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RESEARCH PAPER

The interaction between public and private R&D expenditure and national productivity

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Starting from the epistemological position of the positive interaction between public and private R&D expenditures at country level for maintaining productivity growth, the purpose of this paper is to provide empiricist–positivist arguments of this stance in order to design R&D policy that supports national competitiveness in fast-changing and turbulent markets

Introduction: epistemological position

Research and Development (R&D) consumes considerable economic and human resources, contributing to the accumulation of intangible capital, which is a main determinant of the competitive advantage of countries. Several econometric studies confirm the positive impact of R&D expenditure on productivity [see Mairesse and Sassenou (1991), Hall and Mairesse (1995) for studies at firm level; Guellec and van Pottelsberghe de la Potterie (2003, 2004) for analysis of OECD countries]. Other research shows that the relationship between R&D expenditure and productivity is insignificant (Lichtenberg and Siegel, 1991; Griliches, 1995; Hall, 1996). The purpose of this paper is to provide empiricist–positivist arguments, underpinned within the economic literature, that support the epistemological position that at country level the increase in R&D expenditure by the government sector (as a percentage of GDP) is a complementary input to R&D expenditure by the business enterprise sector (as a percentage of GDP) in the support of productivity. This stance can play a vital role in the design of the modern political economy of R&D,[1] which fosters the general economic performance of countries as well as their national competitiveness in fast-changing and turbulent markets.

Empiricist–positivist evidence in favour of the epistemological stance

The relationship between public and private R&D expenditure has been the focus of several analyses at firm level (see, for example, Higgins and Link, 1981; Link, 1982; Link and Scott, 1998; Toivanen and Niininen, 1998; Wallsten, 1999; Duguet, 2003; Lööf and Heshmati, 2005), at sector level (see, for example, Levin and Reiss, 1984; Lichtenberg, 1984, 1987), and at country level (Kealey, 1996). These studies

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aim at understanding whether public R&D expenditure is a complement or substitute for private R&D expenditure, but the scientific literature shows ambiguous results. Kealey (1996) analyses the funding of R&D across countries by an historical approach and argues the following economic laws of civil funding:

> The First Law of Funding for Civil R&D states that the percentage of national GDP spent increases with national GDP *per capita*. The Second Law of Funding for Civil R&D states the public funding and private funding displace each other. The Third Law of Funding for Civil R&D states the public and private displacements are not equal: public funds displace more than they do themselves provide. (Kealey, 1996, p.245, original emphasis)

These economic laws of scientific research support the statement that countries whose civil R&D is predominantly funded by industry spend more than those whose civil R&D is predominantly funded by the state (Kealey, 1996).

David *et al*. (2000) survey the economic literature on this topic at firm, sector and aggregate level, with varying results:

> Main findings [by Levy and Terleckyi] are: (1) government contract R&D is positively and significantly associated with private R&D investment and productivity; and (2) 'other' government R&D has no contemporaneous relationship, but does complement private R&D . . . Lichtenberg . . . reports findings that . . . there is no additional impact from public R&D expenditures on private R&D investment . . .. (David *et al*., 2000, p.521)

Levy (1990) finds that five countries exhibit significant overall public–private complementarily effects, whereas two countries show significant substitution effects. (David *et al.*, 2000, p.523)

> Von Tunzelmann and Martin (1998) . . . in only 7 of the 22 countries do they find changes in government-funded R&D have any significant impact on changes in industry-funded R&D, with the sign positive in five of those seven cases . . . Five-sixths of the studies based on data from countries other than US report overall complementarity. (David *et al.*, 2000, p.524)

David *et al.* (2000) show that complementarity effects, between public and private R&D expenditure, are higher than substitution effects, in particular at the national level. Cohen *et al.* (2002, p.1) find that: 'public research is critical to industrial R&D . . . and importantly affects industrial R&D across much of the manufacturing sector'. Guellec and van Pottelsberghe de la Potterie (2003, pp.237–38) show that: 'both fiscal incentives and direct funding stimulate business-funded R&D . . . [and] . . . any type of government support to business R&D is more likely to be effective if it is integrated within a long-term framework'. More recently, at the firm level, Toole and Turvey (2009, p.43) find that a public financing programme creates incentives to follow-on private investments, though it is not an unequivocal result in the economic literature. Coccia (2010), considering Eurostat data, finds a strong positive correlation between R&D expenditure by firms and by government across countries – a value higher than 75% – whereas the partial correlation analysis between these two variables, controlling GDP per capita and GDP growth rate, is also high at 65.3%. In addition, he states that an additional 1% of R&D expenditure by the government sector increases the expected R&D expenditure of the business enterprise sector by 1.41% (Coccia, 2010, p.80). These results are similar to those found by other researchers and confirm, at the aggregate level, the effects of complementarity between public and private R&D expenditure (Coccia, 2008a). In fact, Guellec and van Pottelsberghe de la Potterie, with a sample of 17 OECD member countries and different econometric modelling, indicate that one dollar of direct government funding to business generates a $0.70 marginal increase in business-funded R&D – $1.70 in total R&D (2003, p.232).

Industries and determinants of the interaction between public and private R&D

Beneficial interaction between public and private R&D expenditure has been shown in several industries. For instance, Hamberg reports that government contracts are positively related to private R&D, showing complementarities in industrial chemicals, electronic components and communications equipment, electrical equipment and office machines (reported in David *et al.,* 2000, p.514). Hertzfeld and Mowery, in 1985, show the complementarity between public and private R&D investment relationship from studies of aircraft and civilian space technology (see David *et al.*, 2000, p.521). Toole also finds complementarity in the US pharmaceutical industry: public basic research stimulates private R&D investment after a lag. 'For the estimated lag of 6–8 years, the elasticity of private R&D investment with respect to the stock of public basic research lies in the range of 0.46–0.53' (as reported in David *et al.*, 2000, p.524). Recently, González and Pazó (2008) confirm the absence of crowding out between public R&D support and private R&D investment, and that small firms operating in low technology sectors may not engage in R&D activities in the absence of public subsidies (p.371), whereas Lee (2011) shows, using multi-country data, different effects of public R&D support on firm R&D (p.256):

> Public support tends to have a complementarity effect on private R&D for firms with low technological competence, for firms in industries with high technological opportunities and for firms facing intense market competition. In contrast, firms with high technological competence and firms that have enjoyed fast demand growth in recent years show a crowding-out effect, and firm size and age do not show any discernible differential effect.

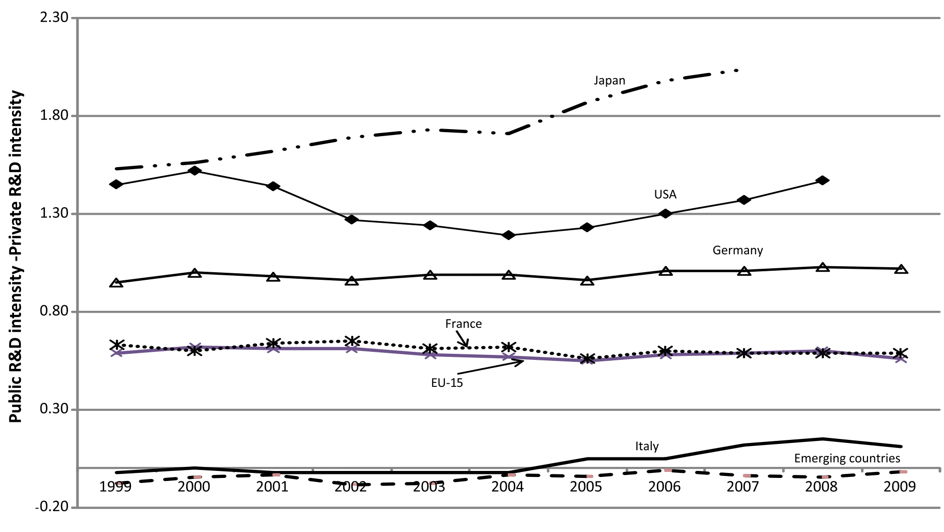
The underlying causes of complementarity effects between public and private R&D are:

> In the simple two-sector model developed by David and Hall ... the nature of the macro-level relationship between private and public R&D investment depends upon four parameters of the system. Complementarity, rather than substitution effects is [sic] likely to dominate where the relative size of the public sector in total R&D input use is smaller, where the elasticity of the labor supply of qualified R&D personnel is higher, where the grant–contract mix of public outlays for R&D performance is skewed more towards the former, and where the rate at which the private marginal yield of R&D decreases more gradually with increased R&D expenditures ... In general, then, the balance of the long-run dynamic effects seems to favor the emergence at higher levels of aggregation of net complementarities, rather than a relationship dominated by 'crowding out', or the substitution of public for private R&D investment. (David *et al.*, 2000, pp.508–9)

Guellec and van Pottelsberghe de la Potterie (2003, p.235) also show that the estimated relationship between government support and privately financed R&D has a shape similar to an inverted U-curve: ‘the elasticity of private R&D with respect to government support increases with the subsidization rate up to a threshold (estimated to be around 10%), then decreases with the subsidization rate, and becomes negative over a threshold of about 20%’. In addition, Coccia (2009) argues that if government funding for civil research is lower than 30% of total R&D intensity (R&D expenditure divided by GDP), there is a beneficial effect on the productivity growth of countries. It is important to bear in mind that there is higher economic performance (in terms of Labour productivity) in countries with lower public financing of R&D (as a percentage of GDP), associated, of course, with a high level of R&D expenditure by the business enterprise sector, which drives applied research (cf. Coccia, 2008a, 2009). These fruitful interactions generate a positive impact on competitiveness of firms and the competitive advantage of nations (Porter, 1990) *if*, *and only if*, public R&D expenditure is targeted to stimulate the R&D of business enterprises (Coccia, 2008b, 2010). Hence, in order to drive the competitiveness of countries, a large portion of public economic resources should be directed towards fostering industrial research. In fact, one of the advantages of industrial research is its proximity to manufacturing processes, such that it transforms scientific and technical knowledge into new products and services. In addition, industrial research evaluates both financial risks and the returns deriving from R&D investments (Hill, 1969).

Dynamics of R&D expenditure trends and interaction with labour productivity across countries

Figures 1 and 2 show interesting empirical evidence from the US, Japan and some European countries. In particular, Figure 1 displays private and public R&D



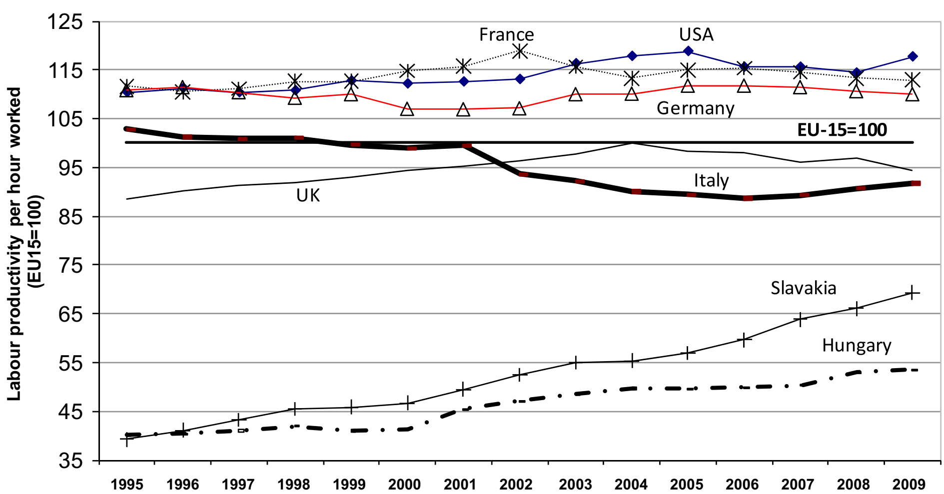
Source: Derived from Eurostat data, 2011.

Figure 1. Private minus public R&D expenditure over time per country

expenditure trends (the difference between these two variables) in the US, 15 countries of the European Union (EU), and Japan (the so-called G3 – Group of Three), as well as in other industrialized nations and a group of emerging countries. The G3 area analysis is important because the world's economic growth is driven by these geo-economic leading players. The dynamics confirm that within the G3 area, private R&D expenditure is higher than public R&D expenditure (trend above the *x*-axis). At the European level, Germany and France display behaviour similar to that of the G3, whereas Italy has different economic behaviour,[2] roughly similar to that of European emerging countries represented by Bulgaria, the Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Romania, Slovenia and Slovakia.

This result suggests that current market forces, and in general the national system of innovation governed by university, industry and government linkages (the Triple Helix), support R&D expenditure by the business enterprise sector across advanced countries. In order to evaluate the effectiveness of the dynamics of R&D intensity for the performance of economic systems, Figure 1 can be compared with Figure 2, showing the labour productivity per hour worked of these countries.

In general, there is low economic performance in countries whose R&D intensity (R&D expenditure/GDP) is driven mainly by R&D expenditure in the government sector. Some emerging countries (Hungary and Slovakia, for example) have an average level of public R&D of about 0.41 (as a percentage of GDP) with private R&D of roughly 0.39% (over 1999–2009). *Vice versa* would have yielded higher productivity.[3] It is also important to note that high public funding for civil R&D can crowd out private funding for R&D, reducing the aggregate level of national R&D expenditure (see Kealey, 1996). For instance, Guellec and van Pottelsberghe de la Potterie (2003) claim that defence-related R&D funding has a crowding out effect on civilian business R&D. Defence-related research performed in public laboratories and universities tends to reduce business incentives to invest



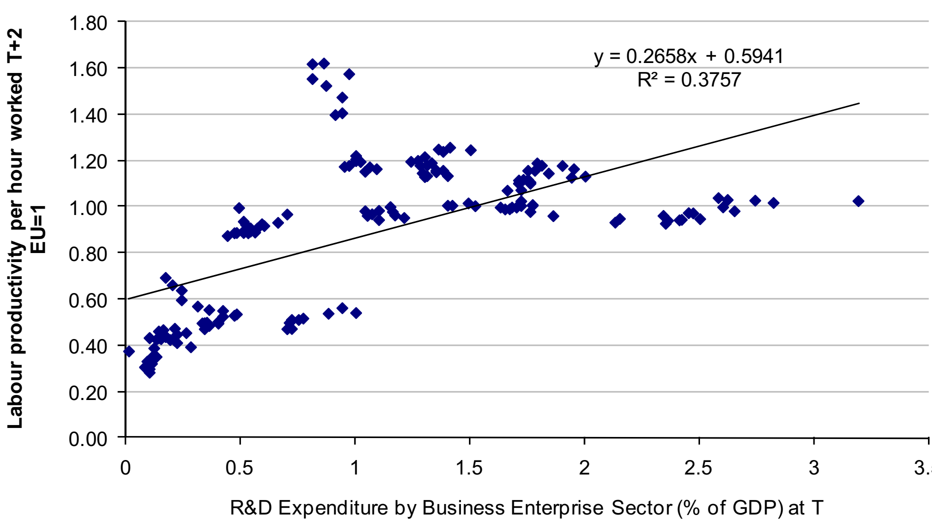
Source: Derived from Eurostat data, 2011.

Figure 2. Labour productivity per hour worked (EU15=100)

in research activities. Figures 3 and 4 show the average impact (using the least squares method) of different components of R&D intensity on labour productivity across countries.[4] These figures display the effect of R&D expenditure by business enterprise and higher education on labour productivity in various countries (the impact of government R&D expenditure on productivity does not provide significant coefficients).[5] Van Pottelsberghe de la Potterie (2008, p.225) shows that academic research is a stimulus for business R&D because the higher education sector generates new technological knowledge which supports applied R&D for the private sector and its innovation processes. Figure 5 shows the trend of R&D expenditures of the higher education sector across countries. It reveals a slight general increase over time, mainly in emerging countries.

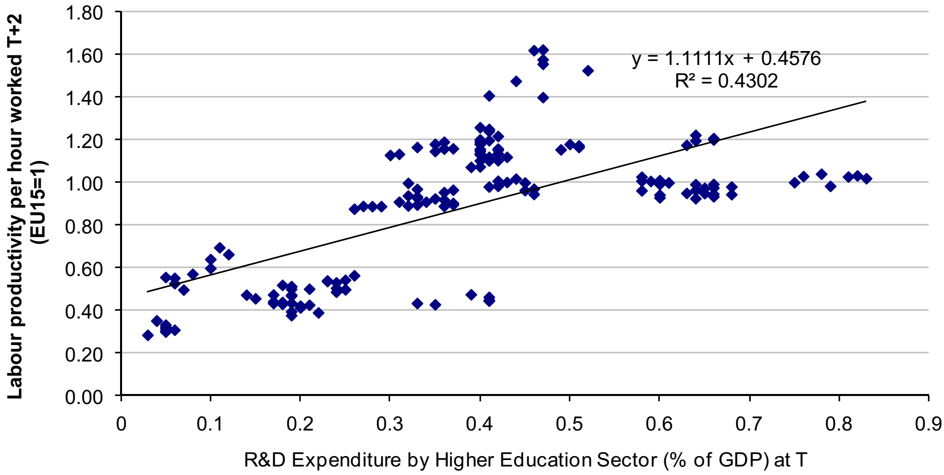
Concluding remarks and political economy implications

The economic literature does not explain totally the complex interaction between public and private R&D expenditure and its impact on productivity across countries. Conflicting conclusions are a consequence of different periods, sectors, and countries being analyzed, and the application of different econometric modelling techniques. This paper looks at the complementarity between public and private R&D in countries that supports productivity growth driven by higher expenditure on private R&D than on public R&D. However, the magnitude of this effect depends on apt policy tools, such as R&D tax credits, subsidization policies, grants and procurement. Guellec and van Pottelsberghe de la Potterie (2003) show that tax incentives have an immediate and positive impact on business-financed R&D. Direct funding and tax incentives are more effective when they are stable over time: firms do not invest in additional R&D when future government support is uncertain. In addition, direct government funding and R&D tax incentives are substitutes.



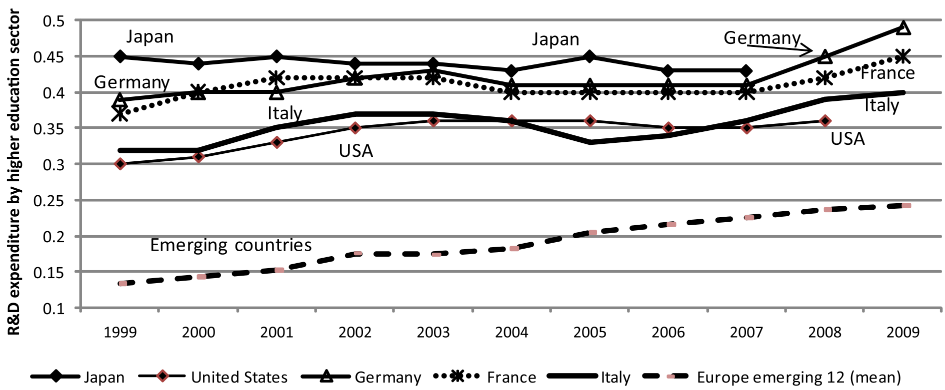
Source: Derived from Eurostat data, 2011.

Figure 3. Impact of business enterprise R&D expenditure on productivity, 1999–2007



Source: Derived from Eurostat data, 2011

Figure 4. Impact of higher education R&D expenditure on productivity, 1999–2007



Source: Derived from Eurostat data, 2011.

Figure 5. Trends in R&D expenditure by the higher education sector across various countries

Defence research performed in public laboratories and universities crowds out private R&D. Civil research is neutral for business R&D (Guellec and van Pottelsberghe de la Potterie, 2003).

Across the industrialized countries, the reduction of the interventionist role of governments in R&D expenditure in favour of market forces is encouraging higher R&D expenditure by business enterprise [Figure 1 and Steil, *et al.* (2002)]. In fact, the European Council in Lisbon (2002) directed European countries towards an increase in national R&D intensity, 56% of which should be financed by business enterprise, in order to bring the European Union to the innovation intensity and growth levels of the US (Room, 2005). This objective should support higher economic performance of countries driven by a new political economy based on a range of policy tools that stimulate R&D expenditure by business enterprise and, as a consequence, national competitiveness.

Of course, this European innovation policy, focused on an R&D-to-GDP ratio of 3% by 2010, did not forecast the global economic downturn of 2007–11, and current high public debt in several European countries. Economists do not believe that European convergence towards US performance (technological catch-up) can be achieved simply by increasing national R&D intensity. Guellec and van Pottelsberghe de la Potterie (2003) argue that many of the targets set for European countries are unrealistic. For instance, Sirilli (2004, p.509, original emphasis) notes that European targets: 'are well beyond Italy's potential, and according to a *natura non facit saltus* … projection, the country will be able to raise the ratio from 1.04% in 2002 to 1.55% in 2010'. Eurostat indicates a mere 1.18% in 2007 for Italy, and in 2011 this level is far from the 3% target, and even from Sirilli's forecast of 1.55%. In addition, Guellec and van Pottelsberghe de la Potterie (2003) claim that R&D expenditure by countries depends on industrial specialization: countries specialized in finance and/or tourism (or mainly diffusion-oriented)[6] would not need a high level of R&D expenditure in order to ensure economic growth, whereas countries specialized in drugs, chemical engineering, biotechnologies, and the ICT industries would need a high level of R&D expenditure to support industrial dynamics driven by new patterns of technological innovations.

As a matter of fact, business R&D intensity is endogenous and affected by the industrial specialization of countries. Moreover, it is important to note that the increase of R&D intensity at country level is a necessary but not sufficient condition for improving labour productivity and the competitiveness of economic systems. To achieve economic and R&D targets at country level, policymakers should design systemic industrial, innovation and science policies that direct R&D money to critical industries driving the economic system, as well as to the vital higher education sector. In fact, the support of academic research can also foster the R&D expenditure of the business enterprise sector [see van Pottelsberghe de la Potterie (2008, p.225) and Figure 5 on trends of R&D expenditure by higher education sectors across countries].

In brief, the economic literature presents conflicting results in this research field. This paper seeks to compensate for some of this deficiency by providing information that will allow policymakers to improve the effectiveness of R&D policy. In all, this empiricist–positivist analysis shows complementarity between R&D expenditure in the government and business enterprise sectors. In addition, when private R&D expenditure is higher than public sector R&D expenditure, there is productivity growth and an increase in competitive advantage of nations.

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Notes

1. The political economy of R&D is a set of rules that supports rational economic decisions by policymakers in the allocation of public and private economic resources. This is done to increase the country's scientific and technological performance in specific research fields, and to improve national competitiveness and welfare.
2. Italy has a level of national R&D roughly equal to 1% of GDP over time. However, since 2004, Italy has been increasing the R&D expenditure of the business enterprise sector, which was 0.61 (as a percentage of GDP) in 2007, whereas R&D expenditure by the government and higher education sectors was 0.39 (as a percentage of GDP).
3. Japan has structural problems in its economic system that have been triggering a reduction in competitiveness:

   > Japan faces a number of external challenges over the long term, most of which relate to the rising importance of China and the associated threat to Japan's pre-eminent political and economic position in the Asia region. The country's long-term outlook is also strongly influenced by its demographics. Current trends indicate that the rate of decline in the working-age population will outpace that in the population as a whole. (Economist Intelligence Unit, available from http://country.eiu.com/ [accessed March 2011]).
4. Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Lithuania, the Netherlands, Norway, Poland, Slovakia, Spain, Sweden, Switzerland, the United Kingdom and the United States.
5. Figures 3 and 4 show regression lines and equations that provide approximate results for the impact of R&D expenditures on labour productivity per hour worked. More accurate effects need the application of refined econometric techniques.
6. Generally speaking, diffusion-oriented systems invest in the higher education sector in order to absorb technological innovation.

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