THE IMPACT OF R&D INVESTMENT ON PRODUCTIVITY

PhD Steliana Sandu, Researcher Rank I, Institute of National Economy, Bucharest, Romania,
Cristina Modoran, Research Assistant, Institute of National Economy, Bucharest, Romania,

ABSTRACT: In the context of the national and European efforts directed to increasing of R&D investment up to 3% of GDP, the debate on the effects of R&D investment has received a new impetus last time. Starting from theoretical and methodological approaches found in the current scientific literature regarding this issue, the paper is focused on the empirical analysis of the effect of R&D investment on total factor productivity in Romania for the period 1996-2006. The results obtained, in line with current research results in Romania or abroad, could be taken into consideration in political decision of R&D investment and in finding appropriate economic measures aiming to stimulate business R&D investment.

Keywords: R&D stock, R&D spillover, R&D effect on TPF

JEL Codes: O52, O41, P40

1. Theoretical and methodological aspects

Significant progress has been reached in recent years to include research and development activities as capital investment in the evaluation of the gross domestic product (Canberra Group II, 2003), considering the contribution R&D activities have to support economic growth, productivity and competitiveness.

Present international debate has focused on considering research and development an important asset for firms, government sector and universities, having in view the fact that the effects obtained by the investor are only a part of the total effects of the investment taking into account important spill-over generated by the R& investment. For this reason, experts and researchers emphasise the necessity to consider the overall effect of R&D on economic growth and productivity. Seen from this perspective, the statistics in several countries include spillover effects when measuring R&D stocks, even though they admit facing methodological difficulties to do so.

When evaluating R&D effects on productivity, the particularities of the R&D investment, which distinguishes it from other types of investment, need to be accounted for. Total effects in this case are composed of the direct effects at the original investor and spillover effects, which can benefit competitors, other industries, suppliers and clients.

Some authors consider that spillovers are superior and more persistent in time than direct effects (Okeibo, 2006). Griliches (2000) estimates private effects to be at the level of 10% and social effects of 25%. There are differences regarding the efficiency of R&D investment, when the different types of effects are considered (private effects and spillovers). For example, Okuba (2006) has found out that the rate of return is 26% for the private investor, while the social rate of return is as high as 66%. Other evaluations have found out a ratio of 3/5 for private spill over in the total effect.

The lag with which R&D expenditure should be considered for the R&D stock, having in view spill over effects is evaluate of two years for applied research and five years for basic research. At the same time, the literature acknowledges the difficulties remaining in determining the rate of return through private returns and through spillovers.

The depreciation rate considered for the calculation of the R&D stock is different for applied and fundamental research. Some authors consider that in the first case the depreciation rate is larger. These differences have a considerable impact on the dimension of R&D stock and on the estimation of the time lag after which the benefits of the R&D investment can occur. A depreciation rate of 15% means that a quarter of the investment is depreciated in two years, half of the stock is depreciated in five years and three quarters in nine years. If a depreciation rate of 9% would be considered, a quarter of the depreciation of the investment would take place in four years, half in eight years and three quarters in 15 years. The influence of the depreciation is enforced by the differences when considering the appropriate time lag considered for the investment to enter the R&D stock.

Another methodological difficulty regarding the capitalisation of R&D investment refers to the necessary distinction between different activities included in the investment category. There is consensus that both, private and government or university research, should be considered investment (Canberra II Group, 2006; Robbins, 2006; Okubo et al., 2006). In this case a difference should be made between R&D activities, which have economic value, and those, which do not have a contribution towards economic growth, and should therefore not be treated as investment.

Private R&D expenditure are generally treated as investment, as this type of expenditure is performed with the purpose of extracting profit, therefore having a commercial character. On the other hand, university and government funded research are not dominated by a commercial purpose, therefore only a reduced share of this expenditure can bring direct profits. Empirical studies have shown mixed evidence. Some authors have found out that public investment in R&D does not have a positive impact on productivity growth, while others have found evidence of a positive effect, although inferior to private R&D investment. It is also considered that including all types of R&D expenditures into investment would represent an overestimation of R&D investment. Double counting problems, frequent in statistical reports regarding public and private R&D expenditure would further worsen this evaluation.

Some experts consider that, if one could calculate how many new technologies, adopted as a consequence of the research activity in governmental sector, lead to an increase in productivity of companies, public R&D could be considered investments. Others consider that public R&D expenditure contributes to the growth of productivity either directly through new technology and equipment design, job creation, human capital development or indirectly by stimulating the growth of private R&D expenditure (Toole, 2007). The opinions of different authors regarding the share of fundamental research which could be considered to have commercial efficiency and as a consequence be included in the category of investments, ranges from a quarter to two thirds (Fraumeni and Okuboo, 2005).

Empirical studies, which focus on the impact of R&D investment on productivity, are confronted with a series of difficulties, which could bias the results of the analysis or could create problems in the interpretation and the comparison of the results with those of similar studies. Among these difficulties we mention:

- Insufficiency of available data and shortcomings of current estimation models which make difficult a clear identification of the contribution of R&D investment to the growth of productivity. Therefore the estimations regarding the elasticities of R&D investment have a wide range of values, depending on the sample, on the estimation methods, on the time frame considered, etc. Another important aspect deriving from the limited access to relevant data is the different treatment of R&D investment in models at macro- or microeconomic level.
- There are differences in the type of analysis chosen, whether the approach is using cross section or time series. Most empirical studies rely on cross section data. The results of empirical studies, which analyse the relationship between the investment in R&D and the growth of total productivity factor using time series, in comparison with the results of empirical studies using aggregated data have lower estimated coefficients.
- R&D investment induces spillover effects, which can benefit other companies, industries or even other economies, which do not contribute to the investment. The difficulty in measuring and estimating this type of effects make the results more subjective when compared to

the results of studies referring to the direct benefits of companies and industries investing in R&D activities.

- The utilisation of different R&D definitions makes difficult the comparison of empirical results. Researchers focusing on technological change prefer a broader conceptualisation, which includes every effort which contributes to the growth of the knowledge stock and which could stimulate innovation. As it is impossible to measure and delimit all activities, which contribute to the growth of the knowledge stock of an economy, available data include only R&D expenditure, that reflects only a portion of the investment in this area. Therefore we can say that the results of empirical studies reflect only the effect of formal R&D activities on productivity.

A differentiation is needed between the influence of private and public R&D activity. Empirical studies offer mixed evidence. At times the conclusion is drawn that the government wastes funds on R&D activity. One should not forget that private R&D benefits from the academic research financed by the government, which is performed in the public sector.

A series of methodological difficulties can arise in the process of the design of empirical studies to study the relationship between R&D investment and productivity.[1]

1. *Defining the R&D stock.* When determining the R&D stock, the first step is to identify and measure its elements. These should be the elements, which directly influence the evolution of productivity, having their values specified in national income accounts. Most empirical studies show that productivity growth rate is affected directly only by private funded research. Specialised literature includes analyses which suggest that applied or experimental research financed by public funds and performed in productive sectors affect overall productivity, but to a lesser extent.
1. *Selecting the deflator*, which would convert annual R&D expenditures in constant real values, which are not affected by inflation, gives rise to specific problems.
2. After the estimation of the annual investment in research and development, the *time lag* needs to be determined, which reflects the time needed from the moment R&D activities are performed to the manifestation of the impact on productivity. Leo Svaikauskas (2004) applies a lag of two years for applied research and five years for basic research and development. Other empirical studies apply lags of one and three years, respectively. The time horizon surely depends, to a great extent, on the type of the innovation project, on the nature of activity and on the industry where the investment takes place.

2. An evaluation of the impact of R&D investment on productivity in Romania[2]

Technical progress is considered to be the main source of long-term productivity growth within the framework of modern growth theories (Solow, 1957; Romer, 1990). The purpose of the present analysis is to estimate the effect of the investment in R&D on the evolution of the total factor productivity in Romania for the timeframe 1996-2006.

The econometric specification used to determine this impact has as foundation a simple Cobb-Douglas production function. The purpose of the econometric analysis is to isolate the effect

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[1] Leo Sveikauskas: „The contribution of R&D to productivity growth", Monthly Labor Review Online, March, 1986,vol.109, nr.3; Zvi Griliches: "Issues in assessing the contribution of research and development to productivity growth", în :R&D and Productivity : The econometric Evidence, NBER, University of Chicago Press, 1998, p.17-45

[2] This empirical study is based on the methodological approach of Dominique Guellec şi Van Pottelsberghe de la Potterie ,), *R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries,* OECD, STI Working Papers, 2001.

of R&D investment on the total factor productivity. The overall R&D investment impact will be estimated, as well as impact dissociated according to the source of funding (private or public funds). The following econometric equation will be used for this purpose:

$$TFP_t = \exp(\mu_t) ICD_{t-1}^{\beta_{CD}} \cdot ROC_t^{\sigma_{oc}} \quad (1)$$

where TFP represents the total factor productivity, ICD represents the total investment in R&D and ROC represents the capacity utilisation rate, expressed as 1 minus the unemployment rate. This last variable is introduced to control for the influence of the business cycle on the total factor productivity. The coefficients β_{CD} and σ_{oc} represent the elasticity of total factor productivity with respect to R&D investment and to capacity utilisation rate. The index *t* captures the year, while μ is the residual coefficient of the econometric specification.

To account for the impact of R&D investment differentiated according to funding sources the econometric specification will be adapted as follows:

$$TFP_t = \exp(\mu_t) ICDP_{t-1}^{\beta_{CDP}} \cdot ICDB_{t-1}^{\beta_{CDB}} \cdot ROC_t^{\sigma_{oc}} \quad (2)$$

where ICDP represents public investment in research and development and ICDB private R&D investments.

In this econometric equation R&D investment does not have an instant impact on productivity, therefore the stock of investment of the previous time period is considered. In the case of public R&D investment, the literature considers a two-year lag necessary for the manifestation of effects.

To obtain a linear econometric specification, we will utilise the logarithmic form of the econometric equations:

$$LTFP_t = \beta_{CD} LICD_{t-1} + \sigma_{oc} LROC_t + \mu_t \quad (3)$$

and

$$LTFP_t = \beta_{CDP} LICDP_{t-2} + \beta_{CDB} LICDB_{t-1} + \sigma_{oc} LROC_t + \mu_t \quad (4)$$

Data regarding the capital R&D expenditure on the basis of which the stocks of R&D investments were calculated, as well as the data regarding the capacity utilisation rate were taken from the statistics published by the National Institute of Statistics. The figures for the total productivity factor for 1996-2006 were calculated by Ghizdeanu and Neagu (2003) and were further updated by the authors to be included in the Convergence Programme for Romania. R&D investment stocks were calculated in constant prices using 2000 as basis year.

To identify the effects of R&D investment, capital R&D stocks were calculated, this measure of R&D investment being preferred to the R&D expenditure flows. To calculate research and development stocks the permanent inventory method was used, opting for a depreciation rate of 20%, a depreciation rate widely accepted in similar studies. Therefore, the R&D stock (CD) at the time *t* is equal to the new investment from the time *t* (cd) plus the stock at time *t-1* minus the corresponding depreciation:

$$CD_t = cd_t + (1-\delta)CD_{t-1}\ , \quad (5)$$, where

CD_t - represents the stock of research and development at time *t*, and cd_t represents the flow of investment in research and development corresponding to the same time period *t*.

To calculate the initial stock a constant average growth rate of investment in the past λ is considered, so as:

$$CD_t = cd_t + (1-\delta)cd_{t-1} + (1-\delta)^2 cd_{t-2} + (1-\delta)^3 cd_{t-3} + \cdots$$
$$= cd_t + (1-\delta)\lambda cd_t + (1-\delta)^2\lambda^2 cd_t + (1-\delta)^3\lambda^3 cd_t + \cdots = \frac{cd_t}{1-\lambda(1-\delta)} \quad (6)$$

The evolution of stocks thus calculated (in constant 2000 prices) is depicted in Figure 1. Starting with 2000, a strong increase in R&D stocks can be observed. It is noteworthy that until 2001 private stocks are superior to public stock, a situation that is reversed starting with 2001. For

2005 and 2006 we can notice that public R&D investment stocks are almost double compared to private ones.

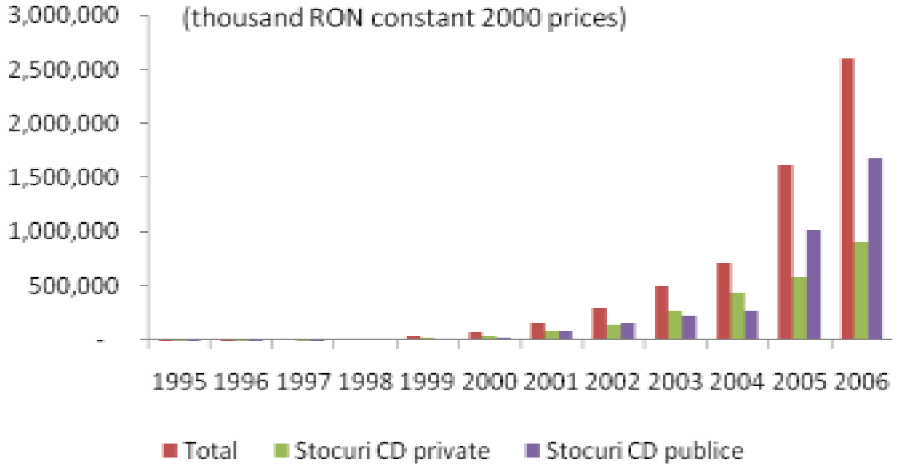

Fig. No. 1. The evolution of R&D stock

Source: own calculations; National Institute of Statistics

The evolution of the total productivity factor during the same time period is less spectacular (see Fig. No. 2.). One can observe a slight diminution during 1996-1999, followed by a modest but constant growth starting with 2000.

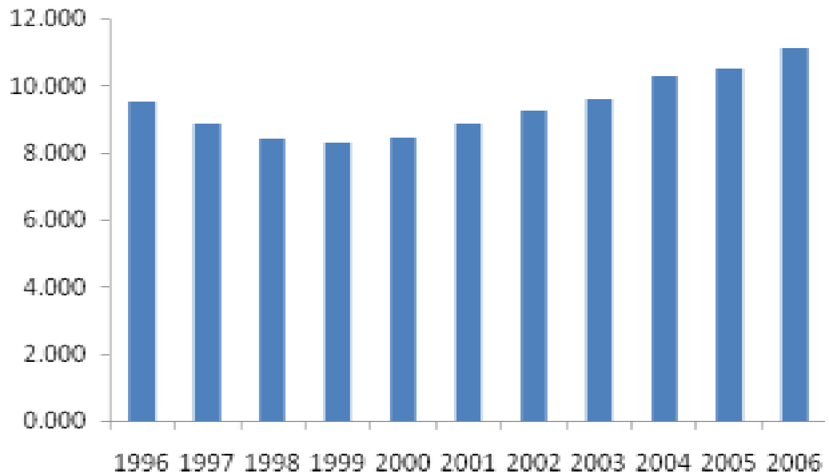

Fig. No. 2. Total Productivity Factor

Source: Ghizdeanu and Neagu (2003); Convergence Programme for Romania

When simple regression is applied (OLS) we obtain the results presented in Tables 1 and 2 for equations (3) and (4).

Table no. 1.

Dependent variable – LTFP(t)	Coefficient	Standard Error	Value of t-statc
LICD(t-1)	0.0100751	0.0031336	3.22
LROC(t)	3.477235	0.3345154	10.39
Adjusted R^2	0.9525		

It can be noticed that the coefficients for both the total research and development stock (LICD) and the control variable (capacity utilisation rate – LROC) are significant. Both independent variables have a positive influence on the dependent variable, the total productivity factor. According to the results obtained, an increase of the R&D investment stock of 1% leads to an almost equal increase (1.01%) in the total productivity factor.

Table no. 2.

Dependent variable – LTFP(t)	Coefficient	Standard Error	Value of t-stat
LICDP(t-2)	-0.0215476	0.0206389	-1.04
LICDB(t-1)	0.0401309	0.0287373	1.40
LROC(t)	3.46725	0.5475214	6.33
Adjusted R^2	0,9506		

When R&D capital stocks are delimited corresponding to the source of funding (public or private), only the coefficient of the control variable remains statistically significant. It is also important to notice that there are changes in the sign of the coefficients of the two explaining variables. Public investment in R&D seems to have a negative influence on the total productivity factor.

The results obtained through simple regression (OLS method) for time series have to be considered with great care. The high values of R^2 indicating a high explanation power of the model may be due to the existence of a common trend of the variables, without necessary implying a correlation between the variables. Therefore, it is important to test for possible biases in the results, such as autocorrelation (Durbin-Watson test) or nonstationarity of the time series (Dickey-Fuller test).

The Durbin-Watson test gives a value of d=2.04265. This value is close enough to the ideal value of 2, in order to allow us to consider that there is no autocorrelation problem. When Dickey-Fuller test is applied, the null hypothesis is rejected (the time series is stationary) for LICD and LICDB, while LTFP, LICDP and LROC are nonstationary time series.

To obtain robust empirical results we have chosen the error correction model (ECM) for the regression in equation (4). The results obtained are presented in Table 2. Equation (4) has been slightly modified in order to further distinguish between R&D capital investment in universities and in government funded research units. The equation thus expanded is presented below:

$$LTFP_t = \beta_{CDP} LICDPub_{t-1} + \beta_{CDP} LICDGuv_{t-1} + \beta_{CDB} LICDB_{t-1} + \sigma_{oc} LROC_t + \mu_t \quad (7)$$

Table no. 3.

Dependent variable – LTFP(t)	Coefficient	Standard Error	Value of z
LICDPub(t-1)	-1.888413	0.2847838	-6.63
LICDUniv(t-1)	-0.1159634	0.1336073	-0.87
LICDB(t-1)	2.382241	0.2467706	9.65
LROC(t)	19.13838	4.187899	4.57

The coefficients obtained for the R&D investment stock in both private and government sectors, as well as the coefficient of the control variable (capacity utilisation rate) are statistically highly significant at the level of 1%. The coefficient corresponding to the R&D capital stock in universities is not statistically significant; therefore the present study cannot offer a clear answer as to the importance of R&D investment in this sector on the growth of the total productivity factor.

The impact of investment in research and development in the governmental sector on the growth of the total productivity factor is found to be negative. Therefore, an increase of 1% in the R&D capital expenditure in this sector is correlated to a decrease of 1.89% of the total productivity growth. This negative impact of research and development capital expenditure in the government sector is consistent with the result of other similar empirical studies. Possible explanations and limitations of this analysis can be found in the short lag with which R&D public expenditure has entered the regression. Due to the short time series available, a longer lag could not be considered in the present empirical study. Considering the fact that a large proportion of the public R&D expenditure goes to fundamental research, for which a lag of five years has been recommended in the literature, this study might capture only a short time effect, while the long term results might be different.

A highly significant positive impact is found for investment in research and development performed by the private sector. An increase of the investment stock of R&D in this sector by 1% has as consequence an increase by 2.38% of the total factor productivity.

The results of the present study are similar to those obtained by similar empirical analyses in other countries, according to which the efficiency of the R&D investment in the private sector is superior to the efficiency in the public sector. Private actors are more oriented towards profit maximisation and commercial benefits at firm level. On the other hand it can be argued that the research results obtained by the public sector rely also on the results of fundamental research obtained in the government sector. While basic research does not offer immediate benefits, it is nonetheless important.

3. Conclusions

The activity of research and development has a determining role in the dynamics of productivity and economic growth. Research and development performed in the private sector carries significant externalities. Moreover, it increases the absorptive capacity of the business sector for technologies brought by multinational corporations or developed in government or university research units. Therefore, the overall benefits (social benefits) associated with business R&D are larger that the private effects, which justifies the public support of R&D activities in the private sector.

The government needs to equally support R&D activities in the public sector through appropriate funding, as these activities have a significant impact for the long-term economic growth of the country. As the impact of R&D investment in public research units seems to be lower, policy makers should consider the redesign of the principles and modes of financing of research and development in government units, especially those concerning priorities setting, as well as performance monitoring and evaluation. Of course, this orientation needs to be specified for each economic field, considering the spillover effects generated by research and development in the respective activity field, as well as the specific relationship between public and private research. The impact of research and development on productivity depends on the intensity of effort of private research activities. In a lot of cases, private research develops technologies, which have previously been produced, tested and evaluated in public research units. Therefore, it is important that research and development policies encourage the interconnection between public and private research, which will facilitate the flow of knowledge between the two sectors.

Policy makers should ensure an open environment for imported technologies, by supporting the inflow of goods, which incorporate a high degree of technological complexity, of human capital and of ideas. But it is equally important to ensure that local firms dispose of the necessary technological capacity to exploit these new technologies. Empirical studies have shown that the level of R&D investment is a condition for an efficient utilization of foreign technology. Therefore, the option of remaining mere spectators, being satisfied with the imitation of technological progress obtained by other countries, represents an inefficient alternative. That is why, Romanian policy makers should stimulate the R&D investment and create a favourable environment for increasing their return.

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