Regional efficiency of knowledge economy in the new EU countries: The Romanian and Bulgarian case

Roman, Monica
Academy of Economic Studies Bucharest

February 2010

Regional efficiency of knowledge economy in the new EU countries: The Romanian and Bulgarian case

Monica Roman

Academy of Economic Studies of Bucharest
Department of Statistics and Econometrics
Calea Dorobantilor 15-17, District 1, Bucharest,
Postal Code 010572, Romania
Email: mroman@ase.ro

Biographical notes

MONICA ROMAN is a professor of Statistics and Econometrics, Ph.D in economics since 2000. Her fields of interest are regional studies, human capital, labour economics and economic demographics. She published in Journal for Applied Quantitative Methods, The South-Eastern Europe Journal of Economics, Journal for Studies of Religions and Ideologies, The Romanian Economic Journal, Revista Romana de Statistica, The Romanian Journal of European Studies, Economic Computation and Economic Cybernetics Studies and Research.

Abstract

The economic success is more and more based on upon the effective utilization of intangible assets such as knowledge, skills and innovative potential as the key resource for competitive advantage. For transition countries, such as Romania and Bulgaria, the efficiency of research and development activities is particularly important, since technological progress is one of the core aspects of economic growth. In this article we describe the common features of the two countries, but also the existing differences in respect with knowledge based economy. There are significant regional differences within the countries and marginal regions must close the gap with more developed regions. The paper analyzes research efficiency at the regional level for NUTS2 regions from Romania and Bulgaria between 2003 and 2005, applying a DEA framework. Our main finding is that Bulgarian regions are more efficient in R&D activities compared to Romanian ones. The only Romanian efficient region is Bucuresti Ilfov, while the other two efficient regions are rather small Bulgarian regions, with fewer resources. They show a remarkably high level of research efficiency, whereas some of the larger regions (both from Romania and Bulgaria) lag behind.

Key words: regions, knowledge economy, transition countries, efficiency, DEA

JEL Classification: R11, O31, P27, R58

Introduction

The economic success is more and more based on upon the effective utilization of intangible assets such as knowledge, skills and innovative potential as the key resource for competitive advantage. The term “knowledge economy” is used to describe this emerging economic structure.

The knowledge society “covers every aspect of the contemporary economy where knowledge is at the heart of value added – from high tech manufacturing and ICTs through knowledge intensive services to the overtly creative industries such as media and architecture” (Kok Report, 2004). OECD (2003) defined the investment in knowledge as the sum of R&D expenditure, expenditure for higher education and investment in software. This investment is the key element in promoting scientific and technological progress and an essential tool in decreasing the existing gap between developed and developing countries. Therefore, any country that uses the resources inefficiently could bear a penalty in the form of achieving a much slower progress. Furthermore, if R&D resources are not used effectively, additional investment may be of little help in stimulating progress and the costs in the long run could be painful.

For transition countries, such as Romania and Bulgaria, the efficiency of R&D investment is particularly important, since these two countries are the latest member of EU and they are less developed compared to the rest of the EU countries.

By this paper we intend to analyze the existing gap in the efficiency of R&D investment, at regional level, for the case of Romania and Bulgaria. The method employed in this respect is Data Envelopment Analysis (DEA), a nonparametric method. The evaluation of regional performance in R&D in Romania and Bulgaria, in terms of technical efficiency (TE) thus constitutes the main goal of this research. By this approach we are in the line with the recent research in this field, since only in latest years there are a few examples in the literature discussing R&D efficiency by using quantitative approaches with regard to R&D (see Wang and Huang, 2007, Sharma and Thomas, 2008). At regional level, there are studies conducted on the efficiency of resources, but according to our knowledge, Romania and/or Bulgaria are less represented. We intend to fill in this gap and to perform a comparative analysis at regional level of the relative efficiency of knowledge economy, applied on the two countries from Eastern Balkans.

The rest of the paper is organized at follows. In the next part we review the existing literature on knowledge economy, with a special attention to recent studies on relative efficiency that employs DEA. The second part is devoted to an analysis of the economic context in Romania and Bulgaria, the context in which the research activity is performed. The third part regards the method applied and the data used in our research. The results are presented in the fourth part and they confirm the disastrous situation of research and development in the two countries. Finally, the most relevant conclusions are drawn.

1. Literature review

In conventional thinking of economists, R&D is seen as generating one product: new information. However, Cohen and Levinthal (1989) suggest additional aspects, where R&D is not only generation of new information, but also enhancement of the firm’s ability to assimilate and exploit existing information.

Regarding the R&D activity and growth, Allen (2001) argues that the increase in R&D and acceleration in growth of the capital/labour ratio coincide with increased wage gaps by schooling within industries, and that increases in R&D are associated with wider gaps by experience. In terms of technological change that varies across different industries, it should not be surprised to see correlation between technological change and wage growth for this group that would persist if the pace of change were accelerating.

Caselli and Coleman II (2001) stress the importance of well-known fact that an increase in technical efficiency plays a critical role in long term growth. This fact has led research to concentrate on R&D process and data. While this data is commonly used for analysing developed countries, it is argued that it may be unsuitable for developing countries. This is due to an assumption that developing countries operate inside the technological frontier, so the efficiency gains may be acquired through technology already available in developed and technologically advanced countries. Thus Caselli and Coleman II use computers diffusion in order to encompass both developed and developing countries. The reason lies in the fact that computers have been introduced recently, and computers are clear case of embodied technology. In order to diffuse computers they have to be physically installed, which makes it easier to measure technology adoption. On the other hand, it is very hard to measure diffusion of disembodied technologies. In this respect there is strong evidence that computer adoption is associated with high levels of human capital. Furthermore, good property-rights protection, high rates of investment per worker, and a small share of agriculture in GDP enhance computer adoption. There is also evidence of a negative role of the size of the government and a positive of share of manufacturing in GDP.

More recent, the empirical literature affirms the importance of the level and dynamics of R&D expenditures for economic growth (e.g. Guellec and van Pottelsberghe de la Potterie, 2004). Therefore, the efficient usage of the scarce resources devoted to R&D becomes increasingly important, especially in a globalized world. Countries are exposed to high levels of competition in domestic and foreign markets for innovative products and future technologies. This process forces nations to continuously update their technological capabilities. Countries utilizing their R&D resources inefficiently will be penalized with a growth discount.

Table 1. Studies on R&D efficiency that employ DEA method

Authors	**Data Sets**	**Inputs and Outputs used in DEA model**	**Key results**
Cullmann, Schmidt-Ehmcke and Zloczysti (2009)	OECD data base, PATSTAT	DEA on 30 OECD countries; Inputs: R&D expenditures and labour invested in R&D Outputs: number of patents	Germany, Sweden and United States - the most efficient countries; Mexico and China – low efficiency. The impact of the regulatory environment is analyzed by using the single bootstrap procedure. High regulation in product markets lowers research efficiency in the economy.
Schmidt-Ehmcke and Zloczysti (2009)	OECD data base	DEA on 17 European countries Inputs: knowledge stocks approximated by R&D expenditures and high- and medium-skilled labour to capture manpower. Output: number of patents	Small economies (Belgium, the Netherlands, Ireland) have high efficiency, while United Kingdom, France, and Spain lag behind.
Sharma and Thomas, (2008)	UNESCO Institute of Statistics data base, SCI Expanded data base of the web of science, WIPO Statistics data Base	DEA approach with constant (CRS) as well as variable returns to scale (VRS). Inputs: R&D expenditures, researchers, gross domestic product, population Output: patents granted, publications counts	Japan, Republic of Korea, China lie on the efficiency frontier with CRS; Japan, Republic of Korea, China, India, Slovenia and Hungary are found to be efficient with VRS
Wang and Huang, (2007)	WIPO Statistics data, MSTI data base, SCI expanded data base	Inputs: R&D net capital stock, researchers, technicians, Output: patents granted, publications counts Environmental Variables: like the enrolment rate of tertiary education, the PC density and the English proficiency	About half of the countries are efficient in their R&D activities, higher education can explain variations in R&D input slacks, increasing returns to scale for two thirds of the countries

DEA approach involves the application of the linear programming technique to trace the efficiency frontier. It was originally developed to measure the performance of various non-profit organizations, such as educational and medical institutions, which were highly resistant to traditional performance measurement techniques due to the complex and often unknown relations of multiple inputs and outputs and non-comparable factors that had to be taken into account. In recent years it has been successfully applied in measuring both for-profit and non-profit organizations, such as the effectiveness of regional development policies in northern Greece by Karkazis and Thanassoulis (1998). Coelli, Rao and Battese (1998) introduce the reader to this literature and describe several applications. DEA was launched by Charnes et al. (1978) under the assumption that production exhibited constant returns to scale. Banker et al. extended it to the case where there are variable returns to scale.

The empirical literature using a knowledge production function framework affirms the importance of level and dynamics of research personnel and R&D expenditures as input factors. However, only recently the empirical literature has put more emphasis on the efficient usage of scarce resources. The relevant studies on the efficiency of R&D that applied DEA and have motivated our approach are summarized in Table 1.

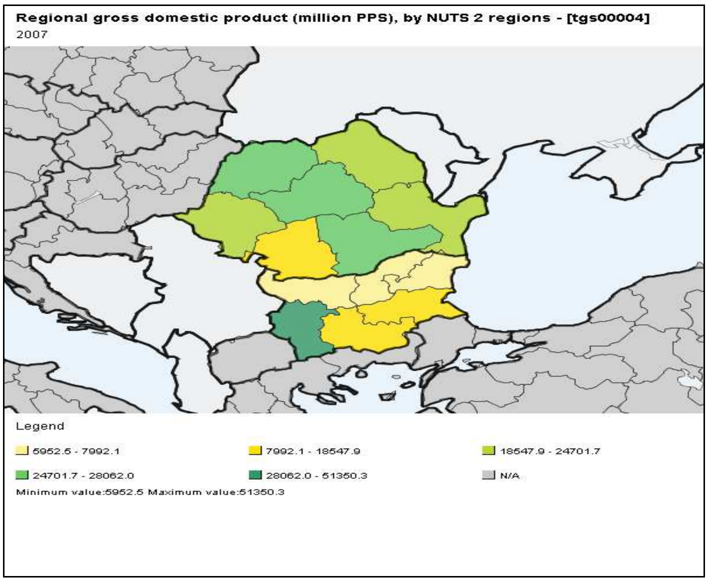
2. Knowledge based economy in Romania and Bulgaria

2.1. The political and macroeconomic context

Bulgaria and Romania both entered the European Union on 1 January 2007, bringing about 30 millions new citizens into the EU fold. This fifth enlargement round means the Union is home to half a billion people and is the world’s largest economy, which has been the case since the 2004 expansion. By their admission, the European Union has been seeking to extend its influence up to the borders of the former USSR and into the Balkans. Romania and Bulgaria also offer a massive pool of cheap labour, which can be exploited by the European corporations and used to further lower the wages in the more prosperous EU countries.

After changing the political regime in 1989, transition in Bulgaria has been marked by a period of initial political instability. It was only in 2001 that a majority managed to stay a full term in Parliament and its government served a full term in office. The positive tendencies of strengthening the institutions, consolidating the party system, separating the powers, decentralising certain aspects of governance have co-existed with the negative ones of political clientelism, crimininalisation of the economy and society, partisan control of the administration and, quite often, of the judiciary (Kolarova, 1999). A huge stumbling block for reforms has been the continuation of former communists in political power in the first years of transition, which has sidelined pertinent issues of democratisation and liberalization.

Figure 1. Romania and Bulgaria. GDP by NUTS2 regions in 2007



Source: based on EUROSTAT Database

Similarly, the process of democratising Romania started from an extreme low point. According to some authors (Mungiu-Pippidi, 1999), under Ceauşescu it was the worst totalitarian regime in Central and Eastern Europe. The loss of social identity, autonomy and entrepreneurship combined with a strong political and economic oligarchy and endemic corruption, have been a continual hindrance on the road to consolidating liberal democratic practices. The political and economic spheres of the country are still plagued by related residual strains as indicated by the European Commission's Roadmap, but firm foundations have already been put in place (Tismaneanu and Kligman, 2001). The political elite of the country needs to make sure that a political stability is maintained, in a contexts of financial and economic crisis and increasing poverty.

While there are differences between Bulgaria and Romania – particularly in terms of economic size, the level of industrialisation and macroeconomic performance – the two new Member States do share several common features. They both faced a significant outflow of labour in the wake of the economic upheavals in the 1990's. After 2000, they are both undergoing rapid economic growth, yet are suffering from relatively low employment levels and serious labour shortages in certain high-skill sectors. The global crisis is strongly affecting both countries and it is proven to be in their case more an economic crisis, than a financial one[1].

During the 1990's Bulgaria faced the loss of its main export markets in the Comecon[2], the disintegration of neighbouring Yugoslavia and a deep financial crisis in 1996/97. Sanctions against Serbia and Iraq also affected the Bulgarian economy. Painful reforms and EU assistance helped Bulgaria find its way out of the crisis and start to improve on pre-1990 living standards. Following the financial crisis of 1996/97, the government introduced a Currency Board to anchor the economy and facilitate the implementation of important structural reforms – moves which boosted investor confidence.

Bulgaria's most evident achievement in recent years has been the stability it has brought to its economy. This stability implied a real economic growth with rates more than double the EU average. Real annual GDP growth stood at 5.5% in 2005 and accelerated to 6% in 2008, compared with 1.7% and 2.8% respectively for the EU-25. Along with investment, consumption- which grew by 6.4%- was the main driver of growth. Despite this progress, Bulgaria still has a long way to go before its economy catches up with the rest of the Union. In 2005, Bulgaria's per capita income was 32.1 % of the EU-2 5 average.

Table 2. Romania and Bulgaria. Main Macroeconomic indictors

Indicators	**Bulgaria**	**Romania**
GDP per capita [PPS]	41.3 [2008]	41.6 [2007]
Real GDP growth rate - % - EUROSTAT estimations	2.7 [2011]	3.5 [2011]
Real GDP growth rate - % -	-5 [2009]	-7.2 [2009]
Employment rate - % -	62.6 [2009]	58.6 [2009]
Unemployment rate - % -	6.8 [2009]	6.9 [2009]
Inflation rate -%-	2.5 [2009]	5.6 [2009]

Source: based on national statistics and EUROSTAT Database

The Romanian economy has a very difficult situation, as a result of four decades of central planning, which brought Romania's economy to the verge of economic collapse in the final years of the Soviet bloc.

The 1990's were a veritable economic roller-coaster ride for Romania, and it was not until 2000 that the economy began to grow on a sustainable basis. After 2000 the significant economic growth

[1] According to EU, the two states need to take rapid and effective measures to prevent severe consequences of crisis http://ec.europa.eu/financial-crisis/pdf/europe2020_factsheet1_bul_en.pdf

[2] the economic counterpart to the Warsaw Pact

was along with the consolidation of the financial system, disinflation and low unemployment rates. In 2004, the economy grew by an impressive 8.4% – which slowed somewhat to 4.1 % the following year – and, in 2006, growth was 7.2%, driven by a broad-based recovery in industrial activity, construction and agriculture. It was also underpinned by a significant rise in private consumption – which grew by nearly 10 % in 2005 – and in investment, which increases by 13 %.

Employment has only recently started to grow, due to the long contraction of several labour-intensive industries, and employment rates remain relatively low. Unemployment amounted to about 7.6% in 2006 and decrease to 6.9% in 2009. Over the next two years, it is expected to remain stable at around the same level, despite robust economic growth.

Romania struggled in transition to turn around its obsolete industrial base. Having now taken large strides in this area, manufacturing is set to become one of its key strengths once it successfully converges with the rest of the EU. The country's considerable potential rests on its broad industrial base, rich agricultural land, diverse energy sources and well-trained workforce. During recent economic and financial crisis, these should be valuable assets to be used in order to diminish the crisis effects and to converge with European Union's economy.

2.2 Indicators of knowledge based economy in Romania and Bulgaria

In the education and training investment, both the Bulgarian and Romania's position are alarming. Public spending on education measured, as a percentage of GDP and the extent of staff training are the lowest in Bulgaria among the 25 European Countries. Bulgaria stands behind Romania in this respect. In addition to this difficult situation, highly-educated Bulgarians and Romanians tend to emigrate abroad. Thus, the quality level of the Bulgarian and Romanian stock of human capital is insufficient and lifelong learning and human development has unsound foundations.

Bulgarian investments in education and training are very low, like those devoted to innovation and therefore these two sectors are facing major difficulties. During the transition, more firms closed their research laboratories. Academia, universities, research institutes and schools experienced serious problems because of strict budget restrictions. The level of public subsidies severely diminished and many high-skilled persons (scientists, engineers, professors and teachers) lost their jobs and hope to achieve their professional ambitions (Bourdeau-Lepage, Kolarova, 2008)

As a consequence, the Bulgarian innovation system is one of the less productive in Europe. Thus, the level of domestic innovation measured by scientific and engineering articles published in physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences, places Bulgaria in 22nd position among European countries, ahead of Romania, Lithuania and Latvia, as expected, Bulgaria does not export R&D intensive products, such as scientific instruments or electrical machinery. Its share of high-technology manufactured exports expressed in percentage of manufactured exports is one of the weakest.

Table 3. Romania and Bulgaria. Selected KBE indictors

Indicators	**Bulgaria**	**Romania**
Science and technology graduates by gender - Tertiary graduates in science and technology per 1 000 of population aged 20-29 years	8.4 [2007]	11.9 [2007]
Gross domestic expenditure on R&D (GERD)	0.49 [2008]	0.58 [2008]
Total researchers, by sectors of performance - Head count - All sectors	13090 [2007]	30740 [2007]
Total researchers, by sectors of performance - Head count - Business enterprise sector	1591 [2007]	7971 [2007]
Total researchers, by sectors of performance - Head count - Government sector	6440 [2007]	6100 [2007]
Total researchers, by sectors of performance - Head count - Higher education sector	4917 [2007]	16510 [2007]
Research and development personnel, by sectors of performance - Head count (% of the labour force) - All sectors	0.48 [2008]	0.31[2008]
Patent applications to the European Patent Office (EPO)	3.97 [2007]	1.87 [2007]
High-tech exports -%-	3.34 [2006]	3.846 [2006]
Individuals regularly using the Internet, - % of individuals aged 16 to 74	40 [2009]	31 [2009]
Enterprises having access to the Internet, -%-(10 employed persons or more)	84 [2009]	73 [2009]

Source: based on national statistics and EUROSTAT Database

Recently, in the context of Bulgaria's accession to the EU, the Bulgarian government has attached high priority to the enhancement of innovation, according to the targets outlined in the Strategy of Lisbon. Thus, in September 2004, the Innovation strategy of the Republic of Bulgaria was adopted. This strategy aims mainly at:

- Supporting R&D and encouraging the cooperation between research, universities and enterprises;
- Improving the funding of innovations; encouraging the introduction of new technologies and increasing the innovation efficiency of enterprises;
- Encouraging the formation of clusters in traditional sectors.

According to EIS 2008 Bulgaria is one of the catching-up countries with an innovation performance well below the EU-27 average but the rate of improvement is one of the highest of all countries and it is a growth leader within the catching-up countries. Relative strengths, compared to the country's average performance, are in human resources, finance and support as well as economic effects.

The entire research and development sector in Romania is undergoing a comprehensive process of restructuring and reorganization on a new basis. Research in Romania is extremely centralized, over 50% of researchers and of the funds directed to this field being still concentrated in the capital, namely the region Bucharest-Ilfov. During the last years, there is a decrease in the number of researchers and an increase of their average age.

The main issue facing the field is the low level of financial backing from public funds. In Romania, research and development expenses totalled 653 million euro in 2007 and its percentage of the GDP was of 0.53%, slightly increased compared to 0.45% in 2006, but still among the lowest levels in the EU. However, according to available data analyzed by EUROSTAT, Romania outruns countries like Cyprus (0.45%), Slovakia (0.46%) and Bulgaria (0.48%). By contrast, champions in R&D expenditure in 2007 were Sweden (3.60% of the GDP), Finland (3.47% of the GDP) and Austria (2.56% of the GDP).

The field is confronted with the outdated R & D infrastructure, failure to adjust to competitive market conditions. Another major problem consists of the still weak link between research and economy and the relatively scarce capability of putting the research results to good use.

With the exception of the Czech Republic, Malta and Romania, most of the R&D personnel in the new Member States were employed in the public sector (government and higher education). This is in contrast to most of the other Member States, where the private sector accounted for the highest share. In Romania, at the level of 2007, the personnel in R&D comprised around 33,000 employees, the equivalent to 0.6% of the total number of employees, one of the lowest percentages in the EU.

According to World Bank's Knowledge Assessment Methodology (KAM), Romania[3] was in 2009 in 47th position out of 145 countries, while Bulgaria was in the same year in 43rd position.

3. Methods and variables

3.1. The Method: Data Envelopment Analysis

We use for our purpose Data Envelopment Analysis (DEA), which is a method proven to be useful in a diverse variety of applications in managing, examining and improving efficiency.

Efficiency is determined as the ratio of outputs in relation to inputs of a given entity that is examined, which is referred to as Decision Making Unit (DMU), the term coined by Charnes et al.

[3] http://info.worldbank.org/etools/kam2/KAM_page5.asp

(1978). This may include non-profit or public organisations, such as hospitals, universities or local authorities. DEA measures the relative efficiency by the observable inputs and outputs of several, different DMUs, assigning them efficiency scores ranging from 0 to 1, the score of 1 given to the most efficient in the group measured. The fundamental difference between traditional statistical approaches and DEA is that while the former reflects the average behaviour of the observations, DEA deals with best performance, evaluating all performances from the efficiency frontier formed by the most efficient DMUs.

This quality points out the usefulness of DEA in benchmarking applications as the notion of best performance is built in to the method itself. More than that, there are identified the inefficient - less productive DMUs compared to the best practice DMUs.

Non-parametric analysis techniques, such as DEA, have several advantages in terms of evaluating the relative efficiency of R&D activities over other parametric methods. DEA is especially valuable where the relative importance of the various inputs employed and outputs produced by a DMU cannot be defined, owing to the absence of market prices. The method also has other advantages, such are the possibility to estimate efficiency of DMUs with multiple inputs and output production technology that allows avoiding calculating a single measure of input or output; a possibility to determine the amount of input to be used or the size of output to be achieved for each organization to become fully efficient.

The purpose of an input-oriented approach is to study by how much input quantities can be proportionally reduced without changing the output quantities produced. Alternatively, and by computing output-oriented measures, one could also try to assess how much output quantities can be proportionally increased without changing the input quantities used. The two measures provide the same results under constant returns to scale but give different values under variable returns to scale.

The analytical description of the linear programming problem to be solved, in the variable-returns to scale hypothesis, is sketched below for an output-oriented specification. Suppose there are k inputs and m outputs for n DMUs. For the i-th DMU, yi is the column vector of the inputs and xi is the column vector of the outputs. We can also define X as the (k×n) input matrix and Y as the (m×n) output matrix. The DEA model is then specified with the following mathematical programming problem, for a given i-th DMU:

$$\begin{cases} \max_{\phi,\lambda} \phi \\ -\phi y_i + Y\lambda \geq 0 \\ x_i - X\lambda \geq 0 \\ N_1\lambda = 1 \\ \lambda \geq 0 \end{cases} \quad (1)$$

In problem (1), θ is a scalar and 1≤ϕ≤∞. ϕ-1 is the proportional increase in outputs that could be achieved by the ith DMU with the input quantities held constant.

The measure 1/ϕ is the technical efficiency score and varies between 0 and 1. If it is less than 1, the DMU is inside the frontier (i.e. it is inefficient), while if it is equal to 1, it implies that the DMU is on the frontier (i.e. it is efficient).

Vector λ is a (n×1) vector of constants that measures the weights used to compute the location of an inefficient DMU if it were to become efficient. The inefficient DMU would be projected on the production frontier as a linear combination of those weights, related to the peers of the inefficient DMU. The peers are other DMUs that are more efficient and therefore are used as references for the inefficient DMU. n1 is a n-dimensional vector of ones. The restriction n1'λ = 1 imposes convexity of the frontier, accounting for variable returns to scale. Dropping this restriction would amount to admit that returns to scale were constant. Notice that problem (1) has to be solved for each of the *n* DMUs in order to obtain the n efficiency scores.

Different assumptions regarding the frontier can be made: the underlying technology determined either by constant returns to scale (CRS), (see Charnes et al., 1978, who first derived the DEA under CRS); or by variable returns to scale (VRS) which assume that scale inefficiencies are present (see Banker et al., 1984, who first allow for VRS). To determine efficiency measures under the variable returns to scale (VRS) assumption, a further convexity constraint Σλ=1 must be considered. Within this framework countries of similar sizes concerning the input requirements are compared.

3.2 Model Specification and Data

A total of 14 regions form the two countries is used in this study. Romania is consisting of 8 NUTS2 development regions, while Bulgaria is consisting of 6. We had to exclude two of Bulgarian regions due to the lack of data. Instead we add one more DMU to our sample, meaning Bulgaria, as country. Therefore, the total sample involved in this research is consisting of 13 DMU.

Quantitative R&D input and output data for these regions and for the two countries were collected and processed. Official data compiled and released by international organizations and national governments, such as EUROSTAT, the World Intellectual Property Organization, the Romanian National Institute for Statistics and etc., are used.

The number of inputs and outputs selected was established according to the necessity of maximizing the discrimination existing in the TE of the units. Several authors proposed some rules in this respect. Dyson at al (1991) recommend a total of two times the product of the number of inputs and outputs variables

The number of units should be at least twice the number of input and output considered. Charnes and Cooper (1991) have suggested, as a rule of thumb, that there should be three times as many DMUs as the number of inputs plus outputs. Therefore, we estimate that the minimum number of DMUs required is achieved by applying the rule of thumb:

$n \geq max\{m * s, 3(m + s)\}$,

where n is number of DMUs, m is number of inputs and s is number of outputs.

According to these results, we used one output and three input variables. In order to decide the most appropriate variables to be used we consider the set of indicators internationally recognized in analyzing knowledge based economy.

We point out that the 23 indicators relate to seven thematic dimensions, as developed in relation to the Barcelona and Lisbon objectives[4];

I. ‘Production and diffusion of ICT’: indicators ICT value added (% of total business sector value added), SMEs ordering over the internet (% of total SMEs), Individuals using the internet for banking (% total)

II. ‘Human resources, skills and creativity’: indicators Pisa reading literacy of 15y (average score), Total researchers (per 1000 labour force in FTE), Participation in lifelong learning (% of working 25-64y), Employed in creative occupations (% total);

III. ‘Knowledge production and diffusion’: indicators BERD performed in service industries (%), EPO high tech patent applications (per million population), Triadic patent families (per million population);

[4] This selection was made by Cherchye, L., Moesen, Rogge, N., Van Puyenbroeck T. (2009) from 115 indicator existing in the literature.

IV. ‘Innovation, entrepreneurship and creative production’: indicators Firm entries (birth rate), GDP (per capita), Early-stage venture capital (% GDP), SMEs reporting non technological change (%);

V. ‘Economic outputs’: indicators GDP per capita (in PPS), Real GDP growth rate (% change on previous year), Total employment growth (% change on previous year);

VI. ‘Social performance’: indicators Long term unemployment rate (% change on previous year), Hampered in daily activities because of chronic conditions (% of population 15+), Rooms per person by tenure status and type of housing (average number of rooms);

VII. ‘Internationalisation’: indicators Technology balance of payments (% GERD), Co authorship share on international S&E articles (% of international articles), and Foreign PhD students (% of total PhD enrolment).

The number of patents is probably the most important indicator of research output and the seeking of patent protection is an indication that inventors expect their ideas to be used. Following the existing literature presented in part 1 and using the indicators presented previously, we use patents as the output variable of the model. This indicator quantifies the number of applications to the European Patent Office (EPO) per one million people. The patents are counted in the year of application to the EPO.

The publication of academic papers is also the most common avenue for delivering research ideas and their outcomes, but the data concerning Romania and Bulgaria is not available at regional level and even at national level is unreliable.

From the Patents point of view, Romania lags behind majority of European Countries (Curaj, A., 2007). European Patent Office granted no more than 3 patents per year to the patent applications from Romania. With only 0.85 patent applications per million population compared to 7.23 patent applications per million population in the 10 New Member Countries and 133.59 the average number in EU 15, Romania has to increase 8 times or even 157 times just in order to reach NMS average or EU15 average. The situation is similar in regards the patents granted in US and Japan; at most 3 patents USTPO per year and only two requests for the Japan Patent office in the last 10 years.

More analytical in information could be obtained if we consider the ownership patents application/granted structure, which is: individuals 71%/54%, research institutes10%/13%, universities 1%/5%, companies 18%/28%.

Based on the indicators described above and strongly depending on a quite narrow dataset available at regional level, the three inputs selected regards R&D expenditures, R&D personnel and employment in technology and knowledge-intensive sectors. Employment in technology and knowledge-intensive sectors was selected as an input variable based on the large number of patents that were submitted from these sectors.

EUROSTAT's definition of Knowledge Intensive Sectors features the following categories (with NACE codes in parentheses):

1. Knowledge-intensive high-technology services
   - Post and telecommunications [64]
   - Computer and related activities [72]
   - Research and development [73]
2. Knowledge-intensive market services (excl. financial intermediation and high-tech services)
   - Water transport [61]
   - Air transport [62]
   - Real estate activities [70]
   - Renting of machinery & equipment without operator & of personal & household goods [71]
   - Other business activities [74]
3. Knowledge-intensive financial services
   - Financial intermediation (except insurance and pension funding [65,]
   - Insurance and pension funding, except compulsory social security [66]
   - Activities auxiliary to financial intermediation [67]
4. Other knowledge-intensive services
   - Education [80]
   - Health and social work [85]
   - Recreational, cultural and sporting activities [92]

Physical resources are usually measured in annual total R&D expenditures in official data. Physical resources are usually measured in annual total R&D expenditures in official data. Those in current USD based on the purchasing power parities (PPP) method are released and made available by

EUROSTAT sources. It is noted that total R&D expenditures reported also contain the salaries and wages paid to researchers and other personnel.

Descriptive statistics of the raw data on R&D expenditure and manpower as well as the number of patents are displayed in Table 4.

Table 4. Descriptive statistics of DEA model inputs and outputs

	Minimum	Maximum	Mean	Std. Deviation
Patents	0,0670	5,3040	1,674417	1,7415134
RD_expenditures	14,00	312176	68615.78	94517,49456
RD_personnel	534,00	18590,00	4632.167	5345,25978
Empl_KIS	804,00	57591,00	20249.25	16304,56535

Note: in the table Bulgaria as a country was excluded for comparability reasons and the statistics refer to the 12 regions only. However, in DEA framework Bulgaria was included.

4. Results

Since a certain length of time is required before R&D is completed and outputs are realized, a time lag between inputs and outputs needs to be taken into account in conducting a deterministic DEA evaluation of R&D efforts. Based on the empirical of Cullmann, Schmidt-Ehmcke and Zloczysti (2009), this study sets the time lag to be 2 years. The input data set for 2003 is thus matched with the output data set for 2005.

Table 6. Results from DEA model

DMU	**crste**	**vrste**	**scale**	**returns to scale**
Bulgaria	0.065	0.604	0.108	drs
Severozapaden	1.000	1.000	1.000	-
Severoiztochen	1.000	1.000	1.000	-
Yugozapaden	0.125	0.783	0.160	drs
Yuzhen tsentralen	0.484	0.504	0.960	drs
Nord-Vest	0.079	0.142	0.554	drs
Centru	0.229	0.396	0.578	drs
Nord-Est	0.009	0.017	0.541	drs
Sud-Est	0.067	0.087	0.764	drs
Sud - Muntenia	0.033	0.089	0.367	drs
Bucuresti - Ilfov	0.135	1.000	0.135	drs
Sud-Vest Oltenia	0.148	0.157	0.940	drs
Vest	0.029	0.063	0.454	drs
Mean	**0.262**	**0.449**	**0.582**	

Note: computations were performed using Deap 2.1

DEA model for evaluating inter-regional R&D efficiency includes one output and three inputs. Efficiency scores for all regions studied relative to a best practice frontier are computed using the output-oriented model, thus regions aim to maximize the R&D output resulting from their inputs. Our approach is based both on the VRS assumption and CRS assumption. Summary statistics on relative efficiency scores are presented in Table 6.

The initial DEA based on CRS assumption results show that two regions were technically efficient, Severozapaden, Severoiztochen from Bulgaria. The mean averages were around 0.262 under CRS assumption with minimum values being 0.009 (Nord-Est). The relative efficiency in all of the regions is less than 0.3, with the exception of Yuzhen tsentralen, wich has a TE of .484.

Under VRS assumption there is an increase in TE for all DMUs. The mean increases from 0.262 to 0.449. More than that, the regions from the efficiency frontier are three, in this case: Severozapaden, Severoiztochen and Bucuresti Ilfov.

The difference between the CRS and VRS scores indicates scale efficiency. Table 6 shows that all the units that are not on the efficiency frontier are facing a decreasing return to scale and they are not characterized by an optimal size of the research production process with respect to input allocation.

We sort our sample units into three groups according to their research efficiency:

- technical efficient: Severozapaden, Severoiztochen and Bucuresti Ilfov;
- Medium efficiency (technical efficiency score higher than 0.5): Yugozapaden, Yuzhen tsentralen, Bulgaria ;
- Low efficiency (technical efficiency score less than 0.5): Centru, Nord Est, Sud, Sud Vest, Vest, Nord Vest, Sud Est ; with the exception of Central region, all other Romanian regions have scores less than 0.2, the lowest value is in Nord East region of Romania.

It is easy to notice that Bulgarian regions are more efficient in R&D activities compared to Romanian ones. We notice that there are important variances among observed regions. It has been shown that regions with fewer resources (Severozapaden, Severoiztochen) devoted to research achieve outstanding levels of efficiency and, regions with high level of resources do not show efficiency levels. As shown below, these countries only started recently to adapt their R&D expenditures to increase patent output and this could explain their poor performance. These two countries are characterized by a very low capacity of knowledge production, suggesting that they are still in the phase of imitating and replicating existing technologies, while only little effort is made on innovating.

Conclusions

Bulgaria and Romania both entered the European Union on 1 January 2007, having economic systems less developed compared to other EU members. In their case the efficient use knowledge is particularly important, since it has been proven that technological progress is one of the core aspects of economic growth. We describe the common features of the two countries, but also the differences existing in respect with knowledge based economy. There are significant regional differences within the countries and marginal regions must close the gap with more developed regions, i.e. to enable economically under performing regions to catch up with more prosperous ones.

The present paper analyzes research efficiency at the regional level for NUTS2 regions from Romania and Bulgaria between 2003 and 2005. We consider three inputs: the knowledge stocks approximated by R&D expenditures and manpower captured by the number of researchers and employment in high- and medium-skilled labor. Following the exiting literature, we used number of patents as output variable. The method employed is Data Envelopment Analysis, which has already proved to be useful in this respect.

There is a great variability in our sample, concerning the efficiency of research and development activities. Under the assumption of VRS, three regions were technically efficient, while other three have an efficient score higher than 0.5. Six regions from Romania have an efficiency score less than 0.3, while one region has a score of 0.396. Our main finding is that Bulgarian regions are more efficient in R&D activities compared to Romanian ones. The only Romanian efficient region is Bucuresti Ilfov, while the other two efficient regions are rather small Bulgarian regions, with fewer resources. They show a remarkably high level of research efficiency, whereas some of the larger ones (both from Romania and Bulgaria) lag behind.

The similar situation is identified in other works. Zabala-Iturriagagoitia et al (2007) noticed that small European economies (Denmark, Belgium, the Netherlands, Ireland and Finland) show a higher efficiency in respect to innovation system, compared to United Kingdom, France and Spain. A focus on the Spanish national level yielded similar evidence. Those regions that devote large amounts of resources to R&D and innovation are not the most efficient ones.

Schmidt-Ehmcke and Zloczysti (2009) conclude in their study that small European economies, (Denmark, Belgium, the Netherlands) have a high level of research efficiency, while some of the larger ones, namely, United Kingdom, France, and Spain, show lower TE scores.

One possible explanation could be that a small region tends to show a higher degree of specialization, which could raise efficiency in the industries and could better use its resource. More than that, it may be easier for small countries or regions to link research conducted at universities to private business R&D activities due to the small number of large companies in those countries.

Both Romania and Bulgaria are characterized by a very low rate of knowledge production, suggesting that they are still in the phase of imitating and replicating existing technologies, while only little effort made to innovate. Therefore innovation support policies must be customized to support the particularities of each region and innovation support policies have to be embedded in the territory. This means it is crucial that regions learn from evaluation exercises in order to redefine their policies, and assess the performance and the institutional quality of their R&D activities with greater accuracy.

References

Allen, S. G., (2001), "Technology and the Wage Structure," *Journal of Labor Economics*, University of Chicago Press, vol. 19(2), pp. 440-483

Bojkov, V. D. (2004), Neither here, not there: Bulgaria and Romania in current European politics , *Communist and Post-Communist Studies*, Volume 37, Issue 4, pp. 509-522

Bourdeau-Lepage, L., Desislava, K., (2008),“Knowledge Society and Transition Economies. The Bulgarian Challenge”, *The Journal of the Romanian Regional Science Association*, Vol. 2, No. 2, pp. 53-79

Caselli, F., Wilbur John Coleman II, (2001), "Cross-Country Technology Diffusion: The Case of Computers," *American Economic Review*, American Economic Association, vol. 91(2), pp 328-335

Charnes, A., Cooper, W.W., Lewin A.Y., Seiford, L.M., (1994), “Data Envelopment Analysis: Theory, Methodology and Applications”, Kluwer Academic Publishers

Charnes, A., Cooper W. W., Rhodes. E. (1978), “Measuring the efficiency of decision making units”, *European Journal of Operational. Research* 2: 429-444.

Cherchye, L., Moesen, Rogge, N., Van Puyenbroeck T. (2009) – “Constructing a Knowledge Economy Composite Indicator with Imprecise Data” , Katholieke Universiteit Leuven, series *Center for Economic Studies - Discussion papers*, number ces09.15

Coelli, T., Rao, P., O’Donnell, C. J. and Battese, G. E. (1998) - *An introduction to efficiency and productivity analysis*, Kluver Academic Publishers, Boston, Dordrecht, London

Coelli, T.J. (1996), “A guide to DEAP Version 2.1: a data envelopment analysis (computer) program”, CEPA Working Paper 96/08, Department of Econometrics, University of New England, Armidale, Australia.

Cullmann, Schmidt-Ehmcke, Zloczysti (2009), "Innovation, R&D Efficiency and the Impact of the Regulatory Environment—A Two Stage Semi-Parametric DEA Approach", *DIW Discussion Paper* http://www.diw.de/english/products/publications/discussion_papers/27539.html

Curaj, A. (2007), "Report on the national research system in Romania", CEPES Bucharest, Romania

Dyson, R.G., R. Allen, A.S. Camanho, V.V. Podinovski, C.S. Sarrico and E.A. Shale (2001) - "Pitfalls and Protocols in DEA." *European Journal of Operational Research* 132(2), 245-259.

Farrel, M.J. (1957), "The measurement of productive efficiency", *Journal of the royal statistical society*, Series A, CXX, Part 3, 253-290

Goschin, Z., Constantin, D.-L., Roman, M., Ileanu B. (2008) "The Current State and Dynamics Of Regional Disparities In Romania", *The Journal of the Romanian Regional Science Association*, Vol. 2, No. 2, pp. 80-105

Guellec, P., van Pottelsberghe de la Potterie, B. (2001), "R&D and Productivity Growth, OECD Science and Technology", Working Papers, no. 3

Huggins R and Hiro Izushi (2007), "The Knowledge Competitiveness Of Regional Economies: Conceptualisation And Measurement", *Bank of Valletta Review*, No. 35, Spring

Karkazis, J. And Thanassoulis E. (1998), "Assessing the Effectiveness of Regional Development Policies in Northern Greece", *Socio-Economical Planning Science* Vol 32, no 2. pp. 123-137

Kolarova, R. (1999), "Democratisation in Bulgaria: recent trends", In: M. Kaldor and I. Vejvoda, Editors, *Democratisation in Bulgaria: Recent Trends*, Pinter, London pp. 150–161

Roman, M., (2003), "Resursele umane in Romania. Evaluare si eficienta", *Editura ASE*, Bucuresti

European Union web site, "Facing The Challenge. The Lisbon strategy for growth and employment". *Report from the High Level Group chaired by Wim Kok*, November 2004, Office for Official Publications of the European Communities, ISBN 92-894-7054-2, (the Kok report).

Schmidt-Ehmcke and Zloczysti, P. (2009) "Research Efficiency in Manufacturing – An Application of DEA at the Industry Level", *Discussion Papers of DIW Berlin*, http://www.diw.de/english/products/publications/discussion_papers/27539.html

Sharma, S., Thomas, V. J. (2008), "Inter-country R&D efficiency analysis: An application of data envelopment analysis", *Scientometrics*, 76, pp.483-501

Slavova T. (2008), "A rank order and efficiency evaluation of the EU regions in a social framework", *Empirica* 35, pp. 339–367

Susiluoto, I. (2003) "Effects of ICT on Regional Economic Efficiency", *Helsinki City Urban Facts Office Web Publications*, No. 2003(16), Helsinki.

Wang, E.C., Huang, W. (2007) “Relative efficiency of R&D activities: a cross –country study accounting for environmental factors in the DEA approach”, *Research Policy,* 36(2), pp. 260–273

Zabala-Iturriagagoitia, J. M., Voigt, P., Gutiérrez-Gracia, A., and Jiménez-Sáez, F., (2007) “Regional Innovation Systems: How to Assess Performance”, *Regional Studies*, 41: 5, pp. 661 — 672