R&D and Economic Growth: New Evidence from Some Developing Countries

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Abstract: R&D plays a major role in innovation, raising productivity and increasing economic growth. The purpose of this paper is to estimate the impact of R&D on economic growth of developing countries. To do so we have used a sample of 30 developing countries for which the necessary data were available for the period 2000-2006. We have also used different indicators of R&D. In other words, the share of government expenditures on research in GDP; the number of researchers in each one million population; and the scientific output of the countries were used as 3 different proxies for R&D. Our findings based on panel data regression models indicate that in general no significance positive impact exists in the countries under consideration.

Key words: R&D; Economic Growth; Developing countries; Panel Data.

INTRODUCTION

Recent theories of economic growth draw attention to endogenous technological change to explain the growth patterns of world economies. According to these so-called endogenous growth models, pioneered by Romer (1986), technological innovation is created in the research and development (R&D) sectors using human capital and the existing knowledge stock. It is then used in the production of final goods and leads to permanent increases in the growth rate of output. At the heart of these models is their postulation that endogenously determined innovation enables sustainable economic growth, given that there are constant returns to innovation in terms of human capital employed in the R&D sectors. Therefore research and development (R&D) is a key long-run determinant of productivity and economic growth. R&D constitutes the search for new technology therefore new goods and the central purpose of the economic growth theories is to understand the factors behind long-run growth and to explain differences in growth performances of economies.

In Solow (1956) and Ramsey (1928) models, the long-run growth rate of the aggregate capital accumulation completely depends on the exogenous technological progress and population growth rate. To study endogenous economic growth, many models (for example, Romer, 1996, P96; Aghion and Howitt, 1992; Grossman and Helpman, 1991; Jones, 1995) see technological progress as a production process like production of output.

A number of authors have suggested that new ideas are the engine of growth. It is not our purpose here to systematically review the literature. Instead we will briefly mention some milestones in the development of endogenous growth models with R&D. A pioneer in the area of endogenous growth is Paul Romer. Romer (1990) emphasizes the public-good character of knowledge: ideas, designs, and blueprints are in principal non-rival. However, they may be made excludable through protection by patent law and copyright law. Firms engaged in R&D are then able to protect their inventions during a certain time period and may reap the benefits from their investments. The prospect of (temporary) monopoly profits encourages firms to invest in R&D. Suppose that the production function takes the form

\[ Y = A \sum_{j=1}^{N} K_j^{\alpha j} L^{1-\alpha} \quad (1) \]

Where \( K_j \) is input of the \( j \)th type of the specialized intermediate good and \( N \) is the number of varieties of
the capital goods (cf. Romer (1990), Barro and Sala-I-Martin (1995)). Technological progress yields an expansion in $N$. In equilibrium, the production function can be rewritten to

$$Y = ANK^{\alpha} L^{1-\alpha}$$

(2)

Thus, technological change in the form of a steady increase in $N$ is not subject to diminishing returns, and this property of the production function is essential to generate endogenous growth. The next step in the analysis is to study the expansion in the variety of products. New growth models assume that this expansion requires deliberate effort in the form of research and development. For instance, Barro and Sala-I-Martin assume that the cost to create a new type of product is fixed at $\eta$ units of $Y$. However, most models assume some randomness in the discovery of new products (generating fluctuations at the aggregate level).

Two other economists who made important contributions on the link between R&D and economic growth are Philippe Aghion and Peter Howitt. Aghion and Howitt (1992) develop an endogenous growth model with creative destruction (based on the ideas of Schumpeter). R&D efforts can lead to innovations, i.e. improvements in the general purpose technology. Protection by patent law gives a firm the monopoly right to market a new product. The prospect of monopoly profits encourages firms to develop new and better products, so that the innovating firm can enter the market and the incumbent monopolist is replaced (Schumpeterian creative destruction). Economic growth is determined by the speed of the innovation process. The market solution may not correspond to the socially optimal solution. In the model by Aghion and Howitt, economic growth can be too high or too low. On the one hand, intertemporal knowledge spillovers can reduce R&D investments below the optimal level. By assumption, entrepreneurs only look at the returns to R&D during the life span of their company. The firm is replaced when another entrepreneur develops a better product, but this innovation builds forth on knowledge embodied in the previous product generation. Innovators thus stand on the shoulders of giants. The positive externality of intertemporal knowledge spillover leads to private returns falling short of social returns to R&D, depressing R&D activity below its socially optimal level. On the other hand, by assumption entrepreneurs do not consider the consequences of innovation for the profits of incumbent firms. Innovation yields improved products, and the existing product is driven out of the market (business stealing). The lost profits are not reflected in the private return, but they do reduce the social return to R&D. The negative externality of creative destruction thereby leads to private returns exceeding the social return, possibly triggering excessive R&D activity.

One way to model the idea that R&D matters for growth is to introduce a relationship between TFP (total factor productivity) and the R&D stock (cf. Griffith et al., 2000, 2004), i.e.

$$A = \mathcal{A}(T)$$

(3)

Where $A>0$. The production function then looks like

$$Y = A(T)K^{\alpha} L^{1-\alpha}$$

(4)

This equation says that countries with a larger R&D stock have a higher level of total factor productivity; or, taking first differences, countries with higher R&D investments experience faster TFP growth. The relationship between R&D and TFP as expressed in equation (3) can reflect two effects: innovation and adoption. R&D is an essential factor in the innovation process, and R&D helps firms to build absorption capacity, i.e. the ability to exploit knowledge spillovers (cf. Cohen and Levinthal, 1989). This concept of absorption capacity captures the idea that one has to do basic research oneself in order to understand results of other researchers.

2. Empirical Relationship Between R&D and Economic Growth:

A) Returns to R&D:

There is by now a substantial literature on the impact of R&D on output. Cameron (1998) presents an overview of the empirical literature on the returns to R&D. The impact is often estimated to be quite high. A typical estimate of the social rate of return to R&D would be in the order of 20 to 30 percent when estimated at the industry level, and can be much higher economy-wide (Jones and Williams (1998) even mention an economy-wide social rate of return of around 100%). Estimated private returns to R&D are in the order of 7-14%. Discrepancies between marginal private and marginal social returns to R&D imply that the incentives for firms to invest in R&D are sub-optimal. Jones and Williams (1998) conclude that there is
substantial underinvestment in R&D: “optimal R&D spending as a share of GDP is more than two to four
times larger than actual spending” (p. 1121).

However, empirical estimates of the returns to R&D are not undisputed. First, the estimates are subject
to measurement errors. For example, econometric specifications do not allow making a distinction between
intended and unintended spillovers, while only unintended spillovers are a market failure. In other words,
knowledge flows which carry a market price and knowledge flows which are not priced cannot be distinguished
in the statistics (cf. Cornet and Van de Ven, 2004). Second, estimates on the returns to R&D might be
unreliable due to specification problems. For instance, Comin (2004) warns that there are many factors omitted
in the typical regression that simultaneously affect TFP growth and the innovators’ incentives to invest in
R&D, and mentions as the most obvious candidates anything that enhances disembodied productivity, like
managerial and organizational practices. When these factors are ignored, the estimated returns to R&D are
biased upwards. Comin pioneers an alternative approach in an attempt to overcome the difficulties that beset
the econometric framework. He starts from the free-entry condition for innovators and the fact that most R&D
innovations are embodied. Upon calibrating his model to US data he finds that the annual contribution of R&D
to productivity growth is smaller than three to five tenths of one percentage point. His analysis implies that,
if the innovation technology takes the form assumed in the literature, the actual US R&D intensity may be
close to the socially optimal one.

b) R&D and Economic Growth:

Overviews of the literature on R&D and economic growth can be found in Cameron (1998) and Jones and
Williams (1998). Here we confine ourselves to a study of Griffith et al. (2000, 2004) in which particular
attention is paid to the ‘two faces’ of R&D (cf. Cohen and Levinthal, 1989). Griffith et al. investigate TFP
convergence in a panel of industries across 13 OECD countries over the 1970-1990 periods. For each industry,
the distance to the technological frontier is used as an indicator for potential technology transfer, where the
technological frontier is defined by the country with the highest TFP in the corresponding industry. Adoption
of technology is then reflected in international convergence of TFP-levels, also called catch-up growth. The
direct effect of R&D shifts the technological frontier. The researchers find that both R&D and human capital
are important for movements towards and shifts of the technological frontier. The authors present estimates
of the total social return to R&D, and the return due to adoption / imitation. Being the technological leader
in most industries, the returns to R&D in the USA are almost fully determined by the direct innovation-effect.
The return to R&D from technology adoption is only 0.5%. Also for the Netherlands it is found that the
innovation-effect is more important than the adoption-effect. Technology adoption is a major determinant of
the social return to R&D for the Scandinavian countries, Italy, Japan, and the UK.

But in this paper we investigate the impact of R&D expenditure on economic growth in some developing
countries. The literature suggests that roughly half of cross-country differences in per capita income and
growth are driven by differences in Total Factor Productivity, generally associated with technological progress.

To date, the literature relative to developing countries is extremely thin. Lichtenberg (1994) works with
a cross section of 53 countries and argues that the return to private R&D is seven times larger than to fixed
investment. Coe, Helpman and Hoffmaister (1997) and a sub-sequent literature (Keller 2001) estimate the
impact of foreign R&D on manufacturing TFP growth in developing countries. These authors argue that
because developing countries own R&D expenditures are so low, they can be ignored. The data employed here
suggest that developing-country R&D is not necessarily insignificant relative to the size of their economies,
and more importantly, the returns are substantial. In fact, the returns to R&D in developing countries are above
those for industrialized countries.

3. Model, Data, and Estimation Methodology:

We study the case of 30 countries from developing countries and use annual data for the 2000 - 2006
periods. This time period and frequency is largely dictated by the availability of data on R&D. Data on R&D
expenditure, GDP, Investment (Gross fixed capital formation) and labor force in constant (2000 US $) prices
are from WDI, and UNESCO.

The basic model to be estimated on panel data for 30 developing countries is a simple Cobb-Douglas
production function and the sample period is 2000-2006.

$$\text{GDP}_{it} = \exp(\alpha_i) \cdot \text{GDP}^{A}_{i,t-1} \cdot \text{L}^{B}_{it} \cdot \text{K}^{B}_{it} \cdot \text{RD}^{A}_{it} \cdot \text{U}^{B}_{it}$$

(5)

The variables (for country i and time t):
GDP is gross domestic production
L is labor force
K is gross fixed capital formation
RD is R&D expenditure
The model can be rewritten as follows:

\[ \ln(GDP_{it}) = \alpha + \beta_1 \ln(GDP_{t-1}) + \beta_2 \ln(L_{it}) + \beta_3 \ln(K_{it}) + \beta_4 \ln(RD_{it}) + \varepsilon_{it} \]  

(6)

We run the regression using panel data techniques. Benefits of panel data are:

- They are more informative (more variability, less collinearity, more degrees of freedom), estimates are more efficient.
- They allow to study individual dynamics (e.g., separating age and cohort effects).
- They give information on the time-ordering of events.
- They allow to control for individual unobserved heterogeneity.

Panel data regression is very efficient for extend estimation methods and theoretical results, as therefore researchers able to use of cross section and time series data for study issues that they can't investigate with cross section or time series data separately. The benefit of panel data is that traditional econometrics methods don't take account heterogeneous between units or groups therefore the results will face to bias risk.

As a general regression model of panel data is as follow:

\[ Y_{it} = \alpha_t + \beta_1 X_{1it} + \beta_2 X_{2it} + \ldots + \varepsilon_{it} \]  

\[ U_{it} = \mu_t + \nu_{it} \]  

(7)

Where \( E(U_{it}) = 0 \) and have constant variance. \( \mu_t \) include fixed effects that show difference between individual, households or countries especial characteristic.

\[ V_{it} \]  

is residual term that:

\[ V_{it} \sim \text{IND}(0, \sigma^2_t) \]  

(8)

First we test heterogeneous between units by F-statistic. If null hypothesis isn't accepted, we use panel data. Null hypothesis is:

\[ H_0: \mu_1 = \mu_2 = \ldots = \mu_N = 0 \]  

\[ H_1 \neq H_0 \]

\[ F = \frac{(RRSS - URSS)}{(N-1)} \]  

\[ \frac{URSS}{(MT - N - K)} \sim F_{(N-1), (NT - N - K)} \]  

(9)

RRSS: Restrict Residual sum Squares
URSS: Unrestricted Residual sum Squares
N=numbers of units
K=numbers of parameters

Then for choice between Fixed Effect (F.E) and Random Effect (R.E) models we used Hausman Test:

\[ H = (b_s - \beta_s)'(\hat{M}_1 - \hat{M}_0)^{-1}(b_s - \beta_s) \sim \chi^2(r) \]  

(10)

Where \( r = \) numbers of parameters, \( \hat{M}_1 = \) covariance matrix for coefficients of F.E model \( (b_s) \),
\[ M_0 = \text{covariance matrix for coefficients of R.E model} \left( \beta \right) \]

In Hausman test null hypothesis show Fixed Effect. In according above tests we run the regression whit Random effect model (GLS method). Table 1 presents the GLS regression results

### Table 1:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
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<tbody>
<tr>
<td>C</td>
<td>0.231272</td>
<td>0.064162</td>
<td>3.604515</td>
<td>0.0004</td>
</tr>
<tr>
<td>Ln (GDP(_t))</td>
<td>0.921455</td>
<td>0.012991</td>
<td>71.42556</td>
<td>0.0000</td>
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<tr>
<td>Ln (L)</td>
<td>0.068373</td>
<td>0.004798</td>
<td>1.425025</td>
<td>0.1559</td>
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<tr>
<td>Ln (K)</td>
<td>0.076145</td>
<td>0.011491</td>
<td>6.626518</td>
<td>0.0000</td>
</tr>
<tr>
<td>Ln (RD)</td>
<td>-0.005009</td>
<td>0.007676</td>
<td>-0.652560</td>
<td>0.5149</td>
</tr>
</tbody>
</table>

**GLS Transformed Regression**

R-squared: 0.999742

Adjusted R-squared: 0.999736

S.E. of regression: 0.029929

Sum squared resid: 0.156760

Durbin-Watson stat: 1.687968

### Table 2: Coefficient Covariance Matrix

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Ln (GDP(_t))</th>
<th>Ln (L)</th>
<th>Ln (K)</th>
<th>Ln (RD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.004117</td>
<td>-0.00049</td>
<td>8.01E-05</td>
<td>-1.07E-06</td>
<td>0.00028</td>
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<tr>
<td>Ln (GDP(_t))</td>
<td>-0.00049</td>
<td>0.000166</td>
<td>-1.62E-05</td>
<td>-9.59E-05</td>
<td>-4.65E-05</td>
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<tr>
<td>Ln (L)</td>
<td>8.01E-05</td>
<td>-1.62E-05</td>
<td>2.30E-05</td>
<td>-4.98E-06</td>
<td>2.98E-06</td>
</tr>
<tr>
<td>Ln (K)</td>
<td>-1.07E-06</td>
<td>-9.59E-05</td>
<td>-4.98E-06</td>
<td>0.000132</td>
<td>-2.57E-05</td>
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<tr>
<td>Ln (RD)</td>
<td>0.00028</td>
<td>-4.65E-05</td>
<td>2.80E-06</td>
<td>-2.57E-05</td>
<td>5.89E-05</td>
</tr>
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</table>

### Table 3: Summary Statistics

<table>
<thead>
<tr>
<th></th>
<th>Ln (RD)</th>
<th>Ln (K)</th>
<th>Ln (L)</th>
<th>Ln (GDP(_t))</th>
<th>Ln (GDP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.447</td>
<td>22.666</td>
<td>15.5388</td>
<td>24.09437</td>
<td>24.14787</td>
<td>Mean</td>
</tr>
<tr>
<td>23.298</td>
<td>22.3888</td>
<td>15.2428</td>
<td>23.71977</td>
<td>23.7404</td>
<td>Median</td>
</tr>
<tr>
<td>2.24249</td>
<td>1.83909</td>
<td>1.63921</td>
<td>1.84953</td>
<td>1.841229</td>
<td>Std. Dev.</td>
</tr>
</tbody>
</table>

### Appendix. List of Countries

<table>
<thead>
<tr>
<th>Country Code</th>
<th>Country Name</th>
<th>Country Code</th>
<th>Country Name</th>
</tr>
</thead>
<tbody>
<tr>
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<td>16 LVA</td>
<td>Latvia</td>
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<td>2 ARM</td>
<td>Armenia</td>
<td>17 LTU</td>
<td>Lithuania</td>
</tr>
<tr>
<td>3 AZE</td>
<td>Azerbaijan</td>
<td>18 MUS</td>
<td>Mauritius</td>
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<td>4 BLR</td>
<td>Belarus</td>
<td>19 MEX</td>
<td>Mexico</td>
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<td>5 BRA</td>
<td>Brazil</td>
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<td>Mongolia</td>
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<td>6 BGR</td>
<td>Bulgaria</td>
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<td>Poland</td>
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<td>Croatia</td>
<td>24 RUS</td>
<td>Russian Federation</td>
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<td>Czech Republic</td>
<td>25 SVK</td>
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<td>Sudan</td>
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<td>Georgia</td>
<td>27 TTO</td>
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<td>Hungary</td>
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<td>14 IRN</td>
<td>Iran, Islamic Rep.</td>
<td>29 TUR</td>
<td>Turkey</td>
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<td>15 KGZ</td>
<td>Kyrgyz Republic</td>
<td>30 VEN</td>
<td>Venezuela, RB</td>
</tr>
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</table>

4. Findings and Concluding Remark:

Based on regression results in table 1 the estimated parameters -except coefficient of R&D- in equation
(6) are significant. The elasticities of labor and gross fixed capital formation are positive and significant. But the R&D elasticity is negative and insignificant. The other words 1% increase in labor and investment increases economic growth about 0.007 and 0.08. But in general no significance positive impact exists in the countries under consideration.

In the context of developing economies such as Turkey, our findings suggest that in order to reach high economic growth, they should increase their R&D activities. Developed countries experience has shown that leader countries in innovation and R&D activities have higher economic growth than the others. This paper's findings show that because of low R&D expenditure in developing countries the effect of this variable on economic growth was not significant. Thus governments in these countries should support R&D sector in institutions and industries.

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