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BEYOND THE R&D EFFECTS ON INNOVATION: THE CONTRIBUTION OF NON-R&D ACTIVITIES TO TFP GROWTH IN THE EU *

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ABSTRACT: A significant part of the innovation efforts carried out across very heterogeneous economies in Europe is under the form of Non-R&D innovation activities. But the traditional macro approach to the determinants of TFP does not handle this issue appropiately. This paper has proposed and estimated an augmented macro-theoretical model to the determinants of total factor productivity (TFP) by jointly considering the effects of R&D endowments and the impact of Non-R&D innovation activities on …firms´ levels of productivity. The estimation of the model for a sample of EU26 countries covering the period 2004-2008 shows that the distinction between R&D and Non-R&D endowments really matters for a number of different issues. First, the results show a sizable differential impact of these endowments on TFP growth, being the impact of R&D twice as big as the impact 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 complements at least for the case of countries with high R&D intensities or high Non-R&D intensities.

JEL Codes: O0, O3, O4

Keywords: TFP, R&D, Non-R&D expenditures, EU countries

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1 Introduction

There is a general consensus in the economic literature that investments in Research and Development (R&D) have a preeminent role in the economic development of countries and regions, being an important driver of innovation and growth. Furthermore, innovation is not only a costly activity but it is also pretty much dependent on the level of regions´ technological capital and absorption capacities. However, in addition to R&D activities, innovation can take place through activities which do not require R&D or acquisition of new technology such as the purchase of advanced machinery, computer hardware and software, the adquisition 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]. Basically these Non-R&D innovation activities can be grouped into three categories (Arundel et al., 2008)[2]. The first category refers to minor modifications or incremental changes to products and processes using existing engineering knowledge (Kline and Rosenberg, 1986, Nascia and Perani, 2002). The second category includes imitations or adoption of innovations developed by users (Kline and Nelson, 2000; von Hippel, 2005; Gault and von Hippel, 2009). Finally, the third category refers to 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 countries show that almost half of innovative European firms did not perform R&D in-house. Small-size firms with weak in-house innovative capabilities, absence of staff with tertiary education and/or lack of exports are more likely to innovate without performing R&D. Sourcing information from suppliers and competitors make firms more prone to innovate through Non-R&D activities.

On top of this, the studies on the existence of knowledge spillovers related to innovation do not always give a clear answer[4]. On one side of the spectrum Robbins (2006) finds mixed evidence in terms of the significance of industry-specific knowledge spillovers at the state level in the United States and a lack of evidence in most manufacturing industries. On the other Mairesse and Sassenou, (1991) and Los and Verspagen, (2000) get robust findings of knowledge spillovers across firms, Scherer (1993) and Branstteter (2001) across industries and Park (1995) across countries.

In this paper we focus on both R&D and Non-R&D innovation expenditures as a way of measuring

[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 4,395 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 transfering knowledge

the innovative efforts carried out in the EU countries and how these expenditures impact on total factor productivity growth (TFP). R&D and Non-R&D innovation spending is expected to increase productivity by for instance reducing the cost of production of existing goods when new and more costly saving inputs processes are introduced, expanding the choice of products which can give rise to scale economies in production, creating new products where its production requires less of the inputs than the old ones or simply by adopting new management techniques, investing in new machines, improving products design, etc. These "best practices" by the firms will therefore generate an outward shift of firms´ production frontiers.

As for studies investigating innovation-productivity relation, some empirical analysis of the effect of innovation on the firm's productivity and efficiency used the standard methodology of estimating a Cobb-Douglas production function such as Potters et al. (2011) for the case of Europe, Kancs and Siliverstovs (2012) for the OECD countries[5]. An alternative approach to these type of studies has been 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, or Griffith et al. (2006) for France, Germany, Spain and the UK.

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

At a macro level, the endogenous growth theory emphazises the relevant role played by R&D investments in the growth rates and in the processes of 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 basis an equation which

[5] See Griliches (1995) for 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 the innovative 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.

relates R&D endowments with total factor productivity (TFP). However, as the empirical literature based on firm-level studies have shown, Non-R&D innovation activities are also a major channel to increase firms´ productivity. Moreover, in the case of Europe and for the period 2004-2008, the average amounts invested in Non-R&D activities was 10% higher than the resources devoted to R&D (1.55% versus 1.40%, 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 upon 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) are Non-R&D performers (Rammer et al. 2011, Som et al, 2010).

From a policy view to disentangle the effects on both types of expenditure is very important since institutions such as the European Commission devote an important portion of their budgets to finance R&D and Non-R&D activities. At EU level, the expenditures devoted to R&D and Non-R&D in the 2000-2006 Community Support Framework (2000-2006 CSF) amount 19% of the total budget (7% for R&D and 12% for Non-R&D) whereas in the 2007-2013 CSF this figure went up to 23% with a much more important 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 total factor productivity growth incorporating the effects of Non-R&D innovation endowments and on the other (empirical side) we estimate the impacts of such endowments on the level of aggregate productivity. To do that, we take as a basis an equation which regress total factor productivity against R&D and Non-R&D endowments. 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 endowments lies on the robust findings of the impact of Non-R&D endowments on firms´ levels of productivity. Therefore, our approach envisages a simple way of linking the positive impact of Non-R&D endowments on firms´ productivity with TFP improvements at aggregate level (regional or country level). To the best of our knowledge, this is the first paper using a macro approach to deal with the joint impacts of R&D and Non-R&D innovation expenditures on TFP growth. From an empirical side, and regarding the Non-R&D investments, we have to link Eurostat, Community Innovation Survey (CIS) and DG Regio data since CIS data only accounts for private innovation expenditures. We have also used data from Cambridge Econometrics and EU Klems to get countries TFP data. Once the data problems have been sorted out we have empirically estimated our model for the EU countries over the period 2004-2008.

Our findings suggest that the distinction between R&D and Non-R&D endowments really matters for a number of different issues. First, the results show a sizable differential impact of these endowments on TFP growth, being the impact of R&D twice as big as the impact of Non-R&D. Second, absorptive

[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).

capacity is only linked to R&D innovation efforts. and third, the two types of endowments can not strictly been seen as complementary at least for the case of countries with high R&D intensities and high Non-R&D intensities.

The rest of the paper is structured as follows. Section 2 offers an overview of the 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 expenditures are related to productivity growth. Section 4 describes the data. Section 5 contains the econometric estimates and the interpretation of the results. Finally, section 6 contains 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 have played a very important role in the countries´ innovation policies. The average Non-R&D innovation expenditure intensity in the years covered in our analysis (1.55% expressed as a percentage over 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 allotted to R&D and Non-R&D innovation expenditures took in place. Non-R&D expenditure intensities have decreased by 20.5 % from 2004 to 2008 (moving from 1.70 to 1.35) whereas at the same time R&D innovation expenditure intensities have increased by 11.5% (moving from 1.33 to 1.48).

If we break down these data according to the relative economic development of the countries, basically classifying the countries either as belonging to EU15 or 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. The Non-R&D innovation expenditure intensities decreased in the CEEC around 13.3 % (moving from 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 increased in R&D innovation expenditures by 10% (1.89 to 2.09).

Another important feature that can be observed when comparing EU15 versus new Member States is that Non-R&D innovation expenditure intensities are almost 38% higher in CEECs than in EU15, and R&D expenditure intensities are 60% higher in EU15 than in CEECs. Part of the reasons why the new Member States rely more on Non-R&D innovation expenditures to promote innovation would be based on the low-level in-house R&D innovative capabilities of these countries manufacturing and services sectors and the lack of qualified human resources (direct measures of innovative capabilities), small firm sizes and low profile in terms of exporting behaviour (indirect measures of innovative capabilities). These former four factors would be agravated by the fact that the low market access in many CEECs make these markets small and non–profitable markets for innovation and put a penalty for human capital accumulation (Redding and Shott 2003, Lopez-Rodriguez et al. 2007, 2013). These factors together with increasing returns to innovation and localization of the 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 sources of finance for both the initial costs (creating an entry barrier). They may face barriers to raising capital from external sources as well because of a lack of collateral and of a record of past successful R&D projects. Furthermore, small firms can lack the financial resources to maintain a portfolio of several R&D projects to hedge against the risk of failure, which is higher 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 play a significant role to promote innovation in the lagged economies. This pattern is much more accentuated when we break down the countries into CEECs and Western Europe.

Table 1: Comparison of RD and Non-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 RD and Non-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 at providing a conceptual framework to incorporate Non-R&D innovation endowments as key determinants of countries´ total factor productivity 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 type of innovation-linked activities which are also impacting on countries levels of total factor productivity. In other words, we are also taking into account the stocks of innovation capital coming from investments in Non-R&D activities. The economic rationale to incorporate Non-R&D endowments as an important driver for innovation is based on the robust empirical findings on the positive impacts of such endowments on firms´ levels of productivity. Therefore, if we consider an aggregate view (macro approach) of a region or country populated by many firms, improvements from Non-R&D activities at company level should be translated into improvements of productivity at region and country level. Our theoretical approach will envisage a simple way of how the passage from the impact of Non-R&D investments on firms´ productivity can be translated into TFP increases at aggregate (regional or country) level.

Let denote us countries and years by subindexes i and t, respectively. The starting point is the definition of 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 private physical capital. Function $F(.)$ is assumed to satisfy the standard properties: homogeneous of degree one and exhibiting decreasing returns to scale of each factor. In turn, A can be seen as the Total Factor Productivity 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 the firm level productivity studies the effects of Non R&D endowments 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 regions and countries levels of TFP:

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

where rd is the ratio of R&D investments over GDP and nrd the corresponding investment rate in Non-R&D capital stock. $\psi\left(.\right)$ 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 $\alpha_2 = \frac{\partial A}{\partial nrd}\frac{nrd}{A}$. Subindexes have been omitted for sake of simplicity in notation.

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 concept for Non-R&D capital stock. The depreciation rate δ affects the capital stock existing in the previous period; next, following Griffith et al. (2004), we assume that such depreciation rate is null, mainly motivated by the difficulties of empirically measuring how much 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 up 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 both of them, 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 have worked with data for EU26 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 was taken from EU KLEMS[9]. TFP is obtained using the so called growth accounting model which is based on various assumptions, among which the following are important: (i) the production function exhibits constant returns to scale and (ii) product and factor markets are characterised by perfect competition. The growth accounting model divides the growth in output into three different sources: increase in capital, in labour and in total-factor productivity (TFP). Capital contribution is obtained by multiplying the increase in capital by

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

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

capital's share of output; in turn, labour contribution 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. TFP is also called the Solow residual (Solow, 1957). Therefore, measure of TFP depends on the availability and quality of data concerning the other sources of growth.

Despite the fact that our base database for the TFP variable was EUKLEMS, we had to resort to the Cambridge Econometrics data-set 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 have broken down the average growth rate of output per capita for our period of analysis into the TFP growth component and capital-depeening component[11].

In relation to the knowledge capital stocks variables we have followed, on the one hand, Fischer and Varga (2003) and Robbins (2006), who aggregate R&D expenditures for the stocks of knowledge capital R&D driven. On the other hand, following a paralell approach, we have aggregated Non-R&D expenditures for the stocks of knowledge capital Non-R&D driven. The main advantages of R&D as proxy for the stocks of knowledge capital R&D driven is that these data are widely available over long time periods at firm, sector regional and national level. 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 the stocks of knowledge capital of Non-R&D, we have followed several steps which involved linking Eurostat and the Community Innovation Survey (CIS) databases [12] and also using DGRegio data on public expenditures on Non-R&D activities. According to the period of time employed in our analysis we have used the CIS04, CIS06 and CIS08 surveys, respectively.

Since CIS gathers information on total private (firms) innovation expenditures carried out using both R&D and Non-R&D activities, it is quite straightforward to get the stocks of knowledge capital Non-R&D driven by disentangling R&D innovation expenditures from Non-R&D innovation expenditures. The procedure we have followed was first to obtain total country´s private Non-R&D innovation expenditures by substracting from the CIS data the Eurostat data on Business enterprise R&D expenditure (BERD). Once having these data, the next step to get data on total Non-R&D innovation

[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 Cambridge Econometrics dataset are fairly similar than 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.

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

A set of control variables have also been 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 persons aged 25-64 with tertiary education attainment; second, total R&D personnel as percentage of active population; and third, total R&D personnel as percentage of total employment. Also we have included control variables for high tech intensity, which were defined either as patent applications to the European Pattent 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 studies; alternatively, we also measured such a technology transfer effect as the product between the TFP gap and the share of active population with secondary and upper educational attainment. All the data for the set of control variables has been obtained from Eurostat.

5 Econometric results

The econometric strategy we follow next 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. 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 $\beta_3 + \gamma_1 \bar{Ird}$, being $\bar{Ird}$ the average value of the R&D expenses 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, we should note 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, among others) completely vanish. Indeed, Hausman test for checking whether unobserved individual effects are correlated or not with the regressors fails to fulfill its asymptotic assumptions. Furthermore, the Breusch and Pagan lagrangian multipler test for random effects concludes for several specifications (not reported here but available upon request) that there are no significant differences across units and simply running OLS is appropriate. We have then pooled the data and proceeded to estimate the model without taking unobserved-specific characteristics of countries into account.

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

Secondly, 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 have been also estimated for our central results. And thirdly, we offer some alternative specifications as robustness check to confirm our main results.

Table 3: Contributions to TFP growth.

	Griffith et al.(2004) approach		Griffith et al.(2004) approach with NR&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)		
NR&D			0.87 (0.64)	
NR&D(t-1)				-0.77 (0.61)
NR&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
R2 (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 characterization 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 such a distance and the R&D expenditures as percentage of GDP (absorptive capacity). A striking point is that the coefficient of R&D is negative, although not statistically significant. The difference between both columns is that Luxembourg has been ignored by defining the technological frontier in the pair columns, in spite of the fact that this country enjoys the highest TFP level in the period; this has been done to avoid a non-very representative measure of 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)), all the coefficients are not statistically significant. This first battery of results shows then to what extent the strictu sensu replication of the Griffith et al's approach is far from being 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)
NR&D	1.83*** (0.70)	2.22***(0.74)
RD(t-1)*NR&D	-1.11*** (0.45)	-1.44***(0.50)
NR&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 nonR&D	0.18	0.15
R2 (between)	0.62	0.70
Number of Obs	52	52
Number of countries	26	26

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

Table 4 reports the estimations of expression (8), in which all the relevant coefficients appear as significant. 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 expenses practically doubles that of Non-R&D expenditures when both of them are measured according to their rate of return. Indeed, while the range of such contribution of R&D to TFP growth is between [0.30, 0.33], the figure obtained for Non-R&D is within the interval [0.15, 0.18].

The estimated effect of technological transfer, given by the distance of country's TFP level to that of leader country, has a positive sign and in the 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 technological transfer on TFP growth is.

When the interaction between both types of innovation expenditures is considered, a negative impact on TFP growth is clearly found. The underlying explanation of this is based on a clear distinction between the two types of countries at work. On one side, we have economies with a high R&D intensity where the decision of investment in Non-R&D innovation seems not to be for sure very profitable; in this case, the impact of additional investment in innovation activities will be higher if the efforts are focussed on which they really enjoy some competitive advantages: on activities requiring relatively intense R&D innovation expenditures.

On the other side, we have countries where, due to their comparatively lagged economic conditions, investing in Non-R&D innovation expenditures will generate more profits than allocating resources to R&D activities, given the need for having a minimum critical mass in terms of scientific competence, fluid channels to convert basic research into productive innovations and other intangible conditions not very abundant in relatively low-per capita income countries. In this vein, although the message sounds a bit politically incorrect, the most productive way of investing 1 euro in innovation activities is to put it into R&D in those countries with some relatively good capabilities in R&D, while for the economies where R&D innovation expenditures are below a determined threshold the best option is to reinforce the Non-R&D activities in comparison with R&D investments[13].

The absorptive capacity linked to innovation expenditures shows in our model clear indications 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 higher the distance to the technological frontier, the more intense the positive effect of R&D on TFP growth. Actually, when we replicate strictly speaking the Griffith et al model for our sample, the evidence is mixed, with a positive and significant coefficient for the interaction between R&D and

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

the distance to the technological frontier (column (1) in table 3), but a non-significant coefficient when the technological frontier is not defined by Luxembourg (column (2) in table 3).

Placing now the Non-R&D innovation expenses under scrutiny (in column 2 of table 4), we turn down the hypothesis that the effect of such innovation expenditures is more intense in the lagged economies. The column (2) in the table 4 shows a negative but non-significant coefficient for the term where Non-R&D spending multiplies the technological gap. The rationale behind this result is that the distance to the technological frontier is really relevant for measuring to what extent the R&D expenditures impact TFP growth. However, as long as a significant part of the Non-R&D expenses consists of adapting R&D (and also Non-R&D)-based innovations, how far is 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 expenses on TFP growth at EU country level. Some of them have been already taken into consideration when achieving the results previously commented; for instance, an alternative definition of the technological leader, lagged regressors to avoid endogeneity complications, etc. Anyway, we next carry out some additional robustness checks in order to neutralise 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)
NR&D	1.75*** (0.70)	3.69*(2.20)	1.51**(0.69)	1.81***(0.75)
RD(t-1)*NR&D	-1.17*** (0.45)	-1.37*** (0.54)	-1.01**(0.43)	-1.26***(0.49)
$R\&D(t-1)^2$	0.66 (0.46)			
$NR\&D(t-1)^2$		-0.35 (0.39)		
Khdist			-0.18** (0.08)	-0.16**(0.08)
NR&D*TFPgap(t-1)				-1.49 (1.45)
Human capital control	yes	yes	yes	yes
High tech intensity controls	yes	yes	no	no
R2 (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 LUX;* significant at 10%, ** significant at 5%, *** significant at 1%

Firstly, we wonder whether in the previous specification we could be ignoring some non-linear relationships between the regressors related to innovation expenditures and the TFP growth, which were already take into consideration in (8). In essence, we should check whether there are important diminishing returns to both R&D and Non-R&D. We have followed here the usual approach to check such an issue: including the squared variables as additional regressors. Columns (1) and (2) in table 5 report the estimates. Both quadratic terms are not statistical significant. Furthermore, the statistical significance of the original linear terms of R&D and Non-R&D sharply decrease and even the point estimates of the coefficients are substantially affected. This is in line with 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)

Secondly, we have 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 *khdist*. The idea is to capture new links between the technology transfer across countries and TFP growth, using the human capital as channel. This new coefficient is significant and negative in the regression, the remaining relevant coefficients keep their statistical significance and their values do not apart so much from those reported in table 4, which in a sense can be considered as our central result.

Contrary to the interaction between innovation expenditures and distance to technological frontier which was referred above, in the case of human capital the distance plays a significant role. Particularly, given the distance of the economy to the technological leader, higher endowments of human capital dampen TFP growth. A potential explanation could be as follows: as both ingredients of the interaction terms (human capital and distance to frontier) vary in opposite sense (countries with high endowments of human capital use to be close to the frontier, and vice versa), what the negative sign of the estimated coefficient really means is that increasing marginally this imbalance affect negatively TFP growth. It indicates that the social return to human capital is sensitive to the distance to frontier.

Alternative terms with interactions involving human capital have been also taken into consideration, namely, the product between R&D innovation expenditures and the percentage of workers with tertiary studies on the one hand, and the product between R&D too and the share of active population with secondary and upper educational attainment on the other hand. The estimated coefficients are not reported here as long they are 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)
NR&D	1.83***(0.71)	1.16 (0.85)	1.81***(0.71)
RD(t-1)*NR&D	-1.09***(0.46)	-1.27***(0.46)	-1.12***(0.45)
dum_high_rd	0.71 (1.72)		
dum_high_nrd		1.77 (1.29)	
dum_low_rd			0.70 (1.31)
Human capital controls	yes	yes	yes
High tech intensity controls	no	no	no
R2 (between)	0.62	0.61	0.63
Number of Obs	52	52	52
Number of countries	26	26	26

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

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

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

6 Conclusions and policy implications

This paper has proposed and estimated an augmented macro-theoretical model to the determinants of total factor productivity (TFP) by jointly considering the effects of R&D and Non-R&D endowments. Since a significant part of the innovation efforts carried out across very heterogeneous economies in Europe is under the form of Non-R&D innovation activities, the traditional macro approach to the determinants of TFP did not handle this issue appropiately, and thus likely upward bias results in favour of the impacts of R&D on TFP are expected. Our augmented macro-theoretical model which accounts for Non-R&D activities as one of the key sources for innovation and the results of its subsequent estimation can be seen as a step forward on improving 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 on Non-R&D endowments at national levels has been 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 kindly provided by DG Regio.

The main results are summarised next. Firstly, both R&D and Non-R&D have positively affected the TFP growth, with the former having double impact than the latter. Interestingly, it is found that the interaction between both types of innovation investments has a negative effect on TFP growth. The underlying explanation behind it is that this effect is quite sensitive to the type of innovation and the critical mass existing in the different countries. In other words, founded doubts on the (simultaneous) complementarity between R&D and Non-R&D arise in this context.

Secondly, the distance to the technological leader certainly shows a positive impact on TFP growth, supporting the idea of knowledge transfers in favour of technological lagged 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, dealing with local adaptions of R&D (in a sense, this is what Non-R&D actually means), how far the economy is from the technological leaders does not matter so much.

Econometric estimates have been subject to a robustness analysis, 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, and we have confirmed this is not the case.

A number of policy implications can be drawn from our results. Firstly, the empirical evidence makes clear that the distinction between R&D and Non-R&D is relevant enough to be taken into consideration when facing the geographical distribution of innovation policy resources. Particularly, in economies with a high R&D intensity, the most efficient way of increasing TFP through innovation is not rising the resources to Non-R&D but growing the R&D investments. By contrast, concerning with relatively lagged 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 with doubtful probabilities of successful, given the local conditions.

Secondly, we have seen how absorptive capacity influences TFP growth depending upon the type of innovation. There are some indications that this channel exists with R&D innovation expenditures and that is practically absent in the case of Non-R&D expenditures. However, countries are not necessarily placed on a permanent position in the international division between those mainly devoted to R&D activities and those more prone to Non-R&D innovation expenses. 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 technological frontier to other where this becomes really important, and policy-makers should be more pressed to control for the scientific lag of the country. Along all these discussions, as was shown by the econometric results, human capital deserves once again a preferential treatment in any policy mix.

Beyond this paper, further research avenues can be developed for a better understanding of the links between the different types of innovation expenditures and TFP growth. For instance, there is a remarkable scope for improving the theoretical understanding on how Non-R&D innovation decisions may affect TFP. Similarly to the R&D side of innovation, Non-R&D investments should be also determined in the context of optimising agents, following prices/incentives and choosing which part of their innovation efforts is channelized to each type of innovation. This broader conceptual approach may well end up in a more appropriate specification of the regression to be estimated.

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

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