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# Looking beyond the R&D effects on innovation: The contribution of non-R&D activities to total factor productivity growth in the EU

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# Looking beyond the R&D effects on innovation: The contribution of non-R&D activities to total factor productivity growth in the EU*


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**Abstract**

Although non-R&D innovation activities account for a significant portion of innovation efforts carried out across very heterogeneous economies in Europe, how to incorporate them in to economic models is not always straightforward. For instance, the traditional macro approach to estimating the determinants of total factor productivity (TFP) does not handle them well. To counter these problems, this paper proposes applying an augmented macro-theoretical model to estimate the determinants of TFP by jointly considering the effects of R&D and the impact of non-R&D innovation activities on the productivity levels of firms. Estimations from a model of a sample of EU-26 countries covering the period 2004-2008 show that the distinction between R&D and non-R&D effects is significant for a number of different issues. First, the results show a sizable impact on TFP growth, as the impact of R&D is twice that of non-R&D. Second, absorptive capacity is only linked to R&D endowments. And third, the two types of endowments cannot strictly been seen as complementary, at least for the case of countries with high R&D intensities or high non-R&D intensities.



**Keywords:** TFP, R&D, non-R&D expenditures, EU countries.
**JEL Classification:** O0, O3, O4



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# 1 Introduction

There is a general consensus in the economic literature that investment in Research and Development (R&D) plays a critical role in the economic development of countries and regions, as it is an important driver of innovation and growth. Furthermore, it is recognised that not only is innovation a costly activity but that it also depends to some degree on the level of a regions´ technology capital and its absorption capacities. However, in addition to R&D activities, innovation can also take place through activities which do not require direct R&D effort, such as the acquisition of new technology, through e.g., the purchase of advanced machinery, computer hardware and software, the acquisition of patents and licenses, training related to the introduction of new products or processes, market research, feasibility studies and other procedures such as design and production engineering[1]. These actions are classed as non-R&D innovation activities, and can be grouped into three basic categories (Arundel et al., 2008)[2]: (1) minor modifications or incremental changes to products and processes using existing engineering knowledge (Kline and Rosenberg, 1986; Nascia and Perani, 2002), (2) imitations or the adoption of innovations developed by users (Kline and Nelson, 2000; von Hippel, 2005; Gault and von Hippel, 2009), and (3) the combination of existing knowledge in new ways (Grimpe and Sofka, 2009; Evangelista et al., 2002).

These forms of acquiring knowledge and technology are widely used across firms, industries and countries[3]. Results from the third European Community Innovation Survey (CIS-3) for 15 sampled countries show that almost half of European firms considered to be innovative did not perform R&D in-house. Small-sized firms with weak in-house innovative capabilities, an absence of staff with tertiary education and/or a lack of exports were found to be more likely to innovate without directly performing R&D. Furthermore, sourcing information from suppliers and competitors can make firms more prone to innovate through non-R&D activities.

Additionally, studies on the influence of the potential for knowledge spillovers related to innovation are not definitive[4]. On the one hand, Robbins (2006) finds mixed evidence in terms of the significance of industry-specific knowledge spillovers at the state level in the United States, but a lack of evidence in most manufacturing industries. On the other hand, Mairesse and Sassenou (1991) and Los and Verspagen (2000) reported robust findings of knowledge spillovers across firms, while Scherer (1993) and Branstteter (2001) reported these across industries, and Park (1995) across countries.

[1] For instance, process innovation can frequently involve innovative activities which do not require R&D.

[2] The seminal work on the choice between innovating through R&D or through non-R&D activities is by Veugelers and Cassiman (1999). See also Huang et al. (2010).

[3] The 2007 Innobarometer survey of 4395 innovative European firms found that 52.5% of these firms innovated without performing R&D or contracting out R&D (Arundel et al., 2008).

[4] Jaffe (1986) initiated ways of accounting for the appropriability of external flows of knowledge. See also Leppala (2012) for the problems concerning the difficulties of transferring knowledge.

In this paper, we focus on both R&D and non-R&D innovation expenditures, as a means for measuring innovation efforts carried out in EU countries and how these expenditures impact on total factor productivity (hereafter "TFP") growth. Generally, R&D and non-R&D innovation spending is expected to increase productivity by, for instance, reducing the production cost of existing goods when new and more cost-saving input processes are introduced; expanding the choice of products, which can give rise to scale economies in production; creating new products which require fewer production inputs than the old ones; or simply by adopting new management techniques; investing in new machines; or improving product design; etc. These "best practices" by firms can generate an outward shift of the firms´ production frontiers.

A number of studies have investigated the innovation-productivity relationship, and some empirical analyses are reported of the effect of innovation on a firm's productivity and efficiency, using the standard methodology of estimating a Cobb-Douglas production function; studies include Potters et al. (2011) for European countries, and Kancs and Siliverstovs (2012) for OECD countries[5]. An alternative approach to these types of studies is the so-called CDM model (from Crépon, Duguet and Mairesse (1998)). The CDM model has been frequently applied by scholars using data from the Community Innovation Survey (CIS) launched by Eurostat, such as Lööf and Heshmati (2003) for Norway, Finland and Sweden; Janz et al. (2004) for Germany and Sweden; and Griffith et al. (2006) for France, Germany, Spain and the UK.

One general finding from these studies is the positive relationship between innovation and output, as well as the positive effect innovation output has on a firm's productivity. In recent years, similar studies have been conducted for the EU transition countries; Masso and Vahter (2008) used CIS3 (3rd wave of CIS) and CIS4 (4th wave of CIS) data, combined with data from the Estonian Business Register to estimate the same relationship for Estonia. They claim that the character of innovation in a "catching-up economy" is different from that in developed EU countries, as innovation is much more equipment oriented rather than R&D oriented. Consistent with this assumption, they find that process innovations are key to productivity growth in Estonia[6]. Variants of the CDM model have also been applied for Slovenia (Damijan et al., 2005), Ukraine (Vakhitova and Pavlenko, 2010) and Hungary (Halpern and Murakozy, 2009). Finally, Hashi and Stojcic (2010) provided the first comparative study of developed and transitional economies, using 16 countries that participated in the CIS4 survey, including all new EU Member States.

At a macro level, the endogenous growth theory emphasises the role played by R&D investment in

[5] See Griliches (1995) for an overview and Griliches (2000) for an updated assessment.

[6] In a different context (Italian firms), Conte and Vivarelli (2005), studying the links between the inputs of innovation activities (R&D and acquisition of external technology) and the outputs (product innovation and process innovation), found that R&D is strictly linked to product innovation, while the acquisition of external technology is crucial in fostering process innovation.

growth rates and in the convergence of countries and regions. The pioneering works of Romer (1990), Grosman and Helpman (1991), Grossman and Helpman (1994) and Aghion and Howit (1997) examine the link between R&D and growth, taking as a basis an equation which relates R&D activities with TFP. However, as the empirical literature based on firm-level studies has shown, non-R&D innovation activities are also a major channel to increasing a firm's productivity. Moreover, in the case of Europe and for the period 2004-2008, the average sums invested in non-R&D activities was 10% higher than the resources devoted to R&D (1.55% versus 1.40%, as average percentages of the years 2004, 2006 and 2008 expressed as a share of GDP). The non-R&D intensive sector still accounts for 40-60% of the industrial value added (depending on the country) and 50% of all industrial employees (Rammer et al., 2011; Hirsch and Kreinsen, 2008; Som, 2012; Som et al., 2010). Additionally, more than 50% of all innovating firms in the EU (Arundel et al., 2010) do not perform (i.e. they are non-R&D performers) (Rammer et al., 2011; Som et al., 2010).

From a policy point of view, disentangling the effects of both types of expenditure is critical since institutions such as the European Commission devote an important portion of their budgets to finance R&D and non-R&D activities. At the EU level, the expenditures devoted to R&D and non-R&D in the 2000-2006 Community Support Framework (2000-2006 CSF) amount to 19% of the total budget (7% for R&D and 12% for non-R&D); whereas in the 2007-2013 CSF, this figure rose to 23%, with a much higher focus on R&D spending (18% of the total budget) than on non-R&D (5%)[7].

Our goal in this paper is twofold. On the one hand, we model TFP growth incorporating the effects of non-R&D innovation and on the other hand (the empirical side), we estimate the impacts on the level of aggregate productivity. To do this, we take as a basis an equation which regresses TFP against R&D and non-R&D activities. Our theoretical approach of augmenting the conceptual framework of the endogenous growth theory by considering not only R&D but also non-R&D innovation relies on the robust findings of the impact of non-R&D activities on the productivity levels of firms. Therefore, our approach allows a simple way to link the positive impact of non-R&D activities on firms´ productivity with TFP improvements at the aggregate level (e.g. a regional or country level). To the best of our knowledge, this is the first paper proposing using a macro approach to deal with the joint impacts of R&D and non-R&D innovation expenditures on TFP growth. On the empirical side, and regarding non-R&D investments, we linked Eurostat, the Community Innovation Survey (CIS) and DG Regio data since the CIS data only accounts for private innovation expenditures. We also use data from Cambridge Econometrics and EU Klems to get TFP data at the country level. Once the data problems were resolved, we used our model to give empirical estimations for the EU countries over the period 2004-2008.

[7] Non-R&D in the 2000-2006 and 2007-2013 Community Support Frameworks (CSFs) are under the heading of Support to firms and other investments not directly relating to RTDI (See European Commission, DG Regio (2013).

Our findings suggest that the distinction between R&D and non-R&D activities is significant in a number of cases and for a number of different issues. First, the results show a sizable difference in the impact of these endowments on TFP growth, with the impact of R&D being twice as large as the impact of non-R&D. Second, absorptive capacity is only linked to R&D innovation efforts and not non-R&D. And third, the two types of innovation cannot strictly be seen as complementary, at least for countries with high R&D intensities and high non-R&D intensities.

The remainder of this paper is structured as follows. Section 2 offers an overview of R&D and non-R&D expenditures over the period 2004-2008. Section 3 develops a conceptual framework in which R&D and non-R&D activities can be related to productivity growth. Section 4 describes the data. Section 5 outlines the econometric estimates and the interpretation of the results. Finally, Section 6 presents the conclusions and main policy implications.

## 2 R&D and non-R&D innovation expenditures: evolution patterns 2004-2008

In the EU as a whole, non-R&D innovation expenditures play a significant role in many countries´ innovation policies. The average non-R&D innovation expenditure intensity in the years covered in our analysis (1.55% expressed as a percentage of GDP) is 10% higher than the corresponding R&D expenditure intensity (1.40%). However, within this 5-year period a change in the relative importance assigned to R&D and non-R&D innovation expenditures took place. Non-R&D expenditure intensities decreased by 20.5% from 2004 to 2008 (1.70 to 1.35), whereas at the same time, R&D innovation expenditure intensities increased by 11.5% (1.33 to 1.48).

If we break down these data according to the relative economic development of the specific countries, basically classifying the countries either as belonging to the EU-15 or as being part of the so-called Central and Eastern European Countries (CEEC) or new Member States, we can also conclude that the overall general trend observed in the EU as a whole of decreasing importance of non-R&D innovation expenditures and increasing importance of R&D innovation expenditures still holds. Tables 1 and 2 provide detailed information on this. Non-R&D innovation expenditure intensities decreased in the CEEC by around 13.3% (1.91 to 1.65), and R&D expenditure intensities increased by 15% (0.72 to 0.83). However a big change can be observed for Western Europe, especially in terms of non-R&D expenditure intensities where there is a huge fall of around 30% (1.52 to 1.07) and an increase in R&D innovation expenditures by 10% (1.89 to 2.09).

Another important feature that can be observed when comparing the EU-15 countries against new Member States is that non-R&D innovation expenditure intensities are almost 38% higher in CEECs than in the EU-15, and R&D expenditure intensities are 60% higher in the EU-15 than in CEECs.

Part of the reasons why the new Member States rely more on non-R&D innovation expenditures to promote innovation could be based on the low level of in-house R&D innovative capabilities in the manufacturing and services sectors of these countries and the lack of qualified human resources (direct measures of innovative capabilities), small firm sizes, and low profiles in terms of exporting behaviour (indirect measures of innovative capabilities). These former four factors can be aggravated by the fact that the low market access in many CEECs make these markets small and non-profitable for innovation and effectively place a penalty on human capital accumulation (Redding and Shott, 2003; Lopez-Rodriguez et al., 2007, 2013). These factors, together with increasing returns on innovation and localisation of knowledge spillovers, seem to explain the pattern of low R&D innovative activities in these countries. Additionally, R&D often requires high initial investments in laboratory equipment and advanced instruments and large fixed costs over time. Small firms are more likely to lack the internal resources of finance for both these initial costs (thereby creating an entry barrier). They may also face barriers in raising capital from external sources because of a lack of collateral and lack of a record of delivering past successful R&D projects. Furthermore, small firms may lack the financial resources to maintain a portfolio of several R&D projects to hedge against the risk of failure of one or more, which is always a risk for R&D projects. Although, non-R&D innovation expenditures are losing ground in favour of R&D innovation expenditures, it is important to take into account that the former still play a significant role in promoting innovation in the lagging-behind economies. This pattern is much more acute when we break down the countries into CEEC and Western European countries.

Table 1: Comparison of non-RD and RD innovation intensities in the CEEC

| | non-R&D innovation intensities | | | R&D innovation intensities | | |
|---|---|---|---|---|---|---|
| Country | 2004 | 2006 | 2008 | 2004 | 2006 | 2008 |
| BG | 1.15 | 1.49 | 1.97 | 0.49 | 0.46 | 0.47 |
| CZ | 2.32 | 1.90 | 2.21 | 1.2 | 1.49 | 1.41 |
| EE | 2.21 | 4.98 | 2.69 | 0.85 | 1.13 | 1.28 |
| CR | | 1.10 | 1.13 | 1.05 | 0.75 | 0.9 |
| CY | 2.53 | 2.06 | 1.78 | 0.37 | 0.43 | 0.43 |
| LV | 2.72 | 1.84 | 1.31 | 0.42 | 0.7 | 0.62 |
| LT | 1.72 | 0.77 | 0.93 | 0.75 | 0.79 | 0.80 |
| HU | 1.47 | 1.41 | 1.95 | 0.88 | 1.01 | 1.00 |
| MT | 1.00 | 1.37 | 1.40 | 0.51 | 0.60 | 0.55 |
| PL | 1.81 | 1.71 | 1.87 | 0.56 | 0.56 | 0.60 |
| RO | 1.59 | 1.48 | 1.89 | 0.39 | 0.45 | 0.58 |
| SI | 1.55 | 1.36 | 1.16 | 1.39 | 1.56 | 1.66 |
| SK | 2.79 | 2.73 | 1.18 | 0.51 | 0.49 | 0.47 |
| Average | 1.91 | 1.86 | 1.65 | 0.72 | 0.80 | 0.83 |
| Average (2004-06-08) | | 1.81 | | | 0.78 | |

Source: Own elaboration based on CIS 2004, 2006 and 2008 and Eurostat data.

Table 2: Comparison of non-RD and RD innovation intensities in the EU15

| | Non R&D innovation intensities | | | R&D innovation intensities | | |
|---|---|---|---|---|---|---|
| Country | 2004 | 2006 | 2008 | 2004 | 2006 | 2008 |
| BE | 2.18 | 1.25 | 0.99 | 1.86 | 1.86 | 1.97 |
| DK | 0.84 | 0.95 | 0.43 | 2.48 | 2.48 | 2.85 |
| DE | 2.70 | 2.86 | 2.16 | 2.50 | 2.54 | 2.69 |
| IE | 3.01 | 1.75 | 2.01 | 1.23 | 1.25 | 1.46 |
| GR | 1.41 | 1.29 | 1.29 | 0.55 | 0.59 | 0.59 |
| ES | 0.65 | 0.77 | 0.58 | 1.06 | 1.2 | 1.35 |
| FR | 1.21 | 0.99 | 0.82 | 2.16 | 2.11 | 2.12 |
| IT | 1.21 | 0.96 | 0.76 | 1.09 | 1.13 | 1.21 |
| LU | 1.20 | 1.47 | 0.75 | 1.63 | 1.66 | 1.66 |
| NL | 0.61 | 0.67 | 0.90 | 1.93 | 1.88 | 1.77 |
| AT | 1.09 | 0.98 | 0.61 | 2.24 | 2.44 | 2.67 |
| PT | 1.62 | 1.33 | 0.93 | 0.74 | 0.99 | 1.50 |
| FI | 1.94 | 1.78 | 1.04 | 3.45 | 3.48 | 3.7 |
| SE | 1.55 | 1.86 | 1.66 | 3.58 | 3.68 | 3.7 |
| UK | NA | NA | NA | 1.67 | 1.72 | 1.75 |
| Average | 1.52 | 1.35 | 1.07 | 1.89 | 1.95 | 2.09 |
| Average (2004-06-08) | | 1.31 | | | 1.98 | |

Source: Own elaboration based on CIS 2004, 2006 and 2008 and Eurostat data.

## 3 Theoretical framework

This section aims to provide a conceptual framework on how to incorporate non-R&D innovation effects as key determinants of a country's TFP growth. Starting from a standard endogenous growth type of formulation (see, for instance, Aghion and Howit, 1991), where R&D is seen as one of the main drivers for innovation and growth, we extend it to account for other types of innovation-linked activities which also impact on a country's levels of TFP. In other words, we take into account the stocks of innovation capital arising from investments in non-R&D activities. The economic rationale for incorporating non-R&D activities as an important driver for innovation is based on robust empirical findings on the positive impacts of such investments on the levels of productivity in firms. Therefore, if we consider an aggregate view (i.e. a macro approach) of a region or a country populated by many firms, improvements from non-R&D activities at a company level can be translated into improvements in productivity at a regional and country level. Our theoretical approach envisages a simple way of translating the impact of non-R&D investments on firms´ productivity into TFP increases at an aggregate (i.e. a regional or country) level.

Let us denote countries and years by the subindexes $i$ and $t$, respectively. The starting point in our framework is the definition of the standard neoclassical production function:

$$Y_{it} = A_{it} F(L_{it}, K_{it}), \tag{1}$$

where $Y$ is the total output, $A$ is an index of technological efficiency, $L$ is labor and $K$ is the private physical capital. Function $F(.)$ is assumed to satisfy the standard properties of being homogeneous of degree one and exhibiting decreasing returns to scale in each factor. In turn, $A$ can be seen as the TFP which, according to the literature, is usually defined as dependent on the amount of R&D endowments (see, for instance, Aghion and Howit, 2007). In our theoretical framework, we borrow from firm level productivity studies the effects of non-R&D activities to envisage an easy way of augmenting the traditional approach to TFP by linking the macro and micro approaches. Therefore within this augmented framework, both R&D and non-R&D innovation activities are seen as the main drivers of TFP in regions and countries, i.e.:

$$A_{it} = \psi \left( rd_{it}, nrd_{it} \right), \tag{2}$$

where $rd$ is the ratio of R&D investments over GDP and $nrd$ is the corresponding investment rate for non-R&D activities. $\psi(.)$ is assumed to be a Cobb-Douglas-style functional form. Taking logarithms in (2) and differentiating totally with respect to time we have:

$$\frac{\dot{A}}{A} = \alpha_1 \frac{\dot{rd}}{rd} + \alpha_2 \frac{\dot{nrd}}{nrd}, \tag{3}$$

where $\alpha_1 = \frac{\partial A}{\partial rd} \frac{rd}{A}$ and $\alpha_2 = \frac{\partial A}{\partial nrd} \frac{nrd}{A}$. In the notation, the subindexes have been omitted for the sake of simplicity.

Accumulation equations for $rd$ and $nrd$ are defined as:

$$\dot{rd}_{it} = Ird_{it} - \delta rd_{it-1} \quad (4)$$

$$\dot{nrd}_{it} = Inrd_{it} - \delta nrd_{it-1}, \quad (5)$$

with $Ird$ being the investment rate in $rd$ and $Inrd$ the corresponding one for Non-R&D. The depreciation rate $\delta$ affects the capital stock existing in the previous period. Next, following Griffith et al. (2004), we assume that such a depreciation rate is nill; mainly motivated by the difficulties of empirically measuring the extent that knowledge capital disappears as a result of obsolescence.

Dividing (4) and (5) by $rd$ and $nrd$, respectively, and substituing in (3) we obtain:

$$\frac{\dot{A}}{A} = \frac{\partial A}{\partial rd} Ird + \frac{\partial A}{\partial nrd} Inrd, \quad (6)$$

where, given that $A$ is an index of technological efficiency, we have set its value equal to 1 for the sake of convenience. The coefficients accompanying the variables $Ird$ and $Inrd$ are the rates of return to R&D and non-R&D, respectively, in terms of TFP growth. This is the basis of subsequent econometric estimations, which is conveniently augmented to include not only control variables but also non-linear and interaction terms. Regarding these, a new expanded expression of (6) can be written using the following transformation (see again, Griffith et al. 2000, 2004):

$$\frac{\dot{A}}{A} = \beta_1 Ird + \beta_2 Inrd, \quad (7)$$

where $\beta_1 = \frac{\partial A}{\partial rd} + \gamma_1 Inrd + \gamma_2 Ird$ and $\beta_2 = \frac{\partial A}{\partial nrd} + \gamma_4 Inrd$.

# 4 The datasets and the variables

This section provides information on the sources and variables used in the econometric analysis. We assessed data from the EU-26 countries[8]. For our empirical analysis, a variety of datasets have been used. Our main datasets are: EU KLEMS, EUROSTAT, CAMBRIDGE ECONOMETRICS, and CIS. In this paper most of the data on countries´ TFP were taken from EU KLEMS[9]. TFP values were obtained using the so-called growth accounting model, which uses various assumptions, among which the following are important: (1) the production function exhibits constant returns to scale, and (2) product and factor markets are characterised by perfect competition. The growth accounting model divides the growth in output into three different sources: (1) increase in capital, (2) increase in labour, and (3) increase in total-factor productivity (TFP). The capital contribution is obtained by multiplying the increase in capital by the capital's share of output; in turn, the labour contribution

[8]The UK was excluded from the sample since we did not have British data available on non-R&D innovation expenditures.

[9]EU KLEMS is a project funded by the European Commission, and which ran from 2003 until 2008.

is obtained by multiplying the increase in labour by labour's share of output. Because TFP is not directly observable, it is measured indirectly as the change in output that cannot be explained by the (weighted) changes in inputs. Therefore, it is clear that measuring TFP depends on the availability and quality of data concerning the other sources of growth. Note, TFP is also called the "Solow residual" (Solow, 1957).

Despite the fact that our base database for the TFP variable was EUKLEMS, we needed to use the Cambridge Econometrics dataset for computing TFP for Bulgaria and Croatia. For these two countries, and based on the fact that according to national accounts wages and salaries account for about 70% of national income, a first-order approximation to the share of capital is about 0.3[10]. Using this value as the capital´s share and the measures of capital stocks constructed from Cambridge Econometrics, we broke down the average growth rate of output per capita for our period of analysis into the TFP growth component and a capital-deepening component[11].

In relation to the knowledge capital stocks variables, we followed, on the one hand, Fischer and Varga (2003) and Robbins (2006), who aggregate R&D expenditures for the stocks of R&D-driven knowledge capital. And on the other hand, following a parallel approach, we aggregated non-R&D expenditures for the stocks of non-R&D driven knowledge capital. The main advantages of R&D as a proxy for the stocks of knowledge capital R&D driven is that these data are widely available over long time periods at the firm, sector, regional and national levels. For our study, data on R&D expenditures have been taken from Eurostat and they refer to total R&D expenditures (Business enterprise R&D expenditure and public expenditures on R&D) over national GVAs.

In order to get values for the stocks of non-R&D knowledge capital, we followed several steps, linking Eurostat and the Community Innovation Survey (CIS) databases[12] and also using DG Regio data on public expenditures on non-R&D activities. According to the period of time employed in our analysis, we used the CIS04, CIS06 and CIS08 surveys, respectively.

Since CIS gathers information on total private (i.e. firms) innovation expenditures in both R&D and non-R&D activities, it was quite straightforward to get the stocks of non-R&D driven knowledge capital by disentangling R&D innovation expenditures from non-R&D innovation expenditures. The procedure we followed was first to obtain a total country´s private non-R&D innovation expenditure by subtracting the Eurostat data on Business enterprise R&D expenditure (BERD) from the CIS data. Once we had these data, the next step to get data on total non-R&D innovation expenditures was to

[10] Aghion and Howitt (2007) use the same approach for their growth accounting exercise comparing OECD countries.

[11] Taking the share of capital equal to 0.3, the values of TFP obtained using the Cambridge Econometrics dataset are roughly similar to those for the countries for which EUKLEMS data is available.

[12] CIS is a survey of innovation activity in enterprises. The harmonised survey is designed to provide information on the innovativeness of sectors by type of enterprises, on the different types of innovation and on various aspects of the development of an innovation. The CIS provides statistics broken down by countries and is currently carried out every two years across the European Union, some EFTA countries and EU candidate countries.

add the public funds devoted to non-R&D activities to the previous data. This set of data was taken from the European Commission, particularly from the DG Regio data on the *Strengthen Enterprise and Business Environment* heading of the 2000-2006 and 2007-2013 Community Support Framework (CSF) programmes at the NUTS2 level. To accommodate this data to our analysis (country level based), we aggregated DG Regio data at a country level and, in order to obtain yearly data, we annualised them by simply computing the average expenditures over the 7-year periods of the CSFs.

A set of control variables was also added to our baseline estimation. The TFP gap was defined as the distance between the frontier economy and the country $i$ (i.e. the ratio between the TFP for the frontier economy and each country). Human capital was measured using different proxies. First, the proportion of people aged 25-64 having tertiary-level education; second, total R&D personnel as a percentage of the active population; and third, total R&D personnel as a percentage of total employment. Also, we included control variables for high tech intensity, which we defined as patent applications to the European Patent Office by priority year at the national level. Furthermore, the variable *khdist* was defined as the product between the TFP gap and the percentage of workers with tertiary-level education; alternatively, we also measured the technology transfer effect as the product between the TFP gap and the share of the active population with a secondary and upper educational-level of education . All the data for the set of control variables was obtained from Eurostat.

## 5 Econometric results

The econometric strategy we next followed uses the expression (7) as starting point:

$$\frac{\dot{A}_{it}}{A_{it}} = \gamma_0 Ird_{it-1} + \gamma_1 (Ird_{it-1} * Inrd_{it-1}) + \gamma_2 Ird^2_{it-1} + \gamma_3 Inrd_{it} + \gamma_4 Inrd^2_{it} + \boldsymbol{\mu}\mathbf{X}_{it} + u_{it}, \quad (8)$$

where $\gamma_0 = \frac{\partial A}{\partial rd}$, $\gamma_3 = \frac{\partial A}{\partial nrd}$, $\mathbf{X}_{it}$ is a column vector of control variables and $u_{it}$ is the usual regression error. The coefficients in (8) can be used to obtain the rate of return of both types of innovation expenditures in terms of TFP growth. For instance, in the case of non-R&D and with a linear specification (that is, without the term $Inrd^2_{it}$), the rate of return would be $\beta_3 + \gamma_1 \bar{Ird}$, with $\bar{Ird}$ being the average value of the R&D expenditures over GDP across the sample.

Although in principle the availability of data for different countries across Europe and over time would lead to a panel data approach, it is worth noting that the time dimension is so short that the potential gains from estimating cross-sectional time series using the standard procedures (namely, fixed and random effects models, amongst others) completely vanishes. Indeed, the Hausman test for checking whether unobserved individual effects are correlated or not with the regressors fails to fulfil its asymptotic assumptions. Furthermore, the Breusch and Pagan lagrangian multiplier test for random effects concludes, for several specifications (not reported here but available upon request), that there are no significant differences across units and that simply running an OLS is appropriate.

We thus pooled the data and estimated the model without taking into account any unobserved-specific characteristics of the countries included.

The sequence of estimation was as follows. We firstly estimated a Griffith et al. (2004) style equation, principally to show that their approach is not well-suited to our aim, at least in relation to keeping a clear distinction between R&D and non-R&D expenditures. All the econometric specifications below contain a set of control variables for taking into account the distance to the technological frontier, the human capital accumulation, and to what extent the technological intensity may affect TFP growth. Furthermore, we included the variable R&D (and non-R&D when interacting each other) with one lag in order to avoid endogeneity biases.

Second, we present our particular set of econometric specifications, leaving aside the canonical specification by Griffith et al. (2004). The contribution to TFP growth of both types of innovation expenses were also estimated for our central results. Third, we also offer some alternative specifications, as a robustness check to confirm our main results.

Table 3: Contributions to TFP growth

| | Griffith et al.(2004) approach | | Griffith et al.(2004) approach with non-R&D | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| TFP gap (t-1) | 3.06** (1.57) | 4.49*** (1.89) | 0.63 (2.53) | 1.32 (2.48) |
| R&D (t-1) | -4.58 (2.91) | -1.34 (1.10) | | |
| R&D * TFPgap (t-1) | 0.38** (0.22) | -3.11 (1.56) | | |
| non-R&D | | | 0.87 (0.64) | |
| non-R&D (t-1) | | | | -0.77 (0.61) |
| non-R&D * TFPgap (t-1) | | | 0.47 (1.25) | 0.42 (1.25) |
| Human capital control | yes | yes | | yes |
| High tech intensity controls | yes | yes | | yes |
| $R^2$ (between) | 0.45 | 0.61 | 0.40 | 0.57 |
| Number of Obs | 54 | 54 | 52 | 52 |
| Number of countries | 27 | 27 | 26 | 26 |

Source: (1) and (3): with LUX; (2) and (4): w/o LUX;* significant at 10%, ** significant at 5%, *** significant at 1%

A standard characterisation of the Griffith et al. (2004) model is that reported in columns (1) and (2) of Table 3. The TFP growth is positively explained by the distance to the frontier (technology transfer) and by the interaction between the distance and the R&D expenditures as a percentage of GDP (absorptive capacity). One striking point is that the coefficient of R&D is negative, although not statistically significant. The difference between both columns is that Luxembourg was omitted by defining the technological frontier in the pair of columns, in spite of the fact that this country enjoys the highest TFP level in the period; this has been done to avoid a unrepresentative measure of the distance of countries to the technological leader.

When the Griffith et al. (2004) model is estimated, focussing the impact of non-R&D innovation expenses on TFP growth (columns (3) and (4) of Table (3)), none of the coefficients are statistically significant. This first set of results shows to what extent the strictu sensu replication of Griffith et al.'s approach is far from appropriate for our aim. In a sense, what follows next is an empirical re-examination of the canonical model by Griffith et al., where the joint consideration of R&D and non-R&D innovation expenditures becomes a crucial issue.

Table 4: Contributions to TFP growth. Central estimates

| | (1) | (2) |
|---|---|---|
| TFP gap (t-1) | 1.44 (1.35) | 4.54* (2.50) |
| R&D (t-1) | 1.98* (1.07) | 2.54**(1.13) |
| non-R&D | 1.83*** (0.70) | 2.22***(0.74) |
| R&D (t-1) * non-R&D | -1.11*** (0.45) | -1.44***(0.50) |
| non-R&D * TFPgap (t-1) | | -2.13 (1.45) |
| Human capital control | yes | yes |
| High tech intensity controls | yes | yes |
| rate of return to R&D | 0.33 | 0.30 |
| rate of return to non-R&D | 0.18 | 0.15 |
| $R^2$ (between) | 0.62 | 0.70 |
| Number of Obs | 52 | 52 |
| Number of countries | 26 | 26 |

Source: (1) and (3): with LU; (2) and (4): w/o LU;* significant at 10%, ** significant at 5%, *** significant at 1%

Broadly speaking, we consider these estimates as the central ones in our investigation. Both columns show a positive impact of R&D and non-R&D innovation expenditures on TFP growth across the European countries over the period 2004-2008. The positive effect of R&D expenditure is practically double that of non-R&D expenditure when both are measured according to their rate of return. Indeed, while the range of the contribution of R&D to TFP growth is between 0.30 and 0.33, the figure obtained for non-R&D is in the range 0.15 to 0.18.

The estimated effect of technology transfer, given by the distance of a country's TFP level to that of a leader country, is positive and in column (2) is statistically and quantitatively relevant. In other words, the further away a country is from the technological frontier, the higher the impact of technology transfer on TFP growth is.

When the interaction between both types of innovation expenditure is considered, a negative impact on TFP growth is clearly found. The underlying explanation of this is based on there being a clear distinction between the two types of countries involved. On the one side are economies with a high R&D intensity, where the decision to invest in non-R&D innovation does not seem to be very profitable; in this case, the impact of an additional investment in innovation activities will be higher if the efforts are focussed on those activities which could give them a competitive advantage: these are often activities requiring relatively intense R&D innovation expenditure.

On the other side are countries where, due to their comparatively lagging-behind economic conditions, investment in non-R&D innovation expenditures will generate higher profits than allocating resources to R&D activities, especially given the need for a minimum critical mass of scientific competence, fluid channels to convert basic research into productive innovations, and other intangible conditions which are usually not very abundant in relatively low per capita income countries. In this vein, although the message may sound a bit politically incorrect, the most productive way of investing one euro in innovation activities is to put it into R&D in those countries with existing relatively high capabilities in R&D; while for economies where R&D innovation expenditures are below a determined threshold, the best option is to reinforce non-R&D activities over R&D investments[13].

Results from the model clearly show, for absorptive capacity linked to innovation expenditure, that their potential positive effect, when filtering their impact by the relative technological development of economies, does not exist. In fact, the results here are opposite to those posed by Griffith et al. (2004), where the greater the distance to the technological frontier, the more intense the positive effect of R&D on TFP growth was. Actually, when we strictly replicated the Griffith et al. model for our sample, the results were mixed, with a positive and significant coefficient for the interaction between R&D and the distance to the technological frontier (column (1) in Table 3), but a non-significant

[13] In our descriptive analysis carried out in Section 2, we used the average values of R&D and non-R&D over GDP as reference thresholds when classifying countries according to their innovation intensity. But this does mean that they are the critical values above/below which it is more productive to invest in R&D versus non-R&D.

coefficient when the technological frontier is not defined by Luxembourg (column (2) in Table 3).

Now placing the non-R&D innovation expenditureunder scrutiny (column (2) of Table 4), we dispel the hypothesis that the effect of such innovation expenditures is more intense in the lagging-behind economies . Column (2) in Table 4 shows a negative but not significant coefficient for the term where the non-R&D spending multiplies the technological gap. The rationale for explaining this result is that the distance to the technological frontier is significant for measuring to what extent R&D expenditure impacts on TFP growth. However, as long as a significant part of the non-R&D expenditure consists of adapting R&D (and also non-R&D)-based innovations, the distance to the technological leader is not a crucial determinant for the dynamics of TFP.

Certainly, a number of methodological concerns may arise by measuring the impact of innovation expenditure on TFP growth at an EU country level. Some of these concerns have already been taken into consideration in achieving the results previously commented on, such as an alternative definition of the technological leader and lagged regressors to avoid endogeneity complications. We next carried out some additional robustness checks in order to allay potential criticisms to the findings presented so far.

Table 5: Contributions to TFP growth. Robustness checks I

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| TFP gap (t-1) | 0.51 (1.49) | 1.44 (1.36) | 10.38***(4.21) | 11.57***(4.37) |
| R&D (t-1) | -0.86 (2.25) | 2.46** (1.20) | 1.48 (1.05) | 1.93*(1.14) |
| non-R&D | 1.75*** (0.70) | 3.69*(2.20) | 1.51**(0.69) | 1.81***(0.75) |
| R&D (t-1)* non-R&D | -1.17*** (0.45) | -1.37*** (0.54) | -1.01**(0.43) | -1.26***(0.49) |
| R&D $(t\text{-}1)^2$ | 0.66 (0.46) | | | |
| non-R&D $(t\text{-}1)^2$ | | -0.35 (0.39) | | |
| Khdist | | | -0.18** (0.08) | -0.16**(0.08) |
| non-R&D *TFPgap (t-1) | | | | -1.49 (1.45) |
| Human capital control | yes | yes | yes | yes |
| High tech intensity controls | yes | yes | no | no |
| $R^2$ (between) | 0.64 | 0.64 | 0.63 | 0.67 |
| Number of Obs | 52 | 52 | 52 | |
| Number of countries | 26 | 26 | 26 | 26 |

Source: w/o LU;* significant at 10%, ** significant at 5%, *** significant at 1%

First, we addressed whether in the previous specification we might be ignoring some non-linear relationships between the regressors related to innovation expenditure and TFP growth which were already take into consideration (in the regression). This would imply that we should check whether there are important diminishing returns to both R&D and non-R&D expenditures. To address this, we followed the usual approach to check such an issue, i.e. by including the squared variables as additional regressors. Columns (1) and (2) in Table 5 report the estimates. This showed that both quadratic terms are not statistically significant. Furthermore, the statistical significance of the original linear terms of R&D and non-R&D expenditures sharply decreased, and even the point estimates of the coefficients were substantially affected. This is in line with current theoretical and empirical papers on growth, which show a general consensus about the presence of constant (and even increasing) returns to scale with innovation (Grossman and Helpman, 1994; Aghion and Howitt, 1997)

Second, we included an additional regressor defined as the interaction between our measure of human capital (percentage of workers with secondary and university studies) and the distance to the technological frontier, namely . The aim was to capture new links between technology transfer across countries and TFP growth, using human capital as the channel. This new coefficient is significant and negative in the regression; the remaining relevant coefficients maintain their statistical significance and their values do not deviate much from those reported in Table 4, which in a sense can be considered as the central result.

Contrary to the interaction between innovation expenditures and the distance to the technological frontier which was referred to above, in the case of human capital, the distance plays a significant role. In particular, given the distance of the economy to the technological leader, higher endowments of human capital dampen TFP growth. A potential explanation for this could be that: as both ingredients of the interaction terms (human capital and distance to frontier) vary in opposite directions (i.e. countries with high endowments of human capital are close to the frontier, and vice versa), then, what the negative sign of the estimated coefficient really means is that this imbalance effect only marginally negatively increases TFP growth. This indicat es that the social return on human capital is sensitive to the distance to the frontier.

Alternative terms with interactions involving human capital have also been taken into consideration, namely *khdist*, the product between R&D innovation expenditure and the percentage of workers with tertiary education on the one hand, and the product between R&D and the share of the active population with secondary and higher education on the other hand. The estimated coefficients have not been reported here when they were not statistically significant.

Table 6: Contributions to TFP. Robustness checks II

| | (1) | (2) | (3) |
|---|---|---|---|
| TFP gap (t-1) | 1.36 (1.38) | 1.55 (1.34) | 1.49 (1.37) |
| R&D (t-1) | 1.63 (1.36) | 2.19**(1.07) | 2.13**(1.11) |
| non-R&D | 1.83***(0.71) | 1.16 (0.85) | 1.81***(0.71) |
| R&D (t-1) * non-R&D | -1.09***(0.46) | -1.27***(0.46) | -1.12***(0.45) |
| dum_high_R&D | 0.71 (1.72) | | |
| dum_high_non-R&D | | 1.77 (1.29) | |
| dum_low_R&D | | | 0.70 (1.31) |
| Human capital controls | yes | yes | yes |
| High tech intensity controls | no | no | no |
| $R^2$ (between) | 0.62 | 0.61 | 0.63 |
| Number of Obs | 52 | 52 | 52 |
| Number of countries | 26 | 26 | 26 |

Source: w/o LU;* significant at 10%, ** significant at 5%, *** significant at 1%

Third, we checked whether substantial differences across countries in terms of R&D and non-R&D innovation intensities really matter for the consistency of the estimations previously obtained. In order to control for such differences, we re-estimated the equation (8) without quadratic terms, also including dummy variables for high R&D, high non-R&D and low R&D innovation expenditure countries, respectively. Table 6 reports the results. It can be seen that the statistical significance of such dummies are far from the standard critical values. Therefore, grouping countries according to their respective levels of R&D or non-R&D innovation expenditures would not result in better estimates, irrespective of the substantial decrease in the number of observations we would need to address. We also ran regressions including country dummies for Finland, Sweden and Bulgaria, in order to control some indications of exceptional TFP growth that exist in such countries. As the dummy variables were not statistically significant and as the coefficients of central results were unaltered, we have not reported them here.

And finally, alternative measures for the regressors included in $\mathbf{X}$ and additional control variables were considered, with the aim of assessing once again the consistency of our central results. In particular, human capital was proxied by the share of workers with tertiary education over the total active population, with the main findings of our estimations unchanged. Additionally, we included as a regressor the percentage of researchers over the active population, but its statistical significance was not acceptable. Furthermore, we ran regressions with the number of patents over 100 000 inhabitants and a proxy of economic density (GDP over squared kilometres) as control variables but neither appeared to be significant.

## 6 Conclusions and policy implications

This paper has proposed using an augmented macro-theoretical model to estimate the determinants of total factor productivity (TFP), jointly considering the effects of R&D and non-R&D expenditures . Since a significant portion of the innovation effort carried out across the very heterogeneous economies in Europe takes the form of non-R&D innovation activities, the traditional macro approach is not deemed appropriate to estimate the determinants of TFP as a likely upward bias in favour of the impacts of R&D on TFP is expected. In this study, an augmented macro-theoretical model was used which accounts for non-R&D activities as one of the key sources for innovation. The results of the modelling provide a more accurate estimation which greatly improves the understanding of the impacts of innovation activities on TFP.

The model was estimated for a sample of EU countries over the period 2004-2008. The critical issue of building up a measure of the levels of non-R&D endowments at national levels was overcome by linking data from three different waves of the Community Innovation Survey (CIS04, CIS06 and

CIS08), data on R&D from Eurostat and data on public non-R&D funding from DG Regio.

The main results are summarised here. First, both R&D and non-R&D expenditure positively affect TFP growth, with the former having twice the impact of the latter. Interestingly, it was found that the interaction between both types of innovation investments has a negative effect on TFP growth. The underlying explanation behind this is that this effect is quite sensitive to the type of innovation involved and the critical mass already existing in the different countries. In other words, there may be doubts about the (simultaneous) complementarity between R&D and non-R&D in this context.

Second, the distance to the technology leader certainly shows a positive impact on TFP growth, supporting the idea of knowledge transfers in favour of technology lagging-behind economies . When this effect is linked to particular types of innovation expenditures (the so-called absorptive capacity), we find mixed evidence in the case of R&D and no impact for non-R&D; indeed, in dealing with local adaptions of R&D (in a sense, this is what non-R&D actually means), it does not matter how far the economy is from the technology leaders.

The econometric estimates have been subjected to a robustness analysis, including checking whether the presence of non-linear relationships, threshold effects, alternative control variables and changes in the measures of some regressors could modify the main conclusions. In all cases, we have confirmed this is not the case.

A number of policy implications can be drawn from our results. First, the empirical evidence makes it clear that the distinction between R&D and non-R&D is relevant enough that it should be taken into consideration when deciding upon the geographical distribution of innovation policy resources. In particular, in economies with a high R&D intensity, the most efficient way of increasing TFP through innovation is not by increasing the resources committed to non-R&D but rather by increasing R&D investment. By contrast, concerning relatively lagging-behind economies with comparatively high shares of non-R&D over GDP, the best strategy is to expand such innovation expenditures instead of investing substantially in R&D that may have doubtful probabilities of success, given the local conditions.

Second, we have seen how absorptive capacity influences TFP growth but depending on the type of innovation. There are some indications that this connection exists with R&D innovation expenditures but that it is practically absent with non-R&D expenditures. However, countries are not necessarily permanently defined as those mainly devoted to R&D activities and those more prone to non-R&D innovation expenses, as their positions can change. In such a dynamic context, the orientation of innovation policy may then change from a relatively comfortable attitude with respect to the distance to the technology frontier to another where this becomes important, and thus policymakers should be more pressed to take into consideration the scientific lag of the country. Also, in line with discussions in this paper and as shown by the econometric results, human capital once again deserves preferential treatment in any policy mix.

Beyond this paper, further research avenues need to be developed for a better understanding of the links between the different types of innovation expenditures and TFP growth. For instance, there is a large scope for improving the theoretical understanding of how non-R&D innovation decisions can affect TFP. Similar to the R&D side of innovation, non-R&D investments should also be determined in the context of optimising agents, following prices/incentives and deciding which part of the innovation effort is channelled to each type of innovation. This broader conceptual approach may result in a more appropriate specification of the regression to be estimated

An additional extension could involve exploring the way non-R&D innovation resources may be utilised for physical capital accumulation rather than impacting directly on TFP growth. Indeed, as long as a significant part of non-R&D investment can be seen as an investment in new (and more innovative) machinery, it is reasonable to deal with it as an embedded technological progress (see, for instance, Martinez et al., 2008, 2010), which indirectly affects the technology frontier of the economy. Finally, following the recent results by Varga et al. (2014), controlling agglomeration and/or scientific networking within our framework could also be a fruitful research avenue for looking at the impacts of R&D and non-R&D on TFP.

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