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The Macroeconomic Impact of Public Spending in Research and Development: An Initial Exploration for G7 and 15 Oecd Countries

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Abstract: This paper aims to assess the macroeconomic effect produced by fiscal policies targeted at innovation-focused public spending. Specifically, we estimate the fiscal multiplier associated with public R&D investment. We also aim to evaluate whether public innovation investment can crowd in business investment in R&D and generate additional employment. We combine the Local Projection approach with fiscal shocks estimated using Structural Vector Autoregressive modelling by focusing on a panel of G7 and 15 OECD economies for the 1981-2017 period. Our results show that public R&D expenditure produces higher fiscal multipliers than those generally found in the economic literature which focuses on the different components of public spending. Our results also show that this type of public expenditure can generate spillover effects, by crowding in private R&D and generating a positive impact on employment level. Findings are confirmed even when fiscal expectations are included.

Keywords: Government investment in innovation; Business R&D; Fiscal multipliers; Employment multipliers; Local projections.

JEL Code: E62; H50; E24; C33.

INTRODUCTION

The COVID-19 pandemic crisis and the recent energy crisis have once again called attention to the need for industrial policies, understood in a broad sense as public interventions aimed at directing economic growth (see, among others, Mazzucato, 2013; Chang and Andreoni, 2020; Pianta et al., 2020). The emphasis is placed mainly on public investments in innovations which lead to the discovery of new products and production

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processes capable of creating new businesses, industries, jobs and types of work (Mowery, 2010; Foray et al., 2012). This renewed interest for industrial policies occurs after decades characterized by processes of market liberalization and privatization of many national public enterprises, accompanied by a drastic reduction in public investment in research and development (R&D) (Van Reenen, 2021). It is testified by the recent focus of the International Monetary Fund on the need to employ public resources in innovative activities to foster labour productivity and economic growth (IMF 2021). Similarly, both the European Commission (European Commission, 2018a) and the Organization for Economic Cooperation and Development (Larrue, 2021) advocate systemic interventions and a "mission-oriented approach" to innovation to make real progress on complex challenges of our time and engage research investment in meeting such challenges. While the industrial literature recognizes the high-spillover content of public R&D investments and their ability to generate a higher value (Van Reenen, 2020; 2021), a mission-oriented approach to innovation emphasizes that such policies are able to generate additionality within the economic system by creating new industrial landscape that otherwise would not have been possible (Mazzucato, 2018). Despite the renewed interest in the need for industrial policy, little to no evidence exists about the macroeconomic effects of public investment oriented at promoting structural change and technological progress (Deleidi and Mazzucato, 2021; Ziesemer, 2021).

Based on these premises, this work aims to estimate the macroeconomic impact of public investments in innovation using a dataset consisting of 15 OECD countries for the period 1981- 2017. To do this, we will refer to two strands of literature: one on fiscal multipliers, which estimates the impact of public spending on GDP; and one on innovation, which sees the role of the state and public investment in R&D as factors that stimulate economic growth and private investment in R&D. In particular, in this work, we will apply an econometric model based on Local-Projection to quantify the macroeconomic impact of public R&D expenditure on GDP and the effects that this expenditure has on private R&D. This will allow us to evaluate whether public intervention generates spillover effects within the economic system. We will also quantify the impact of public R&D expenditure on the level of employment to assess its societal consequences. The results show that public expenditure on R&D: (i) is associated with higher fiscal multipliers than those of other components of public expenditure; (ii) produces a crowding-in effect on private R&D; (iii) has a positive effect on the level of employment. This last result does not deny that technological unemployment can occur. It suggests, however, that a mission-oriented approach to innovation can foster both employment and labour productivity.

The paper is structured as follows. The next section summarizes the literature on innovations and fiscal multipliers. We then move on to describe the data and methods adopted and subsequently, our findings regarding the macroeconomic effects produced by public investment in R&D. Finally, we conclude by drawing some policy implications.

LITERATURE REVIEW

To assess the impact of public investment in R&D on the economy and the labour market, we refer to both the literature on innovation and fiscal multipliers.

Although recognizing the State's ability to promote and influence innovation and technological change, a part of the literature has limited the scope of public intervention to fixing market failures (Acemoglu et al., 2015; 2016; Van Reenen, 2020; 2021). However, historically, public investment in research and development (R&D) and a mission-oriented approach to innovation have been able to create new industrial landscapes. According to this approach, the public sector acted as an investor of first resort, absorbing the high degree of uncertainty during the early stages of innovation, stimulating private R&D investments and generating additionality within the economic system (Mowery, 2010, 2012; Foray et al., 2012). These public policies turn out to be interdisciplinary and systemic, involving many sectors and actors working together, and solving concrete problems and challenges by finding new technological solutions that are in line with the missions to be achieved (Mazzucato, 2018). In advanced economies some examples of these policies were: i) the Apollo Programme (European Commission, 2018b); ii) the Energiewende Programme (European Commission, 2018c); iii) the Human Genome Programme (European Commission, 2018d). These policies have developed technological and non-technological (mainly, organisational) innovations that have been applied and introduced in various economic sectors, stimulating in turn private investment that otherwise would not have been possible.

Regarding the industrial empirical literature, in recent years several works have underlined the fact that demand management policies can foster both the development and diffusion of innovations (see, among others, Acemoglu and Lin, 2004; García-Quevedo et al., 2017). In this line, several contributions have analyzed the impact of alternative public innovation policies on private innovative activity. This literature provides mixed results regarding the crowding-in or -out effects of public policies on private innovation activities (David et al., 2000; Becker, 2015). Several contributions emphasize the presence of technological spillover and high complementarities between public R&D and private R&D, highlighting crowding-in effects (see, among others, Diamond, 1999; Autant-Bernard, 2001; Aschhoff and Sofka, 2009; Moretti et al. 2019; Deleidi and Mazzucato, 2021). Contrarily, other studies underline the presence of crowding-out effects due to inelastic labour supply and an increase in the price level (see, among others, Wallsten, 2000; Cohen et al., 2011; Kong, 2020). The industrial empirical literature has mainly used microdata although some works have recently assessed the effects at the macroeconomic level to capture the technological spillover effects generated by public R&D investment (Buyse et al., 2020; Rehman et al., 2020). Using the Common Correlated Effects Pooled estimator (CCEP) for a panel of 14 OECD countries for the 1981-2012 period, Buyse et al. (2020) find that government expenditures on R&D have a positive impact on business R&D investment. Rehman et al. (2020) investigate the relationship between public and private R&D for a panel of 10 OECD countries in the 2000-2014 period. Using a system GMM estimation, their result shows that public R&D has a positive impact on private R&D both in pre and post-2008 crisis periods, with a higher impact before 2008. Ziesemer (2021), using a vector error-correction model (VECM) for a panel of seven European countries, shows that a 1% increase in mission-oriented R&D expenditure leads to a 0.705% increase in private sector R&D. Deleidi and Mazzucato (2021), applying an SVAR model to US quarterly data, show that a $1 increase in public defence R&D investment leads to an increase of $0.75 in private R&D investment on impact.

When looking at the macroeconomic literature that estimates the impact of public spending on GDP, in recent years there has been a wide use of econometric models to estimate fiscal multipliers by applying different identification strategies and model specifications. The empirical literature evaluating the impact of government spending shocks on macroeconomic variables usually employs SVAR models and the LP approach.[1] In these studies, total government spending is generally found to have a positive impact on the GDP level. Scholarly-based literature on fiscal multipliers generally agrees with a total public expenditure multiplier close to 1 (Blanchard and Perotti, 2002; Ramey, 2011a; Auerbach and Gorodnichenko, 2012; 2017; Caldara and Kamps, 2017; Ramey and Zubairy, 2018). Regarding the effect of the public expenditure component on GDP, most of the existing studies distinguish between public consumption and investment without finding unanimous results. While several contributions find that the multiplier associated with public investment has a more significant impact on GDP compared to those associated with government consumption (Burriel et al., 2010; Auerbach and Gorodnichenko, 2012; Izquierdo et al., 2019; Deleidi, 2022; Petrović et al., 2021), few studies show that public consumption is more effective in stimulating economic activity (Perotti, 2004; Pappa, 2009; Boehm, 2020). Considering the literature on mission-oriented R&D policies, little to no literature exists, except Ziesemer (2021) and Deleidi and Mazzucato (2021). Ziesemer (2021), using a vector error-correction model (VECM) on a panel of seven European countries, shows that a 1% increase in mission-oriented R&D leads to a 0.56% increase in GDP. Deleidi and Mazzucato (2021) find that defence R&D investment generates a larger effect on the GDP level compared to total public expenditures. In particular, using an SVAR to US quarterly data, they estimate a defence R&D investment multiplier of 5.76 and a generic expenditure multiplier of 0.63 after 32 quarters.

Analysing the effect of government expenditure on labour market variables, it emerges that it has received substantially less attention than its GDP counterpart and offers mixed evidence. Most of the contributions analyse the case of the United States. Monacelli et al. (2010) using an SVAR model find that a rise in public spending equal to 1% of GDP increases employment by 1.6% and lowers the unemployment rate by 0.6 percentage points in the US. For the US economy similar results are obtained by Nakamura and Steinsson (2014) who using historical data on military procurement spending, find that a rise in government expenditures equal to 1% of GDP increases the employment rate by about 1.3-1.8 percentage points. Conversely, Ramey (2013), using three different identification strategies for the US economy, finds that an increase in government spending reduces unemployment. Regarding the effect on employment, she finds that for all but one specification, all the increase is in government employment, not private employment.[2] In recent years, a few contributions assess the effect of the Recovery and Reinvestment Act (ARRA) on labour market variables, finding a positive effect on the employment level (Feyrer and Sacerdote, 2011; Chodorow-Reich et al., 2012; Wilson, 2012).[3] Bruckner and Pappa (2012), using an SVAR model for 10 OECD economies, find that an increase in public spending has a positive impact on both the employment and labour force participation rate, leading to an increase in the unemployment rate. Considering a large panel of OECD countries, Auerbach and Gorodnichenko (2013) find that a one billion dollar increase in government spending creates approximately 44,000 jobs during periods of economic recession. The effects on employment are positive though not statistically significant during periods of economic expansion. By applying SVAR and LP models for a panel of CEE10 economies,[4] Petrović et al. (2021) find that public investment increases employment and decreases the unemployment rate, while public consumption affects neither the employment nor the unemployment rate.

DATA AND METHODOLOGY

Data

To detect the effect of generic fiscal policies and those targeted on R&D spending on GDP, business R&D and employment, we use yearly data provided by OECD, using the Main Science and Technology Indicators (MSTI) database, Economic Outlook, and National Accounts databases. Our analysis is based on 15 countries: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, Portugal, Spain, the UK and the US. To consider potential heterogeneity across countries we also focused our analysis on a panel of G7 economies.[5] The analysis is conducted using yearly macroeconomic data considered for the 1981-2017 period. Our variables of interest are GDP (*GDP*), government expenditures in R&D (*G_I*), private R&D expenditures performed and financed by the private sector (*R&D*), and total employment (*EMP*). We also have a set of control variables: the real long-term interest rate (i), public consumption and investment expenditure net of public spending on research and development (*G_RES*). The variables are expressed in real terms using the GDP deflator and are converted to USD dollars using the PPP index. All variables – excluding the interest rate – are in first differences. Details on the construction of the variables and data sources are provided in Appendix 1.

Methodology

We apply the single equation approach – known as Local Projections (LP) (Jordà, 2005) – to evaluate the dynamical effect of public R&D expenditure shocks on our macroeconomic variables of interest, i.e. for the current and subsequent periods after the realization of the shock. Specifically, the LP estimates single regressions in which the effect of an exogenous shock on the variables of interest is analysed from time t up to $t + h$.

Following the literature on fiscal multipliers (Ramey, 2016; Auerbach and Gorodnichenko, 2017; Ramey and Zubairy, 2018; Deleidi et al., 2020 and 2021), we combine the Local Projection approach with shocks estimated using Structural Vector Autoregressive modelling. Particularly, we first identify government spending shocks ($w_{i,t}$) associated with *G_I* in an SVAR model, and then we introduce those shocks in the LP equation.

In this paper, fiscal shocks are computed using the Blanchard and Perotti strategy (Blanchard and Perotti, 2002). Through this identification strategy, we follow the standard procedure assuming that government spending does not respond contemporaneously to macroeconomic conditions. Indeed, we have a three-equation VAR model where public spending in R&D (*G_I*) is ordered first, private investment in R&S (*R&D*) is ordered second and GDP (*GDP*) is affected by the two expenditures in the contemporaneous relationship. This identification strategy implies that government investment in R&D (*G_I*) is the most exogenous variable and thus takes more than one period to respond to macroeconomic conditions. This assumption is justified by the fact that public R&D investments are strategic investments that reflect political and industrial priorities and are not influenced by the current economic activity (Moretti et al., 2019; Deleidi and Mazzucato, 2021).

Additionally, to consider the role of fiscal foresight and the potential econometric drawbacks of excluding fiscal expectations when estimating multipliers (Blanchard and Perotti, 2002; Ramey, 2011b; Auerbach and Gorodnichenko, 2012)[6], we include government spending forecasts provided by the OECD Economic Outlook ($\Delta G^F_{t|t-1}$) in our analysis.[7] The inclusion of this variable helps us to purify public expenditure shocks from their anticipated component and therefore identify what the literature has defined as unanticipated fiscal expenditure shocks ($w^{unexp}_{i,t}$) (Auerbach and Gorodnichenko, 2012, p. 16). Technically, we augment our VAR model by applying a recursive identification strategy where government spending forecasts ($\Delta G^F_{t|t-1}$) are the first ordered variables. In this way, we can identify unanticipated fiscal shocks ($w^{unexp}_{i,t}$).[8]

Once government spending shocks ($w_{i,t}$) are identified, they are introduced in the LP equation to obtain the impulse response functions (IRFs). The estimated model is formalized as in equation 1:

$$y_{i,t+h} = \alpha_i + \delta_\tau + \beta^h w_{i,t} + \vartheta_1^h z_{i,t-1} + \varepsilon_{i,t+h} \tag{1}$$

where *i* and *t* index countries and time; α_i and δ_τ are country and time fixed effects; *y* is the variable of interest considered at each horizon $h = 0,1 \ldots 5$; $w_{i,t}$ are the structural shocks obtained through the recursive identification; $z_{i,t-1}$ contains the control variables. The control variables included in equation

(1) are: GDP (*GDP*), public investment in R&D (*G_I*), private investment in R&D (*R&D*), total employment (*EMP*), the real interest rate (*i*), and public consumption and investment net of public spending on research and development (*G_RES*).[9] We estimate equation (1) to assess the effects of fiscal expenditure in R&D activities (*G_I*) on our variables of interest (*y*), namely GDP (*GDP*), private R&D (*R&D*), and total employment (*EMP*).

Since our variables are expressed in rates of growth, the β^h coefficient in equation (1) represents the elasticity of the variables of interest *y* to the public R&D expenditures. Therefore, to estimate multipliers, the β^h coefficient must be multiplied by an *ex-post* conversion factor[10] equal to the average value of the variable of interest divided by public investment in R&D (*y/G_I*).[11]

Additionally, following Spilimbergo et al. (2009), Ramey (2016), and Ramey and Zubairy (2018), we also calculate the cumulative multipliers of public investment in R&D. Specifically, the cumulative coefficients are obtained by dividing the cumulative response of the variable of interest *y* (*GDP*, *R&D*, and *EMP*) by the cumulative government R&D expenditure (*G_I*) change that occurred during the observed period (Spilimbergo et al., 2009; Gechert, 2015) multiplied by the ex-post conversion factor. In this way, the cumulative effects allow us to study the response of *GDP*, *R&D,* and *EMP* per unit increase in government spending.

FINDINGS

In this section we show our findings regarding the macroeconomic effects produced by public investment in R&D (*G_I*).[12] Specifically, we display and evaluate local projections for the five years ahead (h = 5) for identification strategies described in the previous section, considering the GDP (*GDP*), private R&D (*R&D*), and total employment (*EMP*) dependent variables. The analysis is carried out considering a panel of 15 OECD countries and a panel of G7 economies.

In all the figures reported below (Figures 1–4), we display the dynamics of government spending in R&D (*G_I*) and the corresponding responses of the GDP (*GDP*), private R&D (*R&D*), and total employment (*TOTEMP*). In Tables 1 and 2 we report the results of the cumulative multipliers. Figure 1 plots the IRFs for the 15 OECD countries, whereas Figure 2 plots the IRFs for the G7 economies. The corresponding cumulative multipliers are reported in Table 1. Considering the model augmented by fiscal expectation, Figure 3 plots the IRFs for the 15 OECD countries whereas Figure 4 plots the IRFs for the G7 economies. The corresponding multipliers are reported in Table 2.

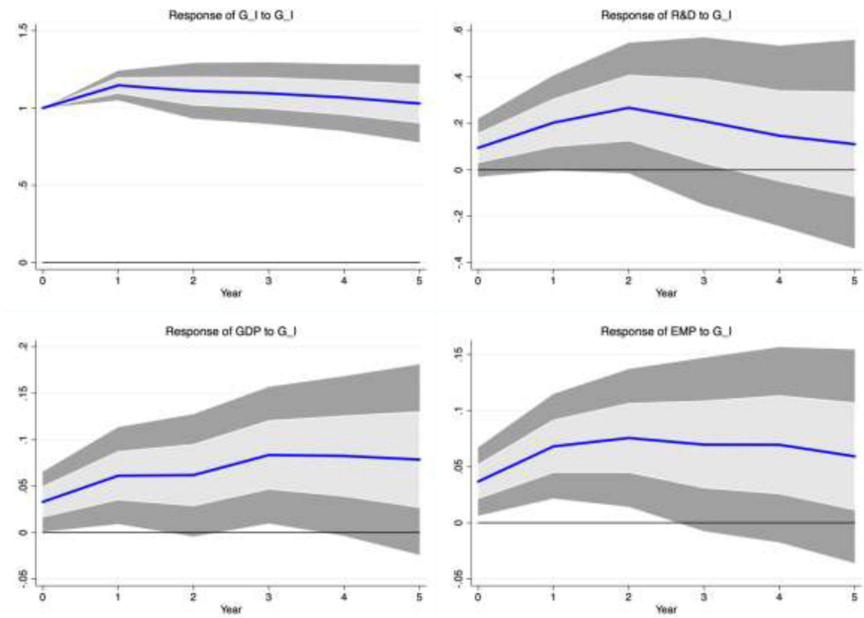

Figure 1. Impulse Response Functions of OECD (shaded areas represent 68% and 95% confidence intervals).

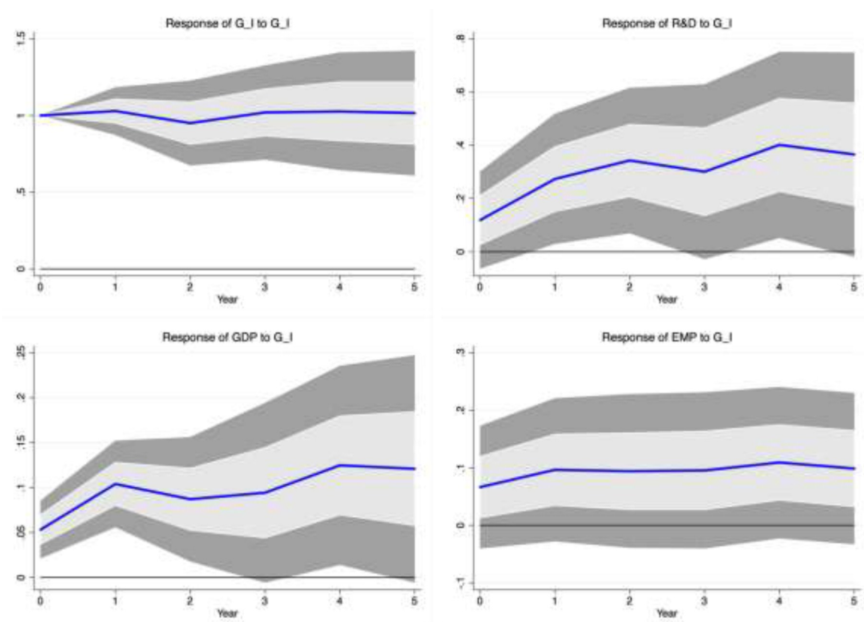

Figure 2. Impulse Response Functions of G7 (shaded areas represent 68% and 95% confidence intervals).

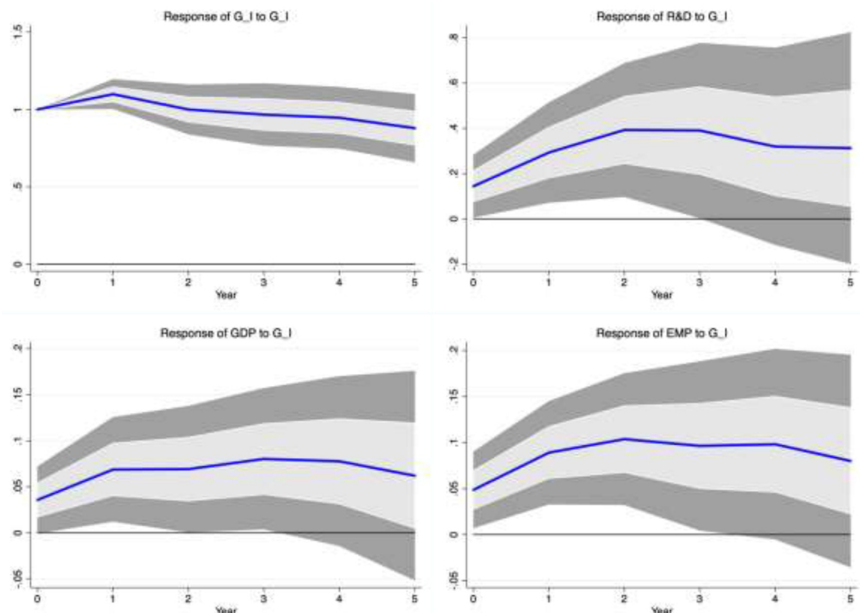

Figure 3. Impulse Response Functions of OECD with fiscal expectations $\Delta G^F_{t|t-1}$ (shaded areas represent 68% and 95% confidence intervals).

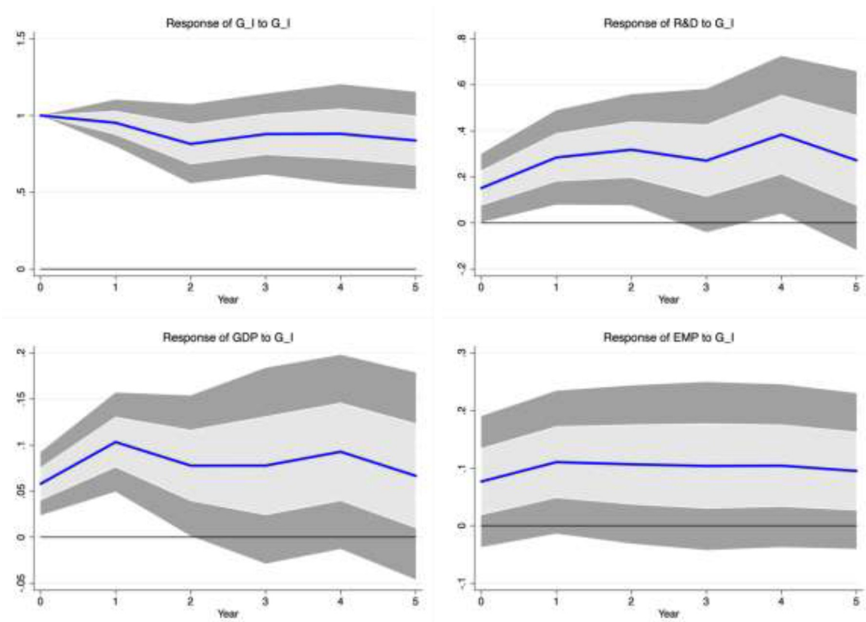

Figure 4. Impulse Response Functions of G7 with fiscal expectations $\Delta G^F_{t|t-1}$. (shaded areas represent 68% and 95% confidence intervals).

The IRFs represent the elasticity of the variables of interest (*GDP*, *R&D*, *EMP*) to the public R&D expenditure shocks (*G_I*). By construction, the public investment in R&D shocks are equal to 1% on impact, whereas their dynamic changes throughout the selected period for the different model specifications and the sample analysed. From our IRFs, we can observe a certain degree of persistence in public investment R&D shocks, as reflected in the positive values five years after the initial shock. Furthermore, the estimated IRFs suggest that public spending in R&D activities can produce persistent macroeconomic effects. The impact on GDP, private R&D, and total employment is positive and statistically significant even five years after the initial shock.

Notably, the cumulative multipliers reported in Tables 1 and 2 show that for the panel of 15 OECD countries public investment in R&D generates positive and relevant effects on private R&D, GDP and total employment. Looking at the impact of public R&D investment (*G_I*) in Table 1, the effects on GDP are significant at all considered horizons. The impact multiplier is equal to 5.53. Five years after the initial shock, the investment multiplier is 10.42 and the average multiplier is 8.42. When including fiscal expectations to identify the unanticipated fiscal expenditure shocks, the estimated multipliers are slightly higher than those obtained in models without expectations as shown in Table 2. Indeed, the computed multiplier is 5.97 on impact, 11.16 after five years, and 9.38 on average. Concerning the effects on private investment in R&D, the results show that public investment in R&D generates a crowding-in effect: the impact multiplier is equal to 0.14 and the five-year multiplier is equal to 0.24, with an average multiplier of 0.23 (Table 1). Also in this case, the model augmented by fiscal expectations produces higher values: the impact multiplier is equal to 0.22, the five-year multiplier is equal to 0.49, and the average multiplier is 0.40 (Table 2). Finally, looking at the labour market variable, namely total employment, the cumulative employment multiplier indicates that a $100,000 increase in public investment in R&D generates 7.93 additional jobs on impact. Five years after the initial shock, the employment multiplier is 12.68, with an average employment multiplier of 11.38 (Table 1). The employment multipliers for the model augmented by fiscal expectations produce a higher result with an average multiplier of 15.68.

Table 1. Cumulative multipliers of *G_I*. Significant estimates are in bold (68%). For the employment multipliers (*EMP*) the values are calculated for $100,000 increases in *G_I*.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Mean
OECD							
	0.14	**0.20**	**0.26**	**0.26**	0.25	0.24	0.23
	5.53	**7.36**	**8.03**	**9.23**	**9.97**	**10.42**	8.42
	7.93	**10.55**	**11.96**	**12.41**	**12.73**	**12.68**	11.38
G7							
	0.19	**0.31**	**0.39**	**0.41**	**0.45**	**0.47**	0.37
	7.56	**11.00**	**11.64**	**12.01**	**13.09**	**13.73**	11.51
	11.71	**14.16**	**15.21**	**15.54**	**16.19**	**16.36**	14.86

Table 2. Cumulative multipliers of *G_I* with fiscal expectations $\Delta G^F_{t|t-1}$. Significant estimates are in bold (68%). For the employment multipliers (*EMP*) the values are calculated for $100,000 increases in *G_I*.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Mean
OECD							
	0.22	**0.32**	**0.42**	**0.47**	**0.48**	**0.49**	0.40
	5.97	**8.32**	**9.36**	**10.43**	**11.05**	**11.16**	9.38
	10.16	**13.72**	**16.31**	**17.38**	**18.20**	**18.32**	15.68
G7							
	0.25	**0.37**	**0.46**	**0.47**	**0.52**	**0.53**	0.43
	8.43	**11.99**	**12.55**	**12.62**	**13.15**	**12.90**	11.94
	13.60	**16.96**	**18.83**	**19.35**	**19.66**	**19.73**	18.02

Similar results are obtained for the panel of G7 economies, with some differences in the magnitude of the effects. Specifically, we find that the macroeconomic effects produced by public investment in R&D are higher in the panel of G7 economies than in the panel of 15 OECD countries, for all variables considered, namely *GDP*, *R&D*, and *EMP*. Looking at the impact on GDP, the impact multiplier is equal to 7.56, the five-year cumulative multiplier is equal to 13.73, and the average multiplier is 11.51 (Table 1). The model augmented by fiscal expectations produces similar multiplicative effects (Table 2): the impact multiplier is equal to 8.43, the five-year multiplier is equal to 12.90, and the average multiplier is equal to 11.94. Concerning the crowding-in effect of public R&D on private R&D, the impact multiplier is equal to 0.19 and the five-year multiplier is equal to 0.47, with an average value of 0.37 (Table 1). The model augmented by fiscal expectations produce higher results: the impact multiplier is equal to 0.25, the five-year multiplier is equal to 0.53, and the average multiplier is 0.43 (Table 2). Finally, considering the effect of public investment in R&D on employment, the cumulative employment multiplier indicates that a $100,000 increase in public investment in R&D generates 11.71 additional jobs on impact. Five years after the initial shock, the employment multiplier is 16.36, with an average employment multiplier of 14.86 (Table 1). Again, the model that includes fiscal foresight indicates that the effect on total employment is stronger: the impact multiplier is 13.60, the five-year cumulative multiplier is 19.73, and the average multiplier is 18.02.

CONCLUSION

The COVID-19 crisis and the recent energy crisis have raised widespread interest in the role that new industrial policies can have in enabling economies to make a structural change towards a greener and more digital economic system. It is precisely in this direction that the European Commission has financed 800 billion euros through the Next Generation EU (NGEU) to boost investments in strategic sectors and areas. In this study, we evaluate the role that the public sector can play in influencing and directing economic growth and the realization of innovations within the economic system by estimating the macroeconomic effects of public R&D investments. Specifically, we evaluate the effect of public investment in R&D on GDP, private R&D, and employment level. To do this, we apply an econometric technique that combines the single equation approach based on the Local Projection with fiscal policy shocks computed using SVAR models considering a panel of 15 OECD countries for the1981-2017 period.

Our results suggest that relying on a public system investing in innovation produces positive and persistent macroeconomic effects. The multiplier effects on the GDP are greater than those highlighted in the fiscal policy literature which focuses on the different components of public expenditure (Gechert, 2015; Deleidi et al. 2021). Moreover, public investment in R&D has been shown to stimulate private R&D investment and generate additionality within the labour market which could not have taken place without public intervention (Van Reenen, 2021; Deleidi and Mazzucato, 2019; 2021). These effects arise from the fact that public spending on R&D not only triggers a demand stimulus but promotes structural transformations within the economic system. However, as the difference in the magnitude of the effect of public investment in R&D across the panel of 15 OECD countries and the G7 economies suggests, the results may be affected by the specific characteristics of countries, including their different degree of technological development. For example, they can be affected by the different degrees to which R&D expenditure is able to activate more technology-intensive sectors (Freeman, 1995; Mowery, 2012).

Notes

1 For an in-depth review of the main identification strategy employed and estimated multipliers using both the SVAR and LP, see, among others, Gechert (2015), Ramey (2016; 2019), Deleidi et al. (2020 and 2021).

2 The only exception is the specification using the Fisher-Peters measure of defence news (based on stock returns) for which she finds that increases in government spending raise both government employment and private employment.

3 Employing an IV-GMM approach, Wilson (2012) finds that ARRA spending in its first year yielded about eight jobs per million dollars spent. Chodorow-Reich et al. (2012), implementing a two-stage least square estimation, show that a $100.000 increase in government spending increases employment by about 3.8 job-years (of which 3.2 were outside the government, health, and education sectors). Feyrer and Sacerdote (2011) show that regions of the country that received more recovery funds experienced faster employment growth. They found that a region's receipt of $100.000 generated between 0.5 and 1 job-years and the magnitude rise to 2 if education spending was excluded.

4 The CEE10 consist of Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the Slovak Republic and Slovenia.

5 Canada, France, Germany, Italy, Japan, the UK and the US.

6 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 means that private expenditure may change when private agents receive information on future changes in fiscal expenditures. Econometrically, when only government expenditure is included in the model, errors can arise because relevant variables – variables capturing fiscal foresight – are omitted and this could lead to biased estimates.

7 Specifically, we use the forecasts made at t - 1 for the growth rate of real government purchases for time t. These forecasts are available from year 1987 and so the empirical analysis in which fiscal expectation are included is carried out for the 1987-2017 period.

8 In this case we have a four-equation VAR model where public expenditure forecasts are the most exogenous variable, public spending in R&D (*G_I*) is the second ordered variable, private investment in R&S (*R&D*) is the third ordered variable and GDP (*GDP*) is the last ordered variable.

9 In models augmented by fiscal expectations we also have as a control variable the government spending forecasts ($\Delta G^F_{t|t-1}$) to control for their effect on the level of our variable of interest (Boehm, 2020; Deleidi et al., 2021).

10 Qualitative and quantitative results do not change if we employ the ex-ante procedure. They are not reported in the paper and are available upon request.

11 The ratios used in the ex-post transformation from elasticities to partial

derivatives are calculated as follows: *R&D/G_I*; *Y/G_I*; *EMP/G_I*. For the 15 OECD countries, they assume the following values respectively: 1.48, 167.67, and 216.05 (employment per 100,000 public *G_I* investment). For the G7 economies they are respectively equal to: 1.58, 141.86, and 176.41 (employment per 100,000 public investment).

12 The effect of total public expenditure on our variables of interest is not reported in the paper since the aim is to evaluate the effect of public investment in R&D. Results (not shown) suggest that total public expenditure produces multipliers close to 1 lower than public investment in R&D. Results are available upon request.

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APPENDIX 1

Name	Variable	Description	Source
Private R&D (**R&D**)	BERD financed by the business sector constant price and PPP	BERD financed by the business sector constant price and PPP	MSTI database
Public R&D (**G_I**)	TOTAL GBARD constant price and PPP	Government budget allocations for investment in R&D	MSTI database
Public consumption and investment net of G_I (**G_RES**)	Public Consumption and investment net of GBARD, constant price and ppp	Sum of Final consumption expenditure of general government and Government fixed capital formation net of GBARD (variables in nominal terms converted to volume by applying the GDP deflator and PPP index)	OECD Economic Outlook No 106 - November 2019 and OECD National Account
Gross domestic product (**Y**)	Gross domestic product constant price and ppp	Gross domestic product, volume at constant price and 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 ($\boldsymbol{\Delta G^F_{t\|t-1}}$)	Growth rate of Public expenditure forecast at time t forecasted at time $t-1$	Sum of Government final consumption expenditure (CGAA) and government fixed capital formation (IGAA)	OECD Economic Outlook n 39-100
Total Employment (**EMP**)	Total Employment	Total Employment (person)	Economic Series for MSTI MSTI database

* 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).

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