DO R&D EXPENDITURES MATTER FOR LABOR PRODUCTIVITY IN OECD COUNTRIES? AN UNRESOLVED QUESTION

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Abstract

The aim of this study is to analyze the relationship between labor productivity and R&D expenditures. We have tested this relationship using a panel of 22 OECD countries that covers the period 1991-2003. A Cobb-Douglas production function was estimated in growth form where physical capital, knowledge capital, human capital, and labor stock were included as the factors of production. The estimation results that also controlled for the effect of openness, and R&D spillovers implied a positive long-run R&D elasticity with respect to labor productivity growth. This result is robust to an alternative model where capital to labor ratio and labor variables are excluded. In this new model, the coefficient of the international trade variable included to account for openness was found to be positive.

Keywords: Research and development expenditures, labor productivity, OECD, panel data.

Öz

OECD Ülkelerinde ARGE Harcamaları İşgücü Verimliliği İçin Önemli mi? Çözülmemiş Bir Soru

Çalışmanın amacı, 22 OECD ülkesi için 1991–2003 dönemi verilerini kullanarak araştırma geliştirme harcamaları ile işgücü verimliliği arasındaki ilişkiyi panel veri yöntemleri kullanarak incelemektir. Bu amaçla, fiziki sermeye,

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bilgi sermayesi, beşeri sermaye ve emekten oluşan bir Cobb-Douglas tipi üretim fonksiyonu tahmin edilmiştir. Bu değişkenlere ilave olarak dış ticaret hacmi ve ARGE yayılımı kontrol değişkenlerinin eklendiği tahmin sonuçlarına göre işgücü verimliliği ile ARGE arasında pozitif bir uzun dönem esnekliği vardır. Bu sonuç, işgücü ve sermaye yoğunluğu değişkenlerinin dışarıda bırakıldığı alternatif bir model için de geçerlidir. Dışa açıklığı yansıtan dış ticaret hacmi değişkeni de bu modelde istatistiksel olarak anlamlı bulunmuştur.

Anahtar Sözcükler: ARGE harcamaları, işgücü verimliliği, OECD, panel veri.

INTRODUCTION

The interconnections between productivity and research and development expenditures (R&D), in turn impact of R&D expenditures on growth has a longstanding study in the literature (Branch, 1974; Mansfield, *et al*., 1971; Griliches, 1979 and 1980; Mansfield, 1980; Ravenscraft, Scherer, 1982; Sterlacchini, 1989; Atella, Quintieri, 2001; Bönte, 2003; Kim, Park, 2006). However, the studies on the components of multifactor productivity change, especially the impact of R&D on labor productivity, are not sizable[1]. This study aims to contribute to this limited literature and investigates the impact of total R&D expenditures on labor productivity by controlling the effects of foreign direct investment, public education expenditures, and international trade for the selected OECD countries.

The impact of R&D expenditures on total factor productivity (TFP) seems to be positive at the first sight. However, Atella and Quintieri (2001) found that the relation is not straightforward as expected for Italian manufacturing industry. The signs of the coefficient estimates depend heavily on the assumptions underlying the production function, in turn on the specification of the model and level of aggregation of the data used. For example, Smith *et al*. (2004) claims that short-run effect of R&D on productivity is insignificant for the Danish case. Interestingly enough, Kim and Park (2006) note that the source of productivity increases in Korean manufacturing industry is efficiency improvements instead of technical progress. This study further analyzes the impact of domestic and foreign R&D presenting that domestic R&D is more effective for technical progress. Frantzen (2003) questions the bidirectional causality for manufacturing sectors of OECD. Although Frantzen (2003) found some evidence on feedbacks between these two variables, the causality seems to run from R&D to TFP. Moreover, this causal structure demonstrates long-run characteristics. Almost for the same period for OECD industries, Griffith *et al*. (2004) end up with the conclusion that R&D has a direct positive contribution to growth through innovation and

indirect positive impact again through technology transfer. Rouvinen (2002) examines the causality between R&D and productivity for a panel of OECD countries. This study once again reveals the fact that R&D causes productivity but not vice versa. Moreover, Rouvinen (2002) further verifies a lag structure as productivity reacts to changes in R&D. The importance of lag structure is also mentioned by Balcombe, Bailey and Fraser (2005) and Esposti and Pierani (2003). Guellec and Potterie (2001) formulates a model for the relation between R&D and multifactor productivity in OECD countries by employing the data throughout the period 1980-1998. They obtain a positive relation between business R&D and multifactor productivity (MFP). The same result is also valid for foreign R&D capital stock.

As outlined above, the empirical evidence for the effect of R&D intensity on TFP is clear cut in some extent whereas the relation between R&D expenditures and labor productivity is more complicated. In an attempt to analyze the effect of wage moderation policy in the Netherlands, Fase and Tieman (2001) study on the interaction between R&D, change in labor productivity and economic growth. In Dutch economy, it is observed that lower productivity seems to create jobs and income since it increases exports and domestic output. Furthermore, this change induces demand-led technological innovations as a result of wage moderation. Wakelin (2001) studies UK manufacturing firms in the context of the relationship between productivity growth and R&D expenditures. A positive contribution of R&D expenditures on productivity is observed. However, the rate of return to R&D is higher for more innovative firms. In his study of Swiss manufacturing sector, Arvanitis (2006) hypothesized that labor productivity is closely related with human capital, knowledge, and innovation. This study concludes that innovation variables have positive significant effects on labor productivity, i.e. a 1% increase in R&D intensity causes 0.05% rise in labor productivity (Arvanitis, 2006).

The main objective of our study is to analyze the impact of R&D expenditures on labor productivity. By employing a Cobb-Douglas production function, we derived a labor productivity growth equation consisting of growth in R&D expenditures, capital labor ratio, labor, human capital, foreign direct investment and an international trade variable. The existing literature also notes the importance of time path for our maintained hypothesis. In order to consider this effect, we introduce a lag structure to our original model. The results indicate a positive long-run elasticity of R&D expenditures with respect to labor productivity growth. Moreover, openness of a country is found to favors labor productivity growth.

The paper is organized as follows: in the next section we will present the data, model, and methodology. The estimation results and discussion are given in Section 3. Finally, Section 4 concludes the paper.

1. MODEL and DATA

The aim of this study is to analyze the contribution of R&D expenditures to labor productivity. The model is tested using a panel of 22 OECD countries for the period 1991-2003. Some OECD countries are omitted from the data set due to missing or insufficient data[2]. The data on total R&D expenditures is obtained from the Research and Development Statistics (known as RDS, OECD 2005) and capital data is obtained from World Development Indicators. The data on other variables is compiled from International Financial Statistics (IFS).

We have based our estimation equation on a version of the Cobb-Douglas production function in its growth rate form. The production function includes the conventional variables of capital and labor as well as the additional factors of knowledge capital and human capital. We also included control variables to capture the effects of technology transfer and spillover and the openness of a country. A knowledge capital variable is included in the production function to account for the effects of technological improvements on labor productivity. The reason for including a human capital variable is to account for the aggregation of investments in activities, such as education, health, on the job training that enhances and individual's productivity in the labor market that can not be captured by the knowledge capital variable.

The production function is given by:

$$Y_{it} = Ae^{\lambda t} K_{it}^{\alpha} L_{it}^{\beta} H_{it}^{\theta} R_{it}^{\gamma} X_{it}^{\mu} e^{\upsilon_{it}} \tag{1}$$

where subscript i=1,2,....,N refers to a cross sectional unit, and the subscript t=1,2,....,T to the time dimension. υ_{it} is a disturbance term, Y_{it} denotes the output of country i at time t, K is the corresponding physical capital stock, L is the labor input, H is the human capital, R is a measure of knowledge capital and X is a vector of control variables included to capture the effects of spillovers and openness of a country. The parameters α, β, γ, θ, μ denote the elasticities of the related variables. We have used R&D expenditures as a proxy for knowledge capital.

By taking the natural logarithm of both sides of equation (1), then differencing with respect to time and rearranging we obtain the following equation in terms of labor productivity;

$$(y-l)_{it} = \lambda + \alpha(k-l)_{it} + \eta l_{it} + \theta h_{it} + \gamma r_{it} + \mu x_{it} + \varepsilon_{it} \tag{2}$$

where $\eta = \alpha + \beta - 1$ and ε_{it} denotes the transformed disturbance term. In equation (2), the lower case letters denote the respective growth rates of the variables included.

Although (2) is specified in such a way that only R&D expenditures at time t have an effect on the labor productivity at time t i.e., a contemporaneous relationship, we have applied different lag structures to the R&D variable to take into account the importance of time path for our maintained hypothesis.

The equation to be estimated is as follows:

$$q_{it} = \lambda + \alpha(k-l)_{it} + \eta l_{it} + \theta h_{it} + \gamma \sum_{p=1}^{k} rd_{it-p} + \mu_1 tr_{it} + \mu_2 fdi_{it} + \varepsilon_{it} \tag{3}$$

where q is labor productivity growth and is computed as GDP divided by number of employees, rd is the growth in the ratio of total R&D expenditure to GDP, $(k-l)$ is the growth in capital labor ratio where capital is measured as gross fixed capital formation and labor as the number of workers, fdi is the growth in the ratio of foreign direct investment to GDP, h is the growth in the human capital variable which is measured as the share of schooling expenditure in GDP and tr is the international trade variable that is equal to the growth in exports plus imports as a share of GDP.

Our basic hypothesis is in conformity with the literature, the rise in R&D expenditures supported with human capital investments will induce labor productivity. Thus, we expect positive and significant coefficients for R&D variables. However, if human capital expenditures are not significant enough to support the complementarity relation between labor and capital as a result of increasing R&D expenditures, we may end up with insignificant and even negative significant parameter estimates. Moreover, our model considers the effect of global international R&D flows by including FDI flows as a proxy for international R&D spillovers. It is generally accepted that with the FDI, the firms investing in a country are efficient ones that are likely to increase the productivity of domestic firms via spillovers. On the other hand, there is also evidence that multinational firms prefer to invest in productive sectors (Aitken

and Harrison, 1999; Serbu, 2006). Besides these arguments the FDI variable may produce ambiguous results by the same reasoning valid for domestic R&D. The international trade variable is expected to generate positive coefficients in that the intensive international competition forces domestic firms to operate more efficiently.

2. ESTIMATION RESULTS

There can be two way causality between R&D expenditures and productivity, therefore before estimating equation (3) we first investigated for a possible causality between these variables. However, the literature generally does not provide diversified methods for Granger (1969) causality tests in panel data models. We employed an approach proposed by Hurlin and Venet (2001), Hurlin (2004), Hansen and Rand (2004) that treats the autoregressive coefficients and regression coefficient slopes as constants. For each cross-section unit i and time period t, we estimated the following panel data model with fixed coefficients[3]:

$$y_{i,t} = \sum_{k=1}^{p} \beta_k y_{i,t-k} + \sum_{k=0}^{p} \theta_k x_{i,t-k} + u_{i,t} \tag{4}$$

where u is normally distributed with $u_{i,t} = \alpha_i + \varepsilon_{i,t}$, p is the number of lags, and $\varepsilon_{i,t}$ are *i.i.d.* $(0, \sigma^2)$. A homogenous and instantaneous non-causality hypothesis (HINC) that is directed towards testing whether or not the θ_k's of $x_{i,t-k}$ are simultaneously null for all individual i and all lag k is tested:

$$H_0 : \theta_k = 0 \ \forall i \in [1, N], \forall k \in [0, p] \qquad i \neq j \tag{5}$$

$$H_1 : \theta_k \neq 0 \ \exists(i, k)$$

For testing Np linear restrictions in (5), the following Wald statistics is calculated:

$$F_{HINC} = \frac{(SSR_r - SSR_u)/(Np)}{SSR_u / [NT - N(1+p) - p]} \tag{6}$$

where SSR_u stands for the sum of squared residuals for model in (4) and SSR_r for the restricted sum of squared residuals under H_o. If individual effects, α_i, are

assumed to be fixed, SSR_u and SSR_r are SSR obtained from the maximum likelihood (ML) estimation that corresponds in this case to the fixed effects (FE) estimator.

The lag length in equation (4) was chosen as 3 using the Akaike Information Criteria (AIC) and Schwarz Information Criteria (SIC). For the lag length of 3, the non-causality from R&D expenditures to labor productivity was rejected with an F statistic of 18.76, whereas the non-causality from labor productivity to R&D expenditures was not rejected with an F statistic of 0.21[4]. Thus, we have estimated the model in which causality runs from change in R&D expenditures to labor productivity growth, in other words equation (3) was estimated.

As mentioned before, since our data set has both time and cross-section dimensions, we are going to employ panel data techniques[5] (fixed and random effect estimators) to estimate the labor productivity growth equation. In addition to those estimators, OLS will be applied to the pooled data. The estimation results are presented in Table 1.

Table 1: Labor Productivity Growth in OECD Countries 1991-2003

Dependent variable: q	OLS		Fixed Effects		Random Effects	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
rd	-0,0105[**]	0,0049	-0,0082[*]	0,0044	-0,0089[**]	0,0043
rd_{t-1}	0,0157[***]	0,0058	0,0130[*]	0,0067	0,0140[**]	0,0062
tr	0,0023	0,0050	0,0057	0,0045	0,0047	0,0045
fdi	-0,0003	0,0005	-0,0002	0,0005	-0,0003	0,0005
H	0,0015	0,0041	0,0012	0,0031	0,0013	0,0034
(k-l)	0,1053[***]	0,0086	0,1019[***]	0,0087	0,1025[***]	0,0087
L	-0,2209[***]	0,0317	-0,2707[***]	0,0408	-0,2542[***]	0,0348
constant	0,0077[***]	0,0005	0,0081[***]	0,0008	0,0079[***]	0,0008
F (Wald for Random Effect)	30,43[***]		26,74[***]		214,05[***]	

Notes:
1. [*]significant at 10, [**]significant at 5, [***]significant at 1 % levels.
2. The standard errors are heteroscedasticity consistent.

According to the Table 1, while the level of R&D expenditure growth is found to affect labor productivity growth negatively, its lag has a positive effect. We have included five lags of R&D expenditure growth into our estimation equation, however, only the first lag was found to be statistically significant. Hence, we reported the estimation results with only the first lag. The results indicate that, the positive impact of R&D activities on productivity occurs with a delay. The coefficient estimate of level R&D expenditures is found negative. Since we have found the human capital variable insignificant, this result could be due to the lack of complementarity between labor and capital. However, the long-run elasticity is found to be positive. In other words, the spending on R&D expenditures leads to an increase in productivity growth in the long-run. The other variable that is found to be significant is the growth of capital labor ratio. Since the increase in capital leads to an increase in marginal productivity of labor, a positive relation is found as expected. Finally, we have found the coefficient of labor growth significantly negative. This result is obvious again since increase in the amount of one input decreases the productivity of that input.

The growth in capital labor ratio and labor are the variables derived from the production function. In the further part of study, we have estimated an ad-hoc model with the variables we particularly show interest. The estimation results are given in Table 2.

Table 2: Labor Productivity Growth Without (k-l) and l in OECD Countries 1991-2003

Dependent variable: q	OLS		Fixed Effects		Random Effects	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
rd	-0,0268[**]	0,0116	-0,0269[**]	0,0065	-0,0268[**]	0,0110
rd_{t-1}	0,0269[**]	0,0108	0,0322	0,0109	0,0292[**]	0,0119
tr	0,0220[***]	0,0077	0,0180[**]	0,0079	0,0190[***]	0,0073
fdi	-0,0001	0,0008	0,0000	0,0009	-0,0001	0,0008
H	-0,0002	0,0066	0,0007	0,0056	0,0005	0,0055
$constant$	0,0078[***]	0,0008	0,0075[***]	0,0012	0,0077[***]	0,0011
F Wald for Random Effect)	4,67[***]		5,76[***]		29,58[***]	

Notes: 1. [*]significant at 10, [**]significant at 5, [***]significant at 1 % levels.
         2. The standard errors are heteroscedasticity consistent.

Table 2 shows that R&D expenditures in level and in lags effect labor productivity similarly as it did in the previous model except that the lagged term in fixed effects model is now found insignificant[6]. The long-run elasticity of R&D expenditures with respect to labor productivity is still positive as expected, so this result is robust to the exclusion of the capital-labor ratio and labor growth variables. An important result of this ad-hoc model is the significance of the international trade variable in all the estimation techniques used. The positive sign indicates that the openness of the countries under study forces firms to operate more productively. This variable was found insignificant in Table 1, which may be attributed to the statistical significance of the capital labor ratio. The positive effect of the international trade may be captured by the capital labor ratio variable due to the existence of capital goods in the composition of imports. Finally, FDI is found to be statistically insignificant in both models. The countries we are studying are mostly the technology transferring ones but not the receiving ones hence, this may be the reason of this insignificancy.

CONCLUSION

In this study we analyzed the contribution of R&D expenditures to labor productivity in 22 OECD countries for the period 1991-2003. We have derived an estimable labor productivity growth equation from a Cobb-Douglas production function which includes the conventional variables of capital and labor as well as the additional factors of knowledge capital and human capital. We also included control variables to capture the effects of technology transfer and spillover and the openness of a country.

According to the estimation results, the initial impact of the growth in the ratio of total R&D expenditure to GDP on labor productivity is negative and insignificant. This stands out as an evidence for the mismatch between the R&D efforts and labor performance. However, this situation ceases to exist after a period and the labor adjusts to new R&D spending and its productivity starts to rise. This explains why the long-run elasticity of R&D expenditure growth is found to be positive. In this respect the policies that favor R&D (tax cuts, subsidies etc.) could help to increase the productivity. The other variables that are found to be significant are the ones coming from the derivation of labor productivity growth equation, capital labor ratio and labor and they are found positive and negative, respectively, as expected.

We have also estimated a model that excludes growth in capital labor ratio and labor. In addition to the R&D expenditure variables, the international trade variable that represents the openness of a country is found to be positively

significant, that is, openness forces the firms to be more productive in order to compete in the international arena. Our international trade variable shows the volume of trade as a percentage of GDP. This may work in two directions for labor productivity: The increase in exports forces labor to increase productivity with the existing capital stock and this explains why the trade variable becomes insignificant when capital labor ratio is added to equation. Moreover, the increase in imports of capital goods may create positive impacts on labor productivity. Foreign direct investment was found insignificant in both models. This is the most unexpected result for us. We consider this variable as also a proxy of technology transfer. However, most of the countries in our data set are generally transfer technology instead of receiving it. Thus, this creates insignificant results for labor productivity. Finally, these results could be interpreted in this way: If the countries want to promote labor productivity, investing in technology rather than in foreign direct investment seems to a better policy.

NOTES

[1] Among others the recent significant examples are Fase and Tieman (2001) and Arvanitis (2006).

[2] The countries included in our study are Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Japan, Korea Republic, Mexico, Netherlands, Poland, Portugal, Spain, Turkey, United Kingdom, and United States of America.

[3] See Hurlin and Venet (2001) for a detailed discussion.

[4] The estimation results can be provided upon request.

[5] For panel data models and estimation techniques, see Hsiao (1986), Mátyás and Sevestre (1996), and Baltagi (2001).

[6] The time variation in R&D expenditure variables are low. Therefore, the fixed effect captures the effect of those variables.

REFERENCES

Aitken, B., A. Harrison (1999) "Do Domestic Firms Benefit from Foreign Direct Investment? Evidence from Venezuela", **The American Economic Review**, 89, 605-618.

Arvanitis, S. (2006) "Innovation and Labour Productivity in the Swiss Manufacturing Sector: An Analysis Based on Firm Panel Data", **Swiss Federal Institute of Technology Working Paper 149**.

Atella, V., B. Quintieri (2001) "Do R&D Expenditures Really Matter for TFP?", **Applied Economics**, 33, 1385-1389.

Balcombe, K., A. Bailey, I. Fraser (2005) "Measuring the Impact of R&D on Productivity from a Econometric Time Series Perspective", **Journal of Productivity Analysis**, 24, 49-72.

Baltagi, B.H. (2001) **Econometric Analysis of Panel Data**, John Wiley & Sons Ltd, New York.

Bönte, W. (2003) "Does Federally Financed Business R&D Matter for US Productivity Growth", **Applied Economics**, 35, 1619-1625.

Branch, B.S. (1974) "Research and Development Activity and Profitability: A Distributed Lag Analysis", **Journal of Political Economy**, 82, 999-1011.

Esposti, R., P. Pierani (2003) "Building the Knowledge Stock: Lags, Depreciation, and Uncertainty in R&D Investment and Link with Productivity Growth", **Journal of Productivity Analysis**, 19, 33-58.

Fase, M.M.G., A.F. Tieman (2001) "Wage Moderation, Innovation, and Labour Productivity: Myths and Facts Revisited", **De Economist**, 149, 115-27.

Frantzen, D. (2003) "The Causality between R&D and Productivity in Manufacturing: An International Disaggregate Panel Data Study", **International Review of Applied Economics**, 17, 125-46.

Geroski, P.A., S. Machin, J. van Reenen (1993) "The Profitability of Innovating Firms", **Rand Journal of Economics**, 24, 198-211.

Griffith, R., S. Redding, J. van Reenen (2004) "Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries", **Review of Economics and Statistics**, 86, 883-895.

Griliches, Z. (1979) "Issues in Assessing the Contribution of Research and Development to Productivity Growth", **Bell Journal of Economics**, 10, 92-116.

Griliches, Z. (1980) "R&D and Productivity Slowdown", **American Economic Review**, 70, 343-348.

Guellec, D., B. Potterie (2001) "R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries", **OECD Economic Studies**, 33, 103-26.

Hurlin, C. (2004) **Testing Granger Causality in Heterogeneous Panel Data Models with Fixed Coefficients**, Miméo, University Orléans.
http://www.univ-orleans.fr/leo/pdf/s24_02_04hurlin.pdf

Hurlin, C., B. Venet, (2001) **Granger Causality Tests in Panel Data Models with Fixed Coefficients**, Miméo, University Paris IX.
http://www.dauphine.fr/eurisco/eur_wp/causalfixed.pdf

Hsiao, C. (1986) **Analysis of Panel Data**, Cambridge: Cambridge University Press.

Kim, T., C. Park (2006) "Productivity Growth in Korea: Efficiency Improvement or Technical Progress", **Applied Economics**, 38, 943-54.

Mansfield, E. (1980) "Basic Research and Productivity Increase in Manufacturing", **American Economic Review**, 70, 863-73.

Mansfield, E., J. Rapoport, J, Schnee, S. Wagner, M. Hamburger (1971) **Research and Innovation in the Modern Corporation**, Norton, New York.

Mátyás, L., P. Sevestre (1996) **The Econometrics of Panel Data: A Handbook of the Theory with Applications**, Boston: Kluwer Academic Publishers.

Ravenscraft, D., F.M. Scherer (1982) "The Lag structure of Returns to Research and Development", **Applied Economics**, 14, 603-20.

Rouvinen, P. (2002) "R&D-Productivity Dynamics: Causality, Lags, and 'Dry Holes", **Journal of Applied Economics**, 5, 123-56.

Serbu, S.G. (2006) "FDI Role in Promoting the Economic Growth - A Problem Still Ambiguous", Available at SSRN: http://ssrn.com/abstract=962346

Smith, V., M. Dilling-Hansen, T. Eriksson, E.S. Madsen (2004) "R&D and Productivity in Danish Firms: Some Empirical Evidence", **Applied Economics**, 36, 1797-1806.

Sterlacchini, A. (1989) "R&D, Innovations and Total Factor Productivity Growth in British Manufacturing", **Applied Economics**, 21, 1549-1562.

Wakelin, K. (2001) "Productivity Growth and R&D Expenditure in UK Manufacturing Firms", **Research Policy**, 30, 1079-90.