y = 0.17$, $I^G = 0.03$, and $Z/Y = 0.22$. Similarly, the consumption, capital, and labor tax rates equal their empirical averages: $\tau^c = 0.15$, $\tau^k = 0.22$, and $\tau^L = 0.19$. The steady state debt-to-GDP ratio is 60% on an annual basis to mimic the Stability and Growth Pact. The response of transfers to deviations of government debt from this target is $\gamma_S = -0.26$ to ensure fiscal solvency. The smoothing term is $\phi_\tau = 0.5$. The duration of public debt is 5 years. In the

[7] Alternatively, we could estimate more parameters as the size of the government spending multiplier depends on many features of the model (Leeper et al., 2017). However, this would rather require a full information approach. It also risks that the estimates for the core parameters are driven by potentially extreme values of the other parameters, which are less relevant for our research question, such as price or wage stickiness.

Table 4: Parameterization for a quarterly frequency

Parameter	Notation	Value
Households		
Discount factor	β	0.996
Substitutability private and public consumption	α^g	–0.24
Inverse Frish labor supply elasticity	ψ	0.5
External habit formation	h	0.7
Share non-saving households	n	0.1
Production and pricing		
Production elasticity private physical capital	α	0.33
Depreciation rate private capital	δ	0.02
Depreciation rate public capital	δ^G	0.015
Private investment adjustment cost parameter	κ^k	12.4
Calvo parameter price adjustments	θ_p	2/3
Calvo parameter wage adjustments	θ_w	3/4
Price indexation	χ_p	0.5
Wage indexation	χ_w	0.5
Elasticity of substitution between good types	ϵ_p	6
Elasticity of substitution between labor types	ϵ_w	6
Policy		
Government consumption/GDP	G/Y	0.17
Government investment/GDP	I^G/Y	0.03
Transfers/GDP	Z/Y	0.22
Consumption tax rate	τ^c	0.15
Capital tax rate	τ^k	0.22
Labor tax rate	τ^L	0.19
Annual debt/GDP	$4\bar{S}$	60%
Debt elasticity transfers	γ_S	–0.26
Transfer smoothing term	ϕ_τ	0.5
Duration long-term bonds	ρ	20
Interest rate smoothing	ϕ^R	0.5
Monetary policy response to inflation	ϕ^π	1.5

monetary policy rule, we set the weight for interest rate smoothing $\phi^R = 0.5$ and the CPI inflation stabilizing weight to $\phi^\pi = 1.5$.

We collect the parameters to be estimated in the vector $\zeta = (\rho^{ig}, \kappa^g, \alpha^{kg})'$. We estimate ζ by minimizing the distance between the empirical impulse response functions $\hat{\Theta}$ and the ones implied by the model, $\hat{\Theta}(\zeta)$, which are a function of ζ. We consider the first 20 elements of each response, excluding the impact reaction of government investment which is set by assumption. Following Christiano et al. (2005), the estimator of ζ solves

$$J = \min_{\zeta} [\hat{\Theta} - \Theta(\zeta)]' V^{-1} [\hat{\Theta} - \Theta(\zeta)], \tag{17}$$

where V is a matrix with the estimated variances of the elements in $\hat{\Theta}$ on the diagonal, which are obtained from the bootstrap. This weighting matrix implies that the minimization aims at centering the model responses within the confidence intervals of the empirical responses by choosing ζ. We focus on the responses of government and private investment, private consumption, and output.

4.3 The transmission of government investment shocks

This section presents the parameter estimates, the matched impulse response functions, and the decomposition of the government investment multiplier. Table 5 shows the point estimates of the parameters in ζ. Appendix C.3 contains the distributions of the estimates for each of the 1000 bootstrap draws for the empirical responses. These distributions are the basis for the confidence intervals reported in Table 5, which we use the gauge the precision of the estimates.

Parameter	Notation	Value	68% CI
Persistence government investment shocks	ρ^{ig}	0.918	[0.796,0.916]
Sensitivity private investment adj. costs to gov. investment	κ^{g}	0.158	[0.085,0.171]
Elasticity of output to government capital	α^{kg}	0.062	[0.020,0.092]

Table 5: Parameter estimates. *Notes:* The table shows the estimated parameter values obtained by matching the impulse response functions of the DSGE model to those of the Proxy-SVAR by minimizing (17). It also shows the 68% confidence intervals (CI) of the estimates obtained from 1000 bootstrap replications.

We find a high autocorrelation of the government investment shocks: $\rho^{ig} = 0.918$. The persistence reflects the secular movements in the public investment ratio, which fluctuates between 0.06 at the beginning of the sample and 0.03 toward the end.

The estimate for the parameter governing the effect of public investment on private investment adjustment costs is $\kappa^{g} = 0.158$. In other words, public investment reduces private investment adjustment costs by 16%. The parameter is precisely estimated with essentially no mass of estimates below zero. The significantly positive value implies a crowding-in of private investment in the short run. We mainly think of this effect as capturing public investment grants. Their main goal is to stimulate private investment. Especially companies whose investment accounts for a high proportion of fixed costs might be encouraged to expand their capacities. Additionally, the cost-reducing effect may reflect higher efficiency of administrative processes. For example, a better digital public infrastructure may accelerate administrative processes such as contracts, tenders, and authorizations. At the same time, there can also be congestion due to the additional,

public investment activities. But the significantly positive point estimate of κ^g suggests that this effect is dominated by the cost-reducing effect.

The estimated output elasticity of public capital is $\alpha^{kg} = 0.062$. The parameter is precisely estimated, the confidence intervals exclude zero. The value suggests positive productivity effects of public capital over the medium term as it raises the marginal productivity of labor and private capital, which leads to an increase in the demand for private goods. For example, a state-financed expansion of the road network simplifies and accelerates the transport and trade of goods and services. The point estimate is a bit lower than the average estimate of 0.106 found in the meta analysis of Bom and Ligthart (2014). It is close to the mean value of 0.09 that Ercolani and e Azevedo (2014) obtain from estimating a RBC model using full information methods. It is in the middle of the range considered in calibrated DSGE models of 0-0.1 (Baxter and King, 1993; Leeper et al., 2010; Ramey, 2021).

Figure 7 shows the model impulse response functions. To see how they match the empirical ones, it also repeats the latter and their confidence bands from Figures 2 and 3. Overall, the model accounts well for the dynamics following the identified government investment shocks, despite having only three degrees of freedom. It replicates them qualitatively and quantitatively. Most of the responses lie within the confidence intervals. In particular, the impact effects are matched decently. The model generates a slowly decaying response of public investment. It replicates the full response of private investment closely. It has some difficulty in matching the complicated empirical responses of private consumption and output which increase, fall, and then increase again, before returning to trend. The bottom panel shows the empirical and the model-implied cumulative government investment to output multiplier. The model replicates the estimated multiplier closely over the full horizon.

To gain further intuition for the effect of the estimated parameters on the size and shape of the government investment multiplier, we perform several counterfactuals. Figure 8 shows the model impulse responses for alternative calibrations. The solid lines replicate the baseline model responses at the estimated values of ζ. The dashed lines show a case where the persistence of the shocks is lowered by setting the autocorrelation to $\rho^{ig} = 0.5$. The shock is essentially back at trend after two years. The shorter stimulus is associated with smaller and less persistent increases in private demand and output, compared to the baseline. However, as government investment

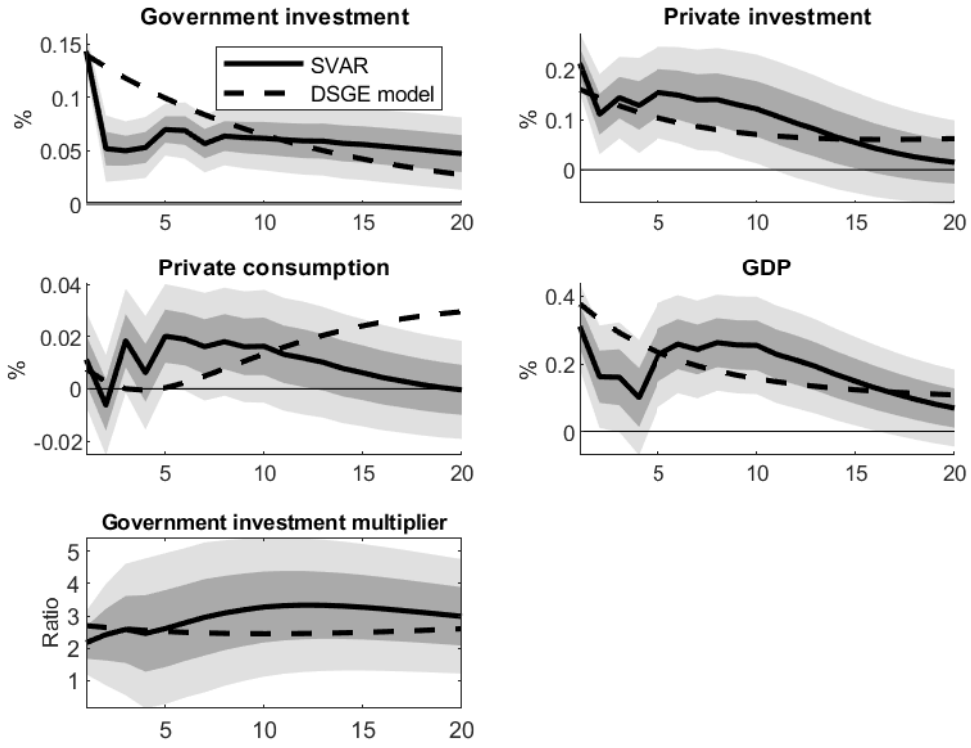

Figure 7: DSGE model and Proxy-SVAR impulse response functions. *Notes:* The figure shows the responses of government investment, private investment and consumption, output, and the cumulative government investment multiplier following a positive government investment shock of one standard deviation over 20 quarters. The solid lines and shaded areas are the point estimates and confidence intervals, respectively, which are from the Proxy-SVAR. The dashed lines are the impulse responses from the DSGE model.

and output are affected similarly, the multiplier hardly changes.

The dotted lines summarize a case where the effect of government investment on private investment adjustment costs is eliminated by setting $\kappa^g = 0$. This modification has no effect on the shock dynamics. However, it has a strong impact on the response of private investment. The latter barely reacts upon impact and rises only gradually as the increase in the public capital shock raises the marginal product of private investment via the production function. Given that the response of private consumption is not affected much by that parameter change, the alternative path of private investment relative to the baseline feeds nearly one-to-one into the response of output. The impact response of GDP is about halved and it takes three years before the counterfactual response converges to the baseline response. This time span gives an indication about the duration of the short run effects implied by the investment adjustment cost reduction

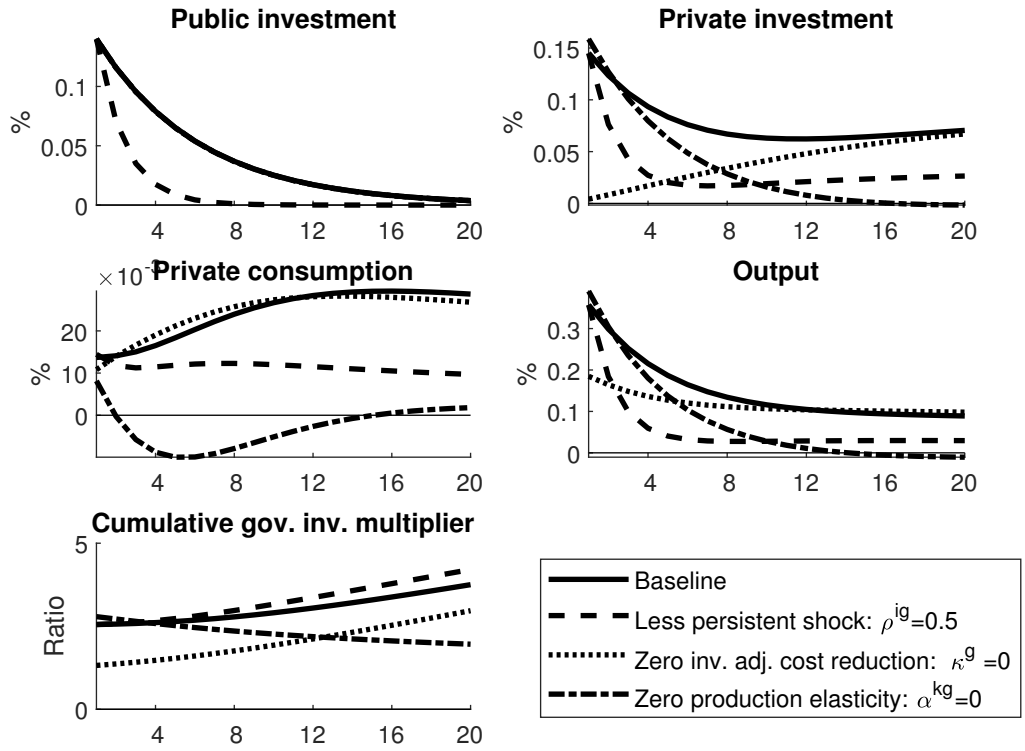

Figure 8: Decomposition of government investment multiplier. *Notes:* The figure shows the model impulse response functions of government investment, private investment and consumption, output, and the cumulative government investment multiplier following a positive government investment shock of one standard deviation over 20 quarters. The solid lines refer to the estimates for ζ. The other lines show counterfactuals where we change the value of one parameter at a time: dashed lines - lower autocorrelation of shock ($\rho^{ig} = 0.5$); dotted lines - no effect of public investment on private investment adjustment costs ($\kappa^{g} = 0$), dash-dotted lines - no public capital in production function ($\alpha^{kg} = 0$).

of government investment. As the differences to the baseline mainly occur at the beginning of the horizon, the multiplier is essentially shifted down and then runs parallel to the baseline multiplier, converging to the latter.

The dash-dotted lines refer to a case in which the elasticity of output to public capital is zero, $\alpha^{kg} = 0$. As before, this change does not affect the shock evolution. The response of government investment is indistinguishable from the baseline. Now, there is hardly an effect on the impact reaction of private investment. Then, the differences to the baseline gradually increase as private investment falls back to trend more quickly. Moreover, private consumption drops persistently below its initial level without the positive wealth effect. Output mimics the private demand dynamics and decays more rapidly. Accordingly, the multiplier does not increase over time, but slightly declines.

The counterfactuals illustrate two main transmission channels of government investment

to output that determine the size and shape of the multiplier. In the short run, government investment reduces private investment adjustment costs. This leads to a crowding-in of private investment for three years and pushes up the short run multiplier. In the long run, government investment raises the production capacity of the economy. This increases the marginal product of private investment and household wealth. Both spurs private demand over time.

5 Conclusion

In this paper, we estimate the macroeconomic effects of exogenous changes in government investment in Germany. First, we build a new and unique narrative instrument from historical financial reports and legislation. We use the instrument in structural vector autoregressions to trace out the dynamic effects of government investment shocks. We find large output effects, both in the short run and long run. The cumulative GDP multiplier is roughly 2 after one year and increases to 3 after five years. Furthermore, we find evidence for crowding-in of private demand.

Then, we build a New Keynesian DSGE model and match the empirical responses to understand the transmission of government investment shocks. The positive short-term effect on private demand and output can be rationalized by the model through a modified private investment adjustment cost function. We find that public investment reduces private investment adjustment costs by 16%. The positive long-term effect on private demand and output can be explained by a productive public capital stock. The estimated output elasticity of public capital is 0.06.

In many advanced countries, demographic change increases the need for government investment in digitization, education, and health. Furthermore, achieving the climate protection targets requires large investments in CO2-neutral production and infrastructure. Our results suggest that government investment can be an effective stimulus both in the short run and in the long run.

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Online Appendix to 'An Estimation and Decomposition of the Government Investment Multiplier'

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A Data and sources

A.1 Construction of the Public Investment Series

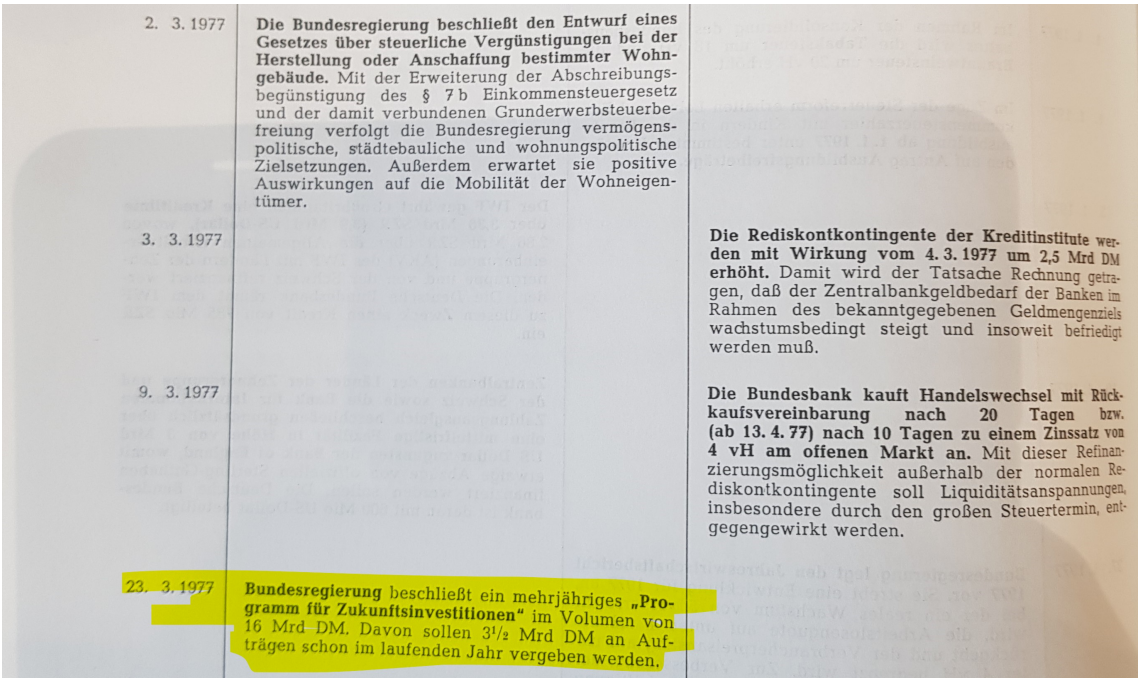
Step 1: Archive of the Federal Ministry of Finance

In the first step we search for historical investment programs in the archive of the Federal Ministry of Finance. We mainly concentrate on the "Finanzbericht" (The financial report) and the Jahreswirtschaftsbericht (Annual economic report), which are detailed reports about the German economy and the revenue and expenditure policy of the federal government. However, the reports are not available in a digital form, only for the recent years. In each report from 1970 there is a detailed time line of government decisions on a daily base which includes tax and law changes, but also announcements of expenditures. Additionally, it is stated if an expenditure measure is investive or not. Sometimes it is also explained in what context (e.g. as stability program after a crisis) the measure is announced. We further often get information about the size and duration as well as dates of announcements and resolution of a program. In total we identify 25 investment programs or measures from the federal government between 1970 and 2019. But not for all measures we get the full information about size, announcement date, duration and cause.

In contrast to consumptive expenditures, transfers or other expenditures, these measures are titled "investments" or "investive". This does not automatically mean that the series contains only public investment by the definition of the National Account Statistics. However, in the reports the definition "investive expenditure" is broader because it not only considers public gross capital formation but also investment grants and allowances. Furthermore, it contains federal government investment assignments to state and municipalities who get additional earmarked funds only for investment purposes. Thus, to some extent it also reflects the investment behavior of German municipalities who take over the largest part of public gross capital formation.

Step 2: Joint Economic Forecast & Legislative Online Service of the German Bundestag

In a next step, we collect further informations about the identified events by using mainly two



2. 3. 1977 **Die Bundesregierung beschließt den Entwurf eines Gesetzes über steuerliche Vergünstigungen bei der Herstellung oder Anschaffung bestimmter Wohngebäude.** Mit der Erweiterung der Abschreibungsbegünstigung des § 7b Einkommensteuergesetz und der damit verbundenen Grunderwerbsteuerbefreiung verfolgt die Bundesregierung vermögenspolitische, städtebauliche und wohnungspolitische Zielsetzungen. Außerdem erwartet sie positive Auswirkungen auf die Mobilität der Wohneigentümer.

3. 3. 1977 **Die Rediskontkontingente der Kreditinstitute werden mit Wirkung vom 4. 3. 1977 um 2,5 Mrd DM erhöht.** Damit wird der Tatsache Rechnung getragen, daß der Zentralbankgeldbedarf der Banken im Rahmen des bekanntgegebenen Geldmengenziels wachstumsbedingt steigt und insoweit befriedigt werden muß.

9. 3. 1977 **Die Bundesbank kauft Handelswechsel mit Rückkaufsvereinbarung nach 20 Tagen bzw. (ab 13. 4. 77) nach 10 Tagen zu einem Zinssatz von 4 vH am offenen Markt an.** Mit dieser Refinanzierungsmöglichkeit außerhalb der normalen Rediskontkontingente soll Liquiditätsanspannungen, insbesondere durch den großen Steuertermin, entgegengewirkt werden.

23. 3. 1977 **Bundesregierung** beschließt ein mehrjähriges **„Programm für Zukunftsinvestitionen"** im Volumen von 16 Mrd DM. Davon sollen 3½ Mrd DM an Aufträgen schon im laufenden Jahr vergeben werden.

Figure A.1: Example for an investment program collected from the BMF Finanzbericht 1977: Program for Future Investment decided on 23th March 1977. *Notes:* The German government decides on a multi-year "Program for Future Investment" with a volume of DM 16 bn, of which DM 3.5 bn are to be placed in the current year.

sources: The German joint economic forecast and the legislative text forms of the German Bundestag. The "Gemeinschaftsdiagnose" (German joint economic forecast) is an independent institution and consists of the five major German economic research institutes (DIW Berlin, ifo Munich, RWI Essen, IWH Halle and ifW Kiel) of the German Leibniz Gemeinschaft. Since 1947 the "Gemeinschaftsdiagnose" forecasts the whole National and Fiscal Account of the German economy twice in a year. Furthermore, it provides detailed information about the German economy and fiscal policy measures which are published in a report, available online since 2007 (See `https://gemeinschaftsdiagnose.de`). We augment our investment program series by additional (e.g. forecasts) or updated informations (e.g. detailed expenditure program after the reunification) from printed reports that are archived in the library of the DIW Berlin for the years prior to 2007. Legislated and draft laws are available by the German Bundestag online. Here, we use this service in order to collect further details about the size and duration of the specific investment programs and as additional proof.

As result of the first two steps we constructed the following list of government investment programs of the German federal state between 1970 and 2018 (SP – Stimulus Package, IP – Investment Program):

1 Urban Development Promotion Program (Städtebauförderungsgesetz)

Initial Date	Duration	Series	Type	Amount (total, in €)
12th March 1971	2 years	1Q1971 – 4Q1972	SP	0.2 bn

Type of investments: Public infrastructure GFC (municpalities), investment grants (federal state to municipalities) in order to customize the municipal infrastructure to the societal and environmental progress.
Short description: Due to the lack of schools, hospitals, larger sports facilities, facilities for the elderly, water supply, sewage and waste disposal and much more, the building fabric is in above-average need of renewal. Therefore, the German government wants to improve the regional economic development with the aim to find other workplaces for those leaving agriculture. In terms of urban development, this requires the development of central places and areas close to the and service areas, the improvement of traffic transport conditions and the expansion of the education expansion of the education system. Furthermore, the German government aims to improve all environmental conditions, the urban redevelopment and infrastructure measures through public investments.
Sources: Federal Ministry of Finance, Finanzbericht 1972, German Bundestag 1972. (`https://dserver.bundestag.de/btd/06/005/0600510.pdf`).

2 Second Stability Program (Zweites Stabilitätsprogramm)

Initial Date	Duration	Series	Type	Amount (total, in €)
9th May 1973	2 years	2Q1973 – 4Q1974	SP	-4.2 bn

Type of investments: investment grants, investment tax in order to reduce high inflationary due to an increasing oil price.
Short description: A strong economic upswing and the renewed acceleration of the inflationary trend have put the economy in a situation in which the stabilization policies appear to be inadequate. In this situation, the federal government adopted a second stability program which, in conjunction with monetary and credit policy measures, is to be budgetary measures, as well as a series of incisive and additional tax policy measures, e.g. suspension of special depreciation allowances for new investments, levying of an investment tax for a maximum period of two years for new investments, the reduction of investment allowances pursuant to the Investment Allowance Act by one-fourth.
Sources:: Federal Ministry of Finance, Finanzbericht 1973, Bericht des Finanzausschusses (7. Ausschuß).
(`https://dserver.bundestag.de/btd/07/005/0700592.pdf`).

3 Program to Promote Employment and Growth with Stability (Programm zur Förderung von Beschäftigung und Wachstum bei Stabilität)

Initial Date	Duration	Series	Type	Amount (total, in €)
6th February 1974	1 year	1Q1974 – 4Q1974	SP	4.0 bn

Type of investments: public GFC, investment grants, reduction of tax depreciation for investments in order to react to the oil price crisis.
Short description: With the "Program to Promote Employment and Growth with Stability" program of December 12, 1974 the course of global economic and financial for 1975 and the economic framework has been set. To promote investments by medium-sized and and small enterprises, the ERP provides investment grants. New investment allowances are introduced. These are profit-independent investment allowances 7.5 % of the acquisition or production costs. Public GFC in the construction sector are increased by additional federal spending. Furthermore the investments provided for in the 1975the federal budget in 1975 are, as far as possible, postponed to the first half of the year and new investment projects can already be started before the promulgation of the of the 1975 budget law. In order to finance public investment to secure private activity, a part of the reserves accumulated as accounts at the Deutsche Bundesbank will be released namely the funds from the surcharge on income and corporate income and corporation tax (stability surcharge).
Sources: Federal Ministry of Finance, Finanzbericht 1974, German Bundestag 1974. (`https://dserver.bundestag.de/btd/07/016/0701646.pdf`).

4 Program for Housing and other Investment (Programm für Bau- und andere Investitionen)

Initial Date	Duration	Series	Type	Amount (total, in €)
27th August 1975	1 year	3Q1975 – 3Q1976	SP	2.9 bn

Type of investments: public infrastructure GFC.
Short description: A investment stimulus package to strengthen construction and other investments and in particular to reduce employment risks, especially in the construction industry, and at the same time and, improve the domestic economic prerequisites for a resurgence in production and employment.
Sources: Federal Ministry of Finance, Finanzbericht 1976.
(`https://dserver.bundestag.de/btd/07/041/0704101.pdf`)

5 Program for Future Investments (Programm für Zukunftsinvestitionen),

Type of investments: increase of public infrastructure GFC (water infrastructure, mobility, energy, housing) in order to reach environmental criteria and long-term growth stimulation.

Initial Date	Duration	Series	Type	Amount (total, in €)
23rd March 1977	5 years	1Q1977 – 4Q1981	IP	6.7 bn

Short description: This program, in which states and municipalities are involved, should consist future-oriented investments in the development of an environmentally friendly infrastructure, for the improvement of transport and the preservation of natural living conditions. The Regulation Statement foregrounds the longer term, growth and structural politic aspect of the program. Business cycle stabilization and employment policy goals are not seen as being particularly topical or even as having priority. The federal government has earmarked DM 8.2 bn for its own share. The Länder (DM 3.4 bn) and the municipalities (DM 2.1 bn) are less burdened than the federal government with a total of DM 5 bn.
Sources: Federal Ministry of Finance, Finanzbericht 1978, Wirtschaftsdienst. (`https://www.econstor.eu/bitstream/10419/135099/1/wd_v57_i08_pp391-398.pdf`).

6 Resolution to Promotion of Economic Growth and Employment (Beschlüsse der Bundesregierung zur Förderung von Wirtschaftswachstum und Beschäftigung)

Initial Date	Duration	Series	Type	Amount (total, in €)
14th September 1977	1 year	3Q1977 – 4Q1978	SP	2.7 bn

Type of investments: investment grants, depreciation allowances in order to stimulate the weak economy.
Short description: Further measures are required to stimulate demand in the economy as a whole and thus to counteract unemployment to a greater extent. In the current situation, it is important to stimulate consumer demand by a sufficient increase in mass purchasing power without additional cost burdens for the economy and also reducing investment risks. In addition to the measures to be taken on the spending side of public public budgets, improvement of degressive tax depreciation for movable assets of the fixed assets and reintroduction of the degressive tax depreciation for buildings.
Sources: Federal Ministry of Finance Finanzbericht 1979.
(`https://dserver.bundestag.de/btd/08/009/0800900.pdf`)

7 Program to Promote Energy-Saving Investments (Programm zur Förderung heiz- und energiesparender Investitionen)

Initial Date	Duration	Series	Type	Amount (total, in €)
1st July 1978	4 years	2Q1978 – 4Q1982 (extended, still exists)	IP	2.2 bn

Type of investments: investment grants for energy-saving housing and infrastructure, public housing GFC in states and municipalities.

Short description: The federal and state governments promote housing modernization to improve the supply of good, affordable housing for broad segments of the population, thereby helping to preserve cities and communities. Modernization is the improvement of housing through structural measures that sustainablye increase the utility value of the dwelling or permanently improve housing conditions. Unless otherwise specified, federal financial assistance is made available between the federal government and the states. To promote energy-saving measures, the Federal Government grants the states financial assistance. The program was permanently extended and still exists.
Sources: Federal Ministry of Finance, Finanzbericht 1979, Gesetzesentwurf Bundestag. (https://dserver.bundestag.de/btd/08/017/0801782.pdf) (https://www.bgbl.de/xaver/bgbl/start.xav?start=%2F%2F*%5B%40attr_id%3D%27bgbl178s0993.pdf%27%5D#__bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl178s0993.pdf%27%5D__1635192870503, https://dserver.bundestag.de/btd/09/003/0900319.pdf).

8 Federal Financial Aid Program for Investments in Saarland (Finanzhilfen des Bundes an das Saarland für bedeutsame Investitionen)

Initial Date	Duration	Series	Type	Amount (total, in €)
29th December 1984	1 year	4Q1984 – 4Q1985	SP	0.3 bn

Type of investments: investment grants, public infrastructure GFC in municipalities.
Short description: The federal government grants financial assistance to the Saarland for particularly significant investments to improve transport infrastructure, measures to create new jobs to replace structural job losses in the steel industry, other measures to improve infrastructure, in particular to open up new business areas.
Sources: Federal Ministry of Finance, Finanzbericht 1985, German Bundestag. (https://dserver.bundestag.de/brd/1984/D576+84.pdf)

9 Balancing Economic Disparities Act (Gesetz zum Ausgleich unterschiedlicher Wirtschaftskraft in den Ländern)

Initial Date	Duration	Series	Type	Amount (total, in €)
07th November 1988	10 years	1Q1989–4Q1998	IP	12.3 bn

Type of investments: public GFC, financial aid of the federal government to states and municipalities for specific investment purposes.
Short description: In order to compensate for differences in economic strength, the grants for a period of ten years starting in 1989 for particularly important investments by the states and municipalities totaling DM 2.45 billion per year. The present bill will result in federal expenditures under the Federal Government under the Structural Assistance Act for the years

1989 to 1998 in total of DM 24.5 billion. The Länder and municipalities will bear at least 10% of the public financing of the investments, i.a. to improve the economic infrastructure, especially traffic, waste management and other development of the environment, promote education and training in the vocational sector, including the universities, R&D investments, urban planning.
Sources: Federal Ministry of Finance, Finanzbericht 1989, German Bundestag.
(`https://dserver.bundestag.de/btd/11/032/1103263.pdf`)

10 Economic Resilience Plan (ERP-Wirtschaftshilfe Investitionen Deutsche Einheit, Erster Nachtragshaushalt)

Initial Date	Duration	Series	Type	Amount (total, in €)
14th February 1990	2 quarters	1Q1990–2Q1990	IP	0.7 bn

Type of investments: public infrastucture GFC and climate protection investments in the GDR.
Short description: The presentation of the supplementary budget is particularly due to the current political developments in the developments in the GDR. The supplementary budget primarily serves the purpose of to finance the immediate traffic and infrastructure investments that have become necessary.
Sources: Federal Ministry of Finance, Finanzbericht 1991, German Bundestag.
(`https://dserver.bundestag.de/btd/11/067/1106775.pdf`)

11 German Reunification Funds (Investitionen/Fonds "Deutsche Einheit")

Initial Date	Duration	Series	Type	Amount (total, in €)
decided 16th May 1990	4 years	1Q1990–4Q1994	IP	10.5 bn (4 bn in 1990)

Type of investments: public infrastructure GFC, grants
Short description: Total expenditures of 58 bn (22 bn in 1990) decided 16th May 1990 but funds is used mainly for social transfers, but also to finance additional public investments already conducted in Q1 (e.g. electricity, traffic and railway system). Mainly investment grants of the federal government to new states and municipalities for infrastructure investment. The total budgeted expenditures for public investments will thus be exceeded by around DM 20.9 bn more than budgeted. The additional public investment have the aim of creating the conditions for the aid programs for the accession area laid down and the awarding of contracts for investments during the provisional budget management at the beginning of the year. The commitment appropriations in the government's draft 1990 supplementary budget are intended in particular to measures to promote the economy, in order to rapidly master the conversion process in the accession area as quickly as possible.

Sources: Federal Ministry of Finance, Finanzbericht 1991, DIW Berlin (1990). (https://dserver.bundestag.de/btd/11/081/1108160.pdf)

12 Extension of the Economic Resilience Plan (ERP-Wirtschaftshilfe Investitionen Deutsche Einheit, Dritter Nachtragshaushalt)

Initial Date	Duration	Series	Type	Amount (total, in €)
29th October 1990	2 quarter	3Q1990–4Q1990	IP	1 bn

Type of investments: public GFC, investment grants. Short description: Additional environmental and infrastructure GFC and investment grants in the GDR of DM 2.063 bn.
Sources: BMF Finanzbericht 1991, German Bundestag.
(https://dserver.bundestag.de/btd/11/081/1108160.pdf)

13 1st Extension of German Reunification Funds (1. Aufstockung des Fonds Deutsche Einheit)

Initial Date	Duration	Series	Type	Amount (total, in €)
27th November 1991	3 years	1Q1992–4Q1994	IP	6.9bn

Type of investments: only partly (1/3), mainly investment grants of the federal government to new states and municipalities for infrastructure investment.
Short description: Further improvement in the financial resources of the Länder and their municipalities in the years 1992 to 1994; Avoidance of federal support measures in favor of the old states, which, after German unification, would be in conflict with the structural problems of the new states, are no longer consistent with the constitution. Increase the German Unity Fund by the current total volume of financial aid for investments (DM 2.45 bn per year) by means of corresponding federal payments to the fund in the years 1992 to 1994. Further increase of the "German Unity" Fund in the years 1992 to 1994 through additional federal payments of DM 3.45 bn.
Sources: Federal Ministry of Finance, Finanzbericht 1992, German Bundestag.
(https://dserver.bundestag.de/btd/12/012/1201227.pdf)
(https://dserver.bundestag.de/brd/1992/D101+92.pdf)

14 Housing investment program ("Program Gebäudesanierung")

Initial Date	Duration	Series	Type	Amount (total, in €)
1st February 2006	4 years	1Q2006–4Q2009	IP	5.9 bn

Type of investments: public building GFC and investment grants for housing.
Short description: At the coalition meeting in Genshagen at the beginning of 2006, however,

part of this agreement was withdrawn or weakened: "Together with the planned tax reductions for modernization and maintenance in private households and the provision of 120 million euros p.a. for the energy-related refurbishment of federal buildings, 1.4 billion euros will be available annually for energy-related building refurbishment from 2006 to 2009. Sources: Federal Ministry of Finance, Finanzbericht 2007, German Bundestag. (https://dserver.bundestag.de/btp/16/16014.pdf)

15 Excellence Initiative ("Exzellenzinitiative")

Initial Date	Duration	Series	Type	Amount (total, in €)
13rd October 2006	10 years	3Q2006–4Q2017	IP	4.6 bn

Type of investments: Education grant, building & equipment GFC, investment grants.
Short description: The government will strengthen the promotion of cutting-edge technologies and increasing the attractiveness of Germany as a research location. In order to strengthen excellence in research at universities and their networking with non-university institutions and the economy, the funding program "Excellence Initiative for the Promotion of Science and Research at German Universities" Future concepts for the expansion of top research, graduate schools and clusters of excellence are funded on a competitive basis. Of the total annual 380 million, the federal government will provide 75 percent. The program has a total volume of €1.9 billion until 2011, with joint financing by the federal and state governments. The Excellence Initiative, another joint program of the federal and state governments, offers German universities the opportunity to sharpen their profiles and to become centers of excellence with high international appeal. Currently, a total of 85 institutions at 37 universities: 39 graduate schools for the promotion of young scientists, 37 clusters of excellence for the promotion of cutting-edge research and 9 concepts for the future, with which universities can establish establish themselves as institutions in the top international arena. In June 2009, the continuation of the initiative until 2017 and an increase in funding by 30% to a total of funding by €2.7 billion was decided. In 2012, approximately €308 million has been earmarked from the federal budget for the Excellence Initiative.
Sources: Federal Ministry of Finance, Finanzbericht 2007, German Bundestag. (https://dserver.bundestag.de/btd/16/007/1600751.pdf) (https://dserver.bundestag.de/btd/17/066/1706601.pdf)

16 University package I ("Hochschulpakt I")

Initial Date	Duration	Series	Type	Amount (total, in €)
14th June 2007	3 years	2Q2007–2Q2010	IP	1.2 bn

Type of investments: Education grant, building & equipment GFC, investment grants.
Short description: In view of forecasts of a temporary sharp rise in demand for demand for university places, the federal and the federal states have concluded the Higher Education Pact. The federal government is providing a total of 565 million euros by 2010, with the states providing the overall overall funding. The federal government is also strengthening pillar of this higher education pact, the federal government is also strengthening research: Projects that are funded by the German Research Foundation (DFG) receive an additional receive compensation for the indirect costs of the project in the amount of the indirect costs incurred by the project in the amount of 20% of the funding sum. In total, the German government will provide around 700 million euros for this purpose.
Sources: Federal Ministry of Finance, Finanzbericht 2008, German Bundestag.
(`https://dserver.bundestag.de/btd/16/092/1609260.pdf`)

17 Childcare Funds ("Sondervermögen Kinderbetreuungsaufbau")

Initial Date	Duration	Series	Type	Amount (total, in €)
22nd December 2007	7 years	4Q2007–4Q2014	IP	4.7 bn

Type of investments: Childcare grant, building GFC, investment grants.
Short description: In 2007, the federal government will set up a special fund for the expansion of childcare through which the federal government can visibly finance the necessary investments throughout the federal territory. The provision of the entire 2007 will give local authorities and citizens the confidence they need to expand childcare for immediate expansion. Investments to expand childcare, 2.15 bn by 2013, in 2013 another 1.85 for entitlement to childcare place and 770 million annually in 2014.
Sources: Federal Ministry of Finance, Finanzbericht 2013, German Bundestag.
(`https://dserver.bundestag.de/btd/16/065/1606596.pdf`)

18 University package II ("Hochschulpakt II")

Initial Date	Duration	Series	Type	Amount (total, in €)
13rd March 2012	3 years	1Q2011–4Q2014	IP	1.5 bn

Type of investments: Education grant, building & equipment GFC, investment grants.
Short description: With the "Higher Education Pact 2020", the federal and state governments want to increase the performance of universities. To this end the federal government is granting lump sums to universities for the expansion of of study places. Starting in 2011, it will also support teaching at universities with the "Teaching Quality Pact", it will also support teaching at universities. For the years 2011 to 2015, the federal government has earmarked a total of 5 billion for the expansion of study places and a total of 1.7 billion

euros for the program allowance and 915 million euros for the Teaching Quality Pact.
Sources: Federal Ministry of Finance, Finanzbericht 2012, German Bundestag.
(https://dserver.bundestag.de/btd/17/076/1707600.pdf)

19 Stimulus Package I ("Konjunkturpaket I")

Initial Date	Duration	Series	Type	Amount (total, in €)
05th November 2008	1 year	4Q2008–4Q2009	SP	8 bn

Type of investments: Machinery and R&D GFC.
Short description: In the worst economic crisis since the Federal Republic of Germany the federal government has supported the economy. Two economic stimulus packages were introduced in Germany at the end of 2008 and the beginning of 2009 respectively - in addition to support measures to stabilize the financial markets, various measures were introduced in Germany at the end of 2008 and the beginning of 2009, to actively counteract the massive economic slump: In November 2008, the Economic Stimulus Package I was launched in November 2008. The measures adopted at the end of 2008 to the beginning of 2009 to stabilize growth and employment represent a mix of different instruments which flow into the economic cycle at different points: Additional- government spending on investment in the transport and construction sectors and on the and construction as well as the Future Investment Act stimulate macroeconomic activity. Companies' willingness to invest will be boosted by the improved tax deductibility of investments, which is limited until the end of 2010.
Sources: Federal Ministry of Finance, Finanzbericht 2009, German Bundestag.
(https://dserver.bundestag.de/btd/17/025/1702568.pdf)// (https://www.bundesfinanzm
de/Monatsberichte/2001-2016/Inhalte/Monatsbericht-Archiv-Downloads/2008/
Monatsbericht_Nov_2008.pdf?__blob=publicationFile&v=4)

20 Stimulus Package II ("Konjunkturpaket II")

Initial Date	Duration	Series	Type	Amount (total, in €)
27th January 2009	2 years	1Q2009–4Q2010	SP	14 bn

Type of investments: Machinery, building and R&D GFC, investment grants.
Short description: The federal government is providing a total of 16.9 billion euros for public investment to strengthen research and economic activity. Of this 4 bn euros is earmarked for additional federal investment. With 10 bn euros to support additional investment by local authorities and the federal states. Added to this are the program to strengthen demand for cars (1.5 billion euros), the central innovation program for SMEs (900 million euros) and funding for research in the field of mobility (900 million euros) and funding for research

in the field of mobility (500 million euros). These temporary measures will be pooled in a special "Investment and Redemption Fund", which has its own borrowing authority and an effective redemption scheme.
Sources: Federal Ministry of Finance, Finanzbericht 2010, German Bundestag.
(https://dserver.bundestag.de/btd/16/117/1611740.pdf)

21 Municipal Investment Promotion Fund: Infrastructure ("Kommunalinvestitonsfördergesetz: Infrastruktur")

Initial Date	Duration	Series	Type	Amount (total, in €)
30th June 2015	5 years	2Q2015–4Q2018	IP	3.5 bn

Type of investments: public infastructure investment.
Short description: To compensate for differences in economic strength across Germany, the federal government supports financially weak municipalities in the Flächenländer and structurally weak areas in the city states with an investment program. For this purpose, the special fund "Kommunal Investment Promotion Fund" provides financial assistance to the federal states for investments by financially weak municipalities in the Flächenländer and structurally weak areas in the city states totaling 3.5 billion euros. The purpose of the special fund "Municipal Investment Promotion Fund" is to promote investments of financially weak municipalities.
Sources: Federal Ministry of Finance, Finanzbericht 2016, German Bundestag.
(https://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/
Oeffentliche_Finanzen/Foederale_Finanzbeziehungen/Kommunalfinanzen/Kommunalinvest
Verwaltungsvereinbarung.pdf?__blob=publicationFile&v=5)

22 Municipal Investment Promotion Fund: Schools ("Kommunalinvestitonsfördergesetz: Schulen")

Initial Date	Duration	Series	Type	Amount (total, in €)
30th June 2015	7 years	2Q2015–4Q2022	IP	3.5 bn

Type of investments: school building investment.
Short description: At the beginning of June 2017, the German Bundestag and Bundesrat passed a package of fiscal policy laws. Thirteen amendments to the Basic Law and numerous provisions in simple law the financial relations between the federal government and the states from 2020 as well as numerous federal competences. Part of the legislative amendments is the inclusion of a new Article 104c in the Basic Law, which enables the federal government to provide grants for investment in education infrastructure by their financially weak municipalities. On the basis of this new article in the Basic Law, the legislature at

the same time amended the Municipal Investment a second chapter to improve the school infrastructure in financially weak municipalities and increased the Municipal Investment Promotion Fund by €3.5 billion. billion euros for this purpose
Sources: Federal Ministry of Finance, Finanzbericht 2016, German Bundestag.
(https://www.bundestag.de/resource/blob/651466/d7ff7277f1c7dd1a0e3f24316454e46e/WD-8-064-19-pdf-data.pdf)

23 University package III ("Hochschulpakt III")

Initial Date	Duration	Series	Type	Amount (total, in €)
14th December 2014	8 years	1Q2016–4Q2023	IP	8.8 bn

Type of investments: Education grant, building & equipment GFC, investment grants.
Short description: The Federal Government and the Governments of the Länder of the Federal Republic of Germany continue their joint efforts in the promotion of science. In addition, the Federal Government and the governments of the Länder of the Federal Republic of Germany are continuing their joint efforts in the promotion of science and and research and to strengthen research, particularly at universities, with the funding of established in the first two program phases of the Higher Education Pact since 2007 grants for funding of research projects by the German Research Foundation (DFG). The federal governments provides 6.252 billion euros in the years 2016 to 2020 for the expansion of study offerings for the additional students expected according to the KMK projections of 2014. New students expected in the third program phase (2016 to 2020), and in the years 2021 to 2023, up to 2.53 billion euros.
Sources: Federal Ministry of Finance, Finanzbericht 2014, German Bundestag.
(https://www.gwk-bonn.de/fileadmin/Redaktion/Dokumente/Papers/BLV-HSPA-III.pdf)

24 Public transportation investment promotion program ("ÖPNV investment Programm")

Initial Date	Duration	Series	Type	Amount (total, in €)
16th June 2016	15 years	2Q2016–4Q2030	IP	2.5 bn

Type of investments: infrastructure and vehicle investment.
Short description: Increase in federal funding for public transport to 2.5 billion euros.
Sources: Federal Ministry of Finance, Finanzbericht 2016, German Bundestag.

25 Digitalization program for schools ("Digitalpakt Schule")

Initial Date	Duration	Series	Type	Amount (total, in €)
15th March 2016	5years	1Q2018–4Q2023	IP	5 bn

Type of investments: public infrastructure and school building investment.
Short description: This Act establishes the Digital Infrastructure Fund as a special federal fund of the Federal Government. The purpose of the special fund is to promote investments in the digital infrastructure and to grant financial assistance to the federal states. The funding of investments, the expansion of fiber-optic gigabit networks is supported, especially in rural regions in particular, while financial assistance will be used to support the development and improvement of the digital infrastructure for schools. The measures will be financed from the revenue generated by the upcoming provision of of frequencies for mobile communications by the Federal Network Agency. Since the amount of the revenue from this allocation and the specific date on which it will be collected the fund will be financed with 2.4 billion from the federal budget to provide start-up funding for the measures. According to the administrative agreement of May 17, 2019, the federal government will provide 5 bn euros for investments in digital education infrastructure within the scope of its constitutional possibilities.
Sources: Federal Ministry of Finance, Finanzbericht 2019, German Bundestag.
(`https://www.bundesfinanzministerium.de/Content/DE/Gesetzestexte/Gesetze_Gesetzesvorhaben/Abteilungen/Abteilung_II/19_Legislaturperiode/Digitalinfrastruck2-Regierungsentwurf.pdf?__blob=publicationFile&v=2`)

Step 3: Adjustments

We normalize each program by the number of periods of duration such that in every quarter the level of public investment is equally affected by the investment program. Furthermore, we divide the quarterly investment amount by the potential output.

A.2 Data description

Bank bond yield: Corporate Benchmarks, Bank Debt Securities, Yield, Macrobond.
Budget balance: Federal Statistic Office, National Accounts Statistics, Series 18 1.3, Budget balance, 1Q1970-4Q2018.
CPI inflation rate: Federal Statistic Office, National Accounts Statistics, Series 18 1.2, Private consumption price deflator, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1970-4Q2018.
Consumption: Federal Statistic Office, National Accounts Statistics, Series 18 1.2, Private Consumption, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1970-4Q2018.

Corporate bond yield: Corporate Benchmarks, Bank Debt Securities, Yield, Macrobond.
Credit spread: Difference between corporate bond yield and one-year rate.
GDP deflator:OECD MEI, National Accounts, National Accounts Deflators, Gross Domestic Product, GDP Deflator, SA, Index, Macrobond.
Gross domestic product: Federal Statistic Office, National Accounts Statistics, Series 18 1.2, Gross Domestic Product, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1970-4Q2018.
Government investment: Federal Statistic Office, National Accounts Statistics, Series 18 1.3, Governmental investments, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1970-4Q2018.
Government construction investment: Federal Statistic Office, National Accounts Statistics, Series 18 1.3, Governmental construction investments, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1970-4Q2018.
Government equipment and machinery investment: Federal Statistic Office, National Accounts Statistics, Series 18 1.3, Governmental equipment and machinery investments, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1970-4Q2018.
Government other investment: Federal Statistic Office, National Accounts Statistics, Series 18 1.3, Governmental other investments, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1970-4Q2018.
Net exports: Differences between exports and imports, Bundesbank, Germany, National Accounts, Use of Gross Domestic Product, Exports (Imports) of Goods & Services 1, 2, 3, Calendar Adjusted, Constant Prices, SA, Index, Macrobond.
One-year rate: Government Benchmarks, Bundesbank, Yield on Debt Securities Outstanding, Yield, Macrobond.
Private investment: Federal Statistic Office, National Accounts Statistics, Series 18 1.3, Non-governmental investments, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1970-4Q2018.
Private construction investment: Federal Statistic Office, National Accounts Statistics, Series 18 1.3, Private construction investment, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1970-4Q2018.
Private equipment and machinery investment: Federal Statistic Office, National Accounts Statistics, Series 18 1.3, Private equipment and machinery investment, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1970-4Q2018.
Private other investment: Federal Statistic Office, National Accounts Statistics, Series 18 1.3, Private other investment, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1970-4Q2018.
Ten-year rate: OECD MEI, Interest Rates, Long-Term Government Bond Yields, 10-Year, Main (Including Benchmark), Macrobond.
Total revenues: Federal Statistic Office, National Accounts Statistics, Series 18 1.3, Total revenues,

price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1970-4Q2018.
Nominal interest rate: FRED, Immediate Rates: Less than 24 Hours: Call Money/Interbank Rate for Germany, 1Q1970-4Q2018.
Real effective exchange rate: FX Indices, BIS, Real Effective Exchange Rate Index, Narrow, Macrobond.
Real short-term rate: Difference between ECB main refinancing rate and realized GDP deflator inflation.
Real short-term rate: OECD MEI, Labour Compensation, Wage Rate, Manufacturing, Hourly, Index, Macrobond.
Unemployment rate: OECD MEI, Labour Force Survey - Quarterly Rates, Unemployment Rate, Aged 15 & Over, All Persons, SA, Macrobond.

B Supplement SVAR analysis

B.1 Specification tests

Equation	Gov. inv.	Priv. inv.	Priv. cons.	GDP	Revenues	Gov. cons.
F-statistic	1.282	0.672	0.871	1.408	0.702	0.624
p-value	0.279	0.612	0.483	0.234	0.592	0.646

Table B.1: Tests for VAR invertibility. *Notes:* The table shows robust F-statistics and p-values testing the null hypothesis that the coefficients on four lags of the instrument for government investment shocks are jointly equal to zero in each of the VAR equations.

Lags	1	1-2	1-3	1-4
F-statistic regression	0.884	0.726	0.536	0.385
p-value regression	0.520	0.746	0.952	0.998
p-value lags instrument	0.164	0.260	0.411	0.734

Table B.2: Tests for instrument predictability. *Notes:* The table shows robust F-statistics and p-values testing the null hypothesis that the coefficients on 1 up to 1-4 lags of the instrument and the endogenous variables are jointly equal to zero. The dependent variable is the instrument.

B.2 Sensitivity analysis SVAR model

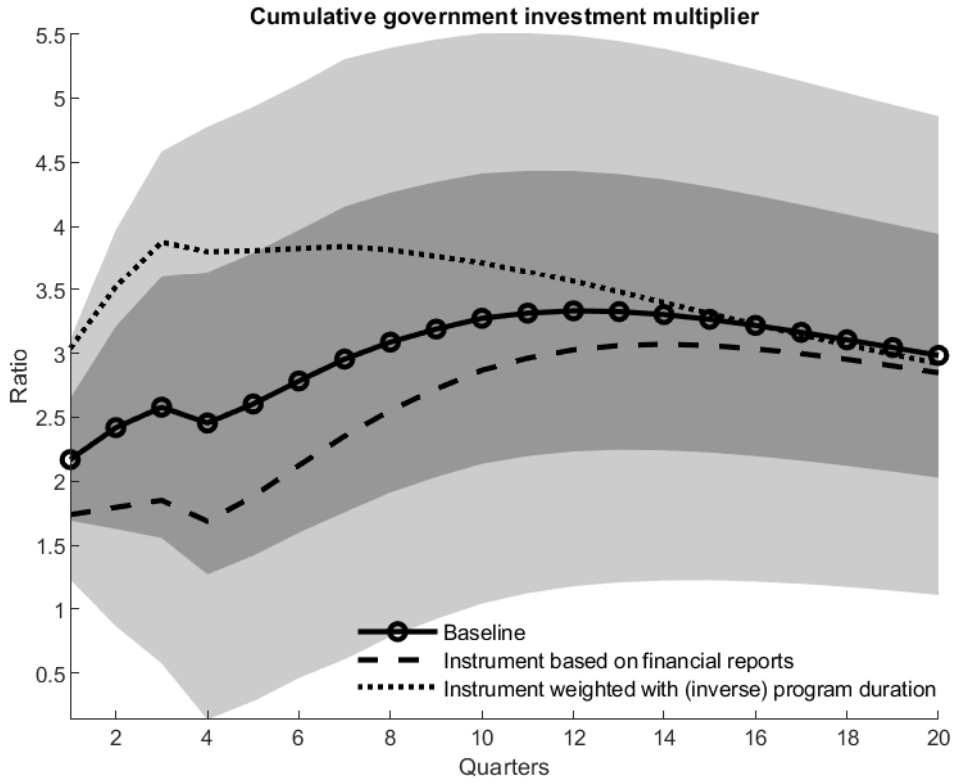


Figure B.2: Sensitivity of output multiplier to alternative constructions of the instrument. *Notes:* The figure shows the cumulative output multiplier of government investment shocks identified with an external instrument over 20 quarters for alternative instruments. The line with circles and the shaded areas (1 and 2 standard error confidence intervals based on 1000 bootstrap replications) refer to the baseline specification where we extend and update the investment program amounts of financial reports by values found in draft laws and other official documents of the German Bundestag and the Joint Economic Forecast. The dotted line shows the multiplier when the total volume of each investment program is related to the program duration. The dashed line shows the multiplier when we construct our instrument only with investment programs from one source, the financial reports.

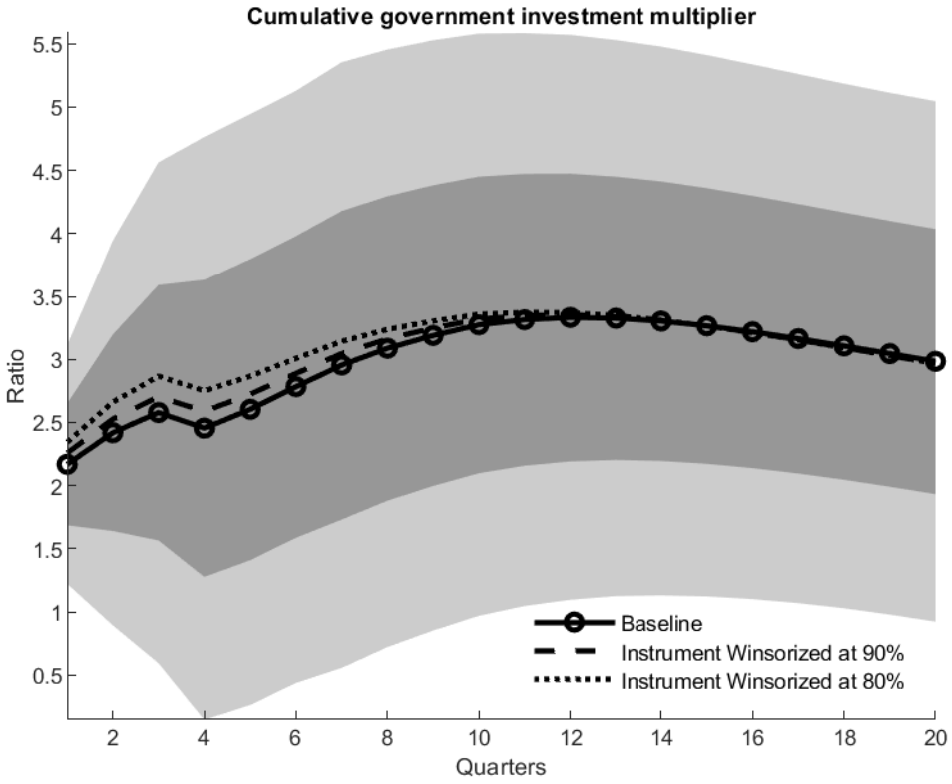


Figure B.3: Sensitivity of output multiplier to Winsorization of the instrument. *Notes:* The figure shows the cumulative output multiplier of government investment shocks identified with an external instrument over 20 quarters for alternative Winsorization of the non-zero instrument observations. The line with circles and the shaded areas (1 and 2 standard error confidence intervals based on 1000 bootstrap replications) refer to the baseline specification. The dashed and dotted line shows the multiplier when the instrument is Winsorized at the 90th and 80th percentile, respectively.

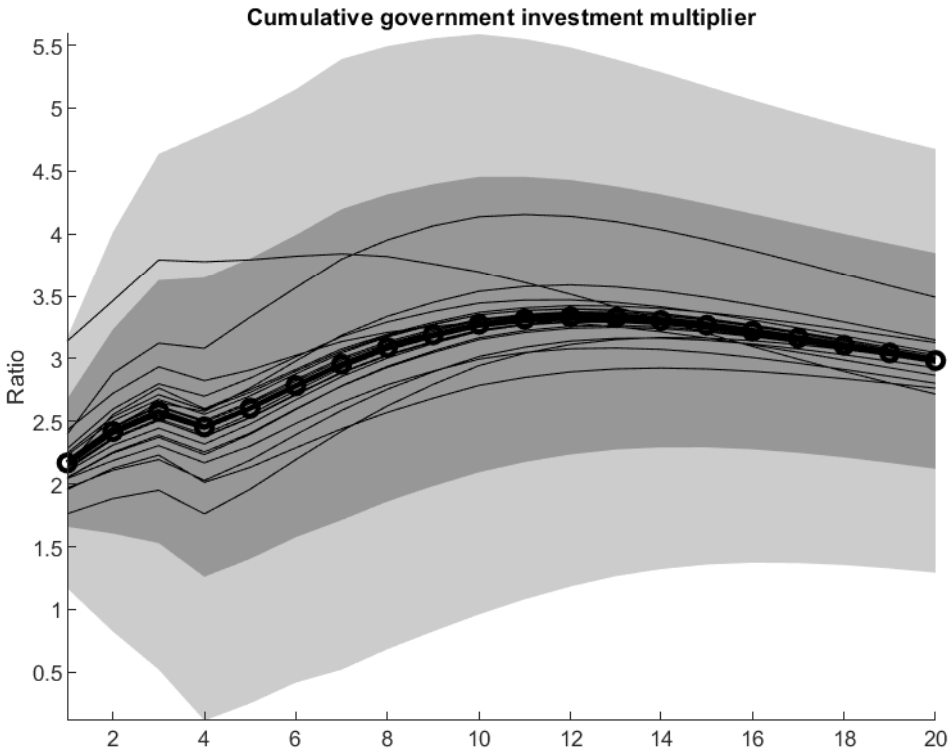


Figure B.4: Sensitivity of output multiplier to dropping non-zero instrument observation. *Notes:* The thin lines show the cumulative output multiplier of government investment shocks identified with an external instrument over 20 quarters when dropping one non-zero instrument observation at a time. The line with circles and the shaded areas (1 and 2 standard error confidence intervals based on 1000 bootstrap replications) refer to the baseline specification.

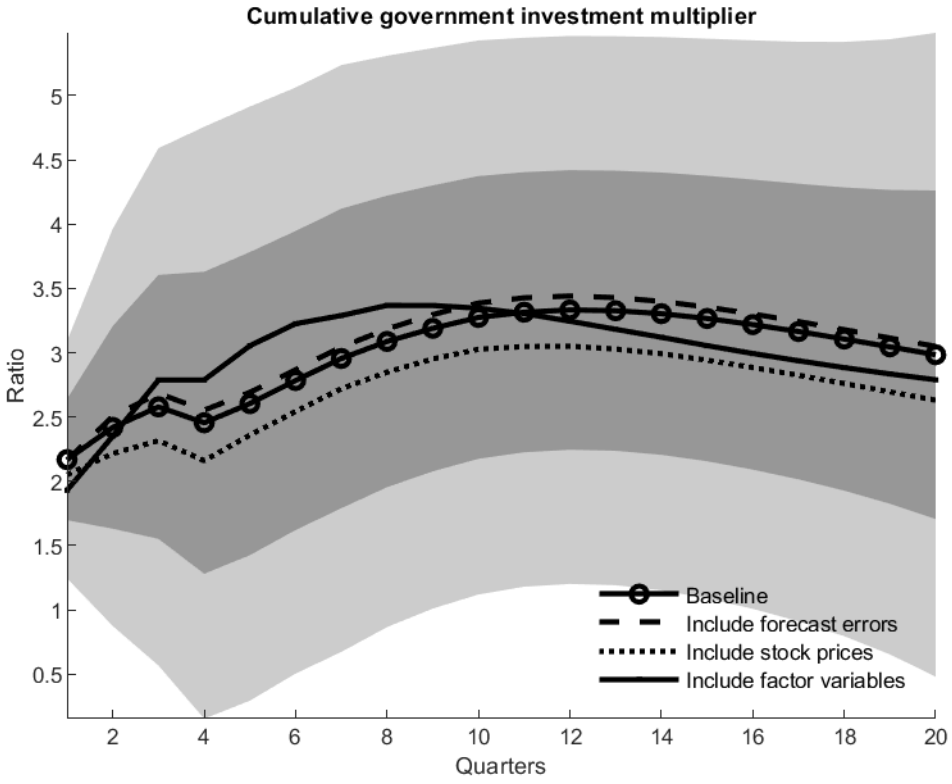


Figure B.5: Sensitivity of multiplier to fiscal foresight. *Notes:* The figure shows the cumulative output multiplier of government investment shocks identified with an external instrument over 20 quarters for alternative endogenous variables. The line with circles and the shaded areas (1 and 2 standard error confidence intervals based on 1000 bootstrap replications) refer to the baseline specification. The dashed, dotted, and dash-dotted line is the point estimate when including forecast errors, stock prices of middle and large firms (MSCI mid & large cap index), or two factor variables (1 financial and 1 real factor), respectively. We calculate the forecast errors from the Joint Economic Forecast Group, which estimates twice a year the semiannual 1-year and 2-years ahead public investment amount based on all available government information. In preparation of the projection the Group requests the Bundesbank and the German government to inform about actual and planned policy measures. We compute the difference between the 1-year ahead forecast of public investment and the first released series.

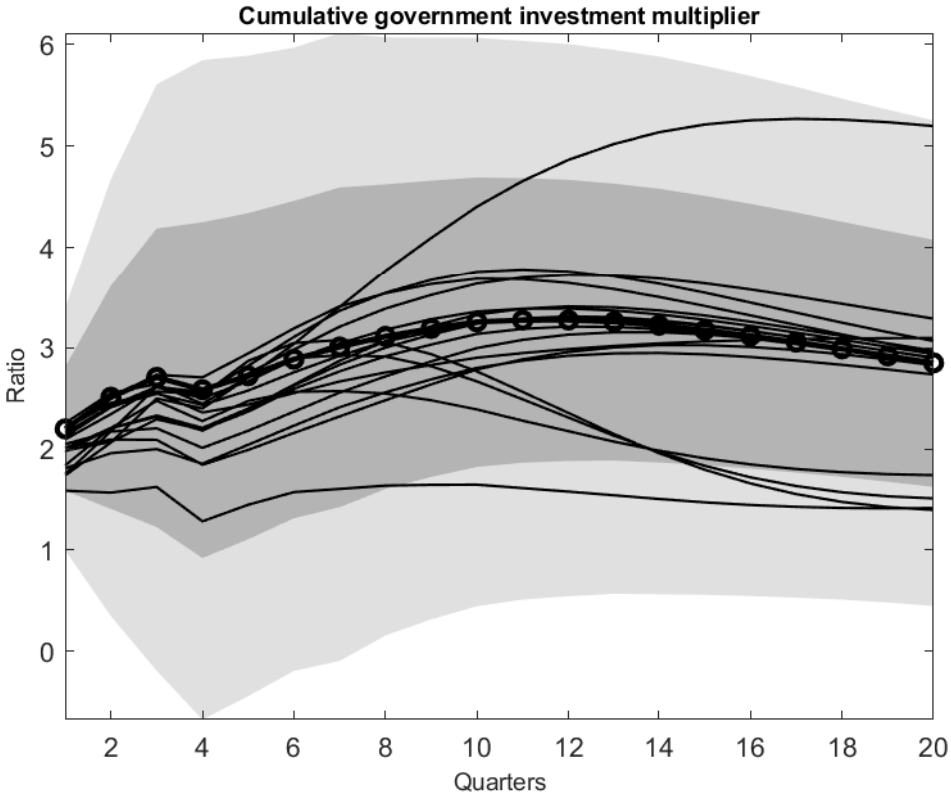


Figure B.6: Sensitivity of output multiplier to alternative endogenous variables. *Notes:* The figure shows the cumulative output multiplier of government investment shocks identified with an external instrument over 20 quarters for alternative sets of endogenous variables. The line with circles and the shaded areas (1 and 2 standard error confidence intervals based on 1000 bootstrap replications) refer to the baseline specification. The other lines show the multiplier when the variables are added one at a time to the baseline model. The additional variables are those shown in Figures 5 and 6.

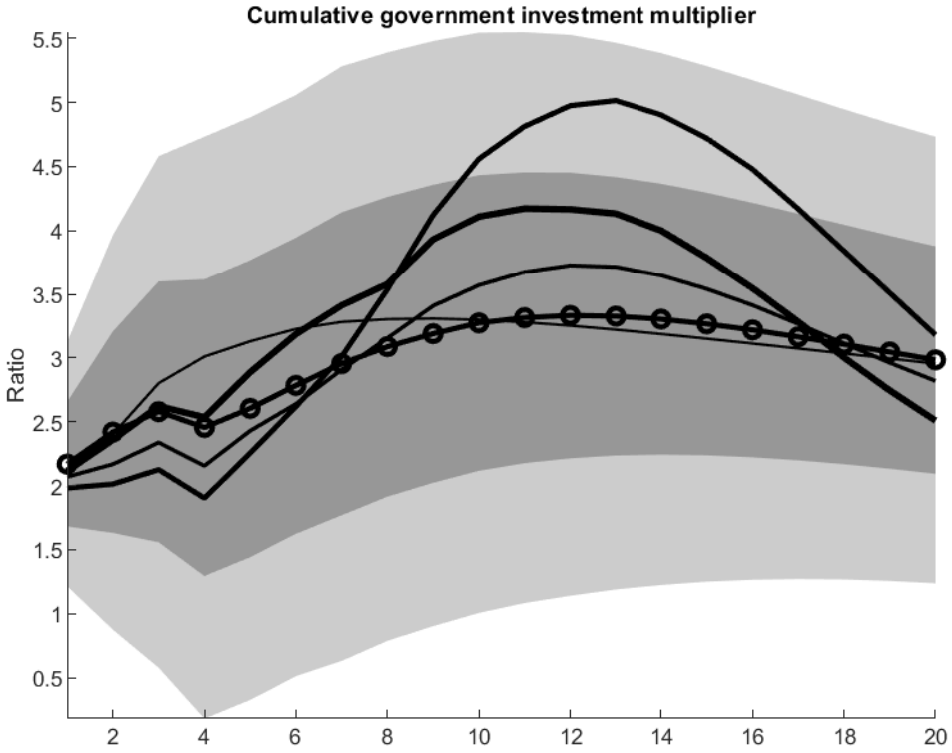


Figure B.7: Sensitivity of multiplier to alternative lag length. *Notes:* The figure shows the cumulative output multiplier of government investment shocks identified with an external instrument over 20 quarters for alternative lag length of the SVAR. The line with circles and the shaded areas (1 and 2 standard error confidence intervals based on 1000 bootstrap replications) refer to the baseline specification with 4 lags. The other lines are the point estimates for $p = 3,5,7,8$. The width of the lines increase with the lag length.

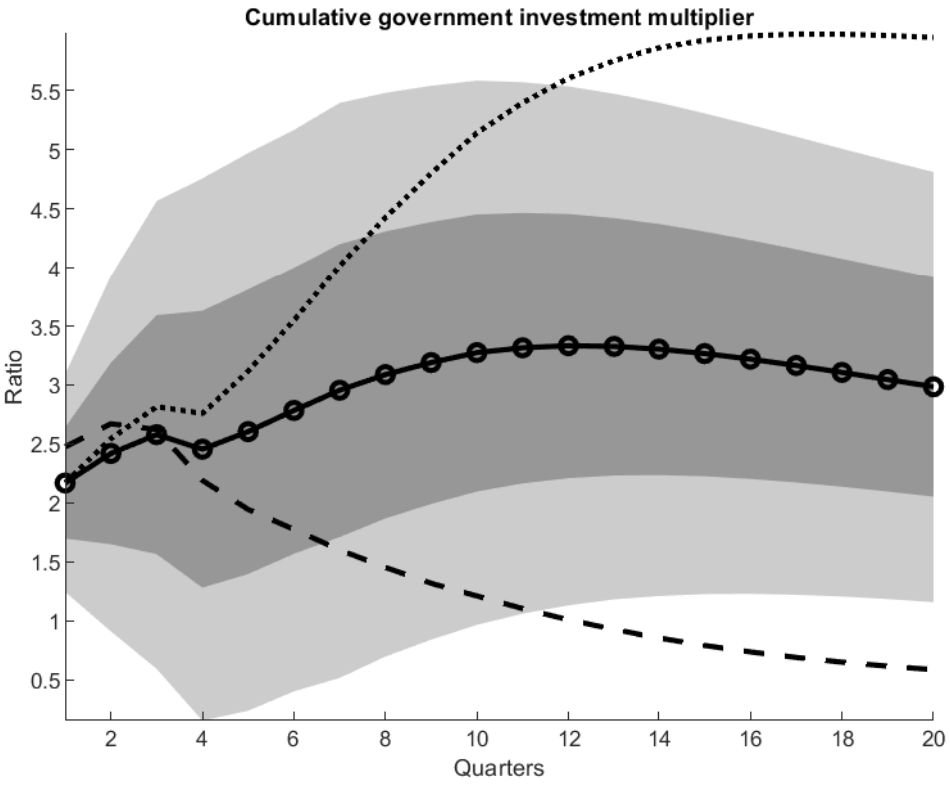


Figure B.8: Sensitivity of multiplier to trends. *Notes:* The figure shows the cumulative output multiplier of government investment shocks identified with an external instrument over 20 quarters for alternative trends assumptions. The line with circles and the shaded areas (1 and 2 standard error confidence intervals based on 1000 bootstrap replications) refer to the baseline specification with linear trend. The dashed and dotted line is the point estimate when excluding the linear trend or including a quadratic trend, respectively.

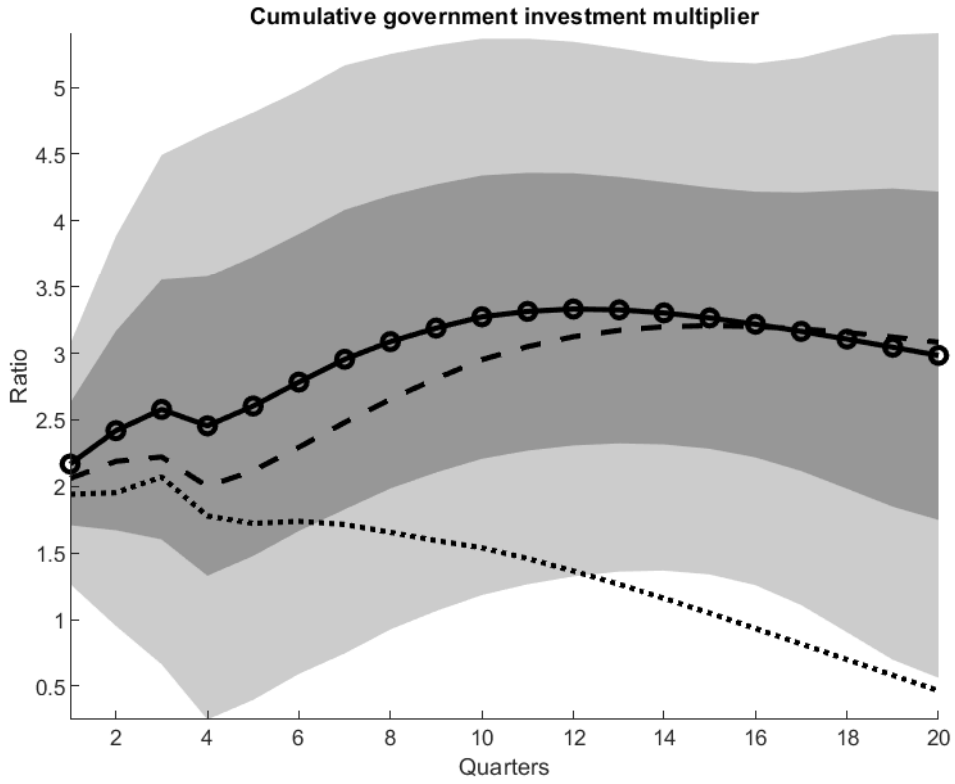


Figure B.9: Sensitivity of multiplier to using aggregate variables or logs. *Notes:* The figure shows the cumulative output multiplier of government investment shocks identified with an external instrument over 20 quarters for alternative transformations of the endogenous variables. The line with circles and the shaded areas (1 and 2 standard error confidence intervals based on 1000 bootstrap replications) refer to the baseline specification in per capita terms and ratios to trend GDP. The dashed and dotted line is the point estimate when using aggregate instead of per capita variables or log-levels instead of trend ratios, respectively.

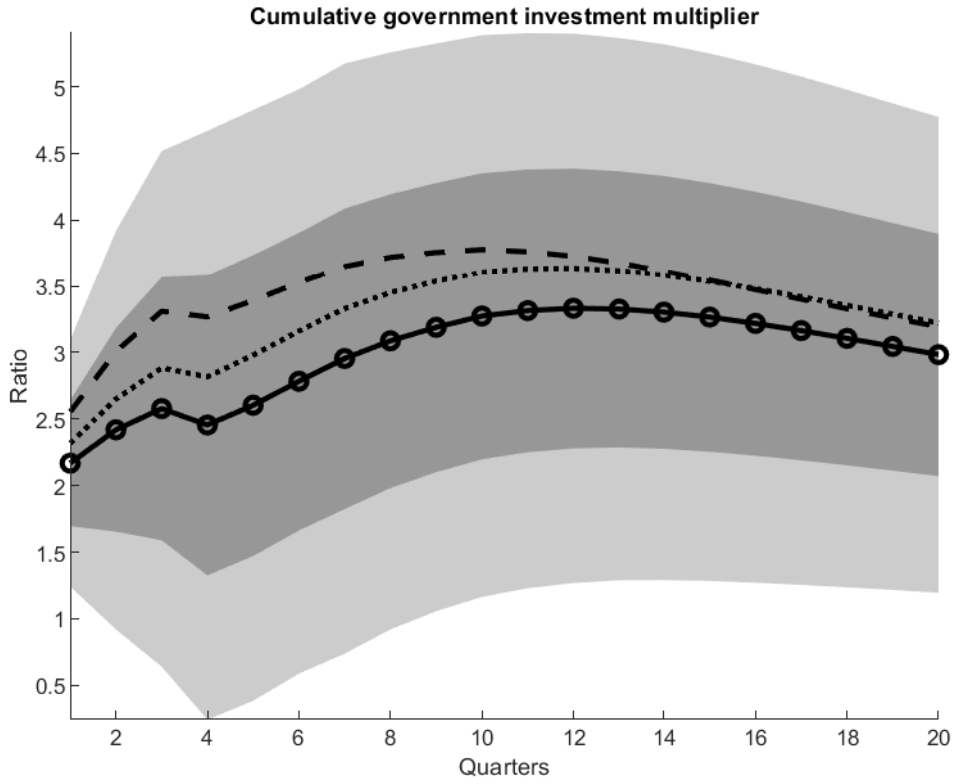


Figure B.10: Sensitivity of multiplier to alternative GDP de-trending. *Notes:* The figure shows the cumulative output multiplier of government investment shocks identified with an external instrument over 20 quarters for alternative de-trending of GDP. The line with circles and the shaded areas (1 and 2 standard error confidence intervals based on 1000 bootstrap replications) refer to the baseline specification using a fifth-order polynomial for computing the trend of log real per capita GDP. The dashed and dotted line is the point estimate when using a third or fourth-order polynomial, respectively.

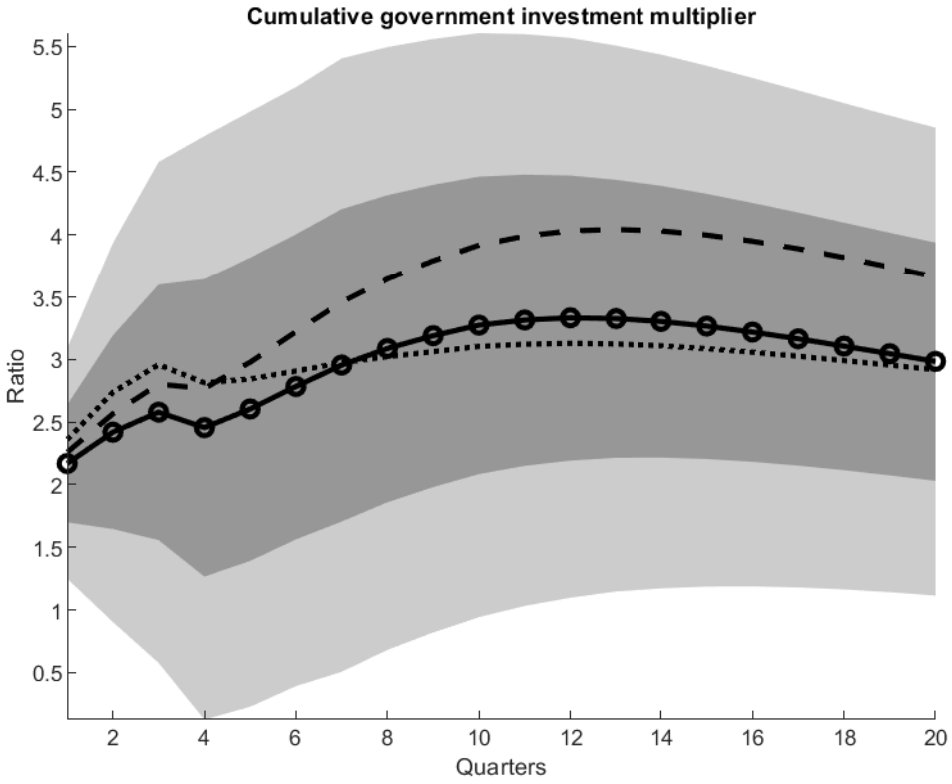


Figure B.11: Sensitivity of multiplier to dropping reunification or financial crisis dummy. *Notes:* The figure shows the cumulative output multiplier of government investment shocks identified with an external instrument over 20 quarters for alternative specifications of the variables. The line with circles and the shaded areas (1 and 2 standard error confidence intervals based on 1000 bootstrap replications) refer to the baseline specification. The dashed and dotted line is the point estimate when excluding the reunification dummy (1989Q4-1992Q4) or when excluding the financial crisis dummy (2008Q3-2009Q1), respectively.

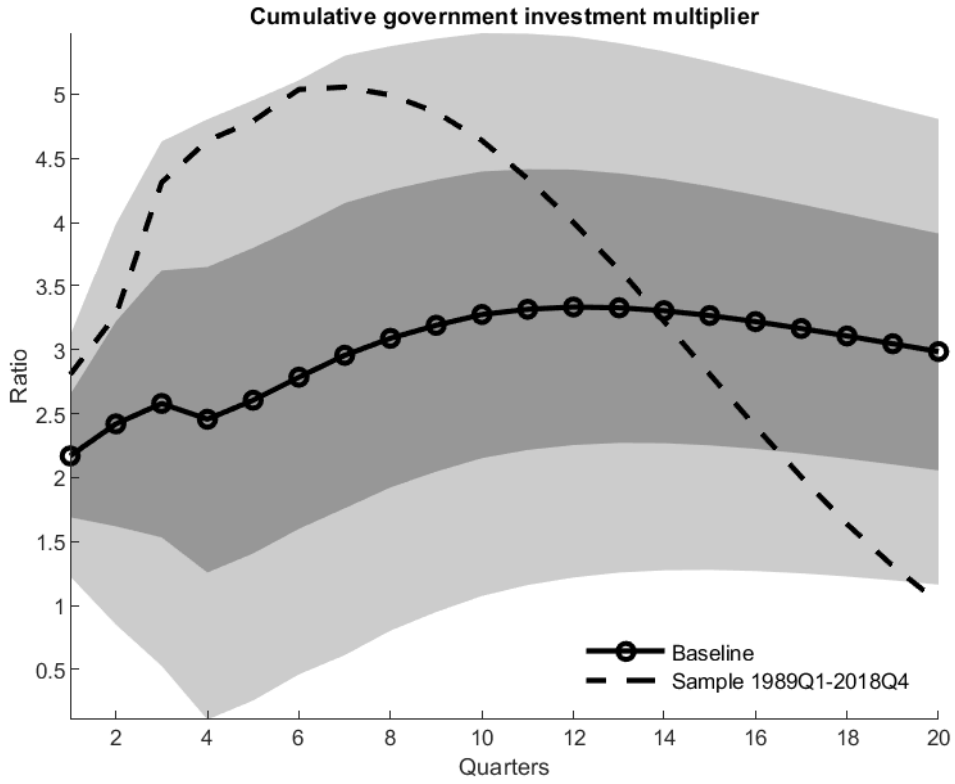


Figure B.12: Sensitivity of multiplier to starting sample after Fall of the Wall. *Notes:* The figure shows the cumulative output multiplier of government investment shocks identified with an external instrument over 20 quarters. The line with circles and the shaded areas (1 and 2 standard error confidence intervals based on 1000 bootstrap replications) refer to the baseline sample 1970Q1-2018Q4. The dashed line is the point estimate for the alternative sample 1989Q1-2018Q4. Although the Fall of the Berlin Wall was in 1989Q4, we start in 1989Q1 to not lose the non-zero instrument observations in 1990 due to the lag structure of the SVAR and to obtain a F-statistic of 13.46. Otherwise the F-statistic would drop to 4.4, generating weak instrument problems. Moreover, we drop the reunification dummy. Given the short sample, we compute trend GDP with a second-order polynomial.

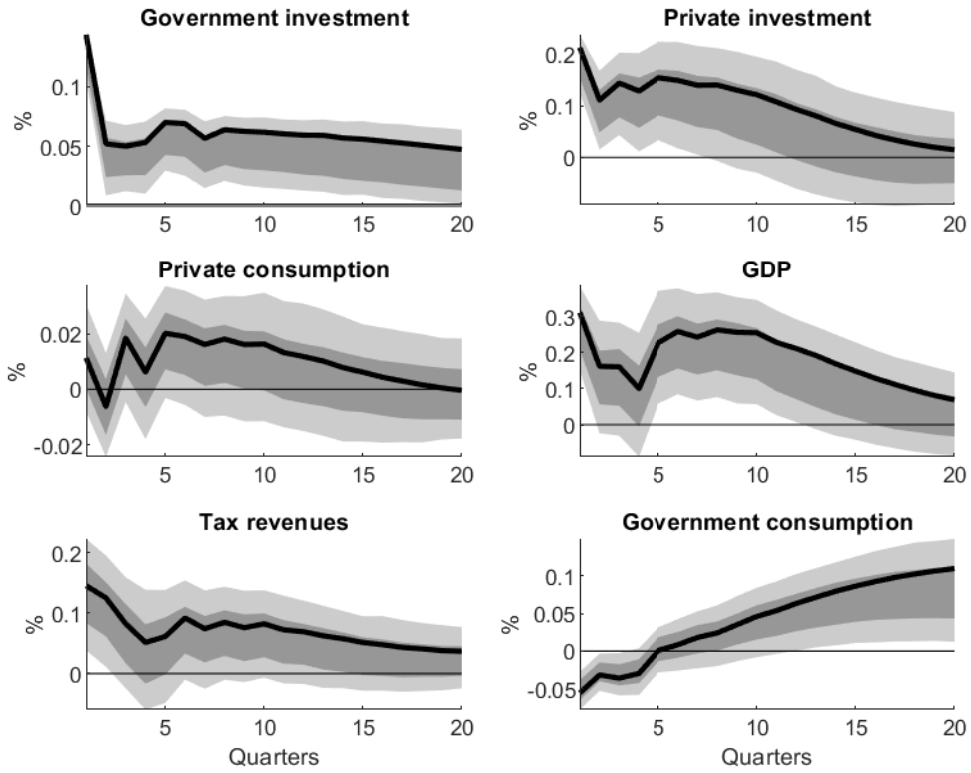


Figure B.13: Sensitivity of impulse responses to using Efron's confidence bands. *Notes:* The figure shows the responses of the baseline variables to a positive government investment shock of one standard deviation identified with an external instrument over 20 quarters. The shaded areas are Efron's 68% and 95% confidence bands based on 1000 bootstrap replications. All variables are expressed relative to trend GDP.

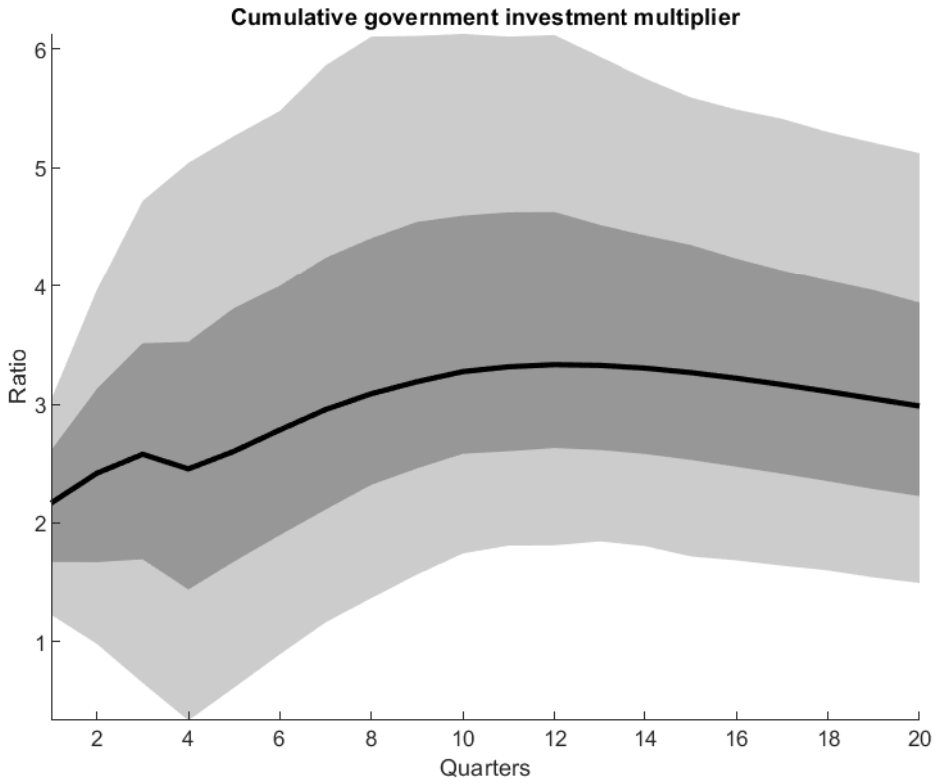


Figure B.14: Sensitivity of multiplier to using Efron's confidence bands. *Notes:* The figure shows the cumulative output multiplier of government investment shocks identified with an external instrument over 20 quarters and Efron's 68% and 95% confidence bands based on 1000 bootstrap replications.

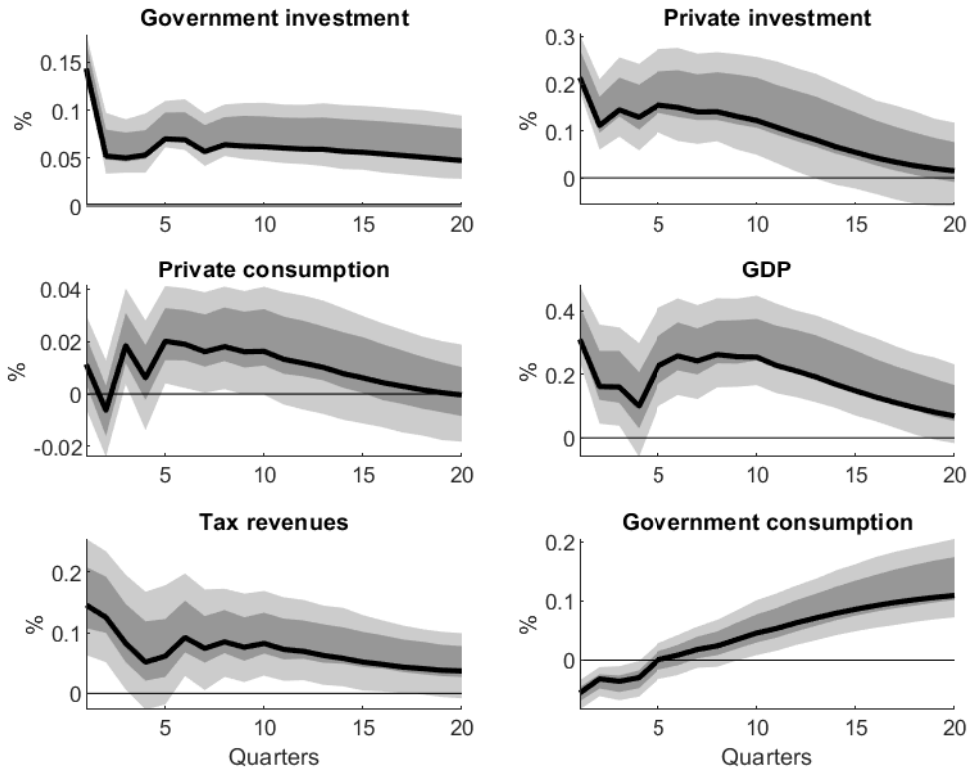


Figure B.15: Sensitivity of impulse responses to using Hall's confidence bands. *Notes:* The figure shows the responses of the baseline variables to a positive government investment shock of one standard deviation identified with an external instrument over 20 quarters. The shaded areas are Hall's 68% and 95% confidence bands based on 1000 bootstrap replications. All variables are expressed relative to trend GDP.

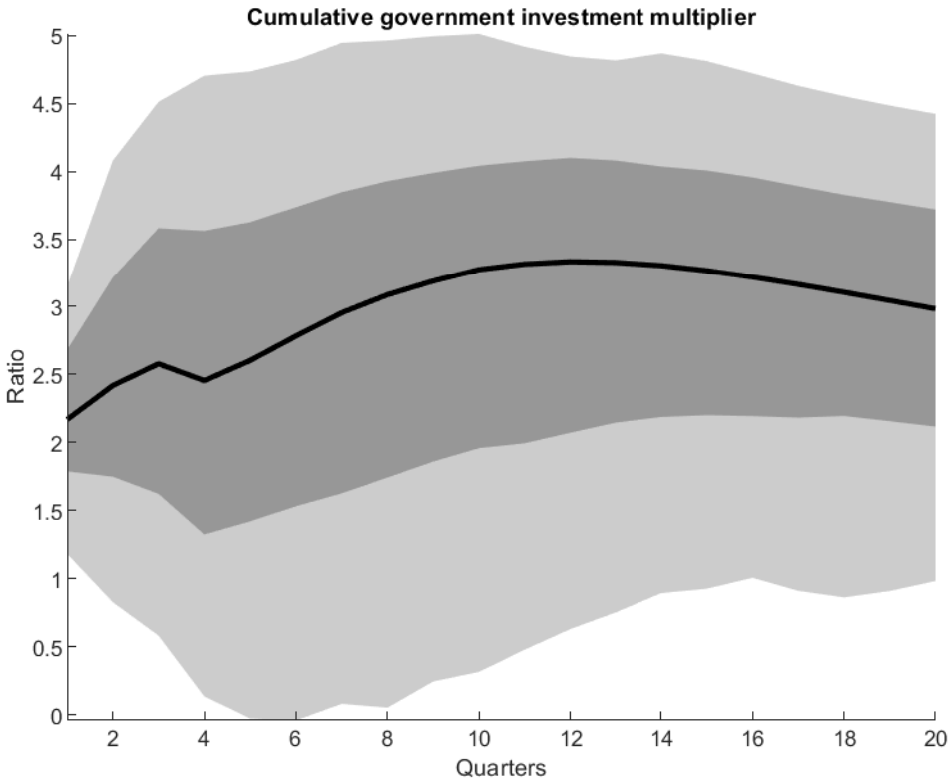


Figure B.16: Sensitivity of multiplier to using Hall's confidence bands. *Notes:* The figure shows the cumulative output multiplier of government investment shocks identified with an external instrument over 20 quarters and Hall's 68% and 95% confidence bands based on 1000 bootstrap replications.

C Supplement DSGE analysis

C.1 Model equations

Marginal utility of consumption

$$\lambda_t^S(1+\tau_t^C) = \frac{1}{C_t^S(j) - hC_{t-1}^S} \tag{18}$$

Intertemporal Euler equation bonds

$$\lambda_t^S = \beta R_t E_t \frac{\lambda_{t+1}^S}{\pi_{t+1}^C} \tag{19}$$

Intertemporal Euler equation capital

$$Q_t^K = \beta E_t \frac{\lambda_{t+1}^S}{\lambda_t^S}\left[(1-\tau_{t+1}^k) R_{t+1}^k \nu_{t+1} - \psi(\nu_{t+1}) + (1-\delta) Q_{t+1}^K\right] \tag{20}$$

Price relation between long-term and short-term bonds

$$P_t^B = \frac{1}{R_t}\left(1 + \rho E_t P_{t+1}^B\right) \tag{21}$$

Composite consumption

$$C_t^S(j) = C_t^{S,P}(j) + \alpha^g G_t \tag{22}$$

Private investment demand

$$Q_t^K = 1 + \kappa^k\left[(I_t - I_{t-1}) - \kappa^g(I_t^G - I_{t-1}^G)\right] - \kappa^k\beta\frac{\lambda_{t+1}^S}{\lambda_t^S} Q_{t+1}^K\left[(I_{t+1} - I_t) - \kappa^g(I_{t+1}^G - I_t^G)\right] \tag{23}$$

Effective private capital stock

$$K_t^S(j) = \nu_t(j)\tilde{K}_{t-1}(j) \tag{24}$$

Private capital stock

$$\tilde{K}_t(j) = (1-\delta)\tilde{K}_{t-1}(j) + I_t(j)\Phi_t(j) \tag{25}$$

Capacity utilization

$$(1-\tau_t^K)R_t^k = \psi'(\nu_t) \tag{26}$$

Non-saving households budget constraint

$$(1+\tau_t^C)P_tC_t^N(j) = \left(1-\tau_t^W\right)\int_0^1 W_t(l)L_t^N(j,l)dl + P_tZ_t^N \tag{27}$$

Wage Phillips curve

$$\left(\frac{K_{2,t}}{F_{2,t}}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\epsilon_w}} = \left(\frac{1-\delta\,\pi_t^{w\epsilon_w-1}}{1-\delta}\right)^{\frac{1}{1-\epsilon_w}} \tag{28}$$

where $K_{2,t} = MRS_tY_te_{w,t} + \frac{\lambda_{t+1}\delta\beta\,\pi_{t+1}^{w}{}^{\frac{\epsilon_w}{1-\alpha}}}{\lambda_t}K_{2,t+1}$ and $F_{2,t} = Y_t + \frac{\lambda_{t+1}\delta\beta\,\pi_{t+1}^{w}{}^{\epsilon_w-1}}{\lambda_t}F_{2,t+1}$ are auxiliary variables. Production function

$$Y_t(i) = K_t(i)^{\alpha}\,L_t(i)^{1-\alpha}(K_t^G)^{\alpha^{kg}} - \bar{O}, \tag{29}$$

Real marginal costs

$$MC_t = (1-\tilde{\alpha})^{\tilde{\alpha}-1}\,\tilde{\alpha}^{-\tilde{\alpha}}\,W_t{}^{1-\tilde{\alpha}}\,R_t^{k\tilde{\alpha}}(K_t^G)^{\frac{\alpha^{kg}}{\alpha^{kg}-1}} \tag{30}$$

Capital-labor ratio

$$\frac{K_t}{L_t} = \frac{\alpha}{1-\alpha}\frac{W_t}{R_t^k} \tag{31}$$

Price Phillips curve

$$\left(\frac{K_{1,t}}{F_{1,t}}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\epsilon_p}} = \left(\frac{1-\delta\,\pi_t{}^{\epsilon_p-1}}{1-\delta}\right)^{\frac{1}{1-\epsilon_p}} \tag{32}$$

where $K_{1,t} = \mu MC_tY_t + \frac{\delta\beta\,\pi_{t+1}{}^{\frac{\epsilon_p}{1-\alpha}}\lambda_{t+1}}{\lambda_t}K_{1,t+1}$ and $F_{1,t} = Y_t + \frac{\lambda_{t+1}\delta\beta\,\pi_{t+1}{}^{\epsilon_p-1}}{\lambda_t}F_{1,t+1}$ are auxiliary variables.

Monetary policy

$$R_t = R_{t-1}{}^{\phi^R}\left[\frac{1}{\beta}\left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi^{\pi}}\left(\frac{y_t}{\bar{y}}\right)^{\phi^y}\right]^{1-\phi^R} \tag{33}$$

Government budget

$$BD_t = P_t^BB_t = P_tZ_t + P_tG_t + P_tI_t^G + (1+P_t^B\rho)B_{t-1} - K_tR_t^k\tau_t^k - L_tW_t\tau_t^W - \tau_t^cP_tC_t \tag{34}$$

Debt rule

$$Z_t = (Z_{t-1})^{\phi_\tau}\left((S_{t-1}-\bar{S})^{\gamma_S}\right)^{1-\phi_\tau} \tag{35}$$

where $S_t = \frac{P_t^BB_t}{P_tY_t}$ is the debt-to-GDP ratio.

Aggregate resource constraint

$$Y_t = C_t + I_t + I_t^G + G_t \tag{36}$$

Aggregate consumption

$$C_t = (1-n)C_t^{S,P} + nC_t^N \tag{37}$$

Aggregate transfers

$$Z_t = (1-n)Z_t^S + nZ_t^N \tag{38}$$

Aggregate labor supply

$$L_t = (1-n)L_t^S + nL_t^N \tag{39}$$

C.2 Steady State

With $P^I = P^C = P = 1$ and $\pi = 1$

Marginal costs

$$MC = \frac{1}{\mu} \tag{40}$$

Government budget

$$BD = 0 \tag{41}$$

Real rate

$$R = \frac{1}{\beta} \tag{42}$$

Rental rate (capital)

$$R^k = \frac{1}{(1-\overline{\tau}^k)}\left(\frac{1}{\beta} - (1-\delta)\right) \tag{43}$$

Real marginal costs

$$W = \left(MC((1-\tilde{\alpha})^{1-\tilde{\alpha}}\,\tilde{\alpha}^{\tilde{\alpha}})R^{k^{-\tilde{\alpha}}}(K^G)^{\frac{\alpha^{kg}}{1-\alpha^{kg}}}\right)^{\frac{1}{1-\alpha}} \tag{44}$$

Capital-labor ratio

$$\frac{K}{L} = \frac{\alpha}{1-\alpha}\frac{W}{R^k} \tag{45}$$

Fixed costs

$$\frac{\bar{O}}{L} = \left(\frac{K}{L}\right)^{\alpha}(K^G)^{\alpha^{kg}} - R^K\left(\frac{K}{L}\right) - W \tag{46}$$

Production Function

$$\frac{Y}{L} = \left(\frac{K}{L}\right)^{\alpha}(K^G)^{\alpha^{kg}} - \frac{\bar{O}}{L}, \tag{47}$$

Private capital stock

$$\frac{I}{L} = \delta\frac{K}{L} \tag{48}$$

Aggregate resource constraint

$$\frac{C}{L} = \frac{Y}{L}\left(1 - \frac{G}{Y}\right) - \frac{I}{L} \tag{49}$$

Transfers

$$\frac{Z}{L} = \left((1-R)\frac{B}{Y} - \frac{G}{Y} - \frac{I^G}{Y}\right)\frac{Y}{L} + \tau^C\frac{C}{L} + \tau^W W + \tau^K R^K \frac{K}{L} \tag{50}$$

Non-saving households consumption

$$\frac{C^N}{L} = \frac{\left(1-\overline{\tau}^W\right)W + \frac{Z^N}{L}}{(1+\overline{\tau}^C)} \tag{51}$$

Saver households consumption

$$\frac{C^{S,P}}{L} = \frac{\frac{C}{L} - n\frac{C^N}{L}}{1-n} \tag{52}$$

Composite consumption

$$\frac{C^S}{L} = \frac{C^{S,P}}{L} + \alpha^g \frac{G}{Y}\frac{Y}{L} \tag{53}$$

Labor supply

$$L = \left(\frac{W(1-\tau^W)}{(1+\tau^C)(1+\epsilon_w)(1-h)\frac{C}{L}}\right)^{\frac{1}{1+\psi}} \tag{54}$$

Price relation between long- and short-term bonds

$$P^B = \frac{1}{(R-1)\rho} \tag{55}$$

Tobins Q

$$Q = 1 \tag{56}$$

Effective private capital stock

$$K^S = \tilde{K} \tag{57}$$

Marginal utility of consumption

$$\lambda = \frac{1}{(1-h)C^S(1+\overline{\tau}^C)} \tag{58}$$

Debt rule

$$S = \frac{P^B B}{PY} \tag{59}$$

C.3 Sensitivity analysis DSGE model

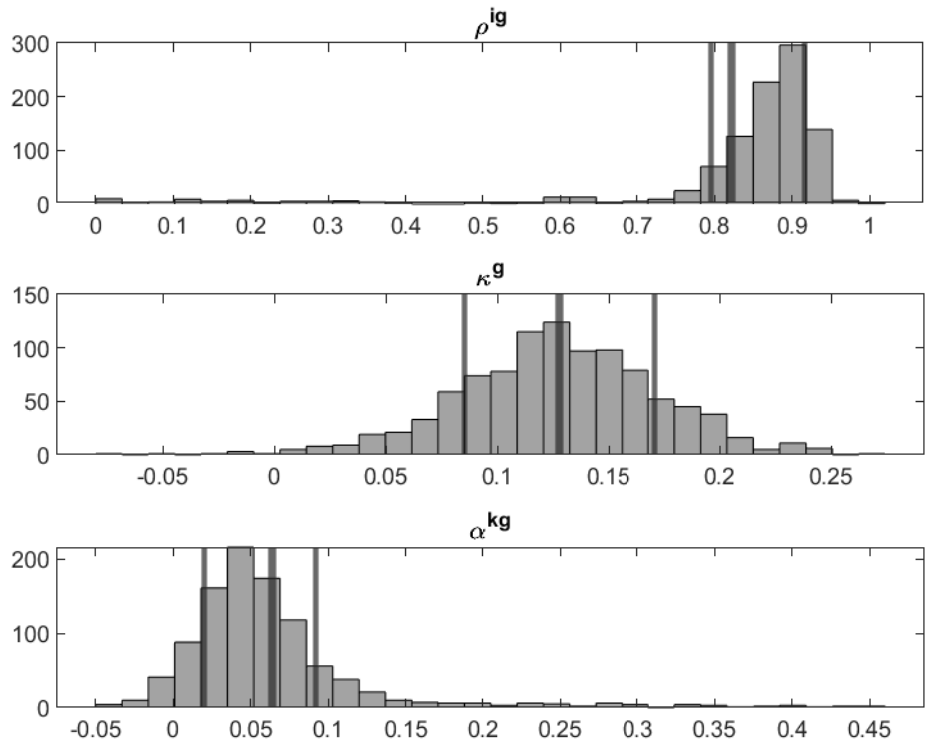


Figure C.17: Distribution parameter estimates. *Notes:* The figure shows the distribution of the estimates for the parameters in ζ for each of the 1000 bootstrap draws that are the basis for the confidence intervals of the empirical responses shown in Figure 2.

We perform a sensitivity analysis. We change the values of selected calibrated parameters and re-estimate ζ. Table C.3 summarizes the results. The first column lists the calibrated parameter. The next three columns contain the estimates for ρ^{ig},κ^{g},α^{kg}, conditional on the alternative calibration. The last two columns report the model-implied cumulative output multiplier. The first row of the results repeats the baseline estimates for comparison.

In the next four rows, we change one parameter related to the households at a time. We increase the share of non-saving households to $n = 0.5$. We assume weak substitutability of private and public government consumption in utility, $\alpha^{g} = 0.2$, instead of complementarity. We lower the labor supply elasticity by doubling ψ to 1. We eliminate habit formation to $h = 0$. All these alterations have limited effects on the parameter and multiplier estimates.

In the next three rows, we change the parameters related to production and pricing. We lower the production elasticity of private capital to $\alpha = 0.3$. We increase the depreciation rates to $\delta = \delta^{G} = 0.025$. We eliminate price and wage indexation by setting $\theta_p = \theta_w = 0$. Again, the implications for the estimates are moderate.

Calibrated	Estimated Parameters			Output multiplier	
	ρ^{ig}	κ^{g}	α^{kg}	1 year	5 years
Baseline	0.918	0.156	0.062	2.362	2.565
$n = 0.5$	0.891	0.086	0.066	2.437	2.767
$\alpha^{g} = 0.2$	0.903	0.130	0.061	2.363	2.566
$\psi = 1$	0.896	0.136	0.079	2.310	2.612
$h = 0$	0.904	0.136	0.058	2.342	2.542
$\alpha = 0.3$	0.905	0.146	0.062	2.338	2.498
$\delta = \delta^{G} = 0.025$	0.905	0.130	0.062	2.367	2.468
$\theta_p = \theta_w = 0$	0.904	0.130	0.059	2.362	2.565
$I^{G}/Y = 0.04$	0.850	0.108	0.086	2.006	2.613
$\phi_\tau = -1$	0.903	0.130	0.062	2.360	2.564
$\phi^{\pi} = 1.2$	0.906	0.125	0.055	2.397	2.554
$\phi^{y} = 0.1$	0.897	0.134	0.076	2.210	2.621

Table C.3: Sensitivity analysis. *Notes:* The table shows the estimates of ζ and the cumulative government investment to output multiplier at the one-year and five-year horizon for alternative calibrations of the non-estimated parameters.

In the final block, we change the policy ratio or parameters, one at a time. We increase the government investment/GDP ratio to $I^{G}/Y = 0.04$. We make fiscal policy more responsive by setting the elasticity of transfers to debt to $\phi_\tau = -1$, we reduce the reponse of monetary policy to inflation to $\phi^{\pi} = 1.2$, and we allow for a positive response of the central bank to output fluctuations through the choice of $\phi^{y} = 0.1$. The largest effect has the increase of the government investment ratio. A higher ratio is associated with lower multipliers (Ramey, 2021) such that the model requires a higher output elasticity to match a given multiplier.