Generic and public R&D fiscal policies: An empirical assessment for OECD Countries

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Abstract

The paper aims to detect the macroeconomic effect produced by generic fiscal policies and fiscal policies targeted on R&D spending. Specifically, we estimate fiscal multipliers associated with more generic fiscal policies and innovation-focused public investment. Furthermore, we evaluate whether the two considered fiscal policies are able to influence business investment in Research and Development. To do this, we combine Panel Structural Vector Autoregressive modelling (P-SVAR) with the Local Projection approach (LP) on a panel of 15 OECD countries for the 1981-2017 period. Our findings support the Keynesian perspective, by showing that demand management policies, both generic and R&D targeted, are able to generate persistent effects on both the GDP level and private R&D. However, the results show that public investment in R&D generates the largest effect on GDP and private R&D than the one produced by more generic public expenditures.

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1. Introduction

The 2008 financial crisis and the sovereign debt crisis of 2010, followed by subsequent attempts to fiscal consolidation, sparked wide interest in the economic effects of discretionary fiscal policy.

Fiscal consolidation – mainly based on a reduction in government spending – was supposed to foster economic growth by increasing private consumption and investment through a reduction in interest rates (Alesina et al., 2015). However, these policies have not been able to boost GDP growth, leading to an increase in the public debt-to-GDP ratio and high unemployment rates.

The ineffectiveness of these policies as well as a need to foster economic activity, have stimulated new debates about the relevance of aggregate demand and in particular government spending as possible engines of private economic activity. In particular, questions have arisen about whether government spending has significant effects on aggregate output and its components (Fatás and Summers, 2018). In parallel, the effects of the crisis have accelerated the debate on the need for a new industrial policy (see, among others, Pianta (2014)). Such policies are aimed at sustaining levels of economic activity by creating new markets and directing private investment towards them (Chang and Andreoni, 2016; Mazzucato, 2016).

The recent interest in how fiscal policy affects the economy is reflected in an ongoing debate, among international institutions and academic scholars, regarding the size of the fiscal multiplier, namely the response of GDP and its component to an exogenous fiscal policy shock. In recent year, a growing body of empirical literature estimate the magnitude of fiscal multipliers, applying different econometric techniques, identification strategies and model specifications. The magnitude assumed by fiscal multipliers varies among different studies and does not lead to a unanimous consensus (Gechert, 2015; Ramey, 2011; 2019). Furthermore, recently the literature has claimed that the composition of government spending is relevant in shaping the dynamics of economic activity, emphasizing the role of public investment[1].

In this line, the literature on Mission Oriented policies (MIOP) has attracted a lot of interest in recent years and in this context there have been calls for a return to such policies to address "grand contemporary societal challenges" (Mowery et al., 2010; Fisher et al., 2018; Mazzucato, 2018).

In particular, the aim of MIOP is to get many sectors and actors working together towards the development of specific technologies in line with missions defined at State level. MIOPs are often interdisciplinary in nature: they require the involvement of both different technologies and many actors. This is also because the missions require the integration of a range of technological and non-technological innovations, and the results derived from these policies should be applicable to a variety

[1]For example, the IMF(2014) have highlighted that public investment plays a key role in sustaining economic growth in both the short and long term, especially during periods of low interest rates, supporting "an infrastructure push".

of economic sectors (Cappellano et al., 2020). These policies focus on concrete problems that require system-wide transformation across different types of sectors and partnerships between public-private organizations as has been demonstrated for example both by the Apollo mission to the moon and the more recent German Energiewende policy to meet ambitious climate change targets (Mazzucato, 2017). This literature emphasizes direct government investment in R&D aimed at creating new markets and promoting structural change in the economic system. In this circumstance the State acts as an "investor of first resort" taking on risk and uncertainty during the early stages of innovation, generating additionality within the economic system and by increasing business expectations about where future growth opportunities might lie (Mazzucato and Penna, 2015; Mazzucato and Semieniuk, 2017). Given the cross-sectoral nature and the multiplicity of actors involved, these policies are able to generate spin-offs through which research and innovation are developed and diffused to other sectors and direct a structural change in the economy (Mazzucato 2013; 2016, Pivetti, 1992). The hypothesis is that such investments have a greater multiplier effect as they involve many different sectors of the economy, create a new landscape that did not exist before and "crowding-in" private investment.

In this regard, MIOP combined with expansionary fiscal policies, are seen as a useful tool for stimulating economic activity, addressing societal challenges, providing direction towards new techno-economic paradigms that do not emerge spontaneously from market forces and fostering the diffusion of innovations.

The existing literature on fiscal multiplier has mainly focused on the effects of total public expenditure on output and its component, without distinguishing between its components. Few contributions distinguish between public consumption and investment (see, among others, Perotti (2004), Pappa (2009), Auerbach and Gorodnichenko (2012), Boehm (2019)), and between defense and non-defense Auerbach and Gorodnichenko (2012). Limited evidence exists on the macroeconomic effects of mission-oriented innovation policies, i.e. classes of public expenditures oriented to promoting structural change and focused on the promotion of innovation. In this regard, Deleidi and Mazzucato (2021) distinguishing between defense R&D investment and generic public expenditure, find that the former generates the largest effect on the GDP and private R&D for US economy.

Building on these considerations the aim of the paper is to look at the macroeconomic effects produced by generic fiscal policies and fiscal policies targeted on R&D spending. To do this, we estimate the effect of public R&D innovation policies and generic government spending on GDP and on private R&D investment. We implement a recent empirical strategy which combines the advantages of the identification strategy of Structural Vector Autoregression (SVAR) modelling with the Local Projections (LP) approach (Auerbach and Gorodnichenko, 2017; Ramey and Zubairy, 2018) on a panel of 15 OECD countries for the 1981-2017 period. Our empirical findings show that expansionary fiscal policies generate Keynesian effects, namely positive and permanent effects on GDP and on investments, both in the short and the long run. However, the results show that public investment in R&D generates the largest effect on GDP and private R&D than the one produced by more generic public expenditures. These results are also confirmed when we consider fiscal foresight (Auerbach and Gorodnichenko, 2012).

2. Literature review

After the 2008 financial crisis the debate on the magnitude of fiscal multipliers became particularly relevant. This has led to a growing empirical literature on the macroeconomic effects of fiscal policy. The impact of fiscal policies on GDP and its components is usually measured through estimates of fiscal multipliers, measuring the response of GDP and its components to an exogenous fiscal policy shock. In recent years, several contributions have empirically estimated the magnitude of fiscal multipliers, applying different econometric techniques, identification strategies and specifications, which have produced mixed results. In the literature (Ramey, 2011; 2019; Gechert, 2015) it has been pointed out that differences in estimates can result from: a) the different models that are employed (DSGE model, VAR model, various single-equation estimation techniques and subnational geographic cross-section estimates); b) different identification strategies of the fiscal shocks (the recursive approach, the so-called Blanchard and Perotti approach; the sign restriction approach; the narrative approach and the natural experiment approach; c) the way in which the multiplier are computed (i.e cumulative multiplier or no-cumulative multiplier) and d) several countries' structural characteristics (i.e. the accumulated public debt, the exchange rate regime and the openness to trade) (Ilzetzki et al., 2013).

Regarding the effect of public expenditure on GDP few contributions distinguish between public consumption and investment, but the results are not unanimous. While Perotti (2004), Pappa (2009) and Boehm (2019) show that public investment is no more effective than government consumption in boosting GDP, Burriel et al. (2010), Auerbach and Gorodnichenko (2012) and Izquierdo et al. (2019) find opposite results. Specifically, Perotti (2004) applying a SVAR model using quarterly data for the 1960-2001 period finds a peak multiplier of 2.32 for public consumption and of 1.68 for public investment in the US economy. Pappa (2009) using the sign restriction identification to quarterly data for 1970-2007 period finds a peak multiplier of 2.52 for public consumption and a government investment peak multiplier of 0.23 for US economy. Boehm (2019) using the local projection method for a panel of OECD countries to quarterly data from 2003 to 2016, finds a cumulative multiplier of 0.76 for public consumption and a cumulative investment multiplier of -0.08 after four quarter. On the other hand, Auerbach and Gorodnichenko (2012) estimate a SVAR model for the 1947-2009 and find a cumulative fiscal multiplier of government investment equal to 2.39 and a government consumption fiscal multiplier of 1.20 after 20 quarterly for the US economy. Burriel et al. (2010) using a SVAR model to quarterly data for the 1981-2007 period, find an impact consumption multiplier of 0.49 and 0.86 respectively for US and EU economy, while the impact investment multiplier is equal to 2 and 1.56 respectively for US and EU economy. Izquierdo et al. (2019) applying a local projection model to quarterly data for the period 1987–2014 for 31 European countries, find a public consumption multiplier equal to 0.25 and a public investment multiplier equal to 0.80 after two year of the spending shock. They motivated their result suggesting that the public investment multiplier involves positive spillovers of productive public capital on private capital, i.e. a public investment shock generates a crowding-in effect of private investment. Additionally, distinguishing between US defense and non-defense spending, Auerbach and Gorodnichenko (2012) find no difference between the peak multipliers of the two expenditure components, while Ramey and Zubairy (2018) using the local projection method find that the former generates the largest effect on the GDP level. Ellahie and Ricco (2017) using a SVAR model for the 1959-2012 period find that non-defense investment provides strong economic stimulus compared to defense investment. They estimate an impact multiplier of 5.76 for non-defense investment, while the corresponding impact multiplier for defense investment is 0.68 for US economy. Finally, Deleidi and Mazzucato (2021) estimate a defense R&D investment multiplier of 5.764 and a generic expenditure multiplier of 0.63 after 32 quarters for the US economy.

Moreover, in recent years, the literature on multipliers has made increasing use of non-linear models aimed at testing whether the effects of fiscal policies are different in different states of the economy, i.e. state dependent multiplier. Auerbach and Gorodnichenko (2012) find that the government spending multipliers are higher in recession than in expansion periods for US economy. Several contributions find similar results using alternative empirical methods and variables describing the state of the business cycle (see, among others, Candelon and Lieb, 2013; Fazzari et al., 2015; Riera-Crichton et al., 2015; Auerbach and Gorodnichenko, 2017). While some contributions point out that state dependent multipliers emerge only when “deep recessions” and “strong expansion” are considered (Caggiano et.al., 2015 and Boitani et al., 2020), Ramey and Zubairy (2018) using a threshold local projections model for the US estimate acyclical spending multipliers, finding no statistically significant differences between government spending multipliers during periods of high and low unemployment rate. Recently, Berge et al., (2021) argue that the inconsistencies found in the literature may arise from the way the recessionary and expansionary states are defined. They show that the government spending multiplier is higher when unemployment is increasing than when it is decreasing, while the multiplier does not depend on whether the unemployment rate is below or above its trend.

In parallel to the fiscal multiplier literature, a broad empirical literature, using both micro and macro data, has estimated the effect of alternative types of fiscal policies on the level of private investment in R&D. These studies report mixed results regarding the "crowding in" and "crowding out" effects of public R&D on private R&D[2]. Diamond (1999) uses NSF aggregate data for the 1953–1995 period to examine the impact of federal spending on basic research on private research spending. He finds strong evidence of a crowd-in effect for the US economy. For French enterprises, Autant-Bernard (2001) finds that public research, producing positive externalities on innovation, favors private R&D expenditures, pointing out that these externalities are strongest within the same geographical area. For German enterprises, Aschhoff and Sofka (2009) show that both direct public R&D investment and public procurement generates a positive effect on private innovative activity. Draca (2013) using US firm-level dataset, shows that defense procurement has a positive impact on private R&D investment, with an elasticity of approximately 0.07. Recently, Rehman et al., (2020) investigate the relationship between public and private R&D by taking into the account economic crisis of 2008 for a panel of 10 OECD countries in the 2000-2014 period. Their results show that public R&D has a positive impact on private R&D both in pre and post 2008 crisis, with a stronger effect in the pre-crisis period. In contrast, other studies have supported the idea that government R&D expenditures crowd out private R&D investment. Lichtenberg (1984) using US Industry-level data for the 1963-1979 period, finds that public R&D reduces private R&D investment. He concludes that when adding industries and time dummy, an additional dollar of federal R&D crowds out eight cents of private R&D investment. Wallsten (2000) using a dataset of 369 firms involved in the Small Business Innovation Research (SBIR) program between 1990 and 1992, estimates a multi equation model where he finds evidence that the grants crowd out firm-financed R&D spending. Guellec and van Pottelsberghe de la Potterie (2003) claim that defense-related R&D funding has a crowding out effect on civilian business R&D, while Civilian public research is neutral for business R&D, for 17 OECD countries in the 1983-1996 period.

3. Data and methodology

3.1 Data

In order to detect the effect on GDP and private Research and Development produced by generic fiscal policies and fiscal policies targeted on R&D spending we make use of yearly data provided by OECD, using the MSTI, Economic Outlook, and National Accounts databases. Our analysis is based

[2] For an in-depth review of the effect of alternative types of fiscal policies on R&D private expenditures, see, among others, David et al. (2000) and Becker (2015).

on a sample of fifteen countries: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, Portugal, Spain, UK and USA. The analysis is conducted by using yearly macroeconomic data for the period 1981-2017[3]. We consider the following variables: GDP (Y), government consumption and investment expenditures (G), private R&D expenditures performed and financed by the private sector (BERD), public R&D expenditures (GBARD), and the real long-term interest rate (i). Specifically, to analyze the effects that different classes of public spending exert on the variables of interest we break down government spending G as: public spending on research and development (GBARD) and the sum of consumption and investment net of public spending on research and development (G_CI). The variables are expressed in real terms using the GDP deflator and are converted to USD dollars using the PPP index. All variables are expressed at logarithmic levels. Details on the construction of the variables and data sources are provided in Appendix 1.

3.2 Methodology

The Local Projections (LP) method (Jordà, 2005) is used to detect the effect of public R&D and generic fiscal expenditures on private R&D and Y. As advocated by Jordà (2005), there are multiple advantages to using the LP method to estimate impulse response functions (IRFs): it can be estimated by simple regression techniques; it is more robust to misspecification and it easily accommodate experimentation with highly nonlinear and flexible specifications.

The LP approach (Jordà, 2005) entails the estimation of individual single regressions in which the variable of interest is considered in each horizon following the realization of the shock. This method can be formalized as follows:

$$y_{t+h} = \alpha_h + \beta^h x_t + \psi^h(L)\, z_{t-1} + \varepsilon_{i,t+h};\ \ for\ h = 0,1,2 \dots, H. \qquad (1)$$

where y is the variable of interest considered at each horizon h = 0, … H; z_{t-1} is a vector of control variables; $\psi^h(L)$ is a polynomial in the lag operator, and x_t is the selected fiscal variable. β^h is the response of y at horizon $t+h$ to the shock at time t. Thus, one constructs the impulse responses as a sequence of the β^h's estimated in a series of single regressions for each horizon h=0,1,…,H.

In addition, following the works by Ramey (2016), Auerbach and Gorodnichenko (2017) and Ramey and Zubairy (2018) we apply an innovative econometric technique aimed at combining standard SVAR modelling with the Local Projections approach. We first identify government spending shocks through a Panel SVAR model (Pedroni, 2013), applying a recursive approach based on a Cholesky factorization where public R&D spending is ordered first and generic fiscal

[3] We use annual data since R&D spending variables, both public and private, are available at this frequency.

expenditures is ordered second. Once government spending shocks are identified, they are substituted in the LP equations to estimate the IRFs.

Our fiscal policy shocks are given by the residual of the first and second equation of a structural VAR with the public R&D (GBARD), generic expenditures (G_CI), private R&D (BERD) and GDP (Y), namely the residuals $\varepsilon_{i,t}$ of the following regressions:

$$gbard_{i,t} = \alpha_i + \tau_t + \gamma_1 GBARD_{i,t-1} + \gamma_2 GDP_{i,t-1} + \gamma_3 G\_CI_{i,t-1} + \gamma_4 int\_rate_{i,t-1} + w_{GBARD\,i,t} \quad 2.a$$

$$G\_CI_{i,t} = \alpha_i + \tau_t + \gamma_4 GBARD_{i,t} + \gamma_1 GBARD_{i,t-1} + \gamma_2 GDP_{i,t-1} + \gamma_3 G\_CI_{i,t-1} + \gamma_4 int\_rate_{i,t-1} + w_{G\_CI\;i,t} \quad 2.b$$

This particular identification strategy has the following implications: (a) public R&D government investment (GBARD) does not respond to other variables included in the model within the year, namely it is the most exogenous variable; (b) generic government spending (G_CI) reacts contemporaneously only to public R&D government investment.

The first implication can be justified by the fact that public R&D investment, are strategic investments that reflect political and industrial priorities and are not influenced by the current economic activity, as suggested by Moretti et al. (2019), Deleidi and Mazzucato (2021); whereas the second can be reasonable by considering that government spending – defined as the sum of consumption and investment – take more than one period to respond to macroeconomic conditions (Blanchard and Perotti, 2002; Beetsma et al., 2009; Born and Muller (2012)).

Once government spending shocks are identified, they are substituted in the LP equations, where $w_{i,t} = x_{i,t}$ and we can estimate the IRFs, to detect the dynamic effect that different components of government spending have on GDP and private R&D.

The estimated model is formalized as in Equation 3:

$$y_{i,t+h} = \alpha_i + \delta_\tau + \beta^h w_{i,t} + \sum_{j=1}^{p} \vartheta_j^h \, z_{i,t-j} + \varepsilon_{i,t+h} \quad (3)$$

where i and t index countries and time; α_i and δ_τ are country and time fixed effects; $w_{i,t}$ is the structural shocks obtained through the recursive identification; $z_{i,t-j}$ contains the control variables: private R&D (BERD), GDP, total government spending (G) and real long-term interest rate (i)[4]. y is the variable of interest considered at each horizon $h = 0, \ldots H$. Specifically, we estimate equation (3) by considering the effects of the fiscal expenditure variables (GBARD and G_CI) on GDP (Model 1) and on private R&D (BERD) (Model 2). In all our regression, we apply Driscoll and Kraay (1998) standard errors to correct for heteroscedasticity, autocorrelation and cross-sectional correlation.

[4] In all specifications, we consider lag equal to one, i.e. j=1.

For each model, variables are expressed in growth rates (Model 1.a, Model 2.a and Model 1.c, Model 2.c) and at logarithmic levels (Model 1.b, Model 2.b and Model 1.d, Model 2.d).

The β^h coefficient in equation (3) represents the elasticity of the variables of interest y to the selected fiscal variables. To estimate fiscal multipliers, it is therefore necessary to multiply β^h coefficient by an ex-post conversion factor equal to the average value of the variable of interest Y in equation 3 divided by the selected fiscal variable[5].In addition, following Ramey and Zubairy (2018), we rescale the fiscal variable shock so that changes in these variables are measured as a percentage of the dependent variable (GDP or private R&D spending). In this way, the coefficients β^h in equation 3 directly represents the fiscal multiplier. (Model 1.c and Model 2.c). Therefore, we do not need any ex-post conversion factor.

Additionally, following Spilimbergo et al., (2009) and Ramey (2016), we estimate the cumulative multipliers of the fiscal variables rather than simply converting elasticities from IRFs. Specifically, the cumulative coefficients are obtained by dividing the cumulative response of the variable of interest y (GDP and private R&D) with the cumulative government expenditure change occurred during the observed period (Spilimbergo et al., 2009). In this way, the cumulative effects allow us to study the response of GDP and private R&D following a unit increase in government spending.

The IRFs represent the response of the variable of interest ($y_{i,t+h}$) to a shock of the fiscal variables realized at period t ($x_{i,t}$). Formally and with reference to equation (1), the IRFs are represented in equation 4:

$$\beta^h = \frac{\Delta y_{+h}}{\Delta x_t} \quad (4)$$

On the other hand, as equation (5) shows, the cumulative effect, is estimated dividing the cumulative change in the variable of interest $y_{i,t+h}$ by the cumulative change in the in fiscal expenditure Δx_t. Specifically, we have:

$$\beta^h_{cum} = \frac{\sum_{h=0}^{n} \Delta y_{+h}}{\sum_{h=0}^{n} \Delta x_t} \quad (5)$$

Thus, cumulative coefficients can be used to assess whether a permanent increase in the fiscal variables produces permanent and long-lasting effects on the variables of interest.

The cumulative fiscal multiplier is estimated in three steps (Ramey and Zubairy, 2018). First, the cumulative change of the dependent variable (GDP and BERD) is estimated between t and $t+h$ in Equation 3. Similarly, as a second step, the cumulative change of government expenditure between t and $t+h$ is calculated by regressing the same equations (Equation 3) with the government

[5]The ratios used in the ex-post transformation from elasticities to partial derivatives are calculated as follows: BERD/GBARD; BERD/G_CI; Y/GBARD; and Y/G_CI. They assume the following values respectively: 1,475341; 0,0423523; 4,297718; and 167,6637.

expenditure (GBARD and G_CI) as the dependent variable, instead of $y_{i,t+h}$. Finally, the cumulative investment multiplier is computed as the ratio between the coefficients β^h estimated in steps one and two multiplied by the ex post conversion factor.

In order to analyze the effect that more generic fiscal policies and innovation-focused public investment have on our variables of interest we estimate the following system of equations:

$$Y_{t+h} = \alpha_i + \tau_t + \beta_1^h \, w_{GBARD_t} + \beta_2^h \, w_{G_{CI_t}} + control_{t-1} + \varepsilon_{1i,t+h} \; (6.a)$$
$$G_{CI_{t+h}} = \alpha_i + \tau_t + \gamma_1^h \, w_{GBARD_t} + \gamma_2^h \, w_{G_{CI_t}} + control_{t-1} + \varepsilon_{2i,t+h} (6.b)$$
$$GBARD_{t+h} = \alpha_i + \tau_t + \delta_1^h w_{GBARD_t} + control_{t-1} + \varepsilon_{3i,t+h} (6.c)$$

where i and t index countries and time; α_i and δ_τ are country and time fixed effects; $w_{i,t}$ are the structural shocks for the fiscal variables - public R&D (GBARD) and generic expenditures (G_CI) - obtained through the recursive identification as shown in equation 2.a and 2.b;$control$ contains the control variables: private R&D (BERD), GDP, total government spending (G) and real long-term interest rate (i). y is the variable of interest considered at each horizon h = 0, … H.

We estimate four model specifications, considering as dependent variable the GDP (Model 1) and the private R&S (Model 2), considering fiscal policy shock of public R&D (GBARD) and fiscal policy shock of generic public expenditure (G_CI). In the first specification (Model 1.a, Model 2.a) the variables are expressed in growth rates. In the second specification (Model 1.b, Model 2.b) the variables are expressed in log level. In the third specification (Model 1.d, Model 2.d) the variables are expressed in log level and we add as a control variable a country specific time trend. Finally, in the last specification (Model 1.c, Model 2.c) the variables are expressed in growth rates and we performe the ex-ante conversion, taking into account the method of conversion of elasticities in multipliers proposed by Ramey and Zubairy (2018). All findings will be provided in the next Section.

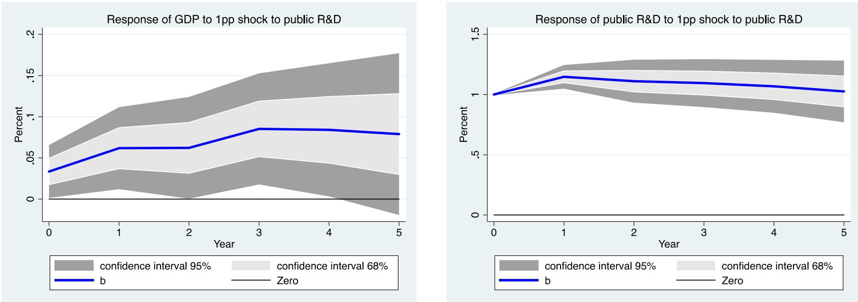
4. Findings

We estimate local projections for six years ahead (h = 5) for four different model specifications, defined in Section 3.2, considering as dependent variable the GDP (Model 1) and the private R&S (Model 2). In all figures reported below, we have displayed both the dynamics of government spending (GBARD and G_CI) as well as the corresponding responses of the GDP (y) and private R&D (BERD).

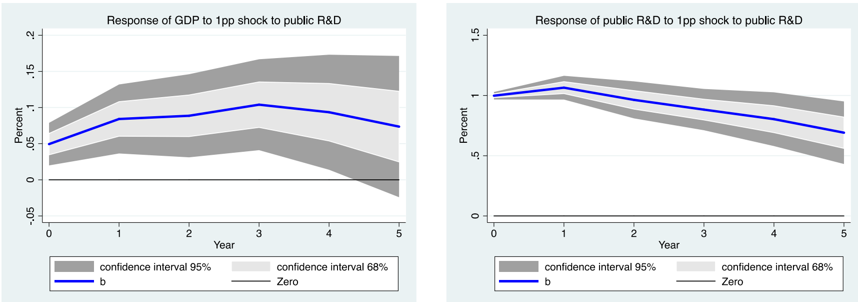
Figure 1 and 2 plots the IRFs of Model 1.a, 1.b, 1.c and 1.d, whereas the results of cumulative fiscal multipliers are reported in Table 1 and 2. IRFs show that the government investment shocks are equal to 1% on impact whereas its dynamic changes throughout the selected period by assuming values other than 1%. For all considered model specifications, the estimated IRFs are all positive reflecting a high persistence both in the shocks and the GDP responses. The results suggest that the components of public spending (both public R&D and non-innovation expenditure) produce persistent effects on the level of economic activity and the effect on GDP is statistically significant even five years after the initial shock. The results show that public investment in R&D generates the largest effect on GDP than the one produced by more generic public expenditures.

Figure 1 IRF of GDP to GBARD shock

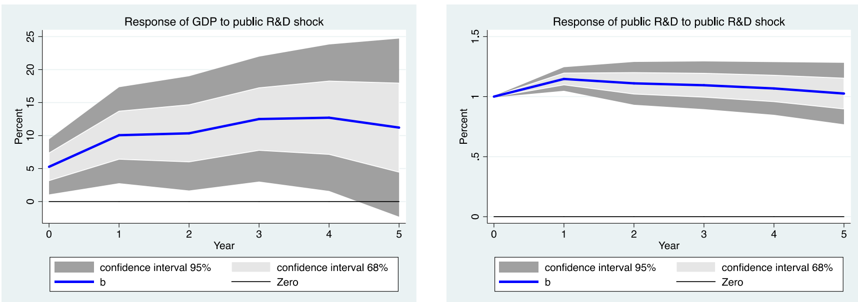
Model 1.a GBARD



Model 1.b GBARD



Model 1.c GBARD



Model 1.d GBARD

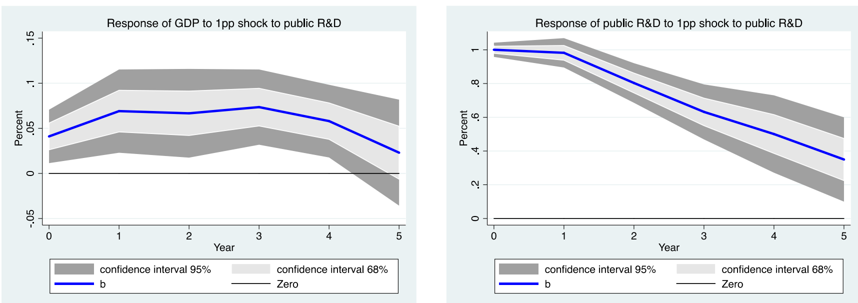


Table 1. Cumulative public R&D fiscal multiplier (GDP)

year	0	1	2	3	4	5
Model 1.a (GBARD)	**5.60**	**7.43**	**8.10**	**9.34**	**10.10**	**10.55**
Model 1.b (GBARD)	**8.30**	**10.86**	**12.31**	**13.99**	**14.93**	**15.31**
Model 1.c (GBARD)	**5.26**	**7.14**	**7.88**	**8.77**	**9.38**	**9.63**
Model 1.d (GBARD)	**6.87**	**9.31**	**10.64**	**12.28**	**13.19**	13.01

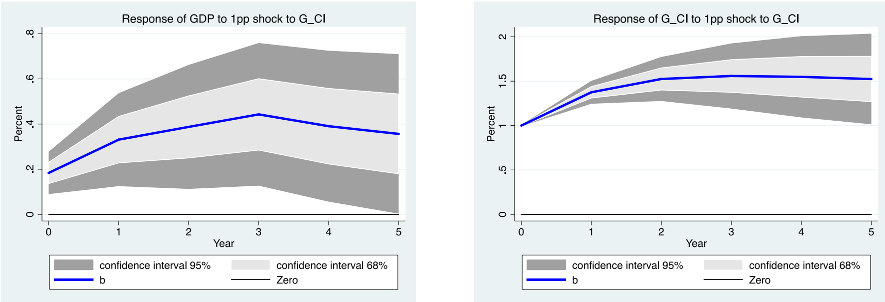
Looking at Table 1, in Model 1.a the impact multiplier is equal to 5.6 and reaches a peak of 10 after five years. Model 1.b, in which the variables are expressed in log level, provides multipliers which are higher than those obtained in Model 1.a. In this case, we estimate an impact multiplier of 8.2 that reaches a peak of 15 five years after the shock. Model 1.c, where the variables are expressed in growth rates and we performed the ex-ante conversion, provides an impact government R&D multiplier that is lower than those obtained in Model 1.a and 2 and equal to 5.2 (Table 1, Model 1.c). In this model the peak multiplier reaches the value of 9.60 after five years. Finally, in Model 1.d in which the variables are expressed in log level and we add as a control variable a country specific time trend, the impact multiplier is equal to 6.8 and the peak multiplier is equal to 13,2 four year after the shock.

Looking at the effects of general public spending (G_CI) (Table 2), the effects on GDP are lower than those generated by public R&D investment, but they are positive and significant. The impact multipliers range from 0.8 (Model 1.c and 1.c) to 1.1 (Model 1.d). Five years after the initial shock the multiplier are still positive and statistically significant ranging from 1 (Model 1.c) to 1,4 (Model 1.d).

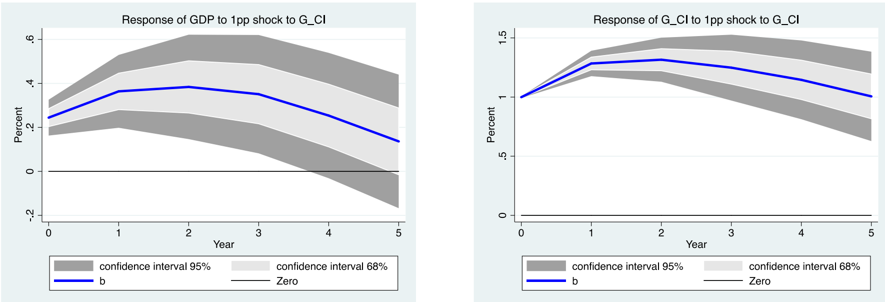
The estimated models clearly show that public expenditure - government R&D and generic public expenditure - produce positive and permanent effects on the GDP level, in line with the Keynesian tradition.

Figure 2 IRF of GDP to G_CI shock

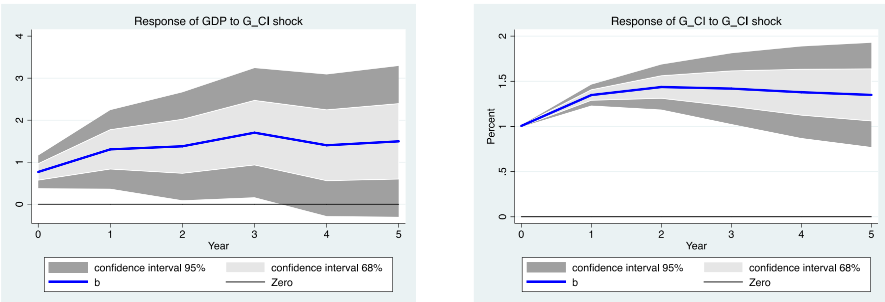
Model 1.a G_CI



Model 1.b G_CI



Model 1.c G_CI



Model 1.d G_CI

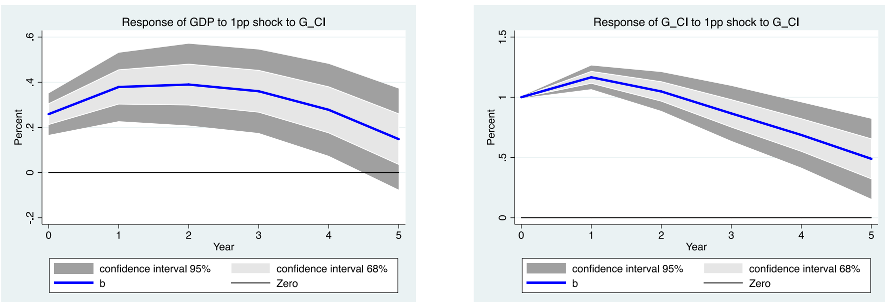


Table 2. Cumulative generic public expenditure (G_CI) fiscal multiplier (GDP)

year	0	1	2	3	4	5
Model 1.a (G_CI)	**0.79**	**0.93**	**0.99**	**1.06**	**1.06**	**1.05**
Model 1.b (G_CI)	**1.05**	**1.13**	**1.16**	**1.17**	**1.12**	1.04
Model 1.c (G_CI)	**0.76**	**0.89**	**0.95**	**1.02**	**1.03**	**1.03**
Model 1.d (G_CI)	**1.11**	**1.27**	**1.37**	**1.46**	**1.50**	**1.48**

Figure 3 and 4 plots the IRFs of Model 2.a, 2.b, 2.c and 2.d, whereas the results of cumulative fiscal multipliers are reported in Table 3 and 4. When we analyze the effects that public expenditure - GBARD and G_CI - have on private R&D, also in this case, public R&D produces the greatest effects (Table 3 and 4).

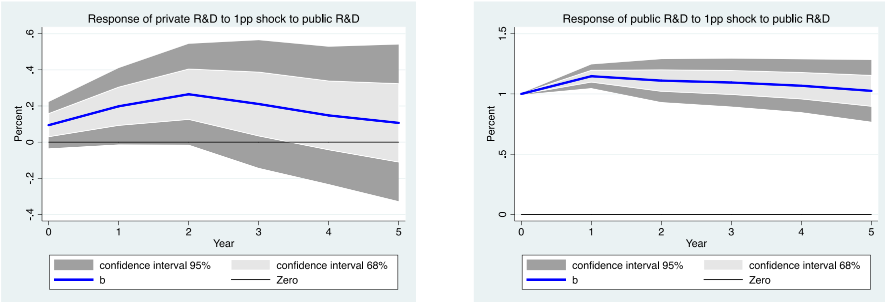
Looking at the public R&D effect in Table 3 the impact multipliers assume values between 0.2 (Model 2.d) and 0.1 (Model 2.c). Three years after the initial shock the multiplier are still positive and statistically significant assuming value ranging from 0.2 (Model 2.a and 2.b) to 0.5 (Model 2.d). Four year after the initial shock the multiplier is statistically significant in Model 2.d assuming the value of 0,5.

Looking at the effect of generic public expenditure (G_CI) in Table 4 it can be seen that the effect per one-unit of spending generated by G_CI is lower than the effect generated by GBARD but they are still positive, even if not always statistically significant. In Model 2.a and Model 2.b the impact multipliers are negative but not statistically significant. From year two the cumulative multiplier become positive and are statistically significant assuming a peak of 0.08 after 3 years in Model 2.c and of 0.027 after 5 years in Model 2.d.

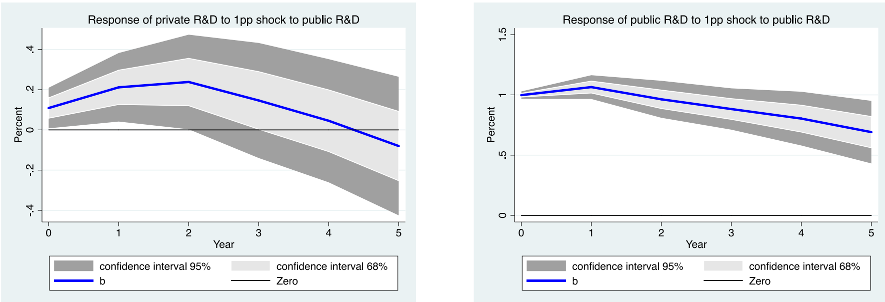
Our result show that public R&D policies produce a positive effect both on the level of output and on the private investment in R&D, which is much greater than the effect produced by generic government expenditures. Specifically, mission-oriented innovation policies (proxied by public R&D) are able to produce a larger fiscal multiplier and to determine a stronger direct crowd-in effect than generic public expenditures. As previously emphasized the high value assumed by the cumulative multiplier might be motivated by the fact that MIOP relate to direct government investment in R&D aimed at creating new markets, promoting structural change in the economic system, involving different sector and encouraging cooperative agreements between public-private organizations (Mazzucato 2013, Mowery, 2012).

Figure 3 IRF of BERD to GBARD shock

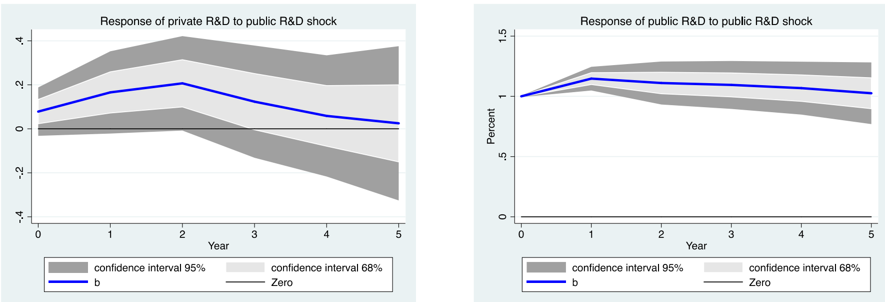
Model 2.a GBARD



Model 2.b GBARD



Model 2.c GBARD



Model 2.d GBARD

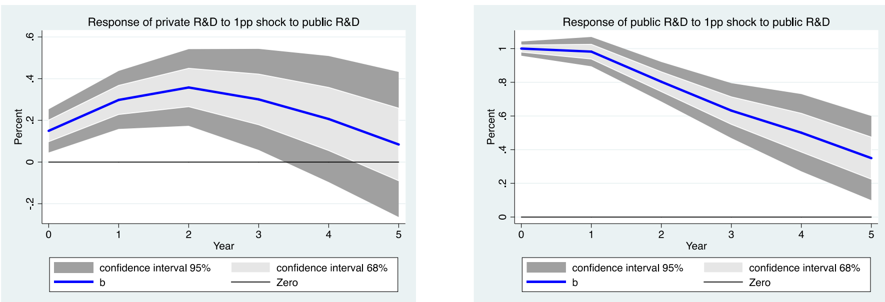
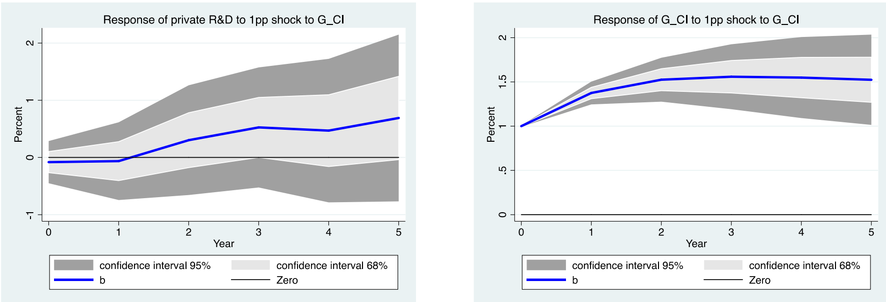


Table 3. Cumulative public R&D fiscal multiplier (BERD)

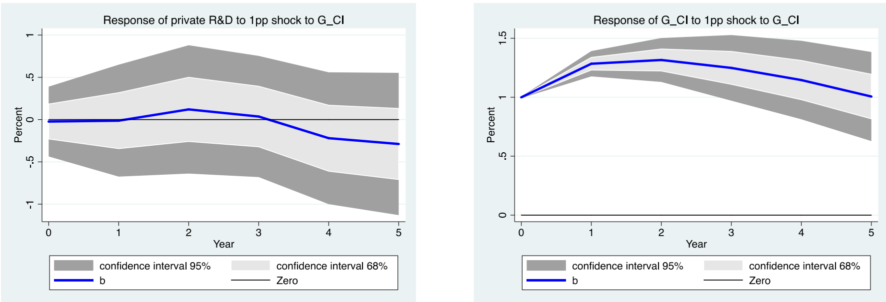
year	0	1	2	3	4	5
Model 2.a (GBARD)	**0.139**	**0.201**	**0.253**	**0.261**	0.250	0.234
Model 2.b (GBARD)	**0.161**	**0.230**	**0.272**	**0.266**	0.235	0.183
Model 2.c (GBARD)	**0.078**	**0.113**	**0.138**	0.132	0.117	0.102
Model 2.d (GBARD)	**0.221**	**0.333**	**0.427**	**0.477**	**0.494**	0.483

Figure 4 IRF of BERD to G_CI shock

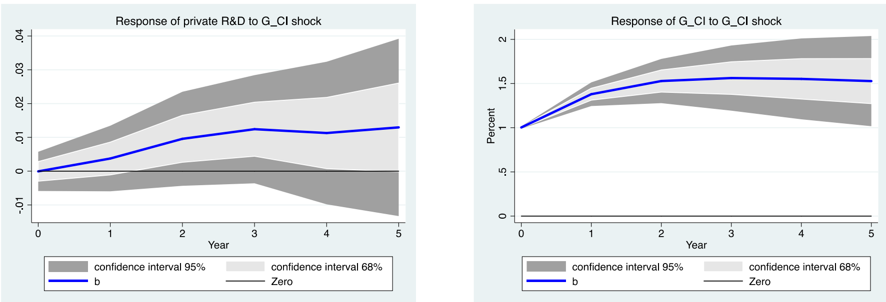
Model 2.a G_CI



Model 2.b G_CI



Model 2.c G_CI



Model 2.d G_CI

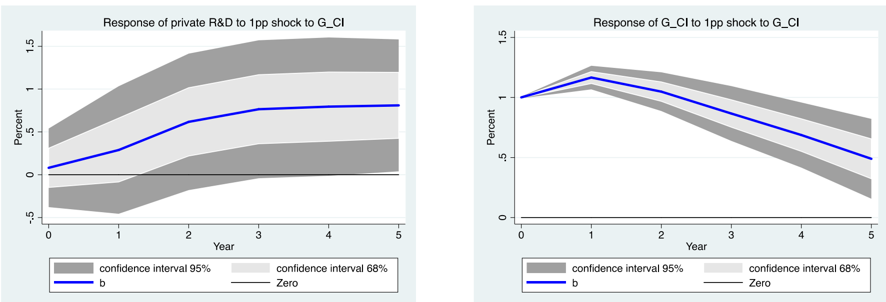


Table 4. Cumulative generic public expenditure(G_CI) fiscal multiplier (BERD)

year	0	1	2	3	4	5
Model 2.a (G_CI)	-0.003	-0.003	0.002	**0.005**	0.007	0.009
Model 2.b (G_CI)	-0.001	-0.001	0.001	0.001	-0.001	-0.002
Model 2.c (G_CI)	0.000	0.002	**0.005**	**0.007**	**0.008**	0.009
Model 2.d (G_CI)	0.003	0.007	**0.013**	**0.018**	**0.023**	**0.027**

5. Fiscal foresight

It is widely recognized by the recent literature on fiscal multipliers that fiscal foresight plays a fundamental role in estimating fiscal multipliers (see among others, Blanchard and Perotti, 2002; Ramey, 2011; Auerbach and Gorodnichenko, 2012). In order to consider this issue, in this section we provide estimations of fiscal multipliers by introducing fiscal expenditure expectations in Models 1 and 2 (Equation 6.a, 6.b and 6.c). Due to decision and implementation lags of fiscal policy, a certain amount of time usually elapses between the moment in which fiscal policy is announced and the moment it is implemented. This implies that, when receiving information on future changes in fiscal expenditures, private agents may modify their consumption and investment expenditures (Blanchard and Perotti, 2002). Econometrically, when only government expenditure is included in the model, errors can arise because relevant variables - variables capturing fiscal foresight - are omitted and the identified fiscal policy shocks may not be truly unexpected. The inclusion of variables capturing fiscal foresight isolates what the literature has defined as an unanticipated or unexpected fiscal policy shock and therefore allows to assess the effect of the unexpected fiscal policy shock (Auerbach and Gorodnichenko, 2012).

To identify pure unanticipated government spending shocks, we follow Auerbach and Gorodnichenko (2012, pp 16) by augmenting our SVAR model with the government spending forecasts ($\Delta G^F_{t|t-1}$). We use the forecasts provided by the OECD in the Economic Outlook, and specifically we use the forecasts made at t-1 for the growth rate of real government purchases for time t [6]. Technically, we apply a recursive identification strategy to a VAR model where government spending forecasts ($\Delta G^F_{t|t-1}$) are ordered first. In particular, Equation 2.a and 2.b are augmented with variables capturing fiscal foresight ($\Delta G^F_{t|t-1}$):

$$gbard_{i,t} = \alpha_i + \tau_t + \beta\Delta G^F_{t|t-1} + \gamma_1 GBARD_{i,t-1} + \gamma_2 GDP_{i,t-1} + \gamma_3 G\_CI_{i,t-1} + \gamma_4 int\_rate_{i,t-1} + w_{gbard^{unexp}}{}_{i,t} \quad 7.a$$

$$G\_CI_{i,t} = \alpha_i + \tau_t + \beta\Delta G^F_{t|t-1} + \gamma_4 GBARD_{i,t} + \gamma_1 GBARD_{i,t-1} + \gamma_2 GDP_{i,t-1} + \gamma_3 G\_CI_{i,t-1} + \gamma_4 int\_rate_{i,t-1} + w_{g_{ci}^{unexp}}{}_{i,t} \quad 7.b$$

The unanticipated fiscal shocks are the residuals $w^{unexp}_{i,t}$ derived from the Equation 7.a and 7.b, while the effect of predictable components is captured by the coefficients β. This helps in purifying public expenditure shocks from their potentially predictable component and, therefore, in constructing impulse responses based only on unanticipated public shocks. Following the procedure carried out for the baseline model, the unexpected fiscal shocks $w^{unexp}_{i,t}$ estimated in Equation 7.a and 7.b are

[6] These forecasts are available since 1987, so this part of the empirical analysis is carried out for the period 1987-2017. Given the availability of data we consider aggregate public expenditure forecasts, i.e.the sum of public consumption and investment.

included in the Local Projections equation as our measure of discretionary fiscal policy ($x_{i,t}$). Additionally, in this case, the anticipated shocks ($\Delta G^F_{t|t-1}$) are also incorporated in the LPs equation in order to control for their effect on the level of economic activity (Boehm, 2019). Therefore, we estimate the following system of equations:

$$Y_{t+h} = \alpha_i + \tau_t + \beta_1^h \, w_{GBARD_t} + \beta_2^h \, w_{G_{CI_t}} + control_{t-1} + \gamma_2^h \Delta G^F_{t|t-1} + \varepsilon_{1i,t+h} (8.a)$$

$$G_{CI_{t+h}} = \alpha_i + \tau_t + \gamma_1^h \, w_{GBARD_t} + \gamma_2^h \, w_{G_{CI_t}} + control_{t-1} + \gamma_2^h \Delta G^F_{t|t-1} + \varepsilon_{2i,t+h} (8.b)$$

$$GBARD_{t+h} = \alpha_i + \tau_t + \delta_1^h w_{GBARD_t} + control_{t-1} + \gamma_2^h \Delta G^F_{t|t-1} + \varepsilon_{3i,t+h} (8.c)$$

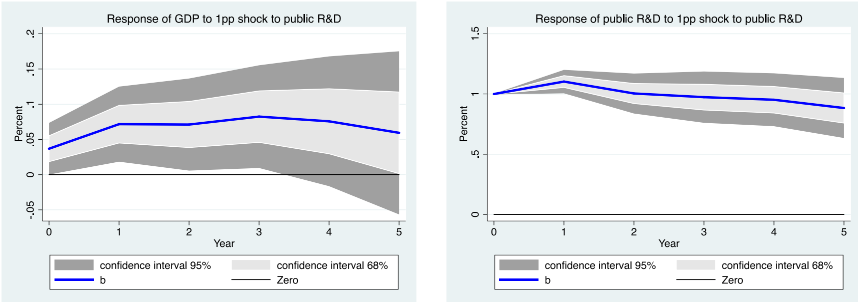
Figure 5 and 6 plots the IRFs of Model 1.a, 1.b, 1.c and 1.d augmented by expectations, whereas the results of cumulative fiscal multipliers are reported in Table 5 and 6. IRFs in Figure 5 and 6 show that the government investment shocks are equal to 1% on impact whereas its dynamic changes throughout the selected period by assuming values other than 1%. For the considered model specifications, the estimated IRFs are all positive reflecting a high persistence both in the shocks and the GDP responses. Even with the introduction of expectations the components of public spending (both public R&D and non-innovation expenditure) produce persistent effects on the level of economic activity and the effect on GDP is statistically significant even five years after the initial shock. The results show that public investment in R&D generates the largest effect on GDP than the one produced by more generic public expenditures.

Looking at the estimates of the models augmented by $\Delta G^F_{t|t-1}$ in Table 1, in Model 1.a the impact multiplier is equal to 6.1 and reaches a peak of 11 after five years. In Model 1.b we estimate an impact multiplier of 7.62 that reaches a peak of 15 five years after the shock. Model 1.c provides an impact government R&D multiplier that is equal to 6.3 (Table 1, Model 1.c). In this model the peak multiplier reaches the value of 10.8 after five years. Finally, in Model 1.d in which the variables are expressed in log level and we add as a control variable a country specific time trend, the impact multiplier is equal to 6.1 and the peak multiplier is equal to 10.9 four year after the shock. The multipliers reported in this section for Model 1.a and Model 1.c are generally larger compared with those obtained in models that do not include expectations.

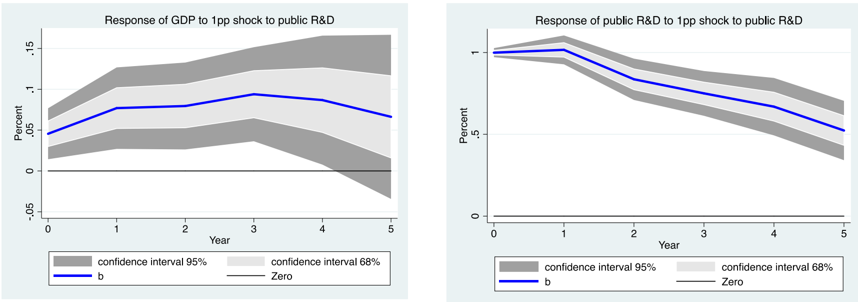
Looking at the effects of general public spending (G_CI) (Table 2), the effects on GDP are lower than those generated by public R&D investment, but they are positive and significant. The impact multipliers range from 0.7 (Model 1.a and 1.c) to 1 (Model 1.b). Five years after the initial shock the multiplier are still positive and statistically significant and equal to 1 in all models.

Figure 5 IRF of GDP to GBARD shock

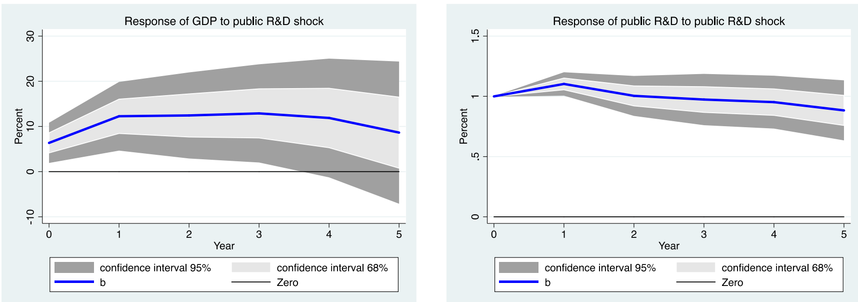
Model 1.a $\Delta G^F_{t|t-1}$ - GBARD



Model 1.b $\Delta G^F_{t|t-1}$ - GBARD



Model 1.c $\Delta G^F_{t|t-1}$ - GBARD



Model 1.d $\Delta G^F_{t|t-1}$ -GBARD

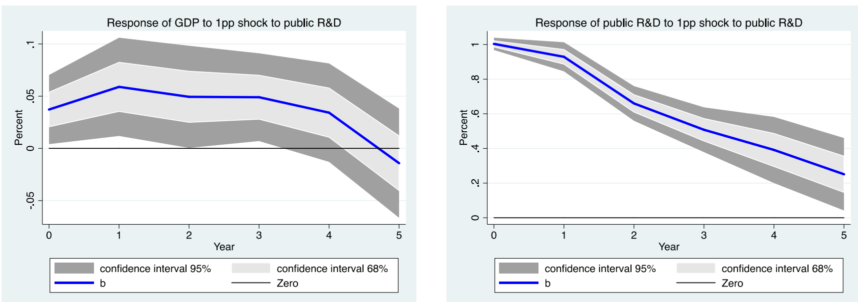
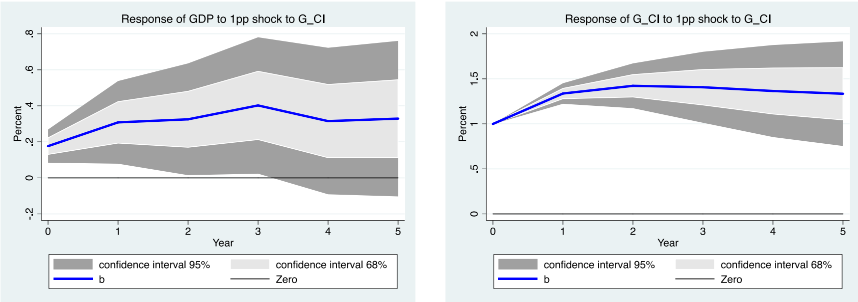


Table 5. Cumulative public R&D fiscal multiplier (GDP)- $\Delta G^F_{t|t-1}$

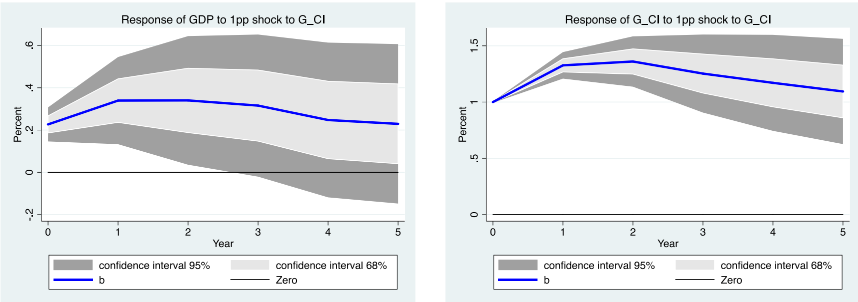
year	0	1	2	3	4	5
Model 1.a (GBARD)	**6.17**	**8.64**	**9.67**	**10.74**	**11.23**	**11,23**
Model 1.b (GBARD)	**7.62**	**10.16**	**11.84**	**13.74**	**14.98**	**15,65**
Model 1.c (GBARD)	**6.37**	**8.86**	**9.99**	**10.77**	**11.10**	**10,90**
Model 1.d (GBARD)	**6.20**	**8.31**	**9.38**	**10.49**	**10.95**	9,58

Figure 6 IRF of GDP to G_CI shock

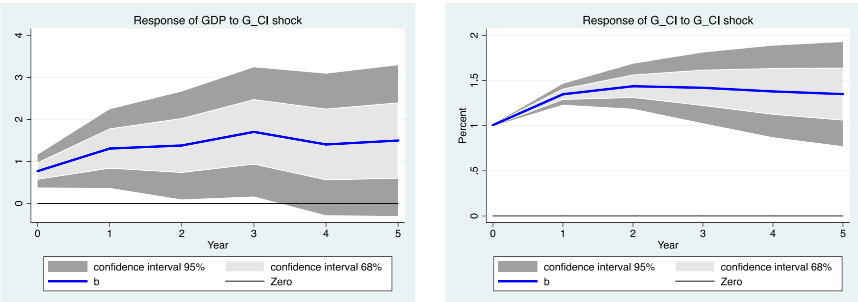
Model 1.a $\Delta G^F_{t|t-1}$ – G_CI



Model 1.b $\Delta G^F_{t|t-1}$ - G_CI



Model 1.c $\Delta G^F_{t|t-1}$ - G_CI



Model 1.d $\Delta G^F_{t|t-1}$ - G_CI

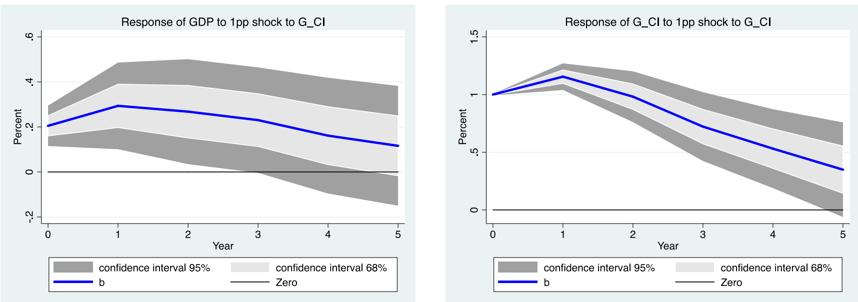


Table 6. Cumulative generic public expenditure(G_CI) fiscal multiplier (GDP)- $\Delta G^F_{t|t-1}$

year	0	1	2	3	4	5
Model 1.a (G_CI)	**0.77**	**0.91**	**0.94**	**1.03**	**1.02**	**1.03**
Model 1.b (G_CI)	**0.99**	**1.06**	**1.07**	**1.08**	**1.05**	**1.03**
Model 1.c (G_CI)	**0.76**	**0.88**	**0.91**	**0.99**	**1.00**	**1.02**
Model 1.d (G_CI)	**0.90**	**1.01**	**1.07**	**1.13**	**1.15**	**1.17**

Figure 7 and 8 plots the IRFs of Model 2.a, 2.b, 2.c and 2.d augmented by expectations, whereas the results of cumulative fiscal multipliers are reported in Table 5 and 6.

When we analyze the effects that public expenditure - GBARD and G_CI - have on private R&D, even when the introduction of expectation, public R&D produces the greatest effects (Table 7 and 8). Looking at the public R&D effect in Table 7 the impact multipliers assume values approximately equal to 0.2 in all four model specifications. (Model 2.a,2.b, 2.c and 2.d). Three years after the initial shock the multiplier are still positive and statistically significant assuming value ranging from 0.3 (Model 2.c) to 0.5 (Model 2.d). Five year after the initial shock the multiplier is statistically significant in Model 2.c and Model 2.a assuming the value of 0.315 and 0.5 respectively.

Looking at the effect of generic public expenditure (G_CI) in Table 8 it can be seen that the effect generated by G_CI is lower than the effect generated by GBARD and as the case without expectation we do not have always significance of estimates. In all Model the impact multipliers are negative but not statistically significant. In this case from year three the cumulative multiplier is positive and statistically significant only in Model 2.d assuming a peak of 0.02 after 5 years.

Table 7. Cumulative public R&D fiscal multiplier (BERD)- $\Delta G^{F}_{t|t-1}$

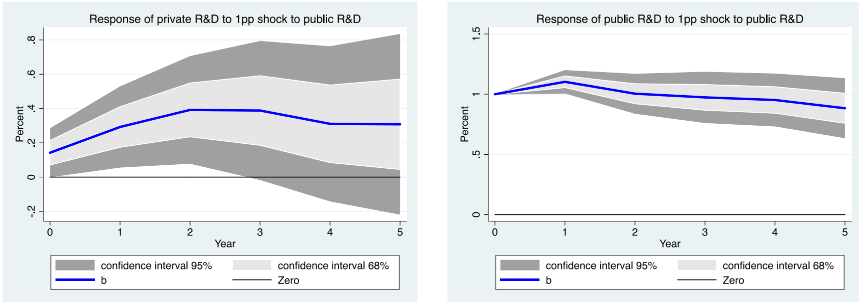
year	0	1	2	3	4	5
Model 2.a (GBARD)	**0.220**	**0.319**	**0.412**	**0.461**	**0.470**	**0.480**
Model 2.b (GBARD)	**0.221**	**0.314**	**0.395**	**0.416**	0.392	0.341
Model 2.c (GBARD)	**0.176**	**0.244**	**0.299**	**0.321**	**0.319**	**0.315**
Model 2.d (GBARD)	**0.241**	**0.354**	**0.469**	**0.518**	0.508	0.455

Table 8. Cumulative generic public expenditure (BERD) fiscal multiplier (BERD)- $\Delta G^{F}_{t|t-1}$

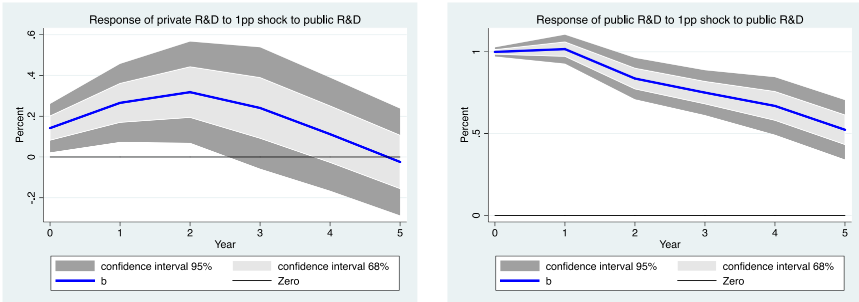
year	0	1	2	3	4	5
Model 2.a (G_CI)	-0.008	-0.012	**-0.009**	-0.005	-0.002	0.002
Model 2.b (G_CI)	-0.004	-0.003	-0.0004	0.002	0.004	0.005
Model 2.c (G_CI)	-0.005	**-0.007**	-0.006	-0.003	-0.001	**0.002**
Model 2.d (G_CI)	-0.005	-0.003	0.002	**0.008**	**0.016**	**0.023**

Figure 7 IRF of BERD to GBARD shock

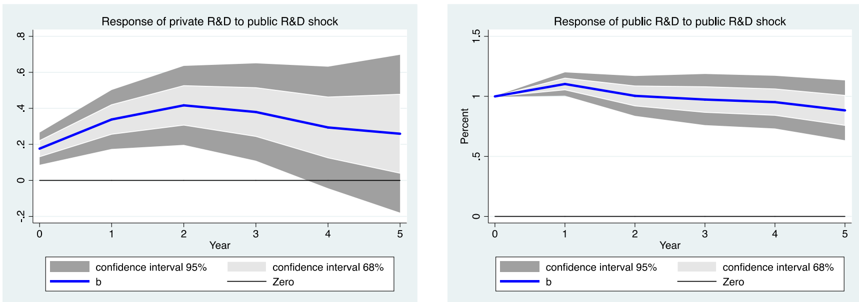
Model 2.a $\Delta G^{F}_{t|t-1}$ - GBARD



Model 2.b $\Delta G^{F}_{t|t-1}$ - GBARD



Model 2.c $\Delta G^{F}_{t|t-1}$ - GBARD



Model 2.d $\Delta G^{F}_{t|t-1}$ -GBARD

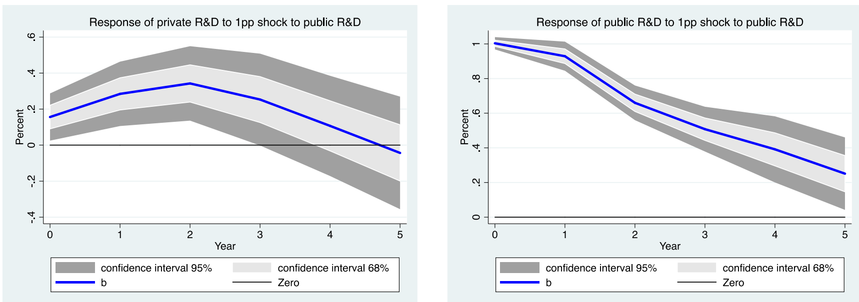
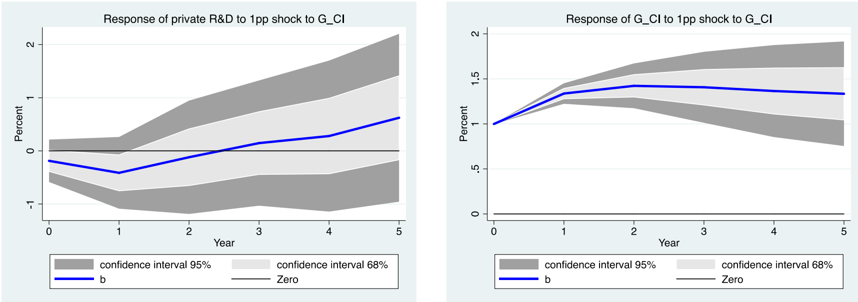
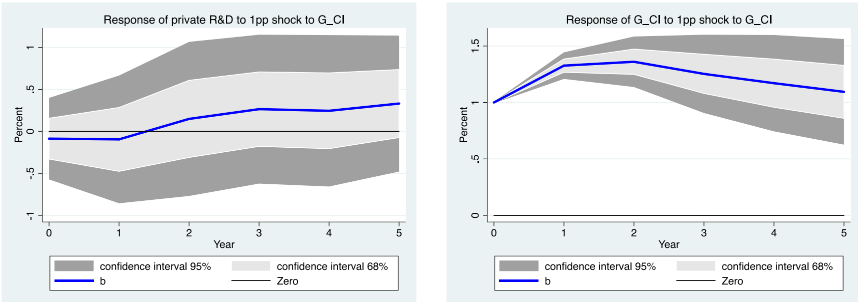


Figure 8 IRF of BERD to G_CI shock

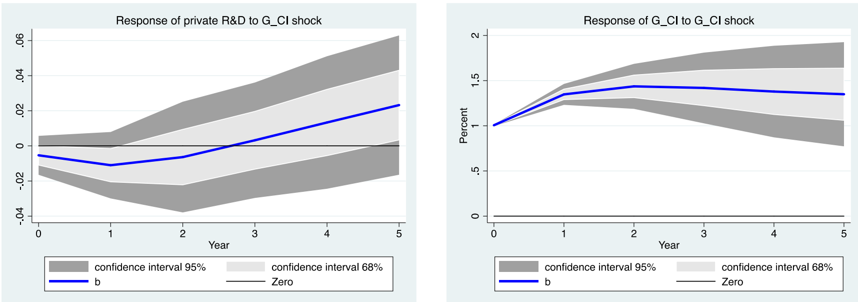
Model 2.a $\Delta G^F_{t|t-1}$ – G_CI



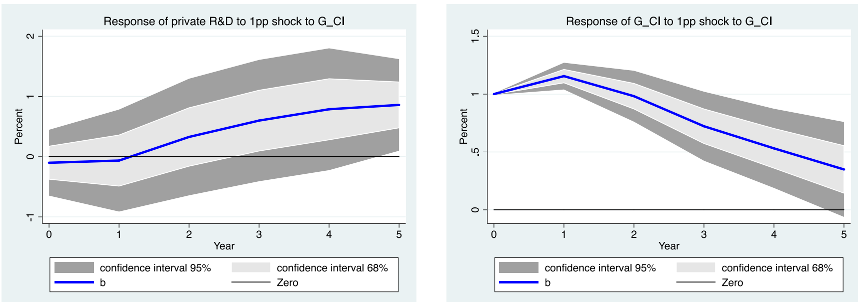
Model 2.b $\Delta G^F_{t|t-1}$ - G_CI



Model 2.c $\Delta G^F_{t|t-1}$ - G_CI



Model 2.d $\Delta G^F_{t|t-1}$ - G_CI



Summing up, we can say that our results are robust to the inclusion of the forecasts into the model and, therefore, to potential problems connected to the predictability of our public expenditure shock. The results suggest that even when controlling for fiscal expectation the components of public spending (both public R&D and non-innovation expenditure) produce persistent effects on the level of economic activity and the effect on GDP level is statistically significant even five years after the initial shock. Even when controlling for fiscal expectation public R&D policies produce a positive effect both on the level of output and on the private investment in R&D, which is much greater than the effect produced by generic government expenditures. These results are in line with Deleidi and Mazzucato (2021), showing that mission-oriented policies produce a larger positive effect on GDP and on private investment in R&D than the one generated by more generic public expenditures.

6. Conclusion

Our article contributes to the ongoing debate among international institutions and academic scholars regarding the role of public spending in boosting the level of economic activity, by assessing the effect on GDP and on private investment in R&D of generic and public R&D fiscal policies in selected OECD countries for the period 1981-2017. To do this, by following the recent works by Auerbach and Gorodnichenko (2017) and Ramey and Zubairy (2018), we combine standard SVAR modelling with the Local Projections approach. Specifically, we first identify government spending shocks through a Panel SVAR model, applying a recursive approach based on a Cholesky factorization where public R&D spending is ordered first and generic fiscal expenditures is ordered second. Once government spending shocks are identified, they are substituted in the LP equations to estimate the IRFs. We also account for the role of fiscal foresight by adding government expenditure expectations to all model specifications.

Our empirical findings show that expansionary fiscal policies generate Keynesian effects, namely positive and permanent effects on GDP and on investments, both in the short and the long run. However, the results show that public R&D fiscal policies generate a larger effect on the level of GDP than generic public expenditures. Such results are confirmed also when we evaluate the responses of private investment in R&D to different fiscal policy shocks: public R&D fiscal policies produce a stronger crowding-in effect on private R&D investment than generic public expenditures. Specifically, the estimated cumulative multiplier for GDP show that mission-oriented innovation policies generate impact multipliers greater than 5 in all model specification that reach peak values of 10.5, 15, 9.6 and 13 in Models 1.a, 1.b, 1.c and 1.d, respectively. Conversely, generic public expenditures generate impact multipliers between 0.8 and 1 according to the different models' specification that reach peak values of 1.06, 1.2, 1 and 1.5 in Models 1.a, 1.b, 1.c and 1.d, respectively.

Considering the effect on private R&D the estimated cumulative multiplier show that public R&D innovation policies generate impact multipliers greater than 0.1 in all model specification that reach peak values of 0.26, 0.27, 0.13 and 0.5 in Models 1.a, 1.b, 1.c and 1.d, respectively. Conversely, generic public expenditures generate impact multipliers not statistically significant and negative in Model 2.a and Model 2.b that reach peak values of 0.005, 0.001, 0.009 and 0.027 in Models 1.a, 1.b, 1.c and 1.d, respectively. These results are also confirmed when we consider fiscal foresight.

Our findings suggest that governments should implement expansionary fiscal policies in order to boost economic activity, both in the short and the long run. In addition, in line with the recent literature on MIOP, governments should invest in R&D, as such public policies by creating new markets and increasing business expectations about where future growth opportunities might lie, generate the largest effect on private investment and GDP.

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Appendix 1

Name:	Variable:	Info:	Source:
private R&D (**BERD**)	BERD financed by the Business sector costant price and PPP	Computed as: BERD costant price and PPP multiplied by percentage of BERD financed by the business sector	MSTI
public R&D (**GBARD**)	TOTAL GBARD costant price and PPP	Government budget allocations for R&D	MSTI
Public expenditure (**G**)	Public expenditure costant price and PPP	Computed as: Sum of Government final consumption expenditure Constant prices and PPP and government fixed capital formation (IGAA), value, local currency, value, local currency. (variables in nominal terms converted to volume by applying the GDP deflator and PPP)	OECD Economic Outlook No 106 - November 2019
Public investment*	Government fixed capital formation (IGAA) costant price and ppp	Government fixed capital formation, deflated using the GDP deflator and PPP	OECD Economic Outlook No 106 - November 2019
Public consumption	Government final consumption expenditure Constant prices and PPP	Final consumption expenditure of general government	OECD National Account
Public consumption and investment net of GBARD (**G_CI**)	Public Consumption and investment net of GBARD, costant price and ppp	Computed as Sum of Final consumption expenditure of general government and Government fixed capital formation net of GBARD	OECD Economic Outlook No 106 - November 2019 and OECD National Account
Gross domestic product (**GDP**)	Gross domestic product costant price and ppp	Gross domestic product, volume at constant purchasing power parities 2010 PPP	OECD National Account
Real Interest_rate (**i**)	long term interest rate – consumer price inflation(change of previous year)	Long-term interest rates refer to government bonds maturing in ten years.	OECD Economic Outlook No 106 - November 2019; Key Short-Term Economic Indicators
Public Expenditure forecast $(\mathbf{G^F_{t\|t-1}})$	Growth rate of Public expenditure forecast at time t forecasted at time $t-1$	Computed as: Sum of Government final consumption expenditure (CGAA) and government fixed capital formation (IGAA)	OECD Economic Outlook n 39-100

* For missing data, we interpolated the series using growth rates of the net investment in non-financial assets. Source: International Monetary Fund, Government Financial Statistics (GFS).