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# Modelling public and private investment in innovation

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# Modelling public and private investment in innovation

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**Abstract**

In this paper we assess the contribution of investment in innovation to GDP growth in a macroeconometric model for the Italian economy. The analysis adopts the model for medium term forecasts (MeMo-It) developed by the Italian Statistical Institute (Istat), where investment is modeled by asset and institutional sector. Adopting this framework, we provide empirical evidence about the complementary relationship between private and public investment in R&D and software. Compared to the existing macroeconometric models, MeMo-It provides a novel framework for policy evaluation that makes possible the generation of alternative scenarios to assess the growth effect of specific policy measures tailored to sustain innovative investment. Our findings support the growth promoting effect of expansionary fiscal policy measures aimed at fostering public investment in innovation.

***JEL:*** E22, E27, O3, E60
***Keywords:*** Macroeconomic modeling, investment in innovation, R&D, software

# 1 Introduction

Business and government investments have been significantly affected by the global financial crisis with public investment remaining particularly low up to 2016. More recently, however, most of the EU member economies experienced a revived dynamism of capital accumulation mainly driven by the contribution of corporate investment (European Investment Bank [2019]). But the average rate of growth of total investment remains low relatively to the pre-crisis period. This is why a broad strand of literature started investigating and debating the causes of investment weakness in the advanced economies. The explanations highlight different drivers of the downturn such as weak aggregate demand, financial constraints, increased political and economic uncertainty or a mixture of them (Bussiere et al. [2015]). Other studies look at the public and private nature of investment emphasizing the relevance of the synergies between government and business sector and the role of public investment in innovation as a driver of long term growth (Archibugi and Filippetti [2018] or Hall et al. [2010] for a comprehensive review). This evidence stimulated also a revived interest in investment models and in the identification of the most effective policy measures to restore investment dynamics.

Existing macroeconomic empirical efforts have been focused either on the the identification of investment determinants as a whole or by asset (Rabanal and Lee [2010], Barkbu et al. [2015], Busetti et al. [2016] and Ketteni et al. [2015]) as well as on the interactions between private and public investment in R&D to test their complementarity/substitutability (David et al. [2000], Guellec and Van Pottelsberghe De La Potterie [2003], Zúñiga-Vicente et al. [2014] and Minniti and Venturini [2017]).
This paper offers a novel integrated approach to investment analysis providing a framework to analyze the synergies between private and public investment in a macro econometric model. The investigation of the factors affecting investment dynamics requires a multidimensional approach capable of taking into account the differential behavior of each asset type (tangible and/or intangible) as well as the institutional characteristics of the sector making the investment (public and/or private).

Our empirical analysis focuses on the Italian economy as Italy is a very good candidate to explore the potential impact of various policy measures to promote investment in innovation and its contribution to the economic recovery (European Commission [2019]) because it experienced particularly profound investment and productivity slowdown after the financial crisis. Further, Busetti et al. [2016] show that in Italy, both firms' and households' capital accumulation have been dampened by a rise in uncertainty, a deterioration in confidence, as well as by higher indebtedness and by tighter financing constraints.

We investigate the macroeconomic effect of an expansionary fiscal policy aimed at fostering public investment in intangible assets (Software and R&D) adopting the model for medium term forecasts built by the Italian Statistical Institute (MeMo-It, see [Bacchini et al., 2013]). Among the existing macroeconomic models, MeMo-It can be classified both as a theory and forecasting model (Blanchard [2018]) also fitting well the data (Pagan [2003]). Compared to the other main Italian macroeconomic models (Bagnai et al. [2017], Cicinelli et al. [2010], Bulligan et al. [2017]), the disaggregated structure of MeMo-It allows a relatively more focused evaluation of specific policy measures. This is even more so for the assessment of fiscal policy measures aimed at fostering investment expenditure as MeMo-It includes investment equations by asset (tangible and intangible).

Our findings support the growth promoting effect of expansionary fiscal policies aimed at fostering public investment in innovation as opposed to measures for public consumption.

The paper is organized as follows. Section 2 provides some descriptive evidence of investment trends in Italy, Germany, France and Spain while section 3 introduces our empirical framework. Section 4 illustrates the empirical results and some policy suggestions while section 5 concludes.

# 2 Investment trends in the EU

Since 2009, the European economies experienced a severe slowdown of capital accumulation that in the more vulnerable economies was mainly driven by declining government investment. More recently investment dynamics started to recover in the EU even if at a different pace in the member states and remaining weaker compared to the US as a large gap in both tangible and intangible investment persist across institutional sectors (European Investment Bank [2019]).

Figure 1 shows the GDP shares of investment for the larger EU economies over the years $2000 - 2017$. All countries have been affected by the financial turmoil but the speed of the recovery differs considerably among them.

In 2017, business sector investment regained strength in the EU fostered by the improvements of world economic outlook and by more favorable credit conditions. At the same time, public investment appeared sluggish and reaching the lowest value over the last 20 years in 2016 (2.7% of GDP, Figure 2). The GDP share of government investment showed a negative trend both in Italy and Spain over the whole period, while in Germany, remained stable

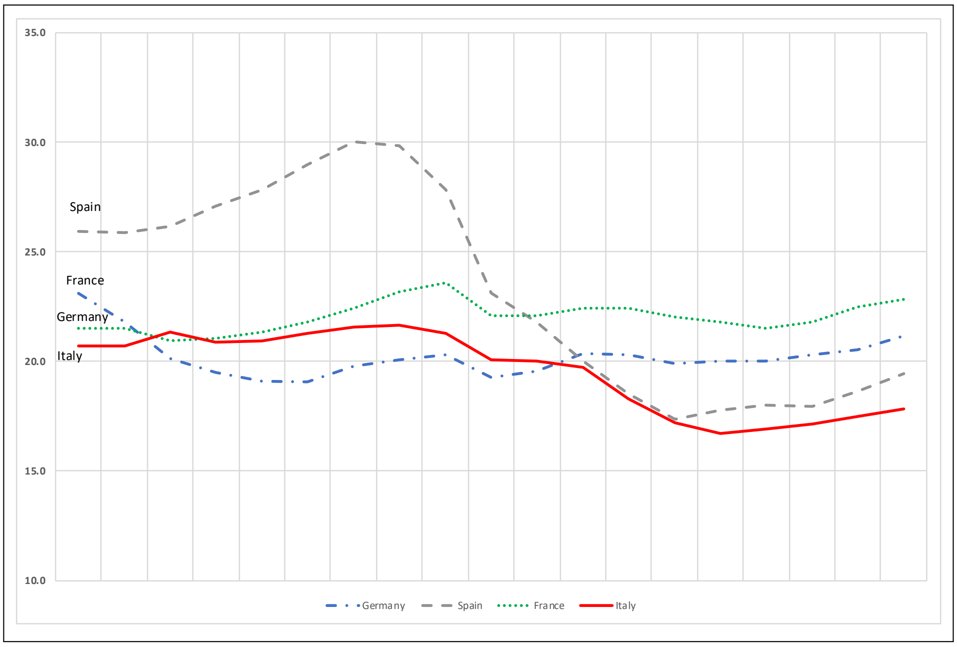


Figure 1: Investment shares of GDP

independently of the great recession.
The downturn of investment expenditure produced differentiated effects on productivity growth across the European economies partly attributable to the different composition of investment expenditure across countries.

The data suggest that traditional tangible investment and intellectual property products (IPP) were the main drivers of investment expenditure since 2013 (European Investment Bank [2019]). As for the tangibles, investment in machinery and equipment reached recently the highest level over the past 22 years remaining the main driver of overall investment growth in the vulnerable countries. On the other hand, IPP investment accounted for most of the recovery of total investment growth in the EU (European Commission [2019], Figure 3)[1]. In the post-crisis period, IPP investment increased in the sample economies driven to a large extent by R&D that gained relevance mainly in Germany, Italy and Spain even if the GDP share remained relatively low in the latter two economies. Software investment decreased significantly in Italy(-3.9%) and to a lesser extent in Germany (-1.2%), remained stable in Spain while surged in France (2.1%).

The individual components of IPP had rather heterogeneous trends across

[1]Unfortunately, data on IPP by asset and institutional sector are not publicly available for most of the EU economies so that we can provide descriptive comparative analysis only about IPP investment for the whole economy.

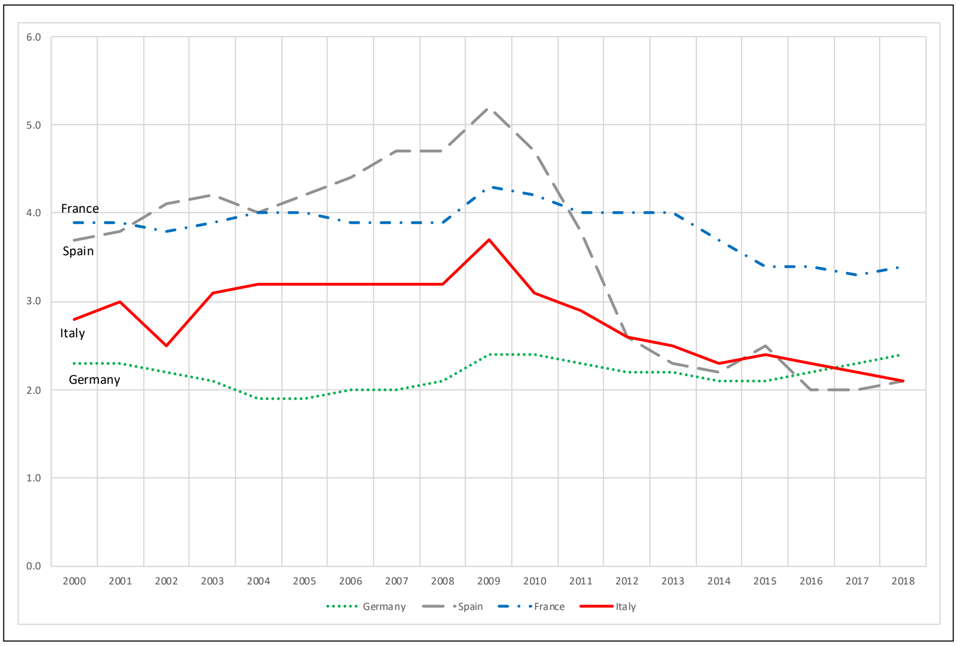


Figure 2: Government Investment shares of GDP


Figure 3: Investment in intellectual property products (Index 2010=100)

the four European economies suggesting that a deeper investigation of the contribution of R&D and software to economic growth in each country is warranted. The purpose of the analysis developed below is to evaluate the potential growth contribution of a fiscal measure aimed at fostering investment in innovation.

In this respect, the extent of investment in innovation is a key element to evaluate the factors affecting productivity growth differentials in the modern economies increasingly centered on intangible assets. This is the purpose of the analysis developed below.

# 3 The empirical framework

The development of an analytical framework for the evaluation of investment policy measures requires a multidimensional system capable of capturing the interactions between the different actors (private and public) involved in the process of capital accumulation and the synergies between the assets (tangible and /or intangible). This is even more relevant for investment in innovation for which both the asset characteristics and the public or private nature of expenditure entails a different impact on economic growth.

More generally, empirical macroeconomic studies on capital accumulation, either for innovative (intangible) or traditional (tangible) assets, rarely looked at investment by asset modeling the different nature of individual assets and their determinants in a macroeconomic framework. In this respect, Bacchini et al. [2018] offers a novel approach for capturing the different behavior of tangible and intangible investment in the short and long run. Another study adopting a similar approach is Ketteni et al. [2015], who investigates the impact of capital heterogeneity on productivity growth distinguishing between ICT, and NON-ICT capital. Further, only few studies were devoted to the development of a comprehensive econometric framework to model R&D and its interrelations with the economic system as this is a rather difficult task.

Macroeconometric analysis of R&D expenditure investigated mainly whether public R&D is either complementary or substitute for private R&D (David et al. [2000], Guellec and Van Pottelsberghe De La Potterie [2003], Zúñiga-Vicente et al. [2014], Minniti and Venturini [2017] and Soete et al. [2017]). On the other hand, the inclusion of R&D in the investment boundaries is a recent improvement in National Accounts (SNA, 2008).

This paper offers a novel approach to study investment by asset and institutional sector in a coherent macroeconomic framework for the Italian economy. Therefore, section 3.1 below introduces the main features of the model (MeMo-It, see [Bacchini et al., 2013]), and then the following sections focus on the system of investments equations by asset and institutional sector embodied in MeMo-It, and illustrate both the theoretical underpinnings (section 3.2) and the empirical results (section 3.3).

## 3.1 The macroeconometric framework: MeMo-It

The macroeconometric model for the Italian economy (MeMo-It) was built by the Italian national institute of statistics (Istat) for releasing the medium term economic projections ([Bacchini et al., 2013] and Istat [2018]). According to the model taxonomy recently introduced by Blanchard [2018], MeMo-It can be defined both a policy model and a forecasting tool lying between the classical Cowles Commission (Klein [1950], Fair [2009]) and the New Keynesian DSGE approach (Galí [2018]). Notice that these two approaches, as illustrated by Kozicki [2012] can be bridged thanks to the recent advancements in time series allowing to model jointly long-run relationships and short run dynamics [2]. This can be achieved thanks to the cointegration property of a block of variables invariant to the widening of the model. Further, each single block is consistent with theoretical and economic assumptions (Jansen [2002])[3].

Although the use of cointegration techniques requires a lot of realism about the difficulties in the measurement of the long run relationships and in the assessment of economic theories, MeMo-It follows this approach instead of assuming a priori the knowledge of the answers.
Therefore, in the light of the modeling dichotomy introduced by Pagan [2003], MeMo-It clearly supports the facts come first credo: the essential quality of empirical models is their ability to fit the data as, given the absence of theoretical truisms, the implications of the economic theories have to be confronted with the data in a systematic way (Juselius and Johansen [2005]). As a result, the present vintage of MeMo-It is a small-medium size model made of 66 stochastic equations and 91 identities representing the aggregate dynamics of households, firms, public administration, and the foreign sector. The supply side of the model plays a central role in the long run as the system converges to the potential output while in the short-run it is the demand side that reacts to any shocks activating the adjustment mechanisms towards the long run equilibrium. Figure 4 provides a synthetic representation of the principal short and long run interactions between the supply and the demand side of the model [4].

The quantitative features of MeMo-It can be illustrated looking at its

[2] For a formal representation see Bårdsen and Fanelli [2015], and for extensive realizations see, among the others, Bårdsen et al. [2012], and Ballantyne et al. [2019]

[3] This view is supported by, among the others, (Hall [1995], Granger [1999], Bårdsen and Nymonen [2009]).

[4] See the appendix for a detailed description of the main model equations.

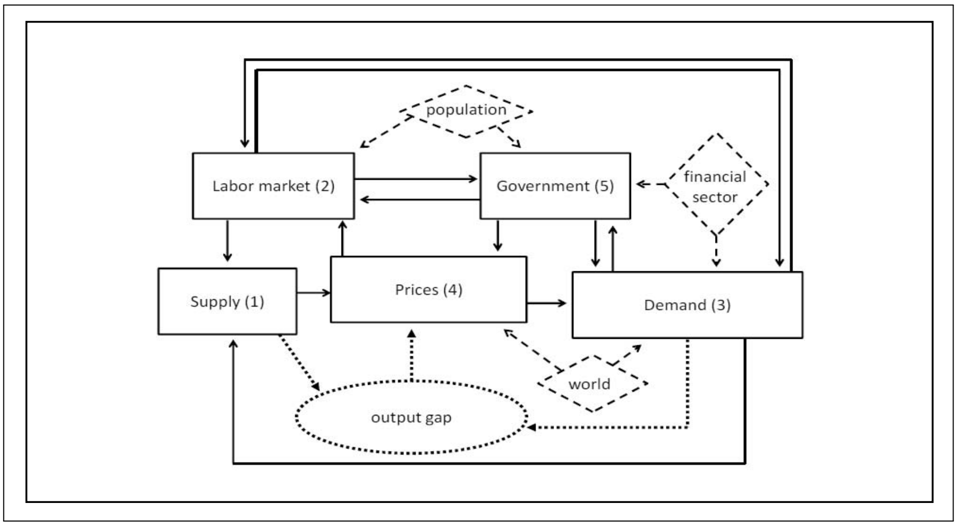


Figure 4: MeMo-It, main blocks interactions

responses in terms of multiplier to four different fiscal expansionary measures amounting to 1 percent of GDP. The multiplier quantifies the effects of permanent changes in exogenous variables, such as fiscal instruments, on endogenous variables (such as GDP and inflation). We take into account four scenarios representing respectively: an increase in public consumption (Scenario 1); an increase of transfers to households (Scenario 2); a reduction of households income tax (Scenario 3) and a reduction in VAT (Scenario 4). In the four cases, we assume that there are no effects on interest rates and on accommodative monetary stance. Table 1 reports the deviations between the shocked scenario and the baseline case.

Table 1: Effect of fiscal multipliers on GDP for 4 fiscal expansionary measures

| | Current Year (t) | t+1 | t+2 | t+3 | t+4 | t+5 |
|---|---|---|---|---|---|---|
| Scenario 1 | 0.7 | 0.7 | 0.7 | 0.5 | 0.3 | 0 |
| Scenario 2 | 0.2 | 0.4 | 0.5 | 0.5 | 0.4 | 0.3 |
| Scenario 3 | 0.2 | 0.6 | 0.8 | 0.8 | 0.7 | 0.5 |
| Scenario 4 | 0.1 | 0.3 | 0.4 | 0.5 | 0.6 | 0.6 |

Note: Percent differences with respect to a baseline scenario

The four fiscal policy instruments generate an improvement of the rate of growth of GDP even if to a different extent. Notice that the changes in both direct and indirect taxes have a persistent impact in the long-run.
Our findings are coherent with the evidence provided by the Bank of Italy by means of their macroeconometric model(Bulligan et al. [2017], Table $B6-B7$)

and the magnitude of the multiplier associated to an increase in public expenditure at t=1 (0.7), supports the results generated by Ramey and Zubairy [2018] suggesting a value ranging between $(0.6 - 1.0)$.
The following section illustrates the analytical module included in MeMo-It to represent the differential behavior of investment by asset and institutional sectors.

## 3.2 The baseline investment model

Our empirical strategy hinges from Caballero [1999], who expresses capital stock as a dynamic function of desired capital stock:

$$k_t^{j,S} = k_t^{*j,S} + u_t^{j,S} \tag{1}$$

where all variables are expressed in logs, $j$ refers to the asset, either tangible, (such as non-residential and machinery and equipment), or intangible (such as R&D and Software), and $S$ indicates the institutional sector, (private or public). $k_t^{*j,S}$ is the desired level of capital stock and $u_t^{j,S}$ measures the transitory discrepancies between actual and desired stock due to adjustment costs. The desired level of capital stock, that is unobservable, can be modeled as a function of income and neoclassical cost of capital, while the transitory discrepancies $u_t^{j,S}$ between the desired and actual capital stock are assumed to be a function of liquidity constraints and uncertainty (see for example de Bondt and Diron [2008] and Gaiotti [2013]).

A similar approach as been adopted by Bacchini et al. [2018], Busetti et al. [2016], Giordano et al. [2019], to explore the determinants of Italian investment by asset. In particular, Bacchini et al. [2018] modeled four assets for the private investment using a Vector Error Correction Model (VECM, Johansen [1995]) where all the determinants (capital stock, output, user cost of capital, liquidity and uncertainty) are a priori endogenous. Moreover, the assumption of capital heterogeneity is supported by our empirical results (see section 3.3) as short and long-run determinants are different across the assets and institutional sectors. Notably, capital heterogeneity is translated into the adoption of different models for tangibles and intangibles. Tangible assets can be expressed in terms of stocks (equation 1) driven by stock adjustments costs and intangibles in terms of flows driven by flow adjustment costs. This latter holds for R&D and software (see Bloom [2007]).

## 3.3 The investment block in MeMo-It

The system of equations included in MeMo-It to model investment by asset and institutional sector is made of 8 stochastic equations and 9 identities. In particular, private and public investments in intellectual property are split between R&D, software and other investments as a residual component to make possible the analysis of their interactions. Other investments include public non-residential and machinery & equipment.

According to the conceptual framework in section 3.2, investments by asset and institutional sector are modeled having in mind a long-run specification relating the level of the stock/investment to its desired value. Investment in innovation, mainly IPP as an aggregate and R&D and Software, are represented by a VECM model of investment flows as opposed to a VECM in terms of capital stock for the tangible assets (non-residential and machinery & equipment).

Investment in innovation, mainly private R&D and software are then represented as follows:

$$\begin{aligned}\Delta\left(\frac{i_t^{rd,B}}{y_t}\right) =& 0.03 + 2.05\Delta(1+tcinv_t) - 3.03\Delta\left(\frac{ires_t + irap_t}{yu_t}\right) \\ &+ 0.39\Delta\left(\frac{i_t^{rd,G}}{y_t}\right) + \epsilon_t\end{aligned} \tag{2}$$

$$\begin{aligned}\Delta i_t^{sw,B} =& -0.2\left(i_{t-1}^{sw,B} - 0.99 i_{t-1}^{rd,B} - 1.79\frac{gossnf_{t-1}}{yu_{t-1}}\right) \\ &+ 0.79\Delta i_t^{rd} - 0.15 bloom_{t-1}^{it} + \epsilon_t\end{aligned} \tag{3}$$

where private investment in R&D ($i_t^{rd,B}$), measured at constant prices and divided by real GDP ($y_t$, equation 2) is a function of public investment in R&D ($\frac{i_t^{rd,G}}{y_t}$) and of three fiscal exogenous variables: the rate of growth of subsidies for private investments (tcinv), the total amount of corporate income taxes (ires) plus regional taxes on business (irap) as a share of nominal GDP ($yu_t$). From equation 2 emerges complementarity between public and private investment in R&D, as well as the influence of subsidies and taxes on private investments, with the expected sign. Private software investment (equation 3) is modeled via an error correction model for which the equilibrium condition is expressed in terms of private investment in R&D (elasticity is close to 1), and the ratio between Gross operating surplus for non-financial corporations sector $gossnf_{t-1}$ and GDP at current prices $yu_{t-1}$, with an elasticity markedly greater than 1. Equation 3 includes also a measure economic and political uncertainty for the Italian economy (*bloom*) affecting investment expenditure in the short-run (?). Public investment in software is modeled as:

$$\Delta i_t^{sw,G} = -0.11(i_{t-1}^{sw,G} - i_{t-1}^{rd,G}) + 1.02\Delta i_{t-2}^{rd,G} + 2.19\left(\frac{gb_{t-1}}{yu_{t-1}} + \frac{gb_{t-2}}{yu_{t-2}}\right) \quad (4)$$

where $\Delta i^{swg}$ is the log-variation of public software investment, $i^{rdg}$ is the logarithm of public investment in R&D and $\frac{gb}{yu}$ is the ratio between the government balance and GDP at current prices.

The investment block in the model also includes an equation for machinery and equipment, one for non-residential business capital stocks and the corresponding perpetual inventory accounting identities, while public investments for these assets are supposed to be exogenous. Both private investment in machinery & equipment and for non-residential are modeled according to a VECM representation build on the relationship of the actual level of the stock compared to the desired one. In the short run also uncertainty and credit conditions play an active role.

The VECM equations for the stocks are:

$$\begin{aligned}\Delta k_t^{nres} =& -0.017(k_{t-1}^{nres} - 0.96y_{t-1} + 0.03uc_{t-1}^{nres}) \\ &+ 0.003\Delta\Delta liq_t + 0.002\Delta\Delta liq_{t-1} + 0.16\Delta y_{t-1} + 0.82\Delta k_{t-1}^{nres} + \epsilon_t\end{aligned} \quad (5)$$

$$\begin{aligned}\Delta k_t^{meq} =& -0.44 - 0.08(k_{t-1}^{meq} - 1.55y_{t-1} + 0.21uc_{t-1}^{meq}) \\ &+ 0.018\Delta liq_t + 0.19\Delta y_{t-1} + 0.83\Delta k_{t-1}^{meq} - 0.03\Delta uc_t^{meq} \\ &- 0.005(\Delta bloom_t^{it} + \Delta bloom_{t-1}^{it}) + \epsilon_t\end{aligned} \quad (6)$$

where $k_t^{nres}$ and $k_t^{meq}$ are the logs of aggregate capital stocks. In the first row of each equation there are the equilibrium correction terms that define the long run relation between capital stock, the volume of GDP $y_{t-1}$ and the user cost of capital $uc_{t-1}^{nres}$ and $uc_{t-1}^{meq}$. While $liq$ is the firm liquidity indicator that can be interpreted as a proxy for the credit conditions (Gaiotti [2013]) in the financial market that drive the short-run fluctuations.
The long run desired capital stock elasticity to output is significantly higher than (lower than) one for machinery and equipment (for non-residential buildings, see equation 6 and 5). The significantly negative estimate of the user cost elasticity supports the prediction of the flexible neoclassical model. The speed of adjustment of actual to desired capital stocks is rather slow, suggesting the presence of both high adjustment costs and implementation lags especially for non-residential buildings.

Finally, the perpetual inventory accounting identities are defined as:

$$I_t^{nres} = \Delta K_t^{nres} + d_t^{nres} K_{t-1}^{nres} \quad (7)$$

$$I_t^{meq} = \Delta K_t^{meq} + d_t^{meq} K_{t-1}^{meq} \quad (8)$$

where the volumes of gross fixed capital formation $I^{nres}$ and $I^{meq}$ are defined as the sum between the changes in the levels of capital stock $\Delta K_t$ and the depreciation rate ($d_t$).
To the best of our knowledge the empirical approach presented in this paper represents an advancement in the macroeconometric literature as we offer a comprehensive and homogeneous framework for policy investment evaluation capable of capturing the many dimensions of investment expenditure.

# 4 Policy implications

The structure of the investment block in MeMo-It (section 3.3) makes possible to test directly the effect of innovation policy measures on the economy. We resort to this framework to evaluate the effects of an expansionary fiscal policy fostering public R&D in the Italian economy and modeled as a shock amounting to 1 billion of euros (0.07 p.p. of GDP). The increase of public R&D, ($i_t^{rd,G}$ in equation 2), generates a positive impact on private R&D ($i_t^{rd,B}$, positive relation with a coefficient of 0.39) that in turn makes private and public software capital accumulation increase.

Notice that the sensitivity of software expenditure is rather similar across institutional sectors, with a long-run elasticity equal to 1 and a speed of adjustment very low in the short-run (0.2 for private and 0.11 for public sector, eq. 3).
Overall the fiscal shock significantly affects IPP investment (4.2 points in the first year, that implies a rate of growth both of total investment (+0.9 points in the first year) and GDP (0.1 points in the first year) lasting in the long term (Table 2). Additionally, the increase of public R&D is expected to positively affect productivity in the long-run via a stronger impact on output than on employment.

Table 2: Effect of fiscal multipliers associated to an increase in public R&D

| | Current Year (t) | t+1 | t+2 | t+3 | t+4 | t+5 |
|---|---|---|---|---|---|---|
| GDP | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 |
| Investment | 0.9 | 1.1 | 1.2 | 1.2 | 1.3 | 1.4 |
| Investment IPR | 4.2 | 4.3 | 4.3 | 4.4 | 4.4 | 4.5 |
| Consumption deflator | 0.0 | 0.1 | 0.0 | 0.0 | -0.1 | -0.3 |
| Employment | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | -0.1 |

Comparing the effect of a fiscal expansionary policy addressed to public investment (Table 2) as opposed to a public consumption based policy (Ta-

ble 1, HP1) and taking into account the magnitudes of the shocks, 0.07 and 1.0 GDP percentage points respectively, suggests a larger growth impact of public investment based measures. As a matter of fact, the impact on GDP is larger and more persistent over time compared to the public consumption policy measure.
These findings corroborate the evidence provided by other studies (see Izquierdo et al. [2019] and Auerbach and Gorodnichenko [2012]) showing a stronger growth impact of expansionary fiscal policies aimed at expanding public investment rather than public consumption.

# 5 Conclusion

This paper illustrates the characteristics of the model for medium term forecasts (MeMo-It) developed by the Italian Statistical Institute (Istat) providing empirical evidence on the effectiveness of expansionary fiscal policy measures on GDP growth. MeMo-It has interesting features in this respect as it accounts simultaneously for the interactions between different capital assets and institutional sectors.
The main contribution of this paper is to show the effectiveness of a data driven macroeconomic model for policy evaluation by means of an empirical exercise to assess the role of public investment in innovation as a driver of growth.
Our findings confirm the fundamental contribution of public investment in innovation (R&D) to GDP growth in the Italian economy. More specifically, we find that public R&D is a relevant driver of private R&D and software investment arguing for complementary between private and public investment. An increase of public R&D equal to 0.07 percentage points of GDP fosters GDP growth by 0.2% and employment by 0.1% thus generating a labor productivity enhancing effect in the first year lasting over the medium term.
Our results emphasize that the promotion of investment in innovation has to be an important objective of tax policy in industrial countries and that the definition of more effective policy measures needs a well targeted macroeconomic model. MeMo-It performs very well for policy evaluation but obviously its theoretical coherency can be can be further improved [Blanchard, 2018].

# Appendix

| Equations | Variables | |
|---|---|---|
| **Supply** | $c = Households\,consumption,\ volume$ | $QR = Rate\,of\,capacity\,utilisation$ |
| [1] $y^* = \alpha l^* + (1-\alpha)k_{bus} + tfp^*$ | $cost = mark\,up$ | $SH = Households\,saving\,rate$ |
| [2] $cost = \alpha(w - tfp^*) + (1-\alpha)uc$ | $fiscal = Fiscal\,variable$ | $tfp^* = total\,factor\,productivity$ |
| [3] $tfp = f(QR, occ, tfp, tfp^*)$ | $hw_{dw} = Nominal\,Household\,Dwelling\,Wealth$ | $tfp^* = potential\,total\,factor\,productivity$ |
| | $hw_f = Nominal\,Household\,Finalcial\,Wealth$ | $uc = user\,cost$ |
| **Price** | $i_g = Public\,Investments,\ volume$ | $ula = Total\,employment$ |
| [4] $\dot{p_v} = f(\dot{gap}, \dot{p_v}, \dot{p_m}, \dot{cost})$ | $i_{ip} = Investments\,in\,intellectual property,\ volume$ | $UR = estimated\,unemplyment\,rate$ |
| [5] $\dot{p_m} = f(\overline{EurDoll}, \dot{oil})$ | $i_{me} = Investments\,in\,machinery,\ volume$ | $w_{pc} = Private\,wage\,income,\ percapita$ |
| [6] $\dot{p_x} = f(\overline{ManExPri}, \dot{p_v})$ | $i_{nres} = Investments\,in\,nonresid.buildings,\ volume$ | $\overline{WTr} = World\,Export,\ realUSD$ |
| [7] $\dot{p_{ch}} = f(\overline{fiscal}, \dot{p_v}, \dot{p_m})$ | $i_{tot} = Total\,Investments,\ volume$ | $x = Export,\ volume$ |
| | $intr = Short\,term\,nominal\,interest\,rate$ | $y = GDP$ |
| **Demand** | $\overline{ITExR} = Italy\,Exchange\,rate,$ | $y^* = potential\,GDP$ |
| [8] $\dot{c} = f(\dot{ydh}, \dot{p_{ch}}, \overline{intr}, \dot{hw_f})$ | $k_{bus} = Business\,capital\,stock$ | $ydh = Households\,disposable\,income$ |
| [9] $\dot{hw_f} = f(\dot{hw_f}, \dot{p_{ch}}, SH)$ | $l^* = potential\,labour\,force$ | |
| [10] $hw_f = f(hw_f, \dot{p_{ch}}, SH)$ | $lf = labour\,force$ | **Parameter** |
| [11] $i_{tot} = f(i_{ip} + i_{me} + i_{nres} + i_{res} + i_g)$ | $m_g = Import\,goods\,and\,service,\ chain\,value$ | $\alpha = Labour\,share$ |
| | $\overline{ManExpPri} = World\,manufactures\,export\,price$ | |
| **Rest of the World** | $NAWRU = Non-acc\,wages\,rate\,of\,unempl.$ | |
| [12] $\dot{x} = f(\dot{x}, \overline{WTr}, \overline{ITExR}, \overline{intr})$ | $occ = Total\,employees\ > 15yrs$ | |
| [13] $\dot{m_g} = f(\dot{m_g}, \dot{p_m}, \dot{y}, \overline{ITExR})$ | $p_{ch} = Households\,consumption\,deflator$ | |
| | $p_d = Investment\,in\,dwellings\,deflator$ | |
| **Labour** | $p_m = Import\,deflator$ | |
| [14] $\dot{w_{pc}} = f(\dot{p_{ch}}, UR, NAWRU, \dot{y}, \dot{ula})$ | $p_v = Value\,addedd\,at\,factor\,costs$ | |
| [15] $\dot{occ} = f(\dot{occ}, \dot{ula}, \dot{w_{pc}}, \overline{fiscal}, \dot{y}, \dot{pv})$ | $p_x = Export\,deflator$ | |
| [16] $\dot{lf} = f(\dot{lf}, \dot{pop}, \dot{occ}, \dot{hw_{dw}})$ | $pop = Population\,in\,the\,age\,15-64$ | |

Notes: lower cases indicate the log of the variables in upper case; a dot over a variable indicates its rate of variation; exogenous variables are indicated with a bar above the name of the variable.

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