MISSION-ORIENTED INNOVATION POLICIES:
A THEORETICAL AND EMPIRICAL ASSESSMENT FOR THE US ECONOMY

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Abstract

The paper investigates the determinants of economic growth from both a theoretical and an empirical perspective. The paper combines the Sraffian supermultiplier model of growth with the Neo-Schumpeterian framework that emphasizes the entrepreneurial role of the state. We aim to detect the macroeconomic effect generated by alternative fiscal policies: generic ones and “mission-oriented” ones. Using a SVAR model for the US economy for the 1947–2018 period, we show that mission-oriented policies produce a larger positive effect on GDP (fiscal multiplier) and on private investment in R&D (crowd-in effect) than the effect produced by generic public expenditures.

Keywords: Mission-oriented innovation policies, Sraffian supermultiplier, SVAR, fiscal multiplier, crowding-in effect.

JEL codes: C32; E22; E62; O25; O30.

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1. Introduction

After the 2007 financial crisis, several advanced countries were steered by austerity measures. Austerity, defined generally as a reduction in government spending to stimulate private investment through reductions in the interest rate, is based on the notion that the government is like a household, that during bad times it should tighten its belt. Post-crisis austerity policies were accompanied by labor market policies focused on increasing competitiveness through a reduction in unit costs. While the assumption was that, besides restoring economic growth and competitiveness, austerity policies would also mitigate financial market speculation and decrease sovereign debt bond spreads, the reality soon became clear: growth did not return, financial markets remained vulnerable, and labor market policies fueled inequality without resulting in higher investment.

Over the last two years, there has been a change of heart in the International Monetary Fund (IMF), which has historically been one of the greatest proponents of austerity and wage cuts, or what some have called neoliberalism. In a paper called “Neoliberalism: Oversold?” (Ostry et al., 2016), the IMF questioned the foundations of austerity, showing how austerity has led to weak growth and rising inequality. Indeed, the chief economist of the IMF, Olivier Blanchard, claimed that austerity had failed because the fiscal multiplier was higher than economists had assumed (Blanchard and Leigh, 2013). Blanchard and Leigh (2013) argue that the fiscal multiplier assumes a positive value equal to 1.5, suggesting that a fiscal consolidation generates a Keynesian effect, thus causing an economic recession rather than an alleged expansion. More recently, the IMF (2014) called for an infrastructure push and for governments to spend on areas like infrastructure to bring back growth, rather than to continue to cut spending. Moreover, former chair of the Federal Reserve Janet Yellen argued that cyclical conditions – determined by changes in aggregate demand – lead to permanent effects on both aggregate supply and potential output through a mechanism typically termed
“hysteresis” (Fatás and Summers, 2016; Yellen, 2016). Therefore, expansionary fiscal policies are supposed to generate positive fiscal multipliers larger than one and produce a permanent effect on the level of output.

In line with these premises, we argue that, rather than positing austerity versus generic public investment, it is essential to assess different types of fiscal policy, that is, tax incentives, generic government spending, and government investment oriented to promoting structural change, as in the case of mission-oriented innovation policies. To do this, the current work provides several theoretical and empirical novelties. Specifically, the paper (i) combines the Sraffian supermultiplier model of growth (Serrano, 1995; Cesaratto et al., 2003; Freitas and Serrano, 2015) with the Neo-Schumpeterian framework that emphasizes the entrepreneurial role of the state (Mazzucato, 2013, 2016, 2018); (ii) considers the macroeconomic effect of mission-oriented innovation policies; and (iii) estimates the effect of mission-oriented innovation policies and generic government spending on GDP (i.e., fiscal multiplier) and on private R&D investment (i.e., crowding-in versus crowding-out mechanism). Our theoretical and empirical findings show that mission-oriented policies generate a larger effect on output and on private investment in R&D than generic public expenditures.

The paper is divided as follows. In Section 2, the supermultiplier model of growth, which includes mission-oriented policies, is presented. After the presentation of data and methods in Section 3, Section 4 provides the empirical findings estimated by means of Structural Vector Autoregression (SVAR) models applied to US quarterly data for the 1947–2018 period. Section 5 concludes with a discussion of the policy implications of our results.
2. The Sraffian Supermultiplier

The Sraffian supermultiplier model, originally presented by Serrano (1995), aims at relating the output determination with the evolution of effective demand. Specifically, output growth is determined by the growth rate of the autonomous components of aggregate demand. In this model, the traditional Keynesian multiplier effect (Keynes, 1936) is related to an investment function grounded on the flexible accelerator principle (e.g., Cesaratto et al., 2003; Freitas and Serrano, 2015). This model is “essentially based on the recognition of the elasticity with which output responds, in the long no less than in the short period, to changes in aggregate demand. Such elasticity, which is at the core of Keynes’s contribution, in the short period is related to the varying utilization of installed capacity, while in the long period is further increased by the possibility of creating new resources, or destroying the existing ones, at different possible speeds” (Trezzini and Palumbo, 2016, p. 504).

The supermultiplier model of growth has some key properties: (i) the extension of the so-called “Keynesian hypothesis” to the long run, namely the idea of savings as determined by investment decisions in both the short and long run (Garegnani, 1992); (ii) an investment function that does not necessarily produce Harrodian instability; (iii) the absence of any necessary relationship between the rate of accumulation and the normal income distribution; (iv) an equilibrium cost-minimizing degree of capacity utilization, which is equal to the normal degree. Recently, the supermultiplier model has been used by a number of economists of different backgrounds (e.g., Allain, 2015; Lavoie, 2016; Hein, 2018; Fazzari et al., 2018). Following the recent contribution of Deleidi and Mazzucato (2018) and the “Schumpeter meets Keynes” family of models (Dosi et al., 2010, 2017), this paper introduces the notion of mission-oriented innovation policies within the Sraffian supermultiplier model of growth. Such a model combines the class of models that extend the principle of effective demand and the “Keynesian hypothesis” to a long-run analysis, with the Neo-Schumpeterian framework.
of evolutionary economics that underlines the relevant role played by targeted public policies in affecting the development and diffusion of innovation processes (e.g., Mazzucato 2013, 2016, 2018).

To start, we need to classify the components of aggregate demand, distinguishing between (i) autonomous and induced, and (ii) capacity- or non-capacity-creating. Table 1 shows this classification where government spending, total consumption, and business expenditures are non-capacity-creating, and only gross investment is able to create productive capacity. We consider public expenditure, autonomous consumption, and autonomous business expenditures as variables independent of current and expected level of income (Cesaratto et al., 2003). Moreover, business expenditure has both exogenous and endogenous components, positively influenced by a specific and targeted type of public expenditure.

Table 1. Classification of demand component

<table>
<thead>
<tr>
<th>Capacity Creating</th>
<th>Non–Capacity Creating</th>
</tr>
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<tbody>
<tr>
<td><strong>Exogenous</strong></td>
<td>Government expenditures, Autonomous consumption, Autonomous business expenditure and Autonomous taxes</td>
</tr>
<tr>
<td><strong>Endogenous</strong></td>
<td>Gross Investment</td>
</tr>
</tbody>
</table>

For the sake of simplicity, we consider a close economy with a government sector and two social classes (workers and capitalists).\(^2\) The current level of output \(Y\) is equal to aggregate demand, which is the sum of consumption \(C\), business expenditure \(BE\), gross investment \(I_i\), and public expenditure \(G\). This is equation (1):

\(^2\) We are assuming a closed economy as we are aware that in an open economy, external constraints can arise and the growth rate of a country can be limited by the balance of payment (see among others Thirlwall, 1979; Cesaratto, 2015).
All variables summarized in equation (1) are considered in real terms. Equations (2) and (3) represent respectively the total consumption of workers ($C_w$) and of capitalists ($C_{\Pi}$), which include an autonomous and an induced component. The former is independent of current income and could be financed in the credit market via an endogenous money creation process (Pariboni, 2016b). The latter is an induced component dependent on the disposable income of workers ($Y_{Dw}$) and capitalists ($Y_{D\Pi}$).

\begin{align*}
C_w &= C_{aw} + c_w \ast Y_{Dw} \\
C_{\Pi} &= C_{a\Pi} + c_{\Pi} \ast Y_{D\Pi}
\end{align*}

$c_{aw}$ and $C_{a\Pi}$ represent autonomous consumption. $c_w$ and $c_{\Pi}$ are respectively the workers’ and the capitalists’ marginal propensity to consume, and we assume that $c_w > c_{\Pi}$ (Kaldor, 1955). We derive the total consumption function (4) by combing equation (2) and (3) and by substituting total taxes ($T = T_w + T_{\Pi}$) and wage and profit shares to disposable incomes ($Y_{Dw}$ and $Y_{D\Pi}$).³ Where $Y_{Dw} \equiv \omega \ast Y - T_w$, $Y_{D\Pi} \equiv (1 - \omega) \ast Y - T_{\Pi}$, $T_w \equiv T_{aw} + t_w \ast \omega \ast Y$, and $T_{\Pi} \equiv T_{a\Pi} + t_{\Pi} \ast (1 - \omega) \ast Y$.

\begin{align*}
C &= C_a - c_w \ast (T_{aw}) - c_{\Pi} \ast (T_{a\Pi}) + [c_w \ast \omega \ast (1 - t_w) + c_{\Pi} \ast (1 - \omega) \ast (1 - t_{\Pi})] \ast Y
\end{align*}

³ Following the Sraffian and, more in general, the classical tradition, income distribution is considered exogenously determined by social and historical factors and by the bargaining power of two opposite classes, namely workers and capitalists. However, a recent paper published by Palley (2018) introduced the labor market and considered the wage share as endogenously determined by the bargaining power of the two different social classes. Specifically, Palley (2018, p. 14) writes: “a higher unemployment rate and weaker worker bargaining power may increase the profit share (i.e., lower the wage share).” As such an analysis goes beyond this paper’s aim, we assume an exogenous income distribution for the sake of simplicity.
The total autonomous consumption is $C_a$, where $C_a = C_{aw} + C_{a\Pi}$. $T_{aw}$ and $T_{a\Pi}$ are the autonomous taxes to workers and capitalists. $\omega$ is the wage share, and $1 - \omega$ is the profit share. $t_w$ and $t_{\Pi}$ are respectively the workers’ and the capitalists’ tax rates.\footnote{Total taxes depend both on an autonomous component and on an endogenous component related to wage and profit shares.}

$$I_i = v \ast (d + g_e) \ast Y \tag{5}$$

The gross investment function is represented in equation (5). In the SSM, gross investment ($I_i$) is fully induced and is positively affected by the replacement coefficient or also termed the rate of depreciation of capital ($d$) and by the capital-normal output ratio ($v$) that represents cost minimizing technical conditions of production.\footnote{Following Girardi and Pariboni (2016), we assume that the actual degree of capacity utilization is equal to the ratio between the actual level of output and the normal level of output. Hence, the normal degree of capacity utilization is equal to one. Subsequently $v = K/y^n$, where $K$ is the actual capital stock and $y^n$ is the normal level of output desired by entrepreneurs. In other words, $y^n$ is the desired output that firms would like to produce given the amount of capital $K$.} Furthermore, the actual level of effective demand and the expected trend growth of effective demand ($g_e$) have a positive influence on the level of investment. In other words, firms increase their capital stock by increasing the level of their investment in order to satisfy a greater expected demand for goods and services.\footnote{Additionally, investment changes when technical innovations occur (Garegnani, 2015). Specifically, innovation produces persistent effects on gross investment by changing the capital-output ratio ($v$) and the depreciation rate ($d$) as new technologies are principally embodied in new capital goods (Dosi et al., 2010).} Additionally, following the “capital controversy,” a demand for investment elastic with respect to the interest rate and the idea of a downward-sloping investment demand function are discarded.\footnote{The “Capital Controversy” provides the theoretical background to refute the existence of a decreasing marginal productivity of capital, a demand for investment elastic with respect to the interest rate, and a natural interest rate that equates investment to full-employment savings. According to Sraffa (1960) and Garegnani (1970), when we assume several production techniques and heterogeneous capital goods, the re-switching of techniques and the reverse capital deepening undermine the neoclassical assumption based on the substitution mechanisms between capital and labor. To be clear, different interest rates allow producers to use the same method of production and therefore the same factor intensity (Garegnani, 1970). Subsequently, we cannot sketch a downward-sloping investment demand schedule summarizing a general negative relationship between} For this reason, the real interest rate is not introduced in equation (5) as a determinant of investment.
Furthermore, the investment function in equation 5 does not imply that the actual
degree of capacity utilization \((u)\) is equal to the normal degree or is desired by entrepreneurs
\((u_n)\), but that a continuous process of adjustment toward the latter is operational. \(u_n\) can be
defined as the normal degree of capacity utilization that minimizes the costs of production
(Kurz, 1986; Girardi and Pariboni, 2018).\(^8\) In the short run, the equilibrium between saving
and investment is achieved by a flexible degree of capacity utilization. In the long run, a slow
and gradual adjustment of the capital stock is driven by changes in long-term expectations
\((g_e)\) and by a flexible accelerator mechanism. However, as firms know that demand
fluctuates, entrepreneurs do not consider any changes in demand as a stable and permanent
change. Further, they adjust their capital stock by increasing (when \(g_y > g_e\)) and decreasing
(when \(g_y < g_e\)) investment gradually over time rather than in one single period through a
flexible accelerator process.\(^9\)

\[ G = G_1 + G_2 \]  

(6)

Equation (6) represents government spending, which is composed of two types of public
expenditure. The former is based on the purchase of goods and services that are directly
fruited \((G_1)\), and the latter is oriented to promoting structural change, namely stimulating

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\(^8\) We define the degree of capacity utilization as the ratio between actual and normal output. It follows that
normal utilization is equal to 1 (see also footnote 4).

\(^9\) As some fluctuations of demand are not considered permanent, entrepreneurs do not immediately undertake a
full adjustment of productive capacity to effective demand; rather, such adjustments occur by a flexible
accelerator process. Notwithstanding, a flexible degree of capacity utilization allows firms to meet all expected
peaks of demand with the current installed capacity (Ciccone, 1986).
technical progress by means of industrial policies ($G_2$). For instance, among the latter, we can include mission-oriented innovation expenditures, which have led to major technological advances, such as the DARPA (Department of Defense) investment on ARPANET, which became the modern-day internet; the ARPA-E (Department of Energy) investments in renewable energy; or the National Institutes of Health investments in the biotechnology sector (Block and Keller, 2009; Mazzucato, 2013, 2018; Bonvillian, 2018). This kind of public expenditure represents a crucial channel through which governments foster and shape innovation processes. Such policies are the most important forward-looking industrial policy oriented to finding solutions for technical problems (Pivetti, 1992), speeding up innovation (Moretti et al., 2016), and stimulating productivity growth (Tavani and Zamparelli, 2018), by leading to new technological opportunities and directions for technical change (Mazzucato, 2013).

$$BE = BE_a + \gamma \ast G_2$$

Equation (7) shows the business expenditure (BE). In BE, we can include managerial expenses, for example, unproductive consumption and R&D private expenditures. However, we split BE into exogenous and endogenous components. In particular, we consider as autonomous $BE_a$, the abovementioned unproductive consumption, such as the purchase of a company car, executive jet, marketing expenditure, etc., and a share of R&D due to an intrinsic capitalist competition. However, firms’ R&D is composed of an endogenous component driven by public expenditure oriented to promote innovation. In other words, specific and target types of public spending, for example, military expenditure, are able to induce and positively influence R&D of private firms (Mazzucato, 2016, 2018; Moretti et al., 2016; Cantner and Vannuccini, 2018; Kattel and Mazzucato, 2018) by generating spin-offs
through which research and innovation are developed and diffused to other sectors, including sectors that satisfy civilian wants and needs (Pivetti, 1992; Mowery, 2010; Crespi and Guarascio, 2018). In each of the above cases, state intervention created a new landscape (rather than simply fixing market failures), which increased private expenditure by means of a mechanism usually termed the crowding-in effect (Mazzucato, 2016, 2018; Kattel and Mazzucato, 2018). Following this reasoning, a crowding-in process may occur for several reasons. First, targeted government expenditures aimed at promoting innovation and creating new markets can stimulate the expectations of business (Mazzucato, 2018). Second, government R&D investment generates technological spillovers that create advantages for other private firms (Moretti and Wilson, 2014). Third, typically R&D activities are based on large fixed costs (for instance, labs, high-skilled labor, and research activities) that can be used for multiple projects. If government finances part of these costs, some of the private R&D investment projects become profitable for private firms (Moretti et al., 2016). Fourth, defense R&D investment affects private R&D by generating spinoffs in both civilian and defense-related industries (Pivetti, 1992; Mowery, 2010). Fifth, public-funded R&D activities could relax financial and credit constraints by lowering the firms’ riskiness associated to such activities (Moretti et al., 2016).

For the abovementioned arguments, we introduce in equation (7) \( \gamma \) – a reaction coefficient greater than zero – that shows how an increase of \( G_2 \) leads to an endogenous rise in firms’ BE. In particular, the size of \( \gamma \) depends on the capacity of industrial policy to capture and involve more sectors in the economy. For instance, an industrial policy focused on one specific sector will show a lower \( \gamma \) compared to a policy that involves several sectors across the economy, as in the case of mission-oriented spending (Mazzucato, 2018).

Equation (1), along with equations (4) to (7), together allow us to obtain the output supermultiplier. Equation (8) shows that the level of output is determined by an autonomous
component of aggregate demand (numerator of equation (8)) and by the supermultiplier (denominator of equation (8)). As shown in equation (8), government spending targeted toward strategic sectors ($G_2$) – as in the case of mission-oriented innovation policies – generates the greatest effects in terms of output growth, while changes in capitalists’ taxes ($T_a\Pi$) produce the lowest effect on GDP.

$$Y = \frac{C_a - c_w \star (T_{aw}) - C_{\Pi} \star (T_{a\Pi}) + BE_a + G_1 + (1 + \gamma) \star G_2}{1 - [c_w \star \omega \star (1 - t_w) + c_{\Pi} \star (1 - \omega) \star (1 - t_{\Pi})] - v \star (d + g_o)}$$ (8)

The numerator of equation (8) is characterized by autonomous components of aggregate demand that, for the sake of simplicity, we call $Z$ in equation (9)

$$Z = C_a - c_w \star (T_{aw}) - C_{\Pi} \star (T_{a\Pi}) + BE_a + G_1 + (1 + \gamma) \star G_2$$ (9)

Moreover, in equation (10), we can denominate the marginal propensity to save as $s$

$$s = 1 - [c_w \star \omega \star (1 - t_w) + c_{\Pi} \star (1 - \omega) \star (1 - t_{\Pi})]$$ (10)

Subsequently, we can substitute equations (9) and (10) in equation (8), and the output supermultiplier can be represented by equation (8.1):

$$Y = \frac{Z}{s - v \star (d + g_o)}$$ (8.1)

As shown in equation (8.1), a rise in the autonomous components of aggregate demand, as well as a reduction in the marginal propensity to save, leads to an increase in total output.

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10 In order to have an economically significant solution, the denominator of equation (8) must be positive.
However, whereas the output trend growth rate is driven by the trend growth rate of the autonomous components (Z), a change in marginal propensity to consume causes a permanent level effect (Freitas and Serrano, 2015). For instance, a single decrease in the marginal propensity to save – for example, determined by an increase in wages share – generates a higher rate of growth of output only in the period immediately after the change of distribution. Notwithstanding, when the supermultiplier effect vanishes, the economy resumes growing at the autonomous components rate (g_z).

Moreover, the output level represented by equation (8.1) is not necessarily combined with a normal degree of the capacity utilization (u_n). However, u_n must be considered as a center of gravitation toward which the actual degree of capacity utilization (u) is presumed to be attracted. This attraction occurs through a continuous tendency of productive capacity to adjust to the trend of effective demand by means of slow, gradual changes in investment behavior (Cesaratto et al., 2003). Such changes occur by means of reconsiderations by entrepreneurs about the expected trend rate of growth of the effective demand (g_e), based on the current rate of growth (g_y). The behavior through time of long-term expectations about the growth of effective demand can be represented by equation (11):

\[ \dot{g}_e = x \ast (g_y - g_e) \quad (11) \]

where x is a reaction coefficient. If x is equal to 1, equation (11) shows a rigid accelerator process. However, because some fluctuations of demand cannot be considered by firms as permanent, a gradual adjustment driven by a flexible accelerator is operative. Hence, x assumes positive values less than 1 (0 < x < 1). As shown in equation (11), the gradual process of the revision of the expectations allows a tendency to the alignment of the actual output growth rate, the expected growth rate, and the rate of growth of capacity. Any
discrepancy between $g_e$ and $g_y$ also denotes a difference between the rate of growth of capacity and the output growth rate. To clarify this issue, it can be useful to start our analysis by simply assuming a fully adjusted position in which normal capacity utilization ($u_n$) is realized. If a divergence between the actual and the expected rate of growth occurs, this leads to a symmetrical deviation of the level of output to the level of normal output, and thus a symmetrical discrepancy between $u$ and $u_n$. The process described by equation (11) allows the required adjustment in the capacity by means of changes in investment (Pariboni, 2015, p. 50). Such a process ceases in the fully adjusted position where $u = u_n$ and $g_y = g_z$.

Analyzing dynamically equation (8.1), we can represent the rate of growth of output in equation (12):

$$g_y = g_z + \frac{v^*(g_e)}{s-v*(d+g_e)}$$

(12)

where $g_z$ is the rate of growth of the autonomous components of aggregate demand, and $g_e$ represents the change over time of the expected trend growth rate of demand. Analyzing dynamically investment function (5), the rate of growth of investment ($g_I$) can be summarized by equation (13):

$$g_I = g_y + \frac{\dot{g}_e}{d+g_e}$$

(13)

11 For an in-depth review on the notion of a fully adjusted position, see among others Serrano (1995), Cesaratto et al. (2003), Cesaratto (2015), and Freitas and Serrano (2015). Additionally, for a review of the static and local dynamic stability conditions of the SSM, see Freitas and Serrano (2015) and Lavoie (2016). Furthermore, for the stability condition of this specific model based on the investment function as in equation (5), see Pariboni (2015) (Appendix A, pp. 87–89, equations A9–A11). Specifically, to have the local stability of the model, the marginal propensity to spend has to be less than one. In our model, $v*(x + d + g_z) + c_w*\omega*(1-t_w) + c_\Pi*(1-\omega)*(1-t_\Pi) < 1.$
meaning that the rate of growth of investment depends on the growth rate of current output and the evolution of expected demand.\footnote{As shown in Deleidi and Mazzucato (2018) and equations (11) and (13), only during the transition toward a new fully adjusted position, an increase in the rate of growth of \( G_2 \) generates the greatest effect in terms of output growth, as compared to the remaining variables controlled by the government. As a consequence, government spending targeted toward strategic sectors (\( G_2 \)) (e.g., mission-oriented innovation policies) – by generating the greatest effect in terms of output growth during the transition from one to a new fully adjusted position – produces the largest effect on expectations of growth (equation 11) and therefore on investment growth (equation 13).}

Additionally, by starting from equation (5) and defining rate of growth of capital as \( g_k = \frac{1}{K} - d \), we can write \( g_k \) as follows in equation (14):

\[
g_k = u (d + g_e) - d
\]

Equation (14) shows that for a given \( g_e \), the accumulation depends on the realized degree of capacity utilization and firms will accumulate faster when \( u \) is higher. Specifically, when \( g_k = g_e \), \( u \) is equal to 1 and \( u = u_n = 1 \) (see also footnote 4); when \( g_k > g_e \), \( u > u_n \) and therefore \( u > 1 \); finally, when \( g_k < g_e \), \( u < u_n \) and then \( u < 1 \).

In light of this model, we can understand that the rate of output growth and investment is strictly related to the rate of growth of autonomous components of aggregate demand passing through a multiplier and an accelerator effect. Therefore, stimulating aggregate demand becomes necessary in terms of output and investment growth, not only during a period of economic slowdown or only in the short run, but in the long run when the possibility of creating new resources and new productive capacity increases and it becomes particularly relevant. In line with other theoretical approaches, among which are the recent “Schumpeter meets Keynes” family of models (Dosi et al., 2010, 2017), fiscal austerity measures negatively affect macroeconomic performances, and simultaneously, expansionary fiscal policies generate positive effects on output throughout the business cycle. Furthermore, if expansionary policies are sufficiently persistent to change entrepreneurs’ expectations of
growth \( (g_e) \), gross investment also has to increase in order to satisfy a greater expected demand for goods and services.

3. Data, methods, and model

To assess the relationships predicted by the macroeconomic model developed in Section 2, we will estimate the effect of mission-oriented innovation policies on selected macroeconomic variables, namely on the level of GDP and on private investment in research and development (R&D). The impact of fiscal policies on GDP and on its component is usually measured through the estimations of the so-called fiscal multipliers, namely the output response to an exogenous fiscal policy shock. In recent years, the debate around the magnitude of fiscal multipliers has assumed particular relevance, especially after the US financial crisis. However, little to no literature exists on the macroeconomic effects of mission-oriented innovation policies, especially in comparison with classes of public expenditure not targeted at promoting radical structural transformation in the economy.

The macroeconomic literature on fiscal policies is based on three main methods for estimating fiscal multipliers: (i) simulations built within dynamic stochastic general equilibrium (DSGE) models (see among others Leeper et al., 2017); (ii) the narrative approach, which consists in building dummy variables corresponding to exogenous historical episodes of changes in fiscal policy stances (see among others Ramey and Shapiro; 1998; Romer and Romer, 2010; Ramey, 2011, 2016); and (iii) Structural Vector Autoregression (SVAR) models, which allow us to isolate exogenous components of the fiscal variables by imposing an identification strategy (see among others Blanchard and Perotti, 2002; Perotti, 2004, 2014; Caldara and Kamps, 2008; Auerbach and Gorodnichenko, 2012). The SVAR method enables us to consider the effects of a broader set of fiscal interventions and to provide an objective quantitative estimate of the effects of an average increase in different
classes of government expenditures. This approach can be regarded as the most general approach as results are not affected by (i) the choice of parameters and the calibration of models, or (ii) the selection of the relevant dummies, which relies on a more qualitative and subjective assessment of the nature of the fiscal episodes.

In parallel to the fiscal multiplier literature, a widespread – though mixed – empirical literature has estimated the effect of alternative types of fiscal policies and effective demand on the level of private investment in R&D. Specifically, Moretti et al. (2016) find strong evidence of a crowd-in effect in defense expenditures. Similarly, Slavtchev and Wiederhold (2016) find that a $1.00 increase in high-tech procurement raises private R&D of $0.21. Geroski and Walters (1995) and Kleinknecht and Brouwer (1999) find a positive effect of the level of effective demand and economic activity on private investment in R&D. In contrast, other studies have supported the idea that the government R&D expenditures crowd out private R&D investment (see among others Bronzini and Iachini, 2014; Goolsbee, 1998; Wallsten, 2000). Specifically, according to the supporters of the crowding-out thesis, “demand shocks” are supposed to: (i) displace scientific and engineering manpower because of an inelastic short run labor supply (Goolsbee, 1998); (ii) increase the level of prices rather than real private R&D investment (Lichtenberg, 1989; 1995; Walker, 1993; Cowan and Foray, 1995).

In the present paper, we will make use of the SVAR model to estimate the effect of alternative classes of fiscal policy for the US economy, considering the period 1947Q1–2018Q3. The estimated SVAR will enable us to simultaneously assess:

1. the magnitude of the fiscal multipliers associated with alternative types of fiscal policies, namely mission-oriented innovation, and generic policies;
2. the effect on private R&D expenditures (crowding-in versus crowding-out effect) generated by the two considered fiscal policies.
Compared to existing literature, this is the first paper to: (i) estimate the fiscal multiplier associated to mission-oriented innovation policies; and (ii) analyze the effect generated by different classes of government spending on GDP and on private investment in R&D.

3.1. Data

To estimate the effect of different classes of public expenditures, we make use of quarterly data for the US economy provided by the Bureau of Economic Analysis (BEA) for the 1947–2018 period. Specifically, the gross domestic product (Y), government consumption and investment expenditures (G), and private research and development expenditure (R&D) are the variables included in the dataset. To account for the effects of different classes of spending, we break down G as follows: (i) G_MO, which is the federal national defense government gross investment in research and development; and (ii) G_R, which is the residual of total government expenditure G when G_MO is subtracted. Following Mowery (2010, pp. 1221–1223), G_MO – which is defense-related R&D funded by public agencies – can be regarded as an example of mission-oriented R&D, where the defense component represents the most important part. Thus, the public defense R&D investment is our proxy for capturing the effect on GDP and on private R&D of mission-oriented innovation policies (G_MO).\(^\text{13}\)

All variables are expressed in real terms as they are divided by the Implicit Price Deflator (2012 base year). As variables are considered in logarithm form and thus findings are expressed in elasticities, it is necessary to multiply each coefficient by the corresponding ex-post conversion factor to obtain the partial derivatives. Only after this transformation do

\(^{13}\) Following Auerbach and Gorodnichenko (2017) and Ramey and Zubairy (2018), taxes are not included in the model as these do not alter the estimates of fiscal multipliers, and the identification of an unanticipated shock to taxes has a higher data requirement compared to the identification of a government spending shock.
coefficients express dollar-change in Y and in R&D, in response to a one-dollar increase in the selected government expenditure. All variables are summarized in Table 2.

Table 2. US Data and Description

<table>
<thead>
<tr>
<th>Data</th>
<th>Description</th>
<th>BEA code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>Gross Domestic Product (GDP)</td>
<td>A191RC</td>
</tr>
<tr>
<td>G</td>
<td>Total Government Consumption Expenditures and Gross Investment</td>
<td>A822RC</td>
</tr>
<tr>
<td>G_MO</td>
<td>Federal National Defence Government Gross Investment, Research and Development</td>
<td>Y076RC</td>
</tr>
<tr>
<td>G_R</td>
<td>Total Government Consumption Expenditures and Gross Investment (excluded G_MO) ( G_R = G-G_MO )</td>
<td>Y006RC</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Gross Private Domestic Investment (R&amp;D), Research and Development</td>
<td>Y006RC</td>
</tr>
<tr>
<td>DEF</td>
<td>GDP Implicit Price Deflator, Index 2012=100</td>
<td>A191RD</td>
</tr>
</tbody>
</table>

3.2. Methods

In this paper, the SVAR methodology is used to detect the effect of G_MO and G_R on R&D and Y. The model includes four variables: G_MO, G_R, R&D, and Y.

As a first step, a standard unit root test is conducted to understand the order of integration of the variables. For this purpose, the Phillips-Perron Test is performed (Phillips and Perron, 1988). As shown in Appendix A.1. (Table A.1), all considered variables are I(1) at level and becomes I(0) when the first difference is considered. Therefore, we make use of variables at the first difference in order to remove trends from the dataset. Secondly, we conduct the optimal lag length of the VAR by minimizing the Akaike Information Criterion (AIC), which suggests 5 quarters as the optimal lag (Appendix A.2., Table A.2).

To estimate a SVAR model, we start by estimating a reduced-form VAR(p) as shown in equation (15):

\[
y_t = c + \sum_{i=1}^{p} A_i y_{t-p} + u_t \quad (15)
\]

The ratios used in the ex-post transformation from elasticities to partial derivatives are calculated as follows: R&D/G_R; R&D/G_MO; Y/G_R; and Y/G_MO. They assume the following values respectively: 0.067; 2.68; 5.05; and 187.26.
where $y_t$ is the $k \times 1$ vector of considered variables, $c$ is the constant term, $A_i$ is the $k \times k$ matrix of reduced-form coefficients, and $u_t$ is a $k \times 1$ vector composed by the error terms.

To study the effect of changes in different classes of government spending on GDP and R&D, we need to isolate the exogenous changes in the fiscal policy stances. To do this, an identification strategy is imposed on the reduced-form VAR($p$), which in turn makes it possible to obtain a SVAR($p$). More formally, a SVAR($p$) can be represented as follows in equation (16) (Kilian and Lütkepohl, 2017):

$$B_0y_t = c + \sum_{i=1}^{p} B_i y_{t-p} + w_t \quad (16)$$

where $B_0$ represents the matrix of contemporaneous relationships between the $k$ variables in $y_t$, $B_i$ is the $k \times k$ matrix of autoregressive slope coefficients, and $w_t$ is the vector of serially uncorrelated structural shocks (Kilian and Lütkepohl, 2017). The covariance matrix of structural errors is normalized: $\mathbb{E}(w_tw_t') = \Sigma_w = I_K$. The identification of the structural model requires us to impose at least $(k^2 - k)/2$ restrictions on $B_0$, usually based on intuitions derived from economic theory (Kilian and Lütkepohl, 2017). The identification scheme is based on short-run exclusion restrictions and a recursive ordering. Specifically, by imposing a lower-triangular structure, the identification strategies used can be summarized as follows in equation (17):

$$B_0y_t = \begin{bmatrix} - & 0 & 0 & 0 & G_{M_Ot} \\ - & - & 0 & 0 & G_{R_t} \\ - & - & - & 0 & R&D_t \\ - & - & - & - & Y_t \end{bmatrix} \quad (17)$$
where ‘–’ indicates an unrestricted parameter and 0 represents zero restriction. In the spirit of Auerbach and Gorodnichenko (2012) and of industrial economic literature (Mowery 2010, Moretti et al., 2016), G_MO is regarded as the most exogenous variable. Within the quarter, G_MO is completely independent of other variables considered in the model as it is assumed to not respond to contemporaneous changes in G_R, R&D, and Y. Such a choice is dictated by the fact that military R&D expenditures are strategic investment, which can be considered as an exogenous component as “allocation decisions were based on assessments by policymakers of the research needs of specific agency missions” (Mowery, 2010, p. 1223). Specifically, changes in military R&D can be considered as exogenous variations reflecting political and military priorities that are independent from, for example, productivity shocks (Moretti et al., 2016). In the second equation, the residual government spending G_R can be affected only by G_MO. In the third equation, private R&D investment is affected within the quarter by G_R and G_MO, but not by the GDP. Here, we assume that firms – in order to change their investments in R&D – have to perceived permanent changes in the level of GDP that cannot be verified in one quarter only. Finally, the fourth equation defines that GDP can be potentially affected by all the other three variables within the same quarter.

After the imposition of restrictions on the contemporaneous matrix, the estimation of \( B_0 \) is implemented by means of the maximum likelihood estimator. Once we have estimated \( B_0 \), we calculate the impulse response function (IRF) as shown in equation (18):

\[
y_t = \mu + \sum_{i=0}^{\infty} \theta_i w_{t-i} \quad (18)
\]

where \( \theta_n \) represents the response of the variables in \( y_t \) to a 1% increase in one of the shocks contained in \( w_t \) after \( n \) quarters have passed. As our variables are expressed in logarithms,
the original IRFs are rescaled by an *ex-post* conversion factor that allows us to convert elasticities into partial derivatives. Only after this transformation can we interpret coefficients as the response of GDP (Y) to a one-dollar increase in government spending. Finally, standard errors are estimated through a Monte Carlo procedure based on 1000 repetitions, and, following Blanchard and Perotti (2002), IRFs are reported with one standard error bound, namely a 68% confidence interval.\(^\text{15}\)

4. Findings

In this section, we report the findings of the estimated SVAR by showing impulse response functions (IRFs) as well as the cumulative multiplier. Specifically, when the IRFs are estimated, the government spending shock is equal to one dollar at the impact, while the dynamic of the shock can change throughout the selected period. To be precise, an exogenous increase in government spending is usually accompanied by a persistent dynamic, implying that an initial government spending shock may build up over time, stabilizing on a value greater than one. This clarification is necessary to comprehend the difference between the IRF, which shows the dynamic effect at some horizon of the response variable after to an initial shock – and the “cumulative multiplier,” which represents the response of Y per unit of government spending. In our analysis, the cumulative multipliers are estimated through the ratio between the cumulative variation of Y and the cumulative change in the considered public expenditure (Spilimbergo et al., 2009). The cumulative multiplier can be expressed as follows in equation (19):

$$M_{\text{cum}} = \frac{\sum_{j=0}^{n} \Delta Y_{(t+j)}}{\sum_{j=0}^{n} \Delta G_{(t+j)}} \quad (19)$$

\(^{15}\) Concerning the choice of standard error bands, see Sims and Zha (1999), Blanchard and Perotti (2002), and Kilian and Lütkepohl (2017, p. 334).
where $\sum_{j=0}^{n} \Delta Y_{(t+j)}$ is the sum of the GDP response (from $t$ to $t+n$) to the sum of the impulse of considered government spending $\sum_{j=0}^{n} \Delta G_{(t+j)}$ (from $t$ to $t+n$). In our analysis, the same estimations are carried out for private investment in R&D. Using this method, we can calculate the response of $Y$ and R&D per unit of spending. In the main text, we report the value assumed by IRFs and the cumulative multiplier after the $ex-post$ transformation. In Appendix B, the value of the elasticities is reported (Table B.1).

**Figure 1.** Impulse Response Functions.

68% confidence interval bands estimated through a Monte Carlo procedure, 1000 repetitions.
In Figure 1, the estimated IRFs show the dynamic response of \( Y \) and R&D to different exogenous public government shocks, namely \( G_{MO} \) and \( G_{R} \). Findings show that mission-oriented innovation policies – proxied by military R&D expenditures \( G_{MO} \) – generate a larger and positive effect both on GDP and on private R&D investment than \( G_{R} \). Moreover, in line with hysteresis literature (Fatás and Summers, 2016; Yellen, 2016), our results illustrate that demand management policies are able to generate permanent and persistent effects on the level of output. Particularly, an increase in government expenditures is found to create a positive and permanent effect both on the level of output and on private investment in R&D.

IRFs in Figure 1 show that an exogenous shock to \( G_{MO} \) and \( G_{R} \) is found to be persistent: \( G_{MO} \) reaches a peak value of 10.63 after 8 years, whereas \( G_{R} \) attains a value of 2.52 after 14 quarters and remains close to that level even after 8 years. When we look at the effect of mission-oriented expenditures \( G_{MO} \) on \( Y \) (Table 3), the multiplier is significant and equal to 23.957 on impact and reaches a peak after 4 quarters assuming a significant value of 54.941. The long-run multiplier, estimated at a horizon of 32 quarters, is not significant and equal to 43.402. The effect of \( G_{MO} \) on private investment in R&D is significant at all considered horizons. Specifically, a \( G_{MO} \) shock generates an effect of 0.745 at the impact and creates a peak of 6.015 after 32 quarters. In this case, the long-run effect on R&D and the peak effect correspond. As shown in Figure 1, an exogenous shock to \( G_{R} \), which represents an increase in government consumption expenditures and gross investment (excluded \( G_{MO} \)), yields a significant effect on \( Y \) at all considered horizons. When the effect on \( Y \) is analyzed, \( G_{R} \) creates an impact multiplier of 0.741, a peak effect after 10 quarters of 1.866 and a long-run multiplier of 1.545. The effect of a \( G_{R} \) shock on R&D is significant only after 7 quarters; it reaches a significant maximum effect of 0.09 after

\[ \text{For the sake of simplicity, we do not report in Figure 1 the response of } G_{R} \text{ to } G_{MO} \text{ and of } G_{MO} \text{ to } G_{R}. \]
18 quarters and a significant long-run effect of 0.088 after 32 quarters. The IRFs reported in Figure 1 and Table 3 provide a clear picture: Mission-oriented 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 $G_R$.

Finally, cumulative multipliers on $Y$ and R&D generated by a one-dollar increase in $G_MO$ and $G_R$ are summarized in Table 4. $G_MO$ generates a significant increase in $Y$ equal to 23.957 at the impact and a non-significant long-run cumulative multiplier of 5.764 after 32 quarters. When the effect of $G_MO$ on private R&D is evaluated, a one-dollar increase in $G_MO$ leads to a significant peak effect at the impact equal to 0.745 and a significant long-run cumulative effect of 0.628 after 32 quarters. The effect per one-unit of spending generated by $G_R$ is lower than the effect generated by $G_MO$. Particularly, $G_R$ produces a peak cumulative multiplier at the impact equal to 0.741 and a long-run cumulative multiplier of 0.631 after 32 quarters. The effect per one-unit of spending generated by $G_R$ on R&D is negative and not significant at the impact but reaches a peak effect of 0.03 after 32 quarters.

<table>
<thead>
<tr>
<th>Table 3. Impulse Response Function</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Shock G_MO</th>
<th></th>
<th>Shock G_R</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R&amp;D</td>
<td>Y</td>
<td>R&amp;D</td>
<td>Y</td>
</tr>
<tr>
<td>Q1</td>
<td>0.745</td>
<td>23.957</td>
<td>-0.004</td>
<td>0.741</td>
</tr>
<tr>
<td>Q4</td>
<td>2.920</td>
<td>54.941</td>
<td>-0.008</td>
<td>0.963</td>
</tr>
<tr>
<td>Q8</td>
<td>4.339</td>
<td>46.678</td>
<td>0.070</td>
<td>1.513</td>
</tr>
<tr>
<td>Q12</td>
<td>5.572</td>
<td>51.949</td>
<td>0.080</td>
<td>1.764</td>
</tr>
<tr>
<td>Q16</td>
<td>5.720</td>
<td>48.246</td>
<td>0.088</td>
<td>1.470</td>
</tr>
<tr>
<td>Q20</td>
<td>5.879</td>
<td>44.257</td>
<td>0.089</td>
<td>1.599</td>
</tr>
<tr>
<td>Q24</td>
<td>5.942</td>
<td>45.278</td>
<td>0.088</td>
<td>1.541</td>
</tr>
<tr>
<td>Q28</td>
<td>5.971</td>
<td>43.402</td>
<td>0.089</td>
<td>1.550</td>
</tr>
<tr>
<td>Q32</td>
<td>6.015</td>
<td>43.402</td>
<td>0.088</td>
<td>1.545</td>
</tr>
<tr>
<td>Peak</td>
<td>6.015</td>
<td>54.941</td>
<td>0.090</td>
<td>1.866</td>
</tr>
</tbody>
</table>

(Q32) (Q4) (Q18) (Q10)

Significant estimates are indicated in bold.
Table 4. Cumulative Multiplier

<table>
<thead>
<tr>
<th></th>
<th>Shock G_MO</th>
<th></th>
<th></th>
<th>Shock G_R</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R&amp;D</td>
<td>Y</td>
<td>R&amp;D</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Q1</td>
<td>0.745</td>
<td>23.957</td>
<td>-0.004</td>
<td>0.741</td>
<td></td>
</tr>
<tr>
<td>Q4</td>
<td>0.646</td>
<td>16.060</td>
<td>-0.006</td>
<td>0.591</td>
<td></td>
</tr>
<tr>
<td>Q8</td>
<td>0.679</td>
<td>10.984</td>
<td>0.009</td>
<td>0.557</td>
<td></td>
</tr>
<tr>
<td>Q12</td>
<td>0.695</td>
<td>9.096</td>
<td>0.018</td>
<td>0.636</td>
<td></td>
</tr>
<tr>
<td>Q16</td>
<td>0.688</td>
<td>7.984</td>
<td>0.023</td>
<td>0.628</td>
<td></td>
</tr>
<tr>
<td>Q20</td>
<td>0.670</td>
<td>7.100</td>
<td>0.026</td>
<td>0.629</td>
<td></td>
</tr>
<tr>
<td>Q24</td>
<td>0.654</td>
<td>6.519</td>
<td>0.028</td>
<td>0.631</td>
<td></td>
</tr>
<tr>
<td>Q28</td>
<td>0.640</td>
<td>6.090</td>
<td>0.029</td>
<td>0.631</td>
<td></td>
</tr>
<tr>
<td>Q32</td>
<td>0.628</td>
<td>5.764</td>
<td>0.030</td>
<td>0.631</td>
<td></td>
</tr>
<tr>
<td>Peak</td>
<td>0.745</td>
<td>23.957</td>
<td>0.030</td>
<td>0.741</td>
<td></td>
</tr>
</tbody>
</table>

(Q1) (Q1) (Q32) (Q1)

Significant estimates are indicated in bold.

Our findings show that mission-oriented innovation policies – proxied by defense R&D expenditures – generate a larger and positive effect both on the level of GDP and on private R&D investment, as compared to generic public expenditures. Such results confirm the theoretical intuitions argued in Sections 2 and 3 as well as some of the insights of the supermultiplier model developed by Deleidi and Mazzucato (2018). Specifically, mission-oriented innovation policies are able to produce a larger fiscal multiplier and to determine a direct crowd-in effect than the effect of generic public expenditures. The crowd-in effect estimated on private R&D is in line with the findings proposed by Moretti et al., (2016). Conversely, our findings are in sharp contrast both with the idea that military spending is contractionary (Perotti, 2014) and with the idea that military R&D expenditures are supposed to generate a crowding-out effect on private R&D (see among others Bronzini and Iachini, 2014; Goolsbee, 1998; Wallsten, 2000). Consistent with the recent hysteresis literature (Fatás and Summers, 2016; Yellen, 2016), our findings show that changes in government spending produce a positive permanent effect on the level of output.
To summarize our results, we found that a substitutability between defense and non-defense private R&D investment does not exist, and in line with Moretti et al. (2016), there is strong evidence of a crowding-in effect. Additionally, mission-oriented innovation policies, proxied by military R&D expenditures, have a larger effect on the level of GDP and on private investment in R&D than generic government expenditures.

5. Concluding remarks

In the paper, we propose a theoretical macroeconomic model that combines the Sraffian supermultiplier framework, which sees the GDP growth as determined by the rate of growth of the autonomous component of demand – with the Neo-Schumpeterian framework, which underlines the relevant role of the state in shaping and directing innovation. The model combines the multiplier and accelerator effect and analyzes the macroeconomic effect generated by alternative fiscal policies by showing that expansionary fiscal policies generate a permanent and positive effect on the output level. In the model, private investment in R&D are introduced and positively related to the classes of public expenditures oriented to promoting structural change, as in the case of mission-oriented innovation policies. A permanent change in the rate of growth of public expenditures targeted toward strategic sectors and focused on the promotion of innovation and mission-oriented policies, generates the largest effect in terms of output and investment growth. Such public policies – by directly stimulating private business expenditure in R&D – create the largest supermultiplier, the highest expectations of growth, and thus the largest effect on private investment.

Additionally, a SVAR model is estimated for the US economy for the 1947–2018 period to assess the effect on GDP and on private investment in R&D of mission-oriented innovation policies and generic government expenditures. Following Mowery (2010), mission-oriented innovation policies are approximated through defense R&D expenditures.
Our estimates show that mission-oriented innovation policies generate a larger effect on the level of GDP than generic public expenditures. Similarly, such results are confirmed when the responses of private investment in R&D are estimated to different fiscal policy shocks: mission-oriented policies produce a stronger crowding-in effect on private R&D investment than generic public expenditures. Specifically, the estimated impulse response functions show that (i) mission-oriented innovation policies generate an impact multiplier of 23.957 and a peak effect on GDP equal to 54.941, as well as a response of private investment in R&D of 0.745 on impact, which reaches a peak effect of 6.015; (ii) conversely, generic public expenditures produce an impact multiplier of 0.741 and a peak effect of 1.866 as well as a non-significant effect on R&D on impact and a significant peak effect of 0.09. Our results confirm the thesis argued by the supporters of the hysteresis perspective, which states that aggregate demand and fiscal policies produce permanent effects on the level of output (Fatás and Summers, 2016; Yellen, 2016).

Our findings suggest that governments should carry out expansive fiscal policies, as they generate positive and permanent effects on output and on investments. However, in contrast to what the IMF (2014) affirmed in a paper entitled “Is It Time for an Infrastructure Push? The Macroeconomic Effects of Public Investment,” we believe that fiscal policies targeted toward the financing of mission-oriented innovation policies are the most efficient in terms of output and investment growth.
References


Appendices

Appendix A.

Appendix A.1.

Findings of the Phillips–Perron unit root test are represented in Table A.1. The test is carried out on all variables considered in the model: G_MO, G_R, R&D, and Y.

**Table A.1.** Unit root test (Phillips–Perron): Trend and intercept

<table>
<thead>
<tr>
<th>Variables</th>
<th>Level Adj. t-statistic</th>
<th>Level P-value</th>
<th>First difference Adj. t-statistic</th>
<th>First difference P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>G_MO</td>
<td>-2.028691</td>
<td>0.5827</td>
<td>-4.161801</td>
<td>0.0058</td>
</tr>
<tr>
<td>G_R</td>
<td>-2.647326</td>
<td>0.2597</td>
<td>-9.652815</td>
<td>0.0000</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>-1.863479</td>
<td>0.6708</td>
<td>-7.315828</td>
<td>0.0000</td>
</tr>
<tr>
<td>Y</td>
<td>-1.166139</td>
<td>0.9145</td>
<td>-11.37623</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

H₀: variables at level and at first difference have a unit root.

Appendix A.2.

**Table A.2.**

Findings of the lag selection based on the Akaike information criterion (AIC) are represented in Table A.2.

<table>
<thead>
<tr>
<th>Lag</th>
<th>AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-22.20299</td>
</tr>
<tr>
<td>1</td>
<td>-24.83965</td>
</tr>
<tr>
<td>2</td>
<td>-24.99617</td>
</tr>
<tr>
<td>3</td>
<td>-25.16099</td>
</tr>
<tr>
<td>4</td>
<td>-25.17647</td>
</tr>
<tr>
<td>5</td>
<td>-25.24551*</td>
</tr>
<tr>
<td>6</td>
<td>-25.23982</td>
</tr>
<tr>
<td>7</td>
<td>-25.21244</td>
</tr>
<tr>
<td>8</td>
<td>-25.23508</td>
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<td>9</td>
<td>-25.18044</td>
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<td>10</td>
<td>-25.14774</td>
</tr>
<tr>
<td>11</td>
<td>-25.11465</td>
</tr>
<tr>
<td>12</td>
<td>-25.07465</td>
</tr>
</tbody>
</table>
Appendix B.

The elasticities are presented in Tables B.1. To estimate fiscal multipliers, the elasticities are multiplied by \textit{ex-post} transformation factors, which are reported in the main text.

<table>
<thead>
<tr>
<th>Table B.1. Elasticities of R&amp;D and Y to G\textsubscript{MO} and G\textsubscript{R} shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>G\textsubscript{MO} Shock</td>
</tr>
<tr>
<td>R&amp;D</td>
</tr>
<tr>
<td>Q1</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Q2</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Q3</td>
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<tr>
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Standard errors are reported in ( )