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ENDOGENOUS REGIONAL DEVELOPMENT IN ROMANIA. A KNOWLEDGE PRODUCTION FUNCTION MODEL

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Abstract:
Results from research - development and innovation sector, embodied in capital, are an undisputed factor of economic growth, included in most macroeconomic models. Drawing on the New Growth Theory that states the importance of R&D in all economic and social domains, as well as its key role in endogenous development, this paper is aiming to assess the nature and the impact of technological progress on the development of Romanian regions in recent years. We try to capture R&D's influence on regional economic growth by means of a knowledge production function model that employs county level data for the period 2001 to 2011. Our main finding is the positive and significant, although relatively small, contribution of technical progress (as captured by R&D expenditures) to regional GDP growth in Romania. This calls for improved regional research and development strategy, able to stimulate balanced territorial distribution of R&D and innovation activities, as well as a closer link with the business sector, in order to take advantage of the economic growth potential of regional R&D activity.

Key words: endogenous growth, R&D, Cobb-Douglas production function, region, Romania

1. Introduction

Research and development (R&D) activities are nowadays largely acknowledged as a main driver of economic growth and are routinely included in the macroeconomic models. Modern research in macroeconomic growth started from the neo-classical models, which considered that long-run growth was based on external sources and consequently viewed population, capital accumulation and technological change as exogenous factors of economic growth (e.g. Swan, 1956; Solow, 1957; Barro, 1997). In opposition to the neoclassical models, the New Growth Theory introduced the concept of endogenous growth and brought theoretical and empirical evidence in favour of human capital and innovation as factors of growth originating inside the economic system.

The delimitation between exogenous and endogenous factors of growth is relevant at regional and local levels as well. Endogenous growth originates inside the regional economy, being created by domestic private or public enterprise, while exogenous growth has external sources, outside the region. One of the main endogenous resources for regional economic growth is technical progress emerging from R&D activities. Recent

European empirical research, such as Drivera (2008) and Buesa (2010) confirmed that regional innovation is crucial for economic growth. In Romania, studies relying on Cobb-Douglas production functions, such as Zaman and Goschin (2007a), Sandu and Modoran (2008) and Zaman and Goschin (2010), revealed the positive impact of R&D expenditures on economic growth at national level, while Silaghi and Medeşfălean (2014) found an unexpected negative coefficient on patents (as proxy for innovation), possibly due to inefficiency in patenting activity. At regional level, Goschin (2014), using a panel data model, reported significant positive impact of R&D expenditures on the regional economic growth process in Romania over 1995-2010. In the same register, Nae (2013), employing Enterprise Survey data, revealed significant influence of endogenous factors like innovation on regional economic growth in Romania, while R&D is found to have only indirect impact, through its effects on patenting activity.

Drawing on the New Growth Theory that suggests the need to increase the role of R&D in all economic and social domains, as the direct source of technological progress and an important resource of economic growth, we aim to assess the nature and the impact of technological change in the development of Romanian regions. The issue is of interest for both central and local public authorities, as they should design economic policies in support of endogenous regional development. Therefore, we intend to test the theory of endogenous economic growth fuelled by innovation in Romania, using data at county level (NUTS3). To this aim we are going to employ the knowledge production function model in order to capture potential R&D influence on regional economic growth.

The remainder of this paper proceeds as follows. Next section briefly explains how exogenous and endogenous technical progress might be modelled using Cobb-Douglas production function framework. Section 3 describes the model to be employed for our county level analysis, alongside variables and data. Section 4 discusses the results and section 5 concludes.

2. The knowledge production function model

The production functions were first introduced by Cobb and Douglas (1928), who used them to test economic hypotheses related to marginal productivity and competitiveness. Solow (1957) further defined the aggregate production function including exogenous technical progress captured by the variable time, as follows:

$$Y_t = A_t K_t^{\alpha} L_t^{\beta} \quad , \qquad (1)$$

where Y denotes the output, while A_t is a function of time which allows for neutral technical progress and K and L represent capital and labour, respectively. Differentiating the previous relation with respect to time and dividing it by Y results:

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \alpha \frac{\dot{K}}{K} + \beta \frac{\dot{L}}{L} \qquad (2)$$

where α and β represent the share of capital and labour in the output and $\frac{\dot{A}}{A}$ is the technical progress determined as a residual.

Further developments of Solow's model allowed for more complex analyses of the effects of technical progress by including into the equation factors such as human capital, technological improvements embodied in capital, multiple sectors and so on. As a direct consequence of increasing the number of explanatory variables in the economic growth models, the share of technical progress in economic growth declined from 87.5% in Solow (1957) to about a third in more recent empirical research (Jorgenson, 1990; Denison, 1985; Matthews et al., 1982).

A new hypothesis, stating the endogenous nature of technical change, emerged in the papers of the advocates of the New Growth Theory: Lucas (1988), Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992). In their view, growth is endogenously generated by innovations triggered by investments in research and development activity and others types of knowledge, such as human capital. Consequently, R&D was introduced in the standard Cobb-Douglas production function (e.g. Griliches, 1980; Mansfield, 1980; Scherer, 1982; Griliches and Lichtenberg, 1984) resulting the following knowledge production function model:

$$Y_t = AD_t^{\beta} K_t^{\alpha_1} L_t^{\alpha_2} e^{\lambda t} \tag{3}$$

where Y_t is output, D_t is the stock of knowledge, L_t is the labour input, K_t is capital input, A is a constant and λ is a trend variable which catches other influences. An important result of applying the knowledge production function model is the opportunity to single out the output elasticity depending on knowledge (parameter β), which might be considered, in a broader view, a measure of social efficiency of scientific knowledge.

One difficult problem related to such models is how to separate knowledge from other production factors. Supporters of New Growth Theory explicitly modelled knowledge as an output of R&D activity and the stock of knowledge D_t was measured either as accumulated capital of R&D, as R&D flow (of expenditures, personnel, etc.) or as R&D intensity (e.g. R&D expenditures relative to turnover at microeconomic level, or relative to GDP at macroeconomic level). Based on data availability and accuracy, R&D expenditures are the most common choice.

The New Growth Theory analyses technological change in the context of economic processes (as knowledge creation is part of the current economic activity), indicating that knowledge and technology are the key factors of increasing returns and therefore the main driving forces of economic growth. The stock of knowledge generated by R&D activity is increasing marginal productivity, thus offsetting the diminishing returns of the other inputs.

Exponents of New Growth Theory also entered the human capital as a new factor of production and explained its potential for increasing returns to all factors of production (Romer, 1986; Lucas, 1988). For instance, the endogenous economic growth model of Romer (1990) is focused on four production factors: capital, labour, human capital and technology, all depending on the technological level of production. Technology is represented by a stock of manufacturing industrial models (designs) of goods, which are accumulated in time, as result of research efforts. Aghion and Howitt (1998) explained growth on the long-run in relation to constant technological progress embodied in new goods, markets and processes.

The New Growth Theory is helping to understand the ongoing change from resource–based economy to a knowledge-based economy, which has major implications for economic theory and practice.

3. Model, variables and data

We start from the New Growth Theory approach on technical progress as endogenously generated by research and development activities. Considering the advantages of Cobb-Douglas model, that made it a common choice in empirical economic growth research, we are going to employ it in order to assess the relevance of technical progress as a factor of endogenous regional development in Romania.

In our model GDP is used as the most appropriate measure of the economic development of the Romanian counties (NUTS 3 level), capital K and labour L enter the model as the traditional production factors, and R&D expenditures are added as a proxy for the endogenous growth potential of the counties (Table 1). Foreign direct investments had been used as a proxy for the production factor capital. Even if FDI data do not reflect entirely the production factor capital, they represent currently the best available information at county level.

Total expenditures are used in this model as a measure of total investments (material and intangible) in the R&D sector. The construction of the R&D data series is usually the key issue for this type of analysis. In many studies the R&D stock is calculated as the accumulated value of R&D expenditure after depreciation, procedure which implies the assumption that all research-development expenditure is accumulated with 100 percent certainty and that the R&D stock depreciates at a certain fixed rate. Since long time-series data, essential for building long time series of flow data for research and development, are rarely available, other studies assume that the growth rate of R&D flow is equal to that of R&D stock (which implies that the ratio of expenditure to stock is stable). We chose to use data on R&D expenditures instead of R&D stock, which brings about the advantage that there is no need for strong assumptions on research and development activity, such as a fixed rate of depreciation and the linear and certain accumulation of knowledge.

Table 1. Variables for the knowledge production function model

Variable	**Description**	**Data source**
GDP	Gross domestic product at county level (RON)	National Institute of Statistics (NIS) database
Capital	Foreign direct investments at county level (RON)	Romanian National Trade Register Office
Labour	Civil employment in the county economy (persons)	NIS database
R&D	County's total expenditures for research and development (RON)	NIS database

We are further going to apply the model of aggregate production functions of Cobb-Douglas type, including R&D expenditures, in the form of the standard knowledge production function model:

$$GDP_i = AK_i^{\alpha} L_i^{\beta} R_i^{\delta} \tag{4}$$

where GDP is the output (Y), α and β stand for the elasticity of output with respect to capital K and labor L, respectively (α, β> 0), A is a constant, and R represent the R&D expenditures. R&D is the variable of interest, as it captures the endogenous technological change that might impact regional economic development.

In order to estimate the model, we are going to use logarithms of the variables, as follows:

$$\ln GDP_i = \ln A + \alpha \ln K_i + \beta \ln L_i + \delta \ln R_i + \varepsilon_i \quad (5)$$

We are going to estimate the parameters of the production function, annually, for the period 2001-2011, using county level (NUTS 3) data from the National Institute of Statistics and from the Romanian National Trade Register Office. Time and space datasets have been built for GDP, foreign direct investments, employed population, total research and development expenditures, for the period 2001 to 2011 and the 42 counties of Romania. Lacking county data on capital, we used foreign direct investments as proxy.

4. Results and discussion

Results of annual parameter estimation of knowledge Cobb-Douglas production function (Table 2) clearly indicate that endogenous technical progress has had a positive and statistically significant contribution to regional economic growth in Romania, in every year of the period under consideration.

Table 2. Annual parameter estimates for knowledge Cobb-Douglas production function, 2001 to 2011

Variable	2001		2002		2003	
	Coefficient	Probability	Coefficient	Probability	Coefficient	Probability
Capital	0.070155	0.1144	0.068029	0.3084	0.021117	0.7110
Labour	0.978998	0.0000	1.014530	0.0000	1.019004	0.0000
R&D	0.056351	0.0252	0.048223	0.0695	0.083588	0.0026
Constant	1.249613	0.0167	1.439624	0.0010	1.823966	0.0000

Variable	2004		2005		2006	
	Coefficient	Probability	Coefficient	Probability	Coefficient	Probability
Capital	0.071142	0.1825	0.067390	0.2195	0.047798	0.3724
Labour	0.932758	0.0000	1.004414	0.0000	1.028033	0.0000
R&D	0.055551	0.0482	0.064180	0.0193	0.063213	0.0078
Constant	2.242087	0.0000	2.041086	0.0000	2.314369	0.0000

Variable	2007		2008		2009	
	Coefficient	Probability	Coefficient	Probability	Coefficient	Probability
Capital	0.027819	0.6371	0.089645	0.0099	0.125711	0.0000
Labour	1.093265	0.0000	0.984025	0.0000	0.945053	0.0000
R&D	0.055576	0.0164	0.038414	0.0058	0.030038	0.0336
Constant	2.402909	0.0000	2.575139	0.0000	2.412848	0.0000

Variable	2010		2011	
	Coefficient	Probability	Coefficient	Probability
Capital	0.119264	0.0194	0.105073	0.0291
Labour	0.927935	0.0000	0.935280	0.0000
R&D	0.025739	0.0683	0.035665	0.0362
Constant	2.658761	0.0000	2.748403	0.0000

The results in Table 2 show that labour had the expected positive influence on the county output and was statistically significant for all years, but the capital (proxied by FDIs) had been insignificant between 2001 and 2007 and became statistically significant since 2008. It is likely that FDI (that we only used in absence of other statistical data on capital at the county level) may not be a suitable option for capturing the production factor capital.

Our results on low but positive impact of R&D on the economic growth in Romania are in accordance with similar findings in Zaman and Goschin (2007b), Silaghi and Medeşfălean (2014), and Goschin (2014).

Of special economic interest is the analysis of the parameters of the production function, as well as the economic policy conclusions arising therefrom. Thus, the estimated parameters allow measuring the contribution of each input (K, L and R) in creating the output Y with the following relations:

- capital's contribution to growth: $\frac{\alpha}{\alpha+\beta+\delta}$,
- labour's contribution: $\frac{\beta}{\alpha+\beta+\delta}$,
- R&D's contribution: $\frac{\delta}{\alpha+\beta+\delta}$.

Based on the previous formulae, we used the estimated parameters to calculate the average contribution of each production factor to regional GDP, over the period 2001 to 2011, obtaining the following results:

- the production factor labour contributed on average by 90% to GDP creation;
- R&D expenditures explain on average 4.5% of regional GDP;
- the capital (using FDIs as proxy) had a contribution of only 5.5%, which suggests that FDIs have relatively small effects on regional economic growth in Romania.

The standard statistical tests carried out have validated the model, which has a high explanatory power (approx. 90%). The high heterogeneity of territorial distribution of the variables used in the model, especially in the case of FDIs, raised estimation problems. To fix the problem, we used White Heteroskedasticity-Consistent Standard Errors & covariance while estimating the annual models (Annexes).

In conclusion, the main result from the annual estimations of the knowledge production function model is the positive and significant, but relatively small, contribution of technical progress (as captured by R&D expenditures) to regional GDP growth in Romania. This should be a concern and alert decision makers at national and local level on economic and social policy mix needed to increase the contribution of technological progress, especially considering the current international trend towards knowledge society. R&D driven technological progress - the main factor of modern economic growth - as demonstrated by the experience of developed countries - should act more strongly in the future regional development of the Romanian economy.

5. Conclusion

Economic theory states the possibility to increase the competitiveness of regional economies and to fuel economic growth by capitalizing on local technological potential which might impact upon businesses.

As the origin of innovations and technological change, research and development is a main source of endogenous growth. We tested this hypothesis for Romanian counties and found positive and significant, although relatively small, contribution of R&D expenditures to regional GDP growth. This calls for improved regional research and development strategy, able to stimulate balanced territorial distribution of R&D and innovation activities, as well as a closer link with the business sector, in order to take advantage of the economic growth potential of regional R&D.

Post-crisis regional programs for development should target diversification of local economies by boosting private investment in R&D, adequate specialization and performance of local research, development and innovation systems, stimulation of innovative activities and technology transfer from universities and research centers to production sector, according to the business needs of local communities, assistance for the development of innovative SMEs, financial support for companies so that they can acquire advanced technologies and improve their production activity.

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Annexes

Estimations from Cobb-Douglas production function including R&D, annually, 2001-2011

2001

Dependent Variable: LOG(GDP_1)
Included observations: 42
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(ISD_1)	0.070155	0.043418	1.615806	0.1144
LOG(PO_1)	0.978998	0.105023	9.321703	0.0000
LOG(RD_1)	0.056351	0.024188	2.329733	0.0252
C	1.249613	0.499265	2.502905	0.0167

R-squared	0.896303	Mean dependent var	7.700897
Adjusted R-squared	0.888116	S.D. dependent var	0.585227
S.E. of regression	0.195753	Akaike info criterion	-0.333537
Sum squared resid	1.456127	Schwarz criterion	-0.168044
Log likelihood	11.00427	F-statistic	109.4840
Durbin-Watson stat	1.823299	Prob(F-statistic)	0.000000

2002

Dependent Variable: LOG(GDP_2)
Included observations: 42
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(ISD_2)	0.068029	0.065889	1.032480	0.3084
LOG(PO_2)	1.014530	0.123799	8.194967	0.0000
LOG(RD_2)	0.048223	0.025819	1.867722	0.0695
C	1.439624	0.404581	3.558305	0.0010

R-squared	0.904738	Mean dependent var	7.939739
Adjusted R-squared	0.897217	S.D. dependent var	0.608348
S.E. of regression	0.195035	Akaike info criterion	-0.340880
Sum squared resid	1.445472	Schwarz criterion	-0.175388
Log likelihood	11.15849	F-statistic	120.2995
Durbin-Watson stat	1.736207	Prob(F-statistic)	0.000000

2003

Dependent Variable: LOG(GDP_3)
Included observations: 42
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(ISD_3)	0.021117	0.056574	0.373261	0.7110
LOG(PO_3)	1.019004	0.121554	8.383132	0.0000
LOG(RD_3)	0.083588	0.025963	3.219476	0.0026
C	1.823966	0.369009	4.942876	0.0000

R-squared	0.920624	Mean dependent var	8.208860
Adjusted R-squared	0.914357	S.D. dependent var	0.598785
S.E. of regression	0.175233	Akaike info criterion	-0.555006
Sum squared resid	1.166853	Schwarz criterion	-0.389513
Log likelihood	15.65512	F-statistic	146.9106
Durbin-Watson stat	2.034236	Prob(F-statistic)	0.000000

2004

Dependent Variable: LOG(GDP_4)
Included observations: 42
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(ISD_4)	0.071142	0.052391	1.357897	0.1825
LOG(PO_4)	0.932758	0.088584	10.52968	0.0000
LOG(RD_4)	0.055551	0.027212	2.041412	0.0482
C	2.242087	0.327385	6.848469	0.0000

R-squared	0.934848	Mean dependent var	8.439265
Adjusted R-squared	0.929704	S.D. dependent var	0.591650
S.E. of regression	0.156867	Akaike info criterion	-0.776450
Sum squared resid	0.935070	Schwarz criterion	-0.610958
Log likelihood	20.30545	F-statistic	181.7495
Durbin-Watson stat	1.944210	Prob(F-statistic)	0.000000

2005

Dependent Variable: LOG(GDP_5)
Included observations: 42
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(ISD_5)	0.067390	0.053983	1.248365	0.2195
LOG(PO_5)	1.004414	0.095893	10.47434	0.0000
LOG(RD_5)	0.064180	0.026275	2.442665	0.0193
C	2.041086	0.339542	6.011286	0.0000

R-squared	0.927854	Mean dependent var	8.548619
Adjusted R-squared	0.922158	S.D. dependent var	0.640156
S.E. of regression	0.178604	Akaike info criterion	-0.516895
Sum squared resid	1.212182	Schwarz criterion	-0.351402
Log likelihood	14.85479	F-statistic	162.9033
Durbin-Watson stat	1.836456	Prob(F-statistic)	0.000000

2006

Dependent Variable: LOG(GDP_6)
Included observations: 42
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(ISD_6)	0.047798	0.052955	0.902621	0.3724
LOG(PO_6)	1.028033	0.103005	9.980379	0.0000
LOG(RD_6)	0.063213	0.022483	2.811533	0.0078
C	2.314369	0.317979	7.278366	0.0000

R-squared	0.934495	Mean dependent var	8.733498
Adjusted R-squared	0.929323	S.D. dependent var	0.636223
S.E. of regression	0.169141	Akaike info criterion	-0.625780
Sum squared resid	1.087125	Schwarz criterion	-0.460287
Log likelihood	17.14137	F-statistic	180.7017
Durbin-Watson stat	1.954964	Prob(F-statistic)	0.000000

2007

Dependent Variable: LOG(GDP_7)
Included observations: 42
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(ISD_7)	0.027819	0.058503	0.475520	0.6371
LOG(PO_7)	1.093265	0.109485	9.985532	0.0000
LOG(RD_7)	0.055576	0.022138	2.510424	0.0164
C	2.402909	0.346065	6.943527	0.0000

R-squared	0.936400	Mean dependent var	8.909312
Adjusted R-squared	0.931379	S.D. dependent var	0.650643
S.E. of regression	0.170440	Akaike info criterion	-0.610470
Sum squared resid	1.103897	Schwarz criterion	-0.444978
Log likelihood	16.81987	F-statistic	186.4938
Durbin-Watson stat	1.837007	Prob(F-statistic)	0.000000

2008

Dependent Variable: LOG(GDP_8)
Included observations: 42
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(ISD_8)	0.089645	0.032999	2.716616	0.0099
LOG(PO_8)	0.984025	0.073496	13.38889	0.0000
LOG(RD_8)	0.038414	0.013142	2.923048	0.0058
C	2.575139	0.337103	7.639030	0.0000

R-squared	0.957576	Mean dependent var	9.105453
Adjusted R-squared	0.954227	S.D. dependent var	0.645535
S.E. of regression	0.138110	Akaike info criterion	-1.031136
Sum squared resid	0.724829	Schwarz criterion	-0.865644
Log likelihood	25.65386	F-statistic	285.9064
Durbin-Watson stat	2.059713	Prob(F-statistic)	0.000000

2009

Dependent Variable: LOG(GDP_9)
Included observations: 42
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(ISD_9)	0.125711	0.024451	5.141311	0.0000
LOG(PO_9)	0.945053	0.072679	13.00319	0.0000
LOG(RD_9)	0.030038	0.013624	2.204771	0.0336
C	2.412848	0.314898	7.662311	0.0000

R-squared	0.952710	Mean dependent var	9.090880
Adjusted R-squared	0.948976	S.D. dependent var	0.642325
S.E. of regression	0.145091	Akaike info criterion	-0.932518
Sum squared resid	0.799953	Schwarz criterion	-0.767026
Log likelihood	23.58288	F-statistic	255.1828
Durbin-Watson stat	1.892736	Prob(F-statistic)	0.000000

2010

Dependent Variable: LOG(GDP_10)
Included observations: 42
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(ISD_10)	0.119264	0.048840	2.441908	0.0194
LOG(PO_10)	0.927935	0.091306	10.16288	0.0000
LOG(RD_10)	0.025739	0.013719	1.876198	0.0683
C	2.658761	0.410253	6.480785	0.0000

R-squared	0.924287	Mean dependent var	9.130794
Adjusted R-squared	0.918310	S.D. dependent var	0.640845
S.E. of regression	0.183163	Akaike info criterion	-0.466485
Sum squared resid	1.274853	Schwarz criterion	-0.300993
Log likelihood	13.79619	F-statistic	154.6317
Durbin-Watson stat	1.612135	Prob(F-statistic)	0.000000

2011

Dependent Variable: LOG(GDP_11)
Included observations: 42
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(ISD_11)	0.105073	0.046332	2.267846	0.0291
LOG(PO_11)	0.935280	0.096466	9.695392	0.0000
LOG(RD_11)	0.035665	0.016428	2.170961	0.0362
C	2.748403	0.482757	5.693135	0.0000

R-squared	0.919890	Mean dependent var	9.178704
Adjusted R-squared	0.913565	S.D. dependent var	0.644287
S.E. of regression	0.189419	Akaike info criterion	-0.399319
Sum squared resid	1.363421	Schwarz criterion	-0.233827
Log likelihood	12.38570	F-statistic	145.4490
Durbin-Watson stat	1.543762	Prob(F-statistic)	0.000000