Research and innovation policy in Italy

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Abstract

Italy's research and innovation are examined in this article moving from the structure of the country's economy and innovation system, examining the dynamics of private and public activities and the impact of policies. As a result of the long recession started in 2008, industrial production and investment experienced dramatic reductions, weakening business performances in R&D and innovation; policies have relied on 'horizontal' tax incentives for R&D, patenting and new machinery, with limited effects. Austerity-driven reduction of public expenditure has led to major cuts in public R&D and university budgets, combined with new rules for evaluation and merit-based financing. As a result, gaps between Italy's research and innovation and EU average performances have increased. Four key policy questions are identified: the possibility for Italians firms to grow with modest technological activities; the longer term impact of underfunding the public R&D and university system; the consequences of a low presence of university graduates in the labour force; the sustainability of the increasing regional divergence within Italy's research and innovation system.

Keywords: R&D, innovation, technology policy, Italy
JEL codes: L6, L8, O31, O33, O52

1. Introduction: weak technology, weak economy[1]

Studies of Italy's economic development have long pointed out its weaker technological capabilities compared to other European countries and a trajectory of growth characterised by low R&D activities and a modest presence in high technology industries.[2] Postwar industrialisation extended

[1] This article builds on the work of the authors for the RIO Reports on Italy for the European Commission-Joint Research Center Research and Innovation Observatory (RIO) (Nascia and Pianta, 2014, 2015; Nascia et al., 2016, 2017, 2018; Pianta 2018b). Comments from our co-authors Lorenzo Isella and Giovanni La Placa are gratefully acknowledged. The findings of this article have been presented at the conference 'Research and innovation in Italy and Europe'organised by the Accademia Nazionale dei Lincei in Rome on 7 February 2018. We thank the President of the Accademia, Alberto Quadrio Curzio, and the participants for their interests and comments.

[2] See, among a large literature, the historical studies of de Cecco (2004), Gomellini and Pianta (2007), Amatori et al. (2013), Barbiellini Amidei et al. (2013), Bianchi (2013); the technological role of state-owned industry is examined in Ciocca (2015) and Antonelli et al. (2015); research,

the range of the country's capabilities, including an important presence in advanced industries – office machinery, telecommunications, pharmaceuticals, etc. – with a major role played by state owned enterprises. The decades from the 1960s to the 1990s were marked by a succession of cycles of technology-driven expansion in new areas, and crises (starting with the 1963 recession) leading to restructuring and consolidation in areas of traditional economic strength.

As economies moved towards the new technological paradigm based on Information and Communication Technologies (ICTs), the role of knowledge production and technological change became more relevant. After the crisis of 1992, the closer integration in Europe's single market and – later - single currency, the challenge for Italy to converge to European levels of R&D activities and move towards a strategy of technological competitiveness became more stringent. External factors that made such convergence difficult included the rules set for the Monetary Union, the liberalisation of international capital flows, the rise of finance; on the domestic side, problems came from the lack of investment, the persisting small size of firms, the burden of a high public debt, the short-termism of domestic political process. Since the 1990s several developments have weakened the country's production system; the large scale privatisation of state owned industries led to a major loss of technological and production activities; widespread foreign takeovers of major Italian firms brought strategic decision power and R&D laboratories outside the country; relocation of production in low-wage countries reduced Italy's industrial base.

As a result, the Italian economy has largely failed to converge towards Europe's economic performances, with a widening gap in terms of R&D, education and technological capabilities. Italy experienced two decades of productivity growth close to zero, resulting in stagnating GDP, low wages and poor employment dynamics. R&D and innovation have played an important role in this lackluster performance, and weak technology activities have emerged as key factors in Italy's economic decline.[3]

The crisis of 2008 and its consequences on Italy's technology and growth have to be viewed in this historical perspective. The country has experienced a decade of recession and stagnation and is falling behind European standards in terms of research and innovation.

In this article we investigate Italy's economic and technological performances in the last decade and examine in detail the policies carried out for research and innovation. We first consider overall R&D efforts, business innovative activities; we then consider the public sector, its R&D budgets, universities and education; we finally address the operation of the innovation system, the specific policies that have been introduced, and identify key challenges for public action.

Italy's 'lost decade'

The crisis started in 2008 has accelerated a weakening of Italy's economy. GDP in 2017 is still 5.4 percentage points below pre-crisis levels; GDP per capita is back to the level of eighteen years ago; industrial production and gross fixed investment recorded losses that reached 25% of their 2007 levels. Since 2016 the Italian economy has experienced a modest recovery; in the second quarter of

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innovation and industrial policy are analysed in Pianta (1996), Fortis et al. (2002), Onida (2004), Lucchese et al. (2016), Fortis and Quadrio Curzio (2018); Italy's industrial decline is discussed in Gallino (2003), Toniolo and Visco (2004); the question of Mezzogiorno is investigated in Prota and Viesti (2012); the European context is examined in Celi et al. (2018).

[3] Several studies have identified the lack of a 'virtuous circle' between technology and economic performance in Italy and other Southern European countries. See Guarascio et al. (2016) and Guarascio and Pianta (2017) for the circular link between R&D, new products, exports and profits; Guarascio et al. (2015) considered the role of business cycles in these relationships. The link between R&D, innovation and profits has been investigated in Bogliacino and Pianta (2013) for industries and in Bogliacino et al. (2016) for Italian firms. Cirillo (2017) documented the different links between technology and skills in Northern and Southern Europe.

2018 Italy's GDP registered, compared to the previous quarter, an increase in real terms of 0.2% and had a 1.1% growth compared to the second quarter of 2017 (ISTAT, 2018a). After an increase in 2017 of 1.5%, Italy's GDP is expected to have a 1.4% growth in 2018, well below the Euro area average (anticipating an increase of 2.3% in 2018), widening the gap with most EU countries (ISTAT, 2018b).
Figure 1 shows the divergence between Italy's GDP and that of the EU and major countries. Compared to 2007, by 2017 Germany had increased its GDP by 12.3%, the EU28 average by 8.3% and even Spain has gone above its pre-crisis level, while Italy was still lagging, with little sign of a full recovery.

Figure 1 here

Much worse is Italy's investment performance, with gross fixed capital formation falling in real terms by 22.9% between 2007 and 2017; in the last two years machinery and equipment expenditure has slightly picked up, while construction remains 35.8% below pre-crisis levels, according to the data made available by Istat[4]. Again, the gap with the EU average and countries such as Germany and France has widened.
The long recession has pushed unemployment rates up, from 6% in 2008 to 12.7% in 2014, with a fall to 10.9% in June 2018; youth unemployment has reached a peak of 32.6%. The precarisation of employment has increased; employees with a fixed-term contract increased from 2.3 million in June 2008 to 3.1 million in June 2018 (ISTAT,2018c).
Industrial production has registered a 25% fall in real terms between 2007 and 2015, followed by a modest improvement. This evolution has been investigated by Lucchese et al. (2016) showing that, compared to 2007 levels, the decline in output by Italian industry is greater in medium-high and medium-low technology sectors (-29% and -32% respectively from April 2008 to July 2015), while the reduction is less dramatic in low technology industries (-19%), and is limited in high tech sectors (-2%), which however account for about 9% only of total value added in manufacturing and for 6% only of total employees (full-time equivalent units in 2013). Moreover, the study has split industrial output between sales to domestic and foreign markets, finding that the fall in domestic demand, worsened by austerity policies, appears to be the key driver of the loss of manufacturing production, while industry's export have returned to pre-crisis levels.
A structural feature of Italy's economy is the small firm size and the inadequate ability of firms to survive and grow. In 2011 Italy's companies above 250 employees were about 3,000 - the 0.1% of all Italian firms - compared with 9,000 in Germany and 4,000 in France; in manufacturing they accounted for 35% only of value added, as opposed to a EU average of 55% (Lucchese et al., 2016; Onida, 2004). In 2015 the 3,472 Italian firms above 250 employees accounted for 30% of the value added and 20% of total employment. In the same year, investment in firms above 20 employees recorded a 12% increase, opposed to the fall by 18.7% of investments in firms below 10 employees (ISTAT, 2017a). Firm creation in 2016 is significantly up. However the 'new' firms that were created in 2011 had 352,000 employees in 2011 and experienced a job reduction to 302,000 in their 2016 employment (ISTAT, 2018d).
The impact of Italy's long recession goes beyond that of a temporary business cycle downturn; a structural change in Italy's economy has emerged, with a decline of production and technological capabilities. Such a weakening of the supply structure has gone hand in hand with the slow dynamics of demand. Exports are the only demand component that recovered rapidly, and export-oriented industries and firms have had above average performances. With low imports due to sluggish domestic demand, Italy's trade balance has consistently recorded a surplus.

[4] Investments data have been downloaded from www.dati.istat.it - Gross fixed capital formation by asset and industry.

Alongside the fall of investment, the reduction of public expenditure has significantly contributed to Italy's long recession. Since 2009, EU-inspired austerity policies have forced a continued reduction of the budget deficit, from 3.0% of GDP in 2014 to 2.5% in 2016, 2.3% in 2017, and an expected 1.6% in 2018 (MEF, 2018), leading to widespread budget cuts, a dramatic fall of public investments and a reduction of public R&D expenditure. Austerity's negative effects on growth, however, have failed to reduce the public debt to GDP ratio – 115.4% in 2010, 131.5% in 2015 and 132% in 2016, 131.8 % in 2017 – which remains a key weakness of Italy's economy (Eurostat, 2018).

2. Italy's Research and Innovation activities

An effective summary's of Italy's technological position in the international context is provided by Figure 2, taken from the OECD Science and Technology Indicators Scoreboard (OECD, 2017, p.26). Countries are represented by circles whose size is proportional to total R&D expenditure in 2015 and they are positioned on the basis of R&D as a share of GDP and number of researchers per employees. On both variables Italy is dramatically lagging behind EU averages; its values are about one third those of Sweden, Finland and Denmark, less than half those of Germany and France and higher than Poland and Turkey alone, among major countries. In terms of size of R&D expenditure Italy has been overtaken by India, Russia and Brazil.

Figure 2 here

In 2015 Italy's total R&D expenditure (GERD) was €22.1 billion, 1.34% of GDP; data for 2016 indicate an increase to €23.2 billion, 1.38% of GDP[5]. In France and Germany 2015 total R&D expenditure was 2.22% and 2.94% of GDP respectively. Italy's R&D efforts are still far from the policy commitments assumed at the EU level; two decades ago Europe2020 strategy set the goal of a 3% R&D to GDP ratio for all countries; less ambitious and more feasible targets were later adopted, and Italy's target is now to achieve a 1.53% ratio by 2020; in order to achieve that goal Italy should increase its R&D expenditure by €2.5 billion, about 11% above current levels.
The long term trends of R&D spending in Europe and major EU countries are shown in Figure 3. The increase in the gap compared to Germany and France has been remarkable, with signs of convergence in the period 1995-2016 and a serious divergence since the crisis of 2007. Italy's R&D has not taken advantage the opportunities offered by the introduction of the Monetary Union and has deeply suffered from the 2007 crisis. Conversely, Germany has reacted to the crisis with an acceleration of its R&D efforts, that increased in real terms by 20% since 2007. France has an intermediate trajectory, but has also distanced Italy in terms of R&D expenditure.

Figure 3 here

Within Italy's R&D, different trajectories have emerged; Figure 4 shows the composition of Italy's R&D efforts. R&D carried out in firms (BERD, including that financed by public funds) has increased substantially between 2006 and 2016. Conversely, government R&D allocations (GBAORD) have systematically fallen since 2007, in the context of the overall reduction of public expenditure. These cuts have also been pointed out by the European Commission in its report on

[5] The latest Istat data (Istat, 2018e) are based on a different methodology from past Istat surveys; in particular, a different imputation procedure for non-responses in the survey on firms has been adopted. Moreover, some R&D organisations previously classified as nonprofit have turned into business firms; this has also affected the sharp fall (-18.6% between 2015 and 2016) in Nonprofit R&D. An overview of data on Italy's R&D and other science and technology indicators is in Consiglio Nazionale delle Ricerche (2018).

Italy for the 2017 European semester: 'Between 2007 and 2015, the Italian government's budget allocated to R&D activities fell from €9.9 billion to €8.3 billion' (European Commission, 2017a).
In 2016, in terms of funding, 52.1% of resources for R&D have been provided by the business sector, 35.2% by the public sector and 9.8% have come from abroad. Business is the largest performer of R&D, with 60.8% of total GERD, followed by universities with 24.2% and public institutions - mainly research organisations - with 12.6% of GERD (ISTAT, 2018e).
In 2013 large firms with more than 500 employees concentrated 62.5% of business performed R&D; small firms with less than 50 employees performed 10.3% (ISTAT, 2015a). The share of foreign funded R&D has remained constant since 2010 at 0.14% of GDP in 2016, below the EU28 average of 0.2% of GDP. The ratio of business performed R&D to GDP at 0.84%, % remains far behind France or Germany, where it reaches 1.5% and 2%, respectively. This gap is rooted in the lower R&D efforts of large firms and and in the scarce number of 'big spenders' in R&D, compared to Germany and France (Sterlacchini, 2017, p.391). The increase in business performed R&D since 2001 has been mainly associated to higher (although not persistent) expenditure by small and medium sized firms, including a strong performance of firms with 249-500 employees (Bonaccorsi and Perani, 2014). Europe's 2017 Industrial scoreboard lists the top 1000 EU firms in terms of R&D; 38 only are Italian, spending a total of €6 billion, two thirds of which is accounted by the top four R&D spenders - Leonardo Finmeccanica (aerospace and defense), Telecom Italia (telecommunications), Unicredit and Intesa Sanpaolo (banking sector). Fiat is now registered as a Dutch company. The 38 Italian companies in the scoreboard record around €6b, equal to the 3% of the total R&D investments in EU with a slight increase between 2016 and 2017, 4%, with a slowdown of R&D in 12 companies. Among the top 1000 EU firms in terms of R&D there are 224 German companies accounting for 76.3 billion of R&D, with an average growth of their spending of 6.7% between 2016 and 2017 (European Commission, 2017b).
In addition to direct expenditures, the role of tax incentives for R&D should also be considered. As documented by the Science, research and innovation 2016 Report of the European Commission, France, the UK and the Netherlands provided greater incentives than Italy (European Commission, 2016b). When the foregone tax income associated to R&D tax incentives is added to the direct expenditure of governments for financing business R&D, the gap between major EU countries and Italy becomes even larger; in 2014 the combined value for France was 0.37% of GDP, for the Netherlands was 0.20%, for the UK 0.17%, while for Italy was 0.05% of GDP (Nauwelaers, 2016, p.144). Since then, however, Italy has introduce generous tax incentives for R&D, as discussed in section 4 below. As a result, signs of R&D dynamism were found by a Unioncamere survey of August 2017, with 11,300 firms expecting a 10-15% increase of their R&D investments; 40% of these firms had no R&D expenditure in 2016 (MEF et al., 2017).

Innovation in firms

R&D expenditures are an indicator of the inputs used for developing knowledge and technologies and have to be complemented with indicators of the outputs in terms of quantity and quality of innovations introduced by firms. Important evidence in this regard is provided by the Community Innovation Surveys. Using these data, the Innovation Union Scoreboard 2017 ranked Italy as a 'moderate innovator' since its performance is well below the EU28 average for many indicators (European Commission, 2017a). The modest (and worsening) innovative performance of Italian firms has been documented by the results of the Community Innovation Survey for the years 2014-2016, published by Istat in 2018 (ISTAT, 2018g; ISTAT 2016a). Considering all types of innovation - in products, processes, organisation and marketing - the share of Italian firms (with 10 employees or more) that have carried out innovative activities during that period was 48.7%, as opposed to 44.6% in 2012-2014 and 51.9% for the 2010-2012 period. The firms engaged in innovations in products and processes only were 38.1% as opposed to 31.9% and 35.5% in previous periods. Among the firms with more than 250 employees this share is 74.9 (an increase over the

previous period), while firms with 10 to 49 employees have a share of innovators of 35% and firms with 50 to 249 employees have a share of 57.6% (ibid., p.1).
Total innovation expenditure in 2016 has been € 30.6 billion, with an increase over the 23.2 billion of 2014. R&D accounts for close to half total expenditure. On average, in 2014 Italian firms have spent for new products and processes 7,800 euros per employee, against 6,200 in 2014. Close to one third of firms has obtained public incentives for innovation, up from one quarter in the previous period. The economic impact of the new products that have been introduced is modest; in 2014 products that are new to the market accounted for 9.8% of sales of innovating firms; another 7.9% was due to products that are new to the firms only (including imitation of products by competitors) (ibid.). In all these indicators Italy has an innovative performance that remains distant from that of major European countries.
New attention has been devoted to the relevance of 'high growth firms' defined as those recording for three subsequent years a growth rate of turnover above 10%; these firms tend to be more present in high technology manufacturing activities. Data for Italy show that such firms account for 5.8% only of the total number of firms, accounting for 9.7% of total employment; most major EU countries – including Germany, the UK, France, the Netherlands – have much higher shares that appear to be associated to a greater dynamism of national economies (Hölzl, 2016, p.250).

International R&D flows

Italy's technological activities have to be set in the context of international R&D flows as foreign know how remains a relevant source of technology and multinational corporations organise their R&D activities at a global scale, affecting developments at the national level. Italy's economy is highly open in terms of trade, investment and technology flows, and is increasingly integrated in global production systems (ICE, 2016). In 2015 in Italy around 9,700 foreign groups produced value added for about €109 billion, employing 1,2 million people.[6] However, the 2008 crisis has led to a fall of foreign investment more severe than in the EU average; as argued by the European Semester Report of the European Commission, 'Foreign direct investment inflows in 2015 were 52% lower than in 2007, while for the EU as a whole they dropped by 42%' (European Commission, 2017a. p.48). As a result of Italy's long recession, inflows of foreign direct investments in the country have remained weak and the relevance of internationalization for research and innovation appears to have slowed down, with signs of recovery in more recent years only. A significant trend has been the takeover of major Italian firms; acquisitions and new ownership arrangements with a dominant position of foreign investors have been frequent, involving among others important firms such as Telecom, Pirelli, Italcementi, Ilva; the prospects for maintaining R&D and managerial activities in Italy is at best uncertain.
Using Istat data on Italy's R&D performers, Cozza and Zanfei (2014) showed that from 2000 to 2010 the share of Italian firms that carry out R&D and belong to a foreign group has declined from about 11 to 7%, with a much slower growth than the number of independent Italian firms that are R&D performers. Moreover, the total amount of expenditures and the number of R&D employees of such foreign-owned firms have declined, while domestic firms expanded. Over the same period foreign-owned firms in Italy also reduced their extra-muros R&D expenditure and the extent of their cooperation with universities (ibid.).
In their contribution to the ICE report on Italy in the international economy, Cozza and Zanfei (2016) note that with regard to R&D "foreign presence in Italy is scarce, weak and increasingly fragile in terms of commitment to research (…). Moreover, foreign multinationals have a very good capacity to develop high technology linkages with firms and institutions at the international level, but have a low propensity to develop technological linkages with Italian firms and institutions, including universities". They conclude that "policies for attracting foreign investment in Italy do not

[6] ISTAT (2017b); finance and insurance industries are excluded.

guarantee by themselves the creations of technological linkages that may favour local development" and argue that "if the gradual disengagement of foreign multinationals from Italian research were to continue, the research and innovation capacities of Italy's productive system would be further impoverished" (Cozza and Zanfei, 2016, p.302-303). Moreover, foreign multinationals in Italy appear to establish less technological links with domestic firms than is the case with Italian-based multinationals (Cozza et al., 2018).

The opposite phenomenon of R&D carried out abroad by Italian multinationals is characterized by very modest activities, compared to those of major EU countries, although with some increase in recent years. In 2007 business R&D expenditure by affiliates abroad as a percentage of domestic R&D was about 3% for Italy, against more than 20% for Germany and close to 50% for Sweden (Cozza and Zanfei, 2014, p.46).

Alongside these quantitative aspects of international technology flows, the quality of Italy's position in the international division of labour is also changing; Italy's firms are increasingly involved in international production in a weaker hierarchical position. Rather than managing the value chain and controlling final markets, a growing number of firms acts as subcontractor in the emerging production system centred in Germany and extending over a number of neighbouring European countries (Stöllinger et al., 2013; Celi et al. 2018). A study on Italy's manufacturing over the 1998-2006 period found that supplier firms to global value chains tend to have lower productivity than Italian firms selling to final markets – controlling for similar levels of innovation and export activities - although such a gap disappears for firms with higher technological and export competences (Agostino et al. 2015).

Besides the R&D flows entering Italy as a result of foreign investment, significant sources of R&D funds have come from the EU Framework Programmes and EU Structural Funds. Framework Programmes (FP6 and FP7), followed by Horizon 2020, have been a relevant channel for the funding of research in Italy. In FP7 calls the success rate of Italian proposals was 18.3% and Italy was the fourth highest financed country (more than €3.6 billion from 2007 to October 2014[7]), after the UK, France and Germany; business participation was strong, with six Italian firms among the top 50 recipients of signed grants for firms in 2007-2013, two universities in the top 50 and six research centres in the top 50[8]. Less successful has been Italy's participation to Horizon 2020; according to a report published in 2017, Italy obtained 4,780 awarded grants, 9.5% of grants awarded by Horizon 2020. Until February 2017 Italy has been financed for €1.7 billion, 8% of total available budget; the success rate of Italian applications is below the EU average; in awarded grants, about 75% of the budget is allocated in the regions of Italy's North-West and Centre (APRE, 2017).

3. The public sector and universities

In the last decade Italy's public R&D has experienced a major decline, with a continuing fall from €9,235 million in 2008, to €7,789 million in 2012 and €7,441 million in 2016, with a 19% fall between 2008 and 2016 (data are in real terms at purchasing power standards, 2005 prices). Figure 5 shows this decline in total civilian government appropriations for R&D (GBAORD). European comparisons further highlight the weakness of Italy's public R&D budgets. In 2016 the Italy's government performed R&D was 0.17% of GDP, well below the EU average of 0.23%. Also the R&D funded by the government is below the EU average: in 2015 only 0.51% against a EU average of 0.63% of GDP. The public sector and universities are by far the main recipients of government direct funding. In the period 2005-2014 only about 10% of public funds have been used to fund R&D performed by the business sector.

[7] Data come from the official web site of the FP7 http://ec.europa.eu/research/fp7/index_en.cfm?pg=country-profile

[8] Seventh FP7 Monitoring Report 2013 11/03/2015

The constraints for reducing public expenditure coming from European-inspired austerity policies have played a role in this fall, but the European Commission itself has argued in the European Semester fiche that Italy's public expenditure on R&D is well below the EU average, pointing out that it produces an output in terms of highly cited papers that is in line with the EU average[9] (European Commission, 2016a, p.3). Moreover, the document argues that the contribution of the private sector is extremely low – in Italy the share of business R&D in GDP is about half the EU average and the share of public R&D funded by private firms is among the lowest in Europe (ibid., p.4).

Figure 5 here

Public R&D cuts have led to lower resources for both general university funding, public research programmes and funding for firms. For universities, in 2017 the government allocated €6,981 million for general university funding (FFO) – a slight increase than in 2015; in 2014 funds were €7,000 million; in 2008 funds were €7,500 million.

For universities and public research organisations a growing share of funding is allocated on the basis of performance indicators, based on ANVUR's research evaluation exercise (VQR); within general university funds (FFO) the share is expected to increase from 13.5% in 2013, to 20% in 2016, to 24% in 2018. Priority funding has been introduced for the 'Departments of excellence'; starting from 2018, €271 million are allocated to top Departments, identified by a MIUR Commission. Additional €45 million are allocated for a €3,000 research bonus to selected researchers. The plan for introducing 500 positions for highly qualified full professors ('Cattedre Natta', with an allocation of €113 million) outside standard academic recruitment processes has been suspended after heavy criticism.

Funds for competitive research calls have also been drastically reduced. Resources for National Research Projects (Progetti di interesse nazionale, PRIN) decreased from €100 million in 2009 to €38.2 million in 2012 and were zero in 2013 and 2014. In November 2015 a PRIN call was launched, with a budget of €91.9 million, that financed 300 projects out of 4300 proposals. In 2017 a new call with a funding of €391 million has been launched.

Resources for Basic Research Projects (Fondo per gli investimenti nella ricerca di base, FIRB) amounted to €29.5 million in the call of 2012. In 2013 and 2014 no new FIRB projects were launched. In 2014 MIUR published the competitive funding call Scientific Independence of Young Researchers (SIR) with a budget of €47 million; it has not been re-financed since then. In 2013 FAR, the larger fund for industrial R&D, was suspended for lack of funding.

Italy's policy of cutting back on R&D spending has been criticised by several institutional actors. In 2015 CRUI, the body representing Rectors of universities, released a document commenting the new allocation of university funds (FFO) and emphasised the reduction of more than €800 million in university funds from 2009 to 2015; as a share of GDP these funds fell from 0.49% of GDP in 2009 to 0.42% in 2015, as opposed to the 0.99% of France and 0.93% of Germany (CRUI, 2015).

A report on innovation, research and universities has been published by the foundation Italiadecide (2017) with an introduction by the head of Italy's association of university Rectors, CRUI. The report examined Italy's university and research system documenting that since 2008 university staff has fallen by 15% and university funds by 20% (Manfredi, 2017). It argued for a new policy of 'strategic investment' in research and universities, with greater resources, more attention to professional degrees and doctorates, to technology transfer and start-ups, to industrial policy and finance for innovation (Italiadecide, 2017).

[9] The variables used are scientific publications within the 10% most cited publications worldwide as a percentage of total scientific publications of the country, fractional counting method and the ratio of such publications and government expenditure on R&D plus higher education expenditure on R&D. See below for an analysis of Italy's scientific output.

The constraints from reduced expenditures have been serious. In the European Semester fiche devoted public expenditure the Commission showed that from 2008 to 2015 Italy's share of public investment in total government expenditure has fallen from 6.2 to 4.5% (EU-28 data were 7.4 and 6.2%); the share of education in GDP from 2009 to 2014 fell from 4.6 to 4.1% (EU-28 data were 5.3 and 4.9%); the share of government budget outlays for R&D in GDP over the same period fell from to 0.62 to 0.50% (EU-28 data were 0.75 and 0.64%). In all fields, Italy's austerity policy has led to a reduction of resources, worsening the previously existing gap with EU-28 averages (European Commission, 2016b).

Universities' funds and personnel

The sharp reduction in public R&D spending is at the root of the decline of university funding and staff, trends that have been highlighted also by the reports of ANVUR (the State Agency for Evaluation of Universities and Research) for 2016 and 2018 (ANVUR, 2016a, 2018). Italy has 61 state universities that account for 90% of registered students in all universities; non-state universities are 30, including 11 distance learning private organisations that account for 3.5% of students.

The resources devoted to the university system have experienced a major reduction. Considering state universities, total resources (in current euros) obtained in 2000 were €9,074m, reaching a maximum of €13,570m in 2008, followed by a continuing fall, down to €12,258m in 2014. In real terms, this amounts to a 25% increase from 2000 to 2008 and to a 14% fall between 2008 and 2014; falling transfers from the central government account for most of this decline in funding (ibid., p.297).

Falling resources and limitations of turnover set by government policy have led to a serious reduction in university staff; between 2009 and 2016 the number of professors and researchers with permanent contracts has decreased by 20% (a loss of 12,000 people, from 60,882 in 2009 to 48,878 in 2016), a fall higher than in other public administrations. Figure 6 shows the evolution of university permanent employment.

Figure 6 here

The figure does not include junior researchers employed with fixed term contracts; in 2016 universities employed 5,357 fixed term researchers and 13,946 post-docs (assegnisti di ricerca) with an annual contract, very low wages and no teaching duties; the number of 'assegnisti di ricerca' peaked at 16,081 in 2013 (ANVUR, 2016a, p.359). The ANVUR report documents that out of the 44,345 that have received an 'assegno di ricerca' from 2009 to 2016, 61% is now out of university employment, 29% remain in the position of 'assegnista di ricerca', 9% is university researcher and less than 1% has become associate professor; 7% only has obtained the habilitation to the position of associate professor (ibid. p.377). These data show how dramatic the reduction of university staff resulting from the policy of recent governments has been; the institutional changes introduced have also failed to open up new effective ways for young scholars to access university careers. A continuing increase in the average age of total university staff has resulted; average age is now 52.6 years; for full professors average age is 60 (ibid. p.387); a major problem is likely to emerge in the next few years when a very large number of current staff will retire.

A major novelty in university recruitment was introduced in 2012 with the new system of habilitation ('Abilitazione scientifica nazionale') with university committees selecting prospective candidates to the positions of full and associate professors; obtaining the habilitation is a necessary condition for applying to competitions for such positions. In the 2016-2018 period, in the first four of the five 'rounds' when applications were accepted, 28,954 scholars presented an application for either full or associate professor (they were 24,294 in the 2012-2014 session).

The success rates for full professors has been 60.2% (was 43.3% in the previous session); the success rate for associate professors has been 54.5% (was 42.8% in the previous session) (ANVUR, 2018). However, the number of positions that were opened up for competition in Italian universities from November 2013 to March 2015 were 3,204 (in 91% of cases for positions of associate professor), just over 10% of the number of habilitations that were granted (ANVUR, 2016a, p. 438). There is no updated information on the share of scholars with 'habilitation' who have obtained a professor position in later years. There is no coherence therefore between the highly complex process that has been introduced for selecting prospective candidates through the habilitation system and the actual operation of the hiring process of qualified new professors. Considering the large number of professors who are approaching retirement, the gap in recruitment is likely to remain serious.

Migration of researchers

A major problem for Italy's high skill human resources is the growing emigration of graduates and researchers. The ISTAT survey on doctorates showed that the proportion of Ph.D. holders living abroad has doubled from 2009 to 2014, reaching 12.9% (ISTAT, 2015b). ISTAT data on migrations show that in 2016 81,184 Italian citizens above 24 years of age migrated abroad, of which 24,678 had a university degree (+9% over the previous year); the share of graduates among migrants is 30%, a value far higher than the ratio of graduates in Italy's labour force (ISTAT, 2017c). More specific data on the migration of scientific researchers have been provided by the OECD, based on the change of national affiliation of authors with at least two published articles in the Scopus scientific database (OECD, 2017). Figures 7 and 8 report the key findings. As shown in Figure 7, from 2002 to 2016 nearly 11,000 researchers migrated from Italy, the highest number in EU countries (out of a total of around 35,000 moving out of a country in the whole EU). The migration outflows accelerated after 2010 and 58% of Italian researchers migrated after 2011. Figure 8 shows that Italy is a net 'exporter' of researchers to all major countries, including the US, the UK, France, Germany and even Spain (OECD, 2017, p.128-129).
The negative trends on the migration of graduates and researchers represent a serious loss for Italy's research and innovation system, a threat to its sustainability in terms of scientific research and teaching, and a major hindrance to catching up with the rest of Europe in terms of R&I.

Figure 7 Figure 8 here

Italy's research output

The ANVUR 2016 Report has documented the output of Italy's research system with an analysis of scientific publications in the SciVal database of Scopus. In the period 2011-2014 Italy's share of world scientific publications is 3.5% - against 6.5 of the UK, 5.8 of Germany and 4.2 of France – with an average annual increase of 4% - against 1.4 of the UK, 1.9 of Germany and 1.5 of France. When the analysis is limited to high quality publications, appearing in the 5% of journals with the highest scientific impact (measured by citations), Italy's share of its publications included in this group in 2014 is 11% - against 13.9 of the UK, 11.8 of Germany and 12.4 of France, just over the EU-27 average of 10.9. Italy's increase has been significant, from a 8.1% share in 2001 (ANVUR, 2016a, p.602,610). The evidence suggests that Italy's scientific output is converging rapidly to the standards of European countries of similar size.
However the number of Italian researchers and the resources available are far lower in Italy than in similar European countries. The result are levels of productivity that in Italy are much higher than in most countries. The number of scientific publications per researcher in 2013 in Italy is 0.61 - against the 0.40 of the UK, 0.29 of Germany and 0.32 of France – the highest among advanced countries (US data are not available). The number of scientific publications per unit of total R&D

expenditure (in millions of US dollars) in 2014 in Italy is 4.04 - against 4.34 of the UK, 1.65 of Germany and 2.10 of France; a similar ranking appears when R&D for higher education only is considered (ibid., p.627-628). Figure 9 presents these data and changes since 2011; Italy is the only country with a consistent increase in productivity, while the UK (the only country with higher levels than Italy) had a declining performance since 2012. Germany, France and the EU28 average show 2015 values that returned to 2011 levels, after a modest increase in intermediate years; their scientific productivity levels are dramatically lower than those of Italy and the UK (ANVUR, 2016b, p.30).

Figure 9 here

When the quality of scientific publications is considered, using the total number of citations received by publications, the picture does not change. The number of citations divided by the total number of researchers in 2014 in Italy is 2.18 - against the 2.42 of the UK, 1.03 of Germany and 1.04 of France. The number of citations divided by total R&D expenditure (in millions of US dollars) in 2014 in Italy is 13.05 - against 14.64 of the UK, 5.59 of Germany and 6.48 of France (ibid., p.629-630).

Data from the ANVUR Report confirm that Italy's university and research system is characterised by a paradox (pointed out already in Nascia and Pianta, 2015). On the one hand there are limited resources with a long term reduction of university personnel and funding. On the other hand Italy's performances in international scientific publications have steadily improved and have converged to those of the main European countries. Italy's researchers – in spite of the poor number of scientists, university funding, R&D expenditure and business R&D efforts – have shown a positive performance, improving the quality and impact of their publications. The available evidence confirms the concerns that such positive performances could be a short term effect that could be undermined if no large increase in the resources and number of researchers is introduced. The lack of hiring of young scholars and the aging of researchers may lead to higher apparent productivity, as younger scholars are less active in publications and less cited. As a large part of senior scholars approach retirement, there is a risk that in future years there will be not enough younger scholars capable to produce high quality research. This danger is made more serious by the large scale emigration of researchers that is taking place (Nascia and Pianta, 2015; Nascia et al. 2016).

Evaluation of universities

Since the 2010 'Gelmini reform', universities and public research organisations have experienced a systematic process of evaluation; ANVUR is the institution in charge of the periodic evaluation of universities and public research organisations falling under the authority of MIUR. The quality of scientific production of professors and researches is regularly assessed by the VQR (Valutazione della qualità della ricerca), that has been implemented for the 2004-2010 and 2011-2014 periods. The VQR is based on bibliometric indicators and on external auditors and is used as the basis for the allocation of the premial share of the FFO and FOE, the general funds for universities and Public research organisations. Quality assurance processes have been introduced for teaching activities, with the activities of 'Nuclei di valutazione' and 'Presidi di qualità' in each university and a complex system of self-evaluation of Degree courses that include student representatives and the consideration of questionnaires by students assessing the quality of teaching. The recruiting of new personnel is subject to the ex ante screening of the Abilitazione scientifica nazionale (ASN) and to the ex post evaluation of the VQR. Finally, ANVUR organises regular visits in universities by external experts in charge of controlling procedures and assessing quality, resulting in a public accreditation report. Similar steps are undertaken for the evaluation of the public research organisations supervised by MIUR (ANVUR, 2016b).

The 2016 ANVUR report identified the areas of strength and weakness on Italian universities. Strengths included the good and improving performance of Italian researchers at the international level, based on publications and citations obtained in the scientific literature; this has happened in spite of a reduction in available funds. ANVUR also documented the overall ability of universities to provide quality teaching, in spite of a high students/teachers ratio and a low expenditure per student (ANVUR, 2016a, Introduction, p.6-7). The weaknesses documented by ANVUR are mainly the result of inadequate funding, rather than of inefficiency in operation; they include the fall in university staff (due to government rules on turnover limitation); uncertainty on careers, leading to a high share of PhDs and 'assegnisti di ricerca' that abandon the research career or move abroad; inadequate funds for student support, managed in different ways across regions; wide disparities across regions in the quality of teaching and research (ibid.).
The evaluation arrangements recently introduced in Italy have burdened universities with a heavy load of bureaucratic work and have often been subject to criticism due to a lack of consensus on appropriate evaluation procedures. Moreover, in a context of diminishing funding for universities, the introduction of evaluation and its use for allocating resources to stronger institutions has introduced widening disparities across regions, universities and academic fields (see the next section on policies). While an evaluation culture is now widely accepted in Italy's universities, serious criticism remains on the implementation of evaluation procedures and on their effective contribution to improving teaching and research in Italy.

Education, skills and human resources

The worst effects of declining public R&D and university funding can be found in the low and declining educational attainments of Italians. In 2015 24.9% of the population aged 30-34 had tertiary education, putting Italy at the bottom of EU countries, well below the EU28 average of 38.5%. Conversely, 80% of people aged 20-24 had completed upper secondary education, not far from the EU average of 82.6% (European Commission, 2016c). The number of graduates in a first-level courses (excluding Masters etc.) peaked in 2005 with 291,189, and amounted to 216,430 in 2014 (ANVUR, 2016a, p.192). The share of youth completing secondary education that moves on to university courses is 42% in Italy against 63% in the EU average.
The European Semester fiche devoted to education pointed out that Italy's share of individuals with tertiary education – at 25% - is below the national target and very far from the 40% goal set by Europe 2020, a level that has now been almost reached by the EU-28 average. Strikingly, a huge difference exist between Italy's rates of graduates for men (20%) and for women (31%) (European Commission, 2016d, p.2-8).
The problem of the low 'stock' of graduates in Italy's population is compounded by the stagnation in the number of graduates and decline in the flow of university enrolment. Administrative MIUR data[10] record 277,853 graduates in the academic year 2009-2010 and 310,778 graduates [11] in the academic year 2016-2017. First-year student enrolments were 307,936 in 2009-2010 and fell to 306,975 in 2016-2017. Figure 10 reports these data. As documented by Anvur (ANVUR, 2018) the fall of enrolments after the academic year 2013/14 showed a recovery in the academic year 2017/2018, that, however, is limited to Northern regions alone.

Fig. 10 here

These developments represent a threat to the level of Italian human capital in the future. The fall in new university students clearly reflects the impact of the long recession, with falling incomes and

[10] Data downloaded from the Anagrafe Nazionale degli Studenti http://anagrafe.miur.it (update 30/07/2018)
[11] MIUR data on graduates include graduates from Master courses.

expectations of social mobility for most Italians. But enrolments have also been discouraged by the steep rise of universities fees, that have increased by 75% in the period 2009-2014 (OECD, 2013); a detailed analysis of university activities is provided below. Lack of employment for graduates has also discouraged university enrolment. According to Eurostat data, in 2015 the employment rates of Italian graduates (aged 20–34) who had completed their education or training between one and three years prior to 2015 is equal to 48.5% only; Greece alone has a lower percentage; in Germany the share is 90.4%. In Italy the employment rate of recent graduates fell by almost 15 percentage points in the last 10 years.[12]

A parallel decline can be found in the number of Ph.D. students, that fell from 12,093 in 2010 to 9,279 in 2016. The reform of Ph.D. system required that funded positions be at least 75% of all positions offered, leading to a fall in Ph.D. courses from 1,761 in 2010 to 967 in 2018, and to a parallel fall in student numbers. A low share of students (about 15.1%) comes from abroad and close to 56% of Ph.D. students has graduated from the same university (ANVUR, 2018). The ISTAT survey on doctorates (ISTAT, 2015b) found that in 2014 91.5% of people who had gained a doctoral degree in 2010 were employed and only about 7% were still looking for a job. However, the PNR 2015-2020 documented that in many firms Ph.D. holders are employed in the same categories as less skilled personnel. Current measures – including the R&D tax credit and the innovative start-up law – provide indirect incentives to firms employing PhDs. Italy's National Research Programme 2015-2020 has introduced the "innovative doctorate", based on the Principles for innovative doctoral training published in 2011 by the European Commission, focusing resources on PhD programmes which are international, intersectoral or interdisciplinary. In 2016, 60% of public funding for Doctoral programmes has been allocated to programmes fulfilling "innovative criteria".

4. The regional divide

The large economic and social disparities between Italy's North and the South are even starker when we examine regional performances in research and innovation. R&D expenditure on regional GDP is 1.4% in the North and 0.9% in the South; patents at the European Patent Office per million inhabitants are 106.8 in the North and 10.1 in the South, the share of employees in high tech industries is 3.7% in the North and 2% in the South (ISTAT, 2015c, p.271).

Considering the long term evolution of total R&D expenditure in Italy's regions, Fig.11 shows – using Eurostat data – the dramatic increase of the gap between Northern regions on the one hand and Central and the Southern regions on the other. While in 1995 the North had a total R&D of about 7 billion euros (at 2005 prices), the South had less than 2 billion. In 2014, Northern regions' R&D was greater than 11 billion euros, while Southern regions had a modest increase to more than 3 billion. Central Italian regions stayed slightly above the R&D values of the South, with a stagnation since 2000 just above the 4 billion mark. A major 'jump' in the gap between the North and the rest of Italy took place since 2007, with a continuing growth trend also during the decade of crisis.

Figure 11 here

Territorial imbalances in innovation have also been documented by innovation surveys, showing that two thirds of innovating firms and three quarters of total expenditure are concentrated in five regions only - Lombardy (with 25% of innovators), Veneto, Emilia Romagna, Piedmont and Lazio.

[12]http://ec.europa.eu/eurostat/statistics-explained/index.php/Employment_rates_of_recent_graduates#Employment_rates_of_recent_graduates

In Italy's Southern and island regions less than 13% of Italian firms innovating in products and processes are located (Istat, 2016a). Additional evidence has been provided by the ANVUR report on the gap between the South and the rest of the country in terms of R&D employment, R&D intensity and access to the EU research programme, (ANVUR, 2018).

A serious divergence has emerged also in university performances - including research outputs, teaching standards, student trends. Southern regions have shown poorer performances and greater reductions in student enrolment, staff and funding (De Angelis et al., 2016). Universities in the South recorded a lower success rate in the 2017 PRIN call and a lower international student mobility (ANVUR, 2018). Student support funds, managed at the regional level, have also shown differing performances, leading to unequal opportunities for the young in Southern regions (ANVUR, 2016a).[13] The ANVUR report argued that the regional management of funds for university students contributes to higher territorial inequalities. However, the 2017 budget law increased student support funds in the south (ANVUR, 2018). The ANVUR report for 2018 pointed out the growing migration of students from the South to universities located in the rest of the country, especially in the North-West; Southern universities have not recovered yet the fall in the number of students compared to 2014 levels (ANVUR, 2018).

This regional divergence is the result of developments in all the areas of research and innovation discussed above. Business activities in Central and Southern regions have been heavily affected by the decline in industrial production, with an increased presence of low technology activities and firms with little R&D. Cuts in public R&D have had a major effect in Southern regions where research infrastructures and universities are weaker. The increasing importance of merit-based funding of universities has also reduced resources for higher education and public research in the South; between 2008 and 2015 the transfers for general university funding (FFO) in current terms have fallen by 4.3% in the North; in the Centre and South the fall has been close to 12% (Fondazione Res, 2016, p.49).

The reduction in university education has been dramatic; from 2003-2004 to 2014-2015 the number on new enrolments has fallen in Sicily and Sardinia by -30.2%; the rest of the South had a fall of 25.5%; the Centre had a reduction of 23.7%; the North experienced a contraction of 11%; in recent years the number of enrolments has increased again in the North and Centre only (ibid, p.11; Viesti, 2018; ANVUR, 2018). The results of the Research evaluation exercise (VQR) conducted by ANVUR for 2011-2014 show some improvements in the performance of Southern Italian universities in terms of products of research and recruitment policies (ANVUR, 2016b).

Public policies on R&D and universities have a serious responsibility in Italy's growing regional disparities in research and innovation. Few policy actions have countered this trend. EU Structural Funds have been available in the PONREC programme, with a total allocation for 2014-2020 of nearly €4.1 billion in five priority areas: (1) industrial research, (2) structural/infrastructural strengthening, (3) clusters and laboratories, (4) smart cities and communities and (5) social innovation; actual spending, however, has been limited. The Smart Specialisation programme has produced some interesting experiences in selected regions, supporting the trajectories of local technological development.

5. Policies for research and innovation

The problems of Italy's research and innovation documented above are the result of long standing weaknesses of the national innovation system and of policy decisions. In this section the main policies for research and innovation recently introduced in Italy are discussed, exploring their impact.

The National Research Programme 2015-2020

The framework for Italy's research and innovation policy is provided by the National Research Programme (PNR) for the years 2015-2020, that was developed by MIUR and approved in May 2015 - with a two-year delay – by CIPE, a Ministerial Committee (MIUR, 2016). Planned investment in research is about €2,5 billion for the period 2015-2017; resources that are mobilised in the programme include all MIUR funds – for universities, public research organisations, research programmes, etc - and EU programmes, including the PON Research and Innovation funds (€1,93 billion) coming from Europe's Regional development fund and the European Social Fund, and from Europe's Structural Fund, and €500 million from the FSC (Fondo Sviluppo e Coesione).
However, the PNR does not include a specific commitment to increase public R&D resources, nor changes in the governance of the R&D system. MIUR funds considered in the PNR are the same general funding lines for universities and public research organisations and the size of prospective additional R&D financing is not clear.
The main fields of action of the PNR include human capital (€1.02 billion); public private partnerships (€487 million); territorial inequalities (€436 million); research infrastructures (€343 million); internationalisation (€107 million). Its six targets include:

- Internationalisation and integration in EU programmes, with a focus on Joint programming initiatives, and with the leadership of the projects PRIMA (Partnership for Research and Innovation in the Mediterranean Area) and Blue Med on space research.
- Human capital empowerment through innovative doctoral courses, some specific programmes and joint public-private partnerships.
- Selective support to Research Infrastructures in Italy, in line with ESFRI (European Strategy Forum on Research Infrastructures) methods.
- Public-private partnerships focused on technological clusters, cooperation with the non-profit sector and support to social innovation programmes.
- Territorial programmes for Southern regions integrated in the National Operational Programme (PON).
- Monitoring and assessment activities of R&I expenditure

The PNR also addresses the areas of specialisation of the national smart specialisation strategy set up in 2015 (see below, MIUR, 2016).

Policies for business research and innovation

While the National Research Programme provides a weak framework for public action on research and innovation, the most important policy effort in recent years has focused on the rise of indirect tax incentives to firms for a wide range of activities, including R&D, patents, human capital, investment in machinery and in the digital technologies of the Industry 4.0 programme.
The approach is typical of "horizontal" industrial and innovation policies where no public priorities are identified in terms of research missions, technologies, industries, social or environmental objectives, and no selective criteria are introduced. The assumption is that firms and markets are efficient and effective in making decisions on R&D and innovation projects and on the direction that technological change may take and that government action should not introduce 'distortions' with 'selective' measures. The rationale for such 'horizontal' policies relied on the expected benefits of continued market liberalisation, the provision of context conditions such as education and infrastructures, rule-setting in line with European Commission actions for new activities (De Vincenti, 2014). However, the effectiveness such 'horizontal' policies is increasingly questioned also at the European level (see the discussion in Pianta, 2014; Pianta et al. 2016; Lucchese at al. 2016; Mazzucato, 2018). The main measures introduced for supporting Italian firms' research and

innovation have been investigated in various reports (Nascia and Pianta, 2014, 2015; Nascia et al., 2016, 2017, 2018) and are summarised here.

R&D tax credit. The R&D tax credit was introduced in 2007 for the years 2008 and 2009. After a two year stop, the measure was reintroduced in 2011, limited to firms financing research projects in partnership with universities and employing highly skilled workers in R&D. The Giavazzi Report (Giavazzi et al, 2012) commissioned by the Monti government raised the issue of additionality of public incentives, based on the concern that that firms could replace their own R&D funds with public R&D subsidies; in 2013 a new tax credit measure was introduced based on incremental expenditures and in 2015 the finance ministry released the operational regulation for the new tax credit scheme. The 2017 Stability law amended the tax credit scheme, available now for 2015-2020, allowing a 50% tax credit for R&D expenditure - both internal and external to firms - exceeding the average of 2012-2014 spending (previously the rate of tax credit for internal R&D was 25%). The maximum amount that firms may obtain as tax credit is raised from €5 million to €20 million. An assessment of this measure by Istat found that in 2015 7,993 private businesses benefitted from the tax credit for around €590 million; the average per firm is modest (less than €75,000), three quarters of recipients are located in Northern regions and no additionality of the tax credit measure was found (ISTAT, 2018f).

The Patent Box. The emphasis put in recent decades on a greater protection of intellectual property rights (IPRs) has brought to Italy – with the 2015 stability law - the 'patent box', a specific tax benefit for firms' earnings coming from patents, trademarks, licenses and software. A deduction from the firm's tax base is provided for 30% of the incomes from patents, trademarks, licenses and software in 2015, 40% in 2016 and 50% in 2017. Patent boxes are indirect, semiautomatic incentives common in the OECD countries. Their objective is to stimulate the production of patents and IPRs, but no empirical evidence on such an impact is available, as argued by Mazzucato (2013). In fact, the 'Patent box' plays a key role in the strategies of large firms to reduce taxation on their technology-related earnings. The global tax planning strategies of multinational companies often 'hide' profits in royalty payments for patents and IPRs, 'locating' them is subsidiaries benefitting of measures such as the 'Patent box'. The public benefits, also in terms of additionality effect, of Italy's 'Patent box' measure are yet to be proved.

Machinery and equipment. In 2013 the government reintroduced an incentive scheme for the acquisition of machinery and equipment by SMEs that has long been a key part of Italy's industrial policy (DL 69/2013 'New Sabatini Law'). SMEs are offered soft loans, with Cassa Depositi e Prestiti (Italy's public bank) providing credit for investment and the Ministry of Economic Development covering the cost of interest reduction. Between April 2014 and June 2015 more than 5,000 SMEs applied to the scheme for an investment of around €1.7 billion. The 2016 budget law has introduced a measure allowing accelerated depreciation of investment up to 140% of the original cost, resulting in a tax reduction on profits. The 2017 stability law confirmed the incentive for machinery investment and increased the incentive in the case of investment associated to the 'Industria 4.0' strategy that could reach a tax benefit equal to the 250% of the expenditures in digital goods.

Loan guarantees for SMEs. A growing emphasis has been put on improving access to financial markets for SMEs, but the main tool that is used is the system of loan guarantees (Fondo Nazionale di Garanzia) established after the credit crunch originated by the 2008 crisis. The fund provides collateral and other instruments allowing SMEs and micro-firms to fund investment through bank loans. In the period 2008-2014 the fund made available €32 billion of collateral (of which 17.6 for manufacturing firms) triggering about €56 billion of new investment (of which 31.2 in

manufacturing) mainly by firms located in Northern regions. In 2014 alone €8.3 billion of collateral led to €12.9 billion of new investments.

Support for start-up firms. In 2012 the government introduced legislation supporting the emergence of innovative "Start-up firms". They were defined as new small firms, established in the past five years, with a turnover lower than €5 million, focusing on technological innovation, located in a EU country with at least one branch in Italy, with no distribution of profits and with at least one of the following characteristics: a) R&D expenditure of at least 15% of sales; b) at least one third of the employees holding a PhD degree or attending a doctoral course and at least 50% of the workforce holding a university degree; c) ownership of at least one patent, trademark or license. Start-up firms are offered indirect incentives (tax holidays, lower administrative costs, some exceptions to labour laws and tax bonus for investors), an earmarked access to the loan guarantee fund, support for their internationalization efforts and access to innovative financial instruments such as crowdfunding. The 2017 Stability law has confirmed such measures. In 2015 the government introduced also the notion of "Innovative SMEs" with softer requirements.

Capitalisation incentives. Over the last years, specific tax incentives have been introduced in order to favour the expansion of capital of undercapitalised firms (Aiuto alla Crescita Economica, set up in 2011). Combined with the accelerated depreciation of investments mentioned above, these measures are estimated to cost €3.5 billion in foregone tax receipts for 2016, with larger firms as main beneficiaries. Moreover, the analysis of the impact of such measures does not find any particular tax advantage for high tech firms (ISTAT, 2016b).

ICTs and the Digital Agenda. A comprehensive policy for the development of ICTs has long been missing in Italy. The 'Digital Agenda' is the current initiative addressing the issue. The Ministry for Economic Development (MISE) has launched in December 2014 the call 'ICT-Agenda digitale' on key enabling technologies, funded by its 'Sustainable Growth Fund'. The same Fund finances with €250 million the Sustainable industry plan (call 'Industria sostenibile', financing projects on sustainable growth and the green economy) and with €500 million the new National research Programme (PNR). In 2014 MISE introduced IT vouchers for SMEs, with a direct funding for the acquisition of IT materials.

EU Structural funds. The National Operational Programme 'Research and Competitiveness' (PONREC) has been co-financed by EU Structural Funds and by Italy's Government with €4.4 billion for the period 2007-2013[14]. The PONREC increased the percentage of resources of Structural Funds spent for R&D from 3.1% in 2000-2006 to 22% in 2007-2013, falling to 15% in the new Programme 2014-2020. This plan includes resources coming from ERDF (the European Regional Developmental Fund) for €1.29 billion, from ESF (the European Social Fund) for €930 million, and from Italy's co-financing for €360 million. MIUR will be in charge of the programme that addresses technological clusters, enabling technologies and research infrastructures.

Foreign investment. In 2013 the government announced the plan 'Destinazione Italia' (Presidenza del Consiglio dei Ministri, 2013) envisaging fifty actions for creating a business environment more attractive for foreign investment; they include simplified bureaucratic procedures, custom reform, an Agency devoted to supporting foreign investment, favourable investment rules and tax incentives.

[14] Resources were reduced in October 2012 after the reprogramming of MISE and MIUR. Funding from the European Regional Development Fund (ERDF) is €3,102 million (http://www.ponrec.it/programma/risorse-finanziarie).

Smart Specialisation Strategy. A significant departure from the 'horizontal' approach to policy came at the European level with the launch of the Smart Specialisation Strategy that asked each region to identify its areas of strength in research and innovation, providing EU funds to support them. Since 2013 Italy's strategy is managed by the government agency Invitalia in cooperation with MISE and MIUR, and has led to an extensive involvement of regional authorities and economic actors; activities are expected to trigger public-private partnerships and the involvement of universities and public research organisations. By 2016 all regions had set up their strategy, leading to five national thematic areas and twelve regional thematic areas of specialisation. The five national areas include: Aerospace and defence; Health, nutrition and life quality; Smart and sustainable manufacturing, energy and environment; Tourism, cultural heritage and creative industries; and Digital agenda, smart communities, infrastructures and smart mobility.
In 2016, the Agency for territorial cohesion assessed current policy measures, pointing out the contrast between the high quality of the research output, the small size of Italy's skill-intensive industries and the lack of a common governance of the R&I system. The document provides details on the governance and monitoring system and on the financial framework (Agenzia per la coesione territoriale, 2016)[15].
A new initiative funding business R&D projects in three technological areas coherent with the national strategy of Smart Specialisation was launched in March 2018 by MISE; the fields identified include smart factories, agrifood and life sciences. The call made available €562.7m for R&D projects addressed to private business and to public-private partnerships, earmarking €387.6m for Southern regions[16].

Industry 4.0

Another departure from the 'horizontal' policy approach has come with the Industry 4.0 strategy introduced in 2016 (renamed in 2017 'Impresa 4.0'). The concept of Industry 4.0 originated in Germany to support the digital transformation of production, challenging US monopoly power in digital networks and platforms. The Italian government identified the specific goal of spreading advanced digital technologies such as robotics and automation, cloud computing, big data, sensors, 3D printers and introduced a wide range of measures (see also Bianchi, 2018).
In 2017 the accelerated depreciation allowance of the cost of acquisition of machinery in the fields associated to 'Industria 4.0' was introduced; other measures included venture capital benefits, high tech infrastructures and university and secondary education support, all financed by the 2017 budget law. The targets of such policy included €10 billion of expected additional private investments in 2017-2018; €11.3 billion of expected R&D and innovation expenditure by business in 2017-2020; €2.6 billion of expected early stage investments in new firms in 2017-2020.
In the 2018 stability law (Legge 205/2017, 29 December 2017; MEF et al., 2017) measures have introduced a preferential treatment for activities related to Industry 4.0 in a variety of policy fields:
- The accelerated depreciation allowance for investment in machinery of 140% of the cost of acquisition is increased to 250% for equipment associated to the fields of 'Impresa 4.0'.
- Out the €330 million allotted for 2018-2023 to tax benefits for the acquisition of machinery ('Nuova Sabatini') one third, around €110 million, is allocated to the activities associated with 'Impresa 4.0'.

[15] The document can be downloaded from: www.agenziacoesione.gov.it/opencms/export/sites/dps/it/documentazione/politiche_e_attivita/Programmazione_2014_2020/Strategie/Strategia_Nazionale_di_Specializzazione_Intelligente_Italia.pdf
[16] http://www.sviluppoeconomico.gov.it/index.php/it/incentivi/impresa/bando-fabbrica-intelligente-agrifood-e-scienze-vita

- Out of €3.5 billion of the resources for Contratti di Sviluppo, funds supporting restructuring projects in areas of industrial crisis, mainly in Southern Italy, €1 billion is associated with Impresa 4.0 activities.
- €100 million is allocated to 'digital trade chains' supporting sales networks of 'Made in Italy' products.
- €3.5 billion is available between 2017 and 2020 for digital infrastructures; targets for 2020 include access for all firms to the 30 mbps bandwidth network; and access for 50% of firms to the 100 mbps bandwidth network.
- €250 million is allocated to tax benefits for the training of the employees involved in the technologies supported by 'Impresa 4.0'.
- New funds are provided for expanding non-university tertiary education (Istituti Tecnici Superiori) with €10 million in 2018, €20 million in 2019 and €35 million in 2020. Other measures support doctoral courses in the relevant fields.

MISE is in charge of the implementation of 'Impresa 4.0' with a multi-level coordinating body that includes six ministries, Cassa Depositi e Prestiti, business organisations, trade unions and Polytechnics (MEF et al., 2017). According to an estimate of the Ufficio Parlamentare di Bilancio, the body in charge of the estimation of the costs of policy measures, the lower tax revenue due to the incentives would amount to €2.3 billion in 2018 and around €4 billion in 2019-2020 (UPB, 2017)

While 'Impresa 4.0' plays a positive role in bringing attention to the technological backwardness of Italian industry and the need for an innovative leap, the methods and direction of the strategy present some problems. First, the focus on digital technologies and advanced automation is relevant in Italy for a rather limited number of companies - which are already technologically advanced. Conversely, Italy's main problem is broadening the number of innovative firms that at present do not have the internal structures and skills – including a significant number of employees with university education - to venture on the uncertain ground of digitalisation. The ISTAT report found that in the first year of the programme mainly large, technologically advanced firms benefitted from such measures; the impact on additional investment is estimated at 0,1% only (ISTAT, 2018f).

Since 2017 the impact of 'Impresa 4.0' has been more relevant, stimulating a new demand of advanced machinery and equipment for domestic producers. ISTAT's index of industrial production for Italian instrumental goods increased from 97.8 in June 2016 to 111.1 in June 2018[17]. The domestic market – including Italian firms benefitting from the incentives of Impresa 4.0 – over the same period had an increase in the index from 95.5 to 111.5. In 2017 the industrial automation sector showed an increase (in current prices, compared to 2016) of sales by Italian producers by 11.6%; imports increased by 12.5% (ANIE Automazione, 2018, p.28).

Impresa 4.0 is having a positive modernization effect and has provided a stimulus to business investment. It remains to be seen whether these effects reach beyond the most advanced group of Italian manufacturing firms and favour a broader technological upgrading of Italian industry.

A second concern is that Impresa 4.0 is inspired to a model of far reaching automation that may reduce human labour and competences and concentrate control over complex processes in few large companies. This trajectory of technological change may have a limited coherence with Italy's industrial structure where small and medium sized firms are prevalent also in the industrial automation sector. There is a risk that such policy may lead to a more polarised industrial structure, lower employment and higher inequalities (Pianta, 2018a, 2018b; Guarascio and Pianta, 2018).

6. Four questions for Italy's research and innovation

The Italian research and innovation system is at a turning point. The historical weaknesses linked to the limited technological activities of the country have been compounded by the consequences of

[17] Data from dati.istat.it.

ten years of crisis. The historical weaknesses of the Italian research and innovation system are well known: a low R&D intensity, production specialization in mature industries, too few large and medium-sized firms, limited activities in high technology, acquisition by foreign multinationals of many Italian innovative companies, difficulties in financing innovation, low public spending for R&D and universities, modest percentage of graduates in the workforce, strong territorial polarisation between some technologically advanced areas in Northern Italy and the rest of the country. The effects of the crisis introduced new fragilities in the system: firms have suffered major losses in production and have reduced investment, weakening the country's capabilities; the introduction of innovations was postponed waiting for a recovery in demand that has long lagged; research and decision-making centres in production systems have been increasingly moved abroad, austerity policies have reduced public spending on research and university, thousands of young researchers and highly qualified graduates have left the country to look for work abroad. The result of the 'lost decade' is a further structural weakening of Italy's research and innovation system.
In the last two years, some signs of attention to research and innovation have emerged: the 2015-2020 National Research Program was approved (late), the Industry 4.0 program was launched, tax incentives were extended to the private R&D for 2015-2020, there have been initiatives on the National Smart Specialization Strategy, funding based on merit of the universities according to the evaluation of the quality of the research. However, the country's total R & D expenditure growth was modest and the amount of public resources was greatly reduced compared to the beginning of the crisis: from 2010 to 2015, public R & D expenditure decreased in real terms by 18%; within this, from 2008 to 2014 public spending for state universities decreased by 14%. On these as other indicators - private R & D, university students, graduates, etc. - in the years of crisis the gap between Italy and other major European countries has widened further.
In addition to limited resources, recent policy measures for research and innovation have some problematic aspects. There is no public demand policy that can create spaces for the investments and innovations of Italian companies. In the incentives for research and measures for Industry 4.0 there remains a 'horizontal' approach which results - after decades of such policies - inadequate to concentrate the commitment of companies towards new technological skills in some key areas for the country. Many measures - those for Industry 4.0 and for example university - can have the effect of increasing the polarization of the system between a few excellences on one side and the rest of the country on the other.
Four key policy questions emerge from this analysis of Italy's research and innovation policy.

a. Can Italian firms grow without technology?

Despite the presence of a significant group of innovative firms with good export performances, the Italian economy is characterised by an overwhelming majority of small and micro enterprises with a low R&D intensity. The concentration of the Italian business sector in the typical activities of the 'made in Italy' is generally associated with low and medium technology activities. Italy's economic structure continues to show a lower presence in high technology manufacturing and service industries, compared to major EU countries. Are these characteristics of Italian firms compatible with good long term economic performances?

Figure 12 here

An interesting way to explore possible answers is to compare the long term evolution of technological efforts and economic growth in Germany and Italy. Figure 12 shows the R&D expenditure per employee and the growth of real value added in industry groups over the long term, 1995-2014; manufacturing industries are grouped in science-based, scale intensive, specialised machine producers and traditional sectors. A double gap between Italy and Germany appears – that in some way representative of a broader divide between Europe's 'core' countries and the Southern

'periphery'. First there is the gap in R&D expenditure per employee – an issue already pointed out above – with Italy's industries lagging behind German research efforts in all fields; in science based industries Italy's modest activities have an R&D intensity that is half the German levels; this gap is visible in all industry groups and even in the traditional industries where Italy is specialised Germany spends much more that Italian firms.

A second gap concerns growth performances; the rate of growth of real value added in Germany is always two or three times the one for Italy. The evidence shows that for both countries technology matters for growth; a clear relationship between higher technological efforts and faster growth emerges for both countries. Simply, Germany and Italy appear to be in two different 'leagues'; science based firms in Germany had an average growth close to 6% per year over two decades – an increase typical of East Asian economies – that was driven by large R&D efforts; the worst performing German industry groups had an expansion of about 3% that was close to the best performing Italian industry group. Such a diverging dynamics between the two major manufacturing countries of Europe documents a new 'hierarchical' structure in technology and industry, and raises major questions on the coherence and cohesion of Europe's economy (see also Celi et al., 2018).

How do recent policies relate to these structural problems of Italy's technology and industry? In a previous study (Lucchese et al., 2016) we have documented how in the last three decades the policies of privatisation, liberalisation and reliance on 'markets' have contributed to weaken Italy's technology and industry. The recent Industry 4.0 programme – discussed in section 5 above - has two positive aspects – the emphasis on the importance of technology and the targeting of resources to specific fields, as opposed to 'horizontal' incentives for all firms. It has, however, two major limits – a model of 'extreme' automation and digitalisation that tends to displace labour and human skills, and a focus on the major Italian firms that already are technologically advanced, with little attention to the need to expand the number of innovative firms, upgrading their competences and technologies in an appropriate way.

The question whether Italian firms may survive and grow without adequate technological efforts has acquired a new urgency. But it is, in fact, an old question for the Italian economy. Already twenty years ago, in 1996, we argued that "we are facing a weakening of the technological base of Italy's industry, which adds to the gap in aggregate indicators of technological activities (...). This dynamics is distancing Italy from the 'virtuous circle' between technology, growth and employment that is common to other advanced countries" (Pianta, 1996, pp.275-276). In the aftermath of the the 1992 currency crisis, and of an export-based recovery driven by a 30% depreciation, we argued that "devaluation, export-led growth, the deepening of the country's specialization in traditional industries and the reduction of the role of technology can be seen as the result of the failure to expand Italy's presence in high technology in the favorable period of the 1980s". The result was that "between 1980 and 1994, employment in industry decreased by 1.4 million, nearly a quarter of the total. After the recession of the 1990s, the combined effect of industry's technological fragility, labor-saving innovations, the international organization of production and competition in more open markets could have an even more serious impact on the decline of the industrial production and employment in Italy" (ibid., pp.276-276; see also Lucchese et al., 2016).

Italy's last twenty years have been marked by economic decline and a systematic retreat of public policy (Pianta, 2012); the decade since the 2008 crisis has seen a deepening of such processes with growing gaps in research, technological activities and investment compared to other European countries. A reversal of such dynamics appears as a crucial challenge for the future of Italian firms.

b. Can public research survive with inadequate funds?

The historical weakness of Italy's public research and innovation system has dramatically worsened in the last decade when austerity policies have led to a major reduction in public expenditure in this field, reducing university funding, the activities of public research organisations and the financing

of private R&D and innovation in areas of policy priorities. The 19% fall in real terms between 2008 and 2016 - documented in Figure 5 above – is without parallels in Europe (with few exceptions of crisis-battered economies, such as Greece). Such a reduction of public research and university activities may lead to a risk of losing the critical mass required for developing high quality science and technology. It is a paradox that such deep cuts have taken place at the same time when major improvements in the research outputs of Italian (largely public) researchers were achieved. We have documented (see Figure 9 above) Italy's high and rising productivity measured in terms of scientific papers (or citations received by them) per million of R&D expenditure, one of the few measures where Italy is well ahead of the UK, France and Germany. This finding shows the quality of Italian research and its relevance in the scientific world. However, as pointed out above, with a declining public research system and large number of university professors approaching retirement without an adequate turnover, the scientific success of Italian scholars could be a temporary effect that may soon be lost in a weakening system, lacking resources and allowing a mass emigration of its young researchers. Restoring public research to the levels of ten years ago, with a large increase in public expenditure for R&D and universities, is an urgent – but feasible – first step for Italy's research and innovation policy.

c. Can the economy do without university education?

As a consequence of the reduction in government funding for public research, resources devoted to universities experienced a 14% fall in real terms between 2008 and 2014 and the number of universities' permanent staff decreased by 20% between 2009 and 2016 (see Figure 6 above). As a result of the 2008 crisis and of reduced public funds, the number of student enrolments in Italy's universities experienced a 20.4% reduction between 2003-2004 and 2014-2015. In latest years enrolments have increased again at a low pace, with the exception of Southern Italy.

This weakening of the university system is particularly negative as Italy has a major gap in the share of university-educated citizens. The most recent OECD data show that in 2017 Italy had a share of 26.8% of youth of 25-34 years of age with a university degree; this is the lowest among European Union countries, with France at 44.3%, Spain at 42.6% and Germany at 31.3% (OECD, 2018).

Public R&D, university funding and education are areas where Italy's gap with EU standards is expanding at a worrying pace.

When we consider education and the quality of Italy's labour force, there is a clear danger of a 'vicious circle' between: a) an economic structure where medium-low technologies are prevalent; b) a modest demand by firms for employees with university degrees; c) stagnant productivity resulting from the combination of low technology and low human skills, leading to gaps in innovation and competitiveness compared to major European countries; d) further reduction in economic activites and concentration at the lower end of international production, with job losses and stagnant wages. The precarisation of Italian labour can be seen, in fact, as a way to 'adapt' to such downward dynamics with a search for price competitiveness based on lower labour costs – as opposed to the technological competitiveness typical of 'core' European countries – and with a shift towards low education, low productivity, low wage, precarious jobs. The negative impact that such a trajectory of flexible, precarious labour may have on innovation performances has already been investigated (Kleinknecht, van Schaik, Zhou, 2014; Wachsen and Blind, 2016; Cirillo, Fana, Guarascio, 2017; Cetrulo, Cirillo, Guarascio, 2018).

The connection between the weakening of Italy's public research and the lack of employment opportunities for graduates is made evident by the growing migration of Italian researchers and highly qualified personnel to other countries (see Figures 7 and 8 above), where employment opportunities and research funds are greater and – often – where individual merit has a greater recognition in academic practices.

d. Can territorial divides be allowed to expand further?

The regional divide in Italy's research and innovation is a mirror image of the divergence between Italy and 'core' European countries. The last decade has seen a deepening of regional disparities as a result of several factors. The long recession after the 2008 crisis has especially hit Central and Southern regions leading to losses of technological and production capabilities; innovation has been discouraged by stagnating demand in poorer regions; R&D activities have been concentrated in the strongest Northern regions; specific policies – on public R&D expenditure, university funding, tax incentives to firms - have actively contributed to deepening regional disparities. We may argue that some Northern regions – Lombardy and Emilia Romagna in particular – have research and innovation standards that are on a par with 'core' European countries, and in fact are increasingly integrated in production and technological systems that are often centred in Germany (see Celi et al., 2018). At the same time, other Northern and Central regions have lost ground in research, innovation and production capabilities, and the gap with Southern regions has seriously increased. The question can be asked whether a geographically reduced base for Italy's best research and innovation performers could be too limited, far from the critical mass required to remain a strong player in Europe's research and innovation. An excessive reliance on few centres of excellence in R&D, academic research and innovation integrated in global networks may end up reducing the diffusion of knowledge in the economy and the transfer of technologies to firms, limiting the potential contribution of research to local development. Conversely, a broader regional presence of R&D and innovation capabilities would allow a diversification of competences, specialisations and economic activities, building a more robust and resilient innovation system.

The concentration of R&D efforts in major Northern regions has also set in motion a large internal migration of university students, graduates looking for employment, highly qualified workers and researchers. On the one hand this supports the positive performance of 'core' regions, but on the other hand further reduces the labour quality and competences available in 'periphery' regions, leading to poorer performances. A novel policy for rebalancing these regional asymmetries would be required in order to prevent a further polarisation and weakening of Italy's research and innovation system.

The European and international context

Finally, these challenges for Italian policy should not be viewed in a national context alone. Within Europe, there is a growing debate on the future of Europe's research and innovation policy, with differing views on the priorities and policy tools of the new 'Horizon Europe' agenda that is expected to replace the current 'Horizon 2020' programme. On the one hand, there is pressure for concentrating EU resources in the major players and in the fields of greater strength, with the risk of worsening the divergence in research and innovation within Europe (Lamy Report, 2017). Conversely, a new departure based on 'mission-oriented' research and innovation programmes, reflecting broader economic, social and environmental priorities, has been proposed (Mazzucato, 2018).

At the international level, a recent important contribution came from the Science Academies of G7 countries that in 2017 produced the joint statement 'New economic growth: the role of science, technology, innovation and infrastructure' (G7 Science Academies, 2017; Quadrio Curzio, 2017). The document urges governments to: "i) expand investment and capabilities in science and pre-competitive technologies; ii) increase investment in infrastructures - both tangible and intangible - that contribute to inclusive development and to progress in science and technology; iii) promote the development of capacities to design, engineer, produce and deliver products and services based on new science and technology; iv) promote open access - subject to appropriate regulations with regard to intellectual property - to advances in science and technology, while preventing the emergence of monopolistic practices; v) share effective practices in policies and programs that

promote innovation, technological diffusion, and efficient infrastructure development (...); vi) ensure that appropriate governance frameworks are adopted, so that the benefits of science and technology are fully realized, while maintaining public trust" (G7 Science Academies, 2017, p.1).
The statement argues that "growing levels of public and private investments in science and technology are needed to address the challenges of sustainable and inclusive growth" and that "current gaps in R&D efforts make it more difficult to access, adopt and expand knowledge and innovation, limiting the realization of their benefits. Public policies should recognize the key role that expenditure for the advancement and diffusion of knowledge, culture, higher education and innovation can play in supporting high quality socio-economic growth, and that these benefits outweigh many short-term concerns for balancing public finances". To this end, G7 Academies argue that "governments can play an important role in stimulating new demand through targeted public research programs, procurement for public services, and public investment in infrastructure" (ibid., p.2).
With regard to corporations, the statement by the Academies of Sciences argues that "in recent years, many corporations have limited investment in research and technology - which requires long investment horizons - and have favoured short-term returns from financial assets, thus presenting a further threat to economic growth. Well-designed public policies could encourage business investment with longer time horizons, supporting also high-risk projects" (ibid.).
These arguments are developed by the G7 Science Academies "in line with Goal 9 of the UN 2030 Agenda for Sustainable Development, which is to 'Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation'. In the aftermath of the 2008 economic crisis that has slowed down world growth, we need to make sure that investment in science, technology, innovation and infrastructure expands its contribution to sustainable and inclusive world growth" (ibid. p.1).
The arguments of the G7 Science Academies statement provide a highly appropriate framework for a long term strategy combining private investment and public policies for restoring Italy's research and innovation capabilities.

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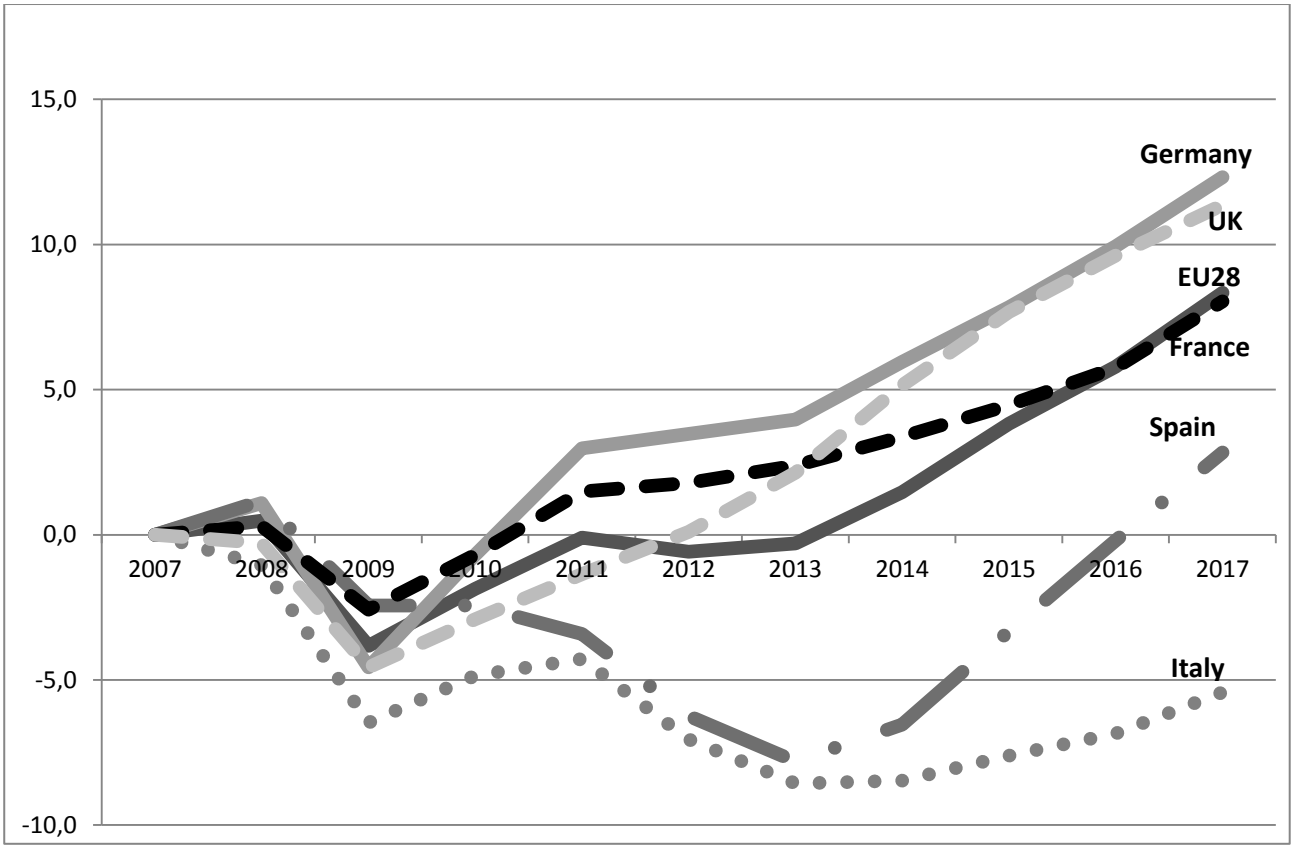
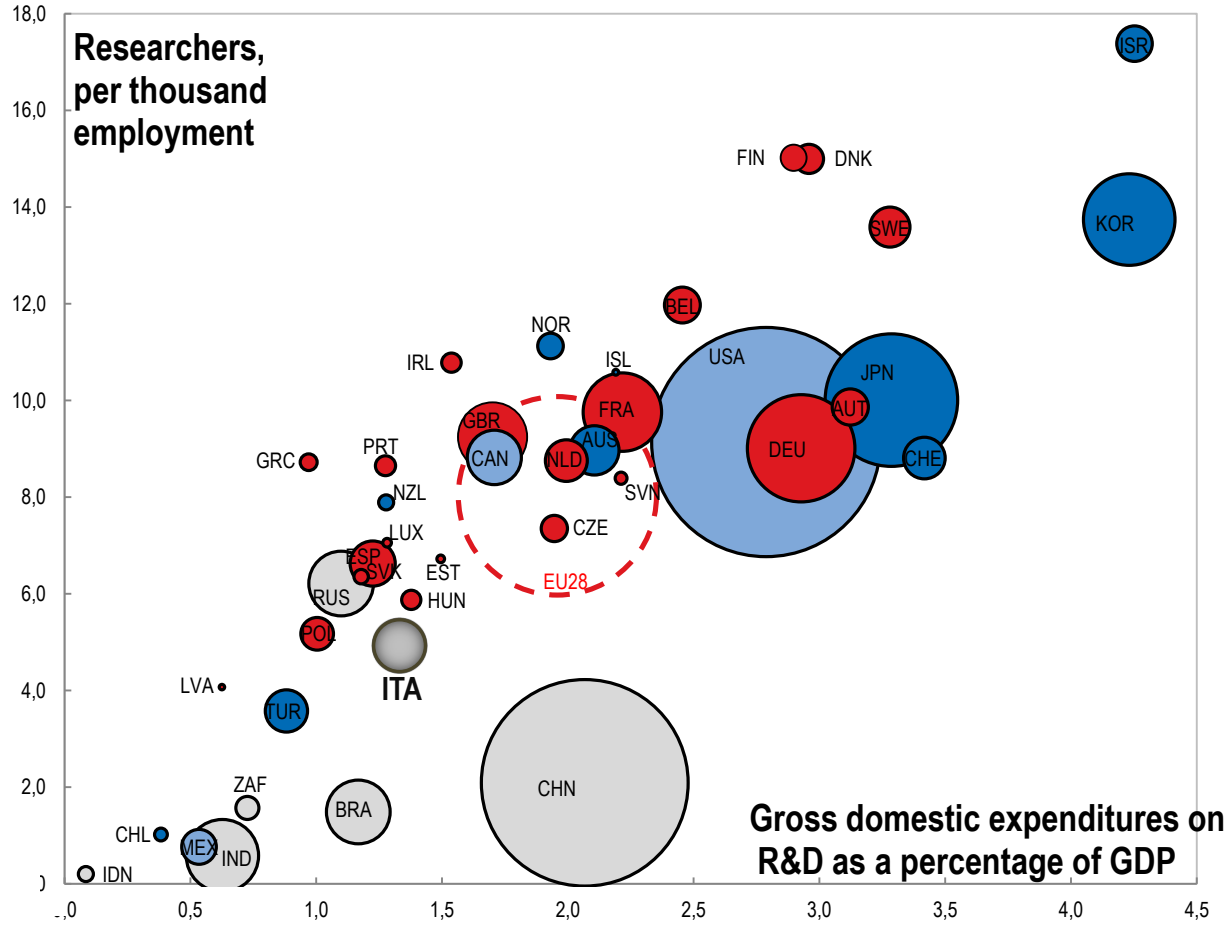
Figure 1. GDP at market prices, 2007-2017

Chain linked volumes, index 2007=100



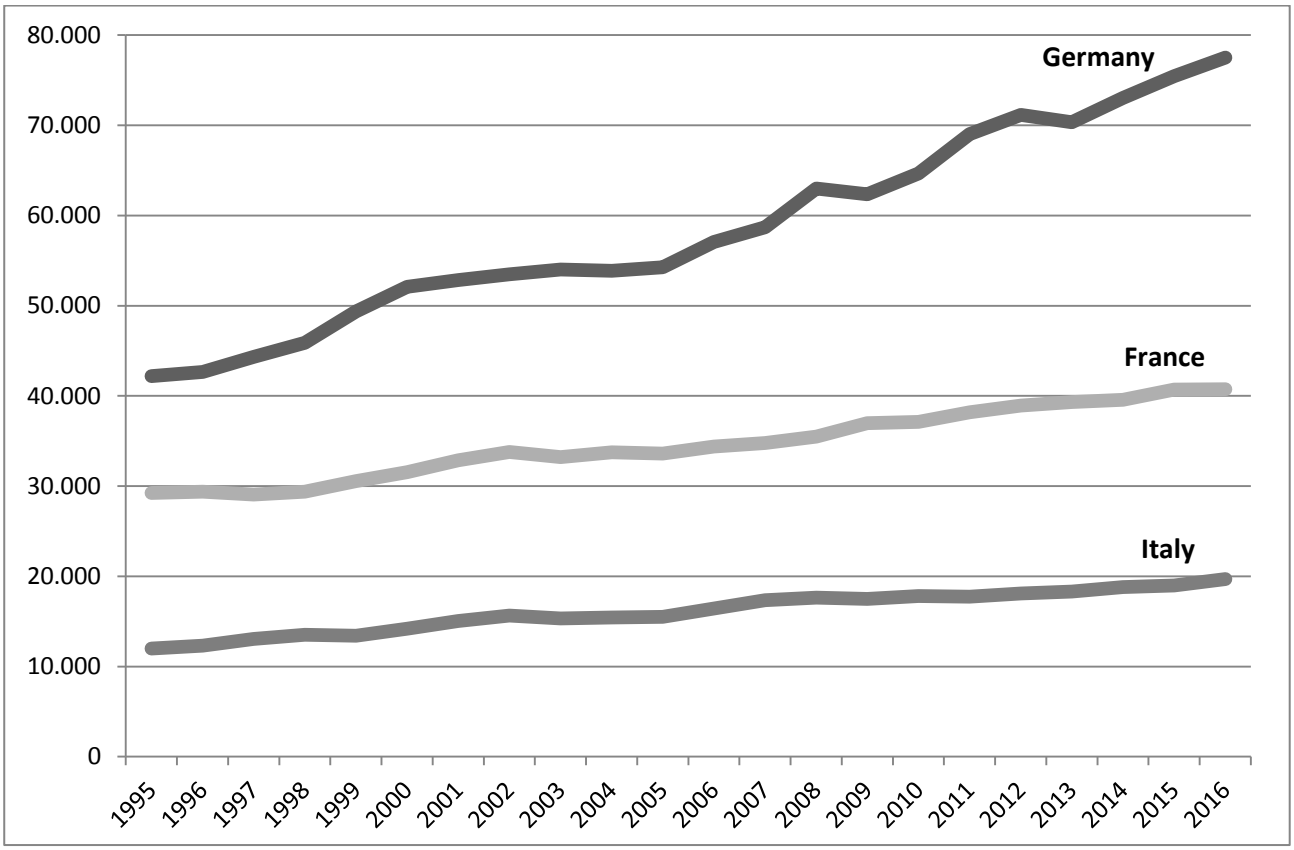
Source: Eurostat

Figure 2. R&D activities in OECD and major countries, 2015



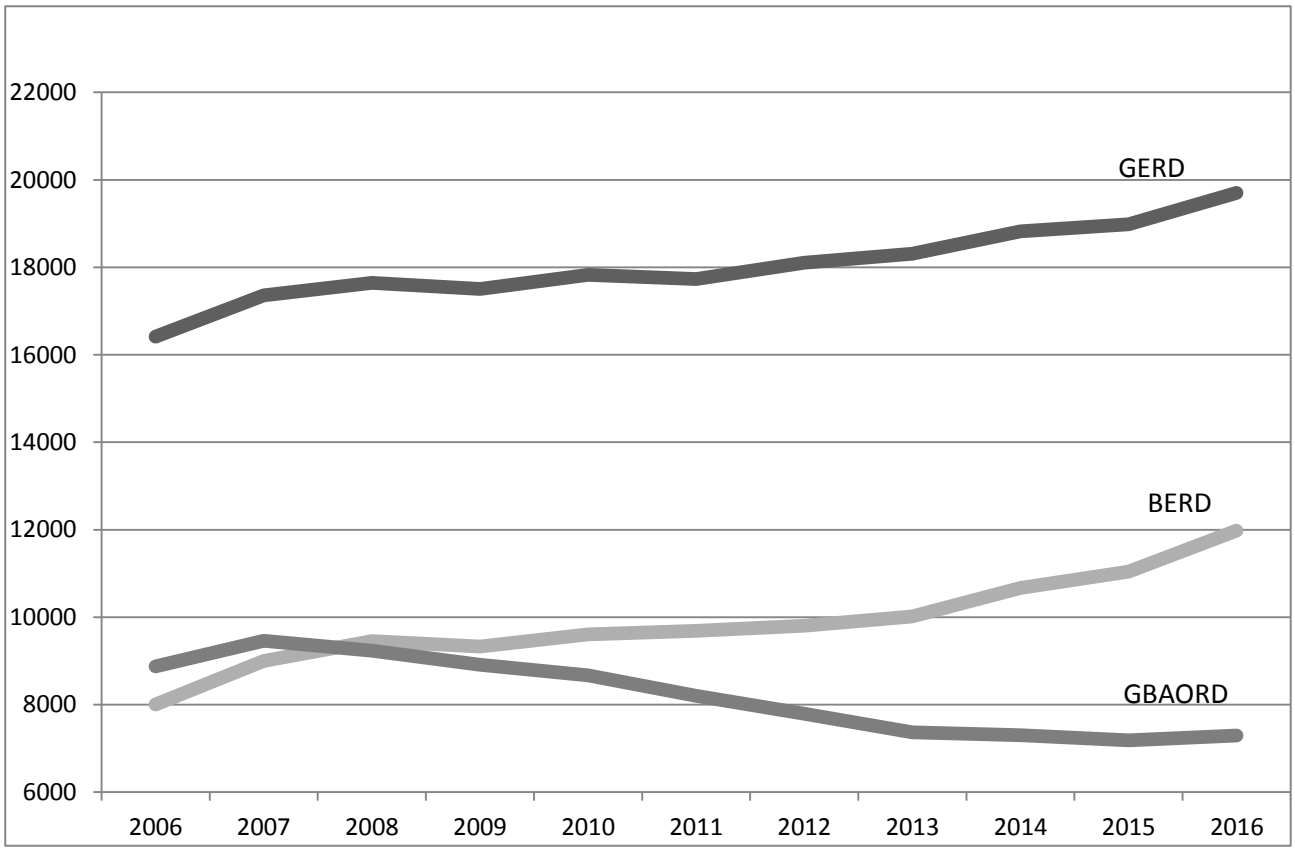
Source: OECD (2017, p.26)

Figure 3. Total R&D expenditure (GERD) 1995-2016 in Italy, Germany and France.
Million euros/purchasing power standards, 2005 prices



Source: Eurostat

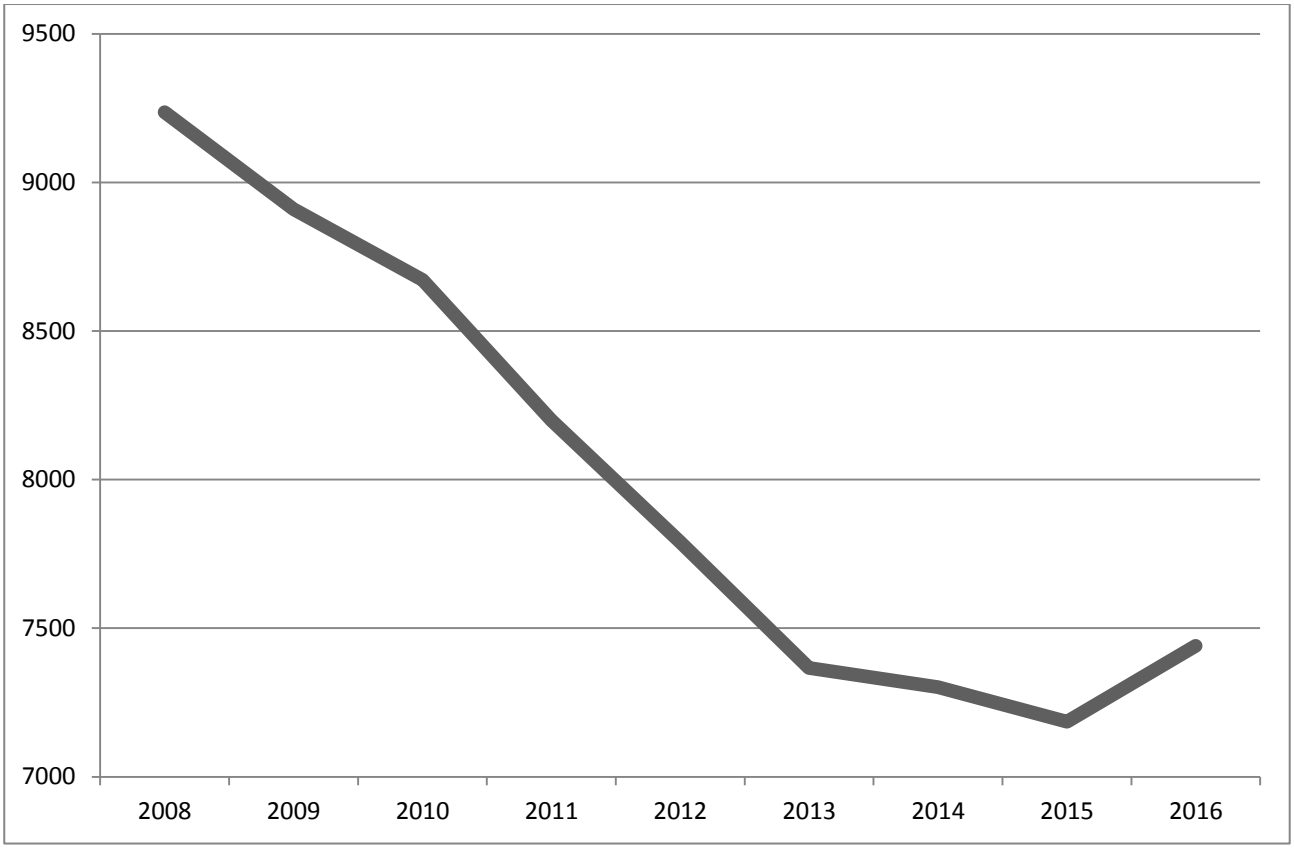
Figure 4. Italy's Total R&D expenditures (GERD), R&D performed by business (BERD), appropriations in government budget (GBAORD)
Million euros/purchasing power standards, 2005 prices



Source: Eurostat-Istat

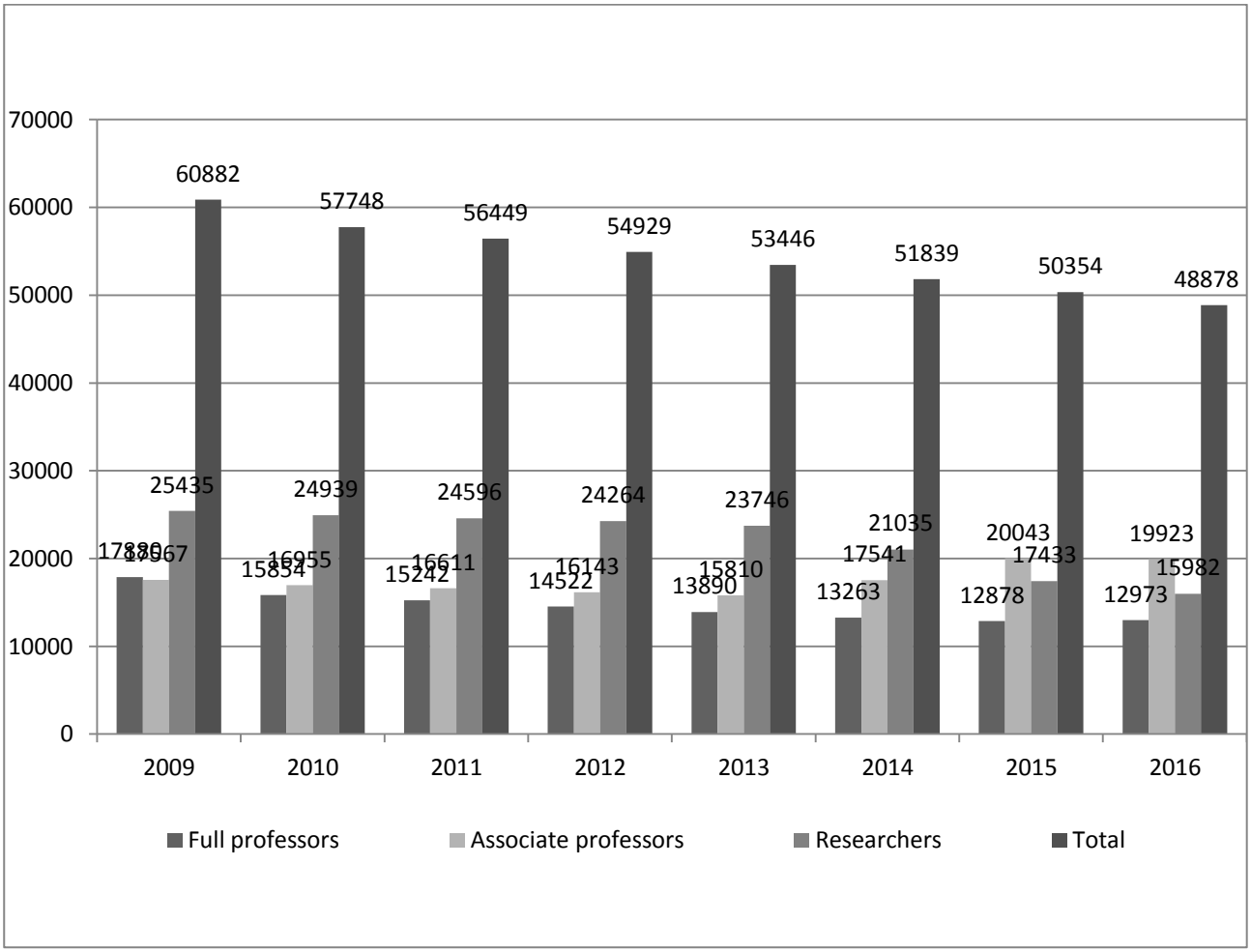
Figure 5. Total public expenditure for R&D (GBAORD) in Italy 2008-2016

Million euros/purchasing power standards, 2005 prices



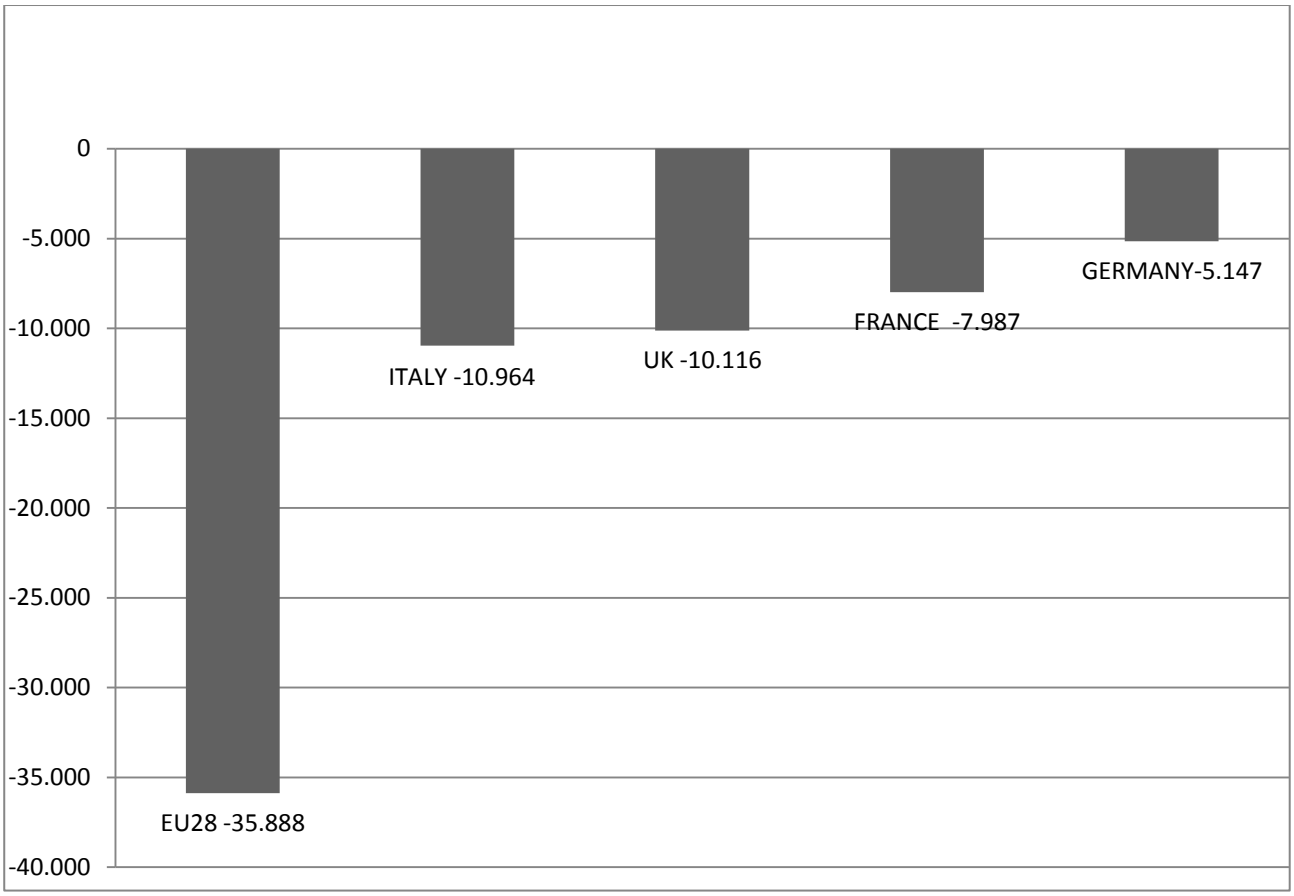
Source: Eurostat

Figure 6 University permanent staff in Italy, 2009-2016



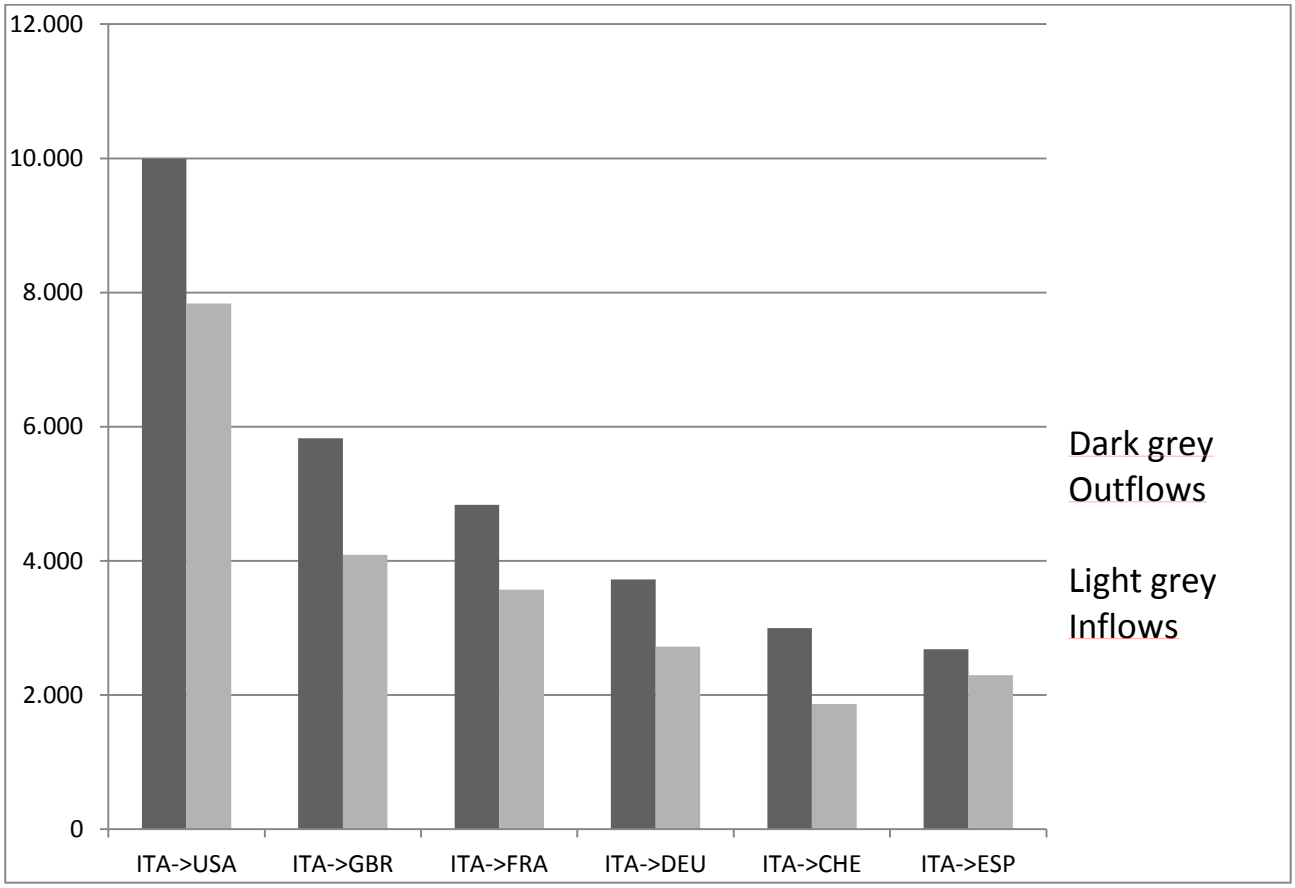
Source: MIUR

Figure 7. International net outflows of scientific authors, 2002-16



Source: OECD (2017, pp. 128-129) https://doi.org/10.1787/sti_scoreboard-2017-17-en

Figure 8. Flows of scientific authors between Italy and other countries, 2006-2016

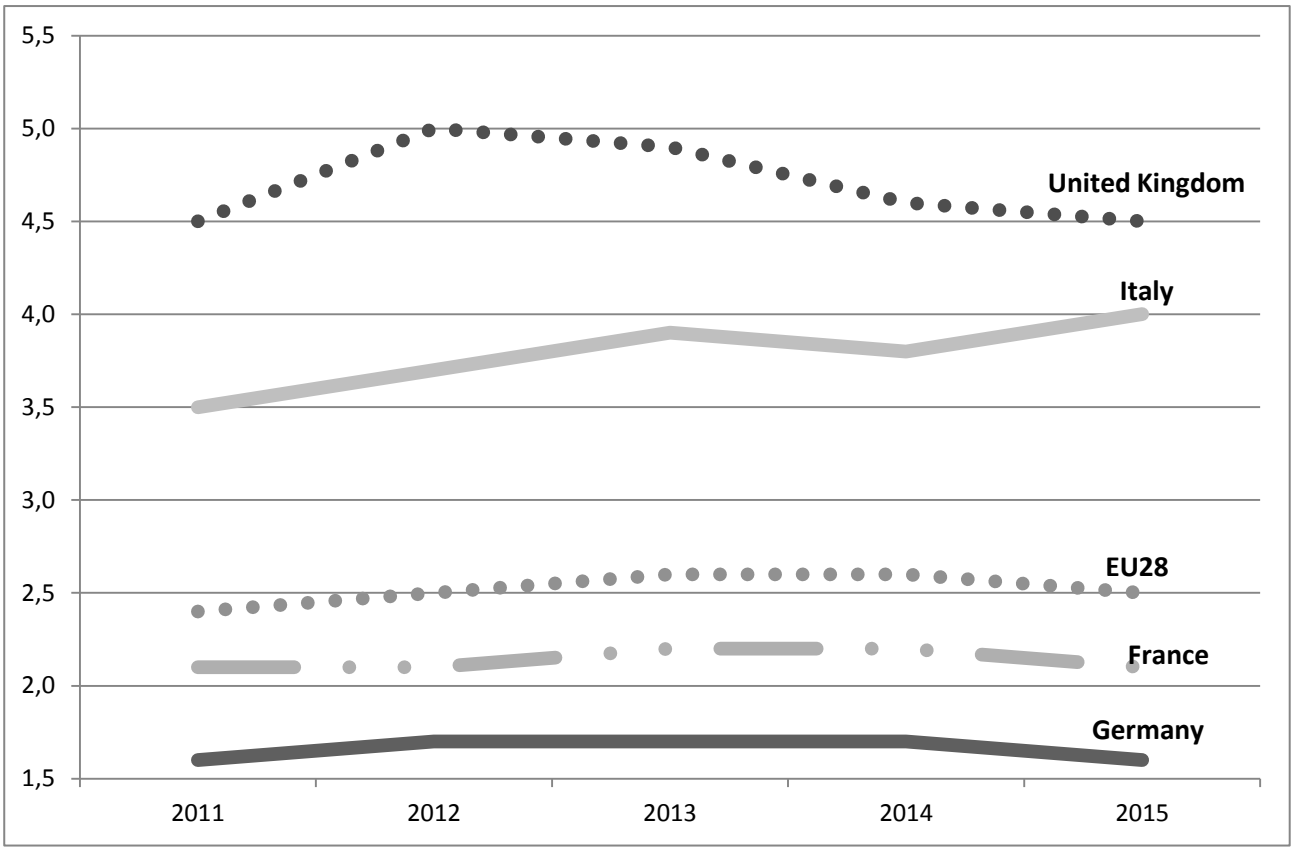


Source: OECD (2017) pp. 128-129 https://doi.org/10.1787/sti_scoreboard-2017-17-en

Fig. 9. Scientific productivity in major countries, 2011-2014.

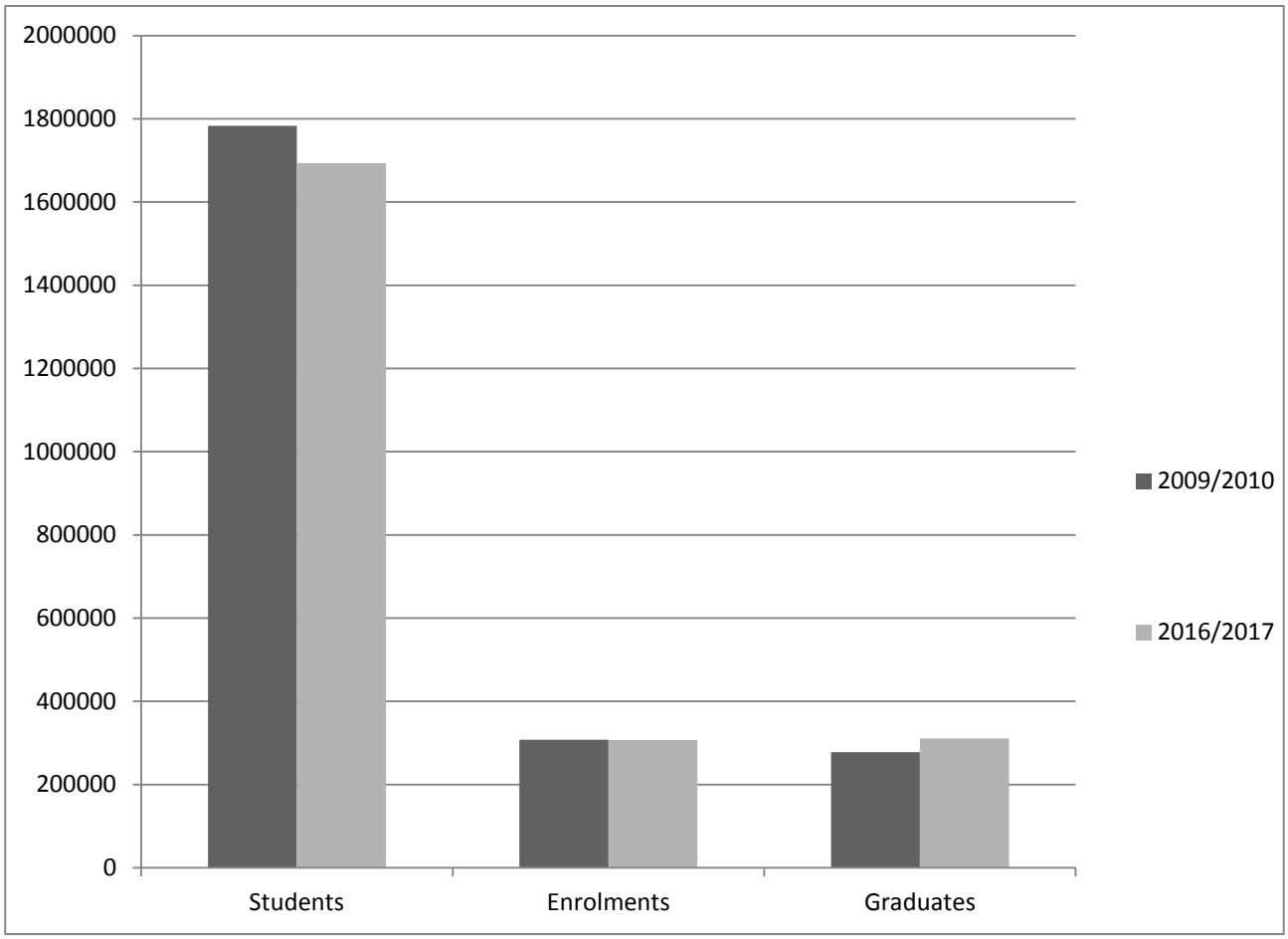
Number of scientific publications per expenditures for R&D.

Expenditures in million US dollars at 2010 Purchasing Power Parities



Source: ANVUR (2016, p.30).

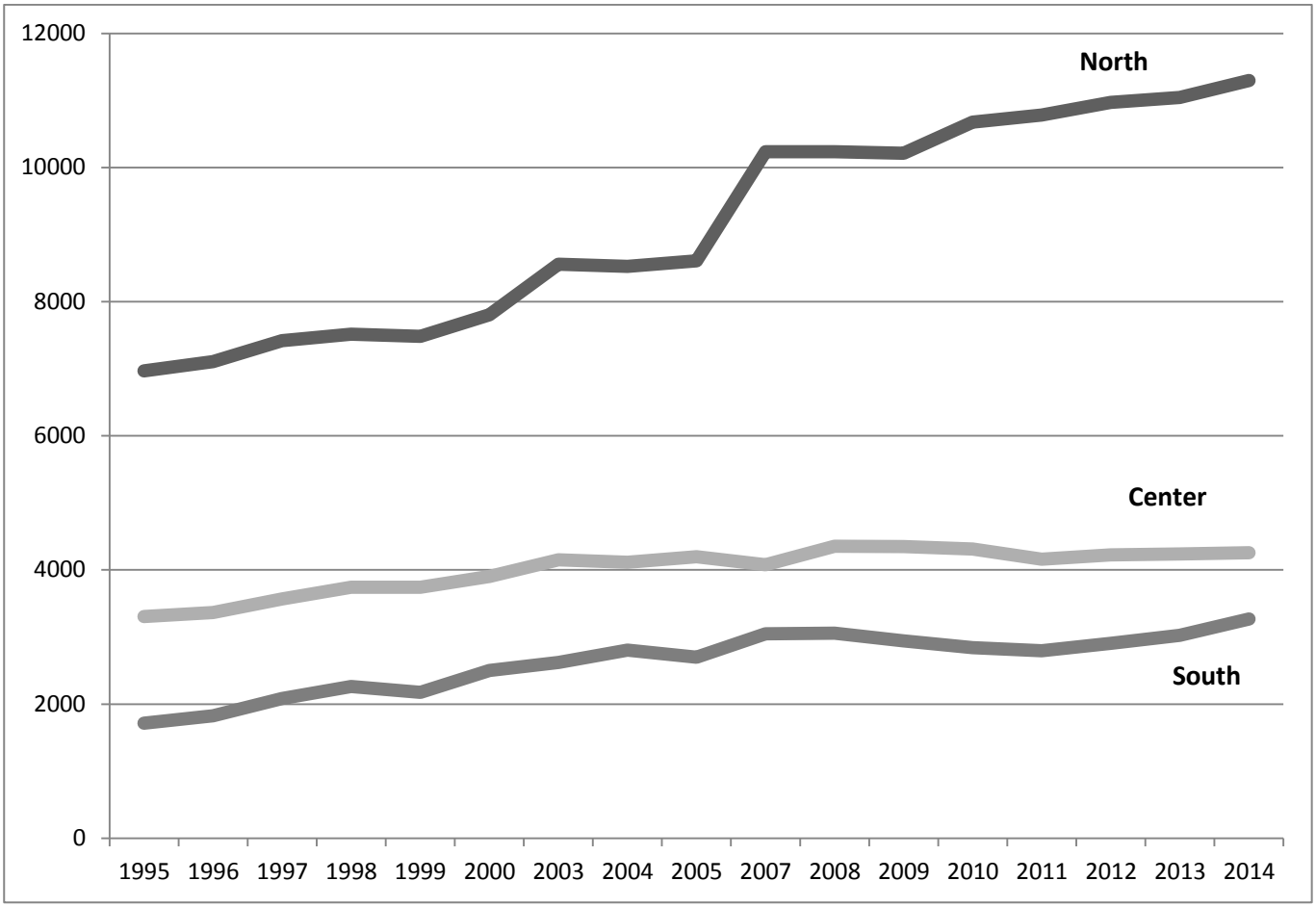
Fig. 10. University students, new enrolments and graduates, years 2009-2010 and 2016-2017



Source: data from the Anagrafe Nazionale degli Studenti http://anagrafe.miur.it (update 30/07/2018)

Figure 11. Total expenditure for R&D in Italian regions, 1995-2014

Million euros/purchasing power standards, 2005 prices



Source: Eurostat

Figure 12. R&D expenditure and value added growth in manufacturing sectors, Germany (DE) and Italy (IT), 1995-2014

Revised Pavitt industry groups :
SB Science based industries
SS Specialised suppliers machinery industries
SI Scale intensive industries
SD Supplier dominated traditional industries