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Josef Nešleha
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Zuzana Rakovská

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Lukáš Marek
Miroslav Svoboda
Zuzana Rakovská

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PREFACE

Dear readers,

it is my pleasure to introduce a collection of papers from the 16th annual international scientific conference **European Financial Systems 2019** organized annually by the Department of Finance of the Faculty of Economics and Administration, Masaryk University in Brno, Czech Republic. This year's conference focused especially on the current issues related to financial markets, accounting, banking sector, insurance, financial literacy, financial law, different tax systems, corporate finance, international finance, public finance and financing of non-profit organizations.

Since the collection of papers presents the latest scientific knowledge in this area, I believe you will get a number of new insights usable for your scientific, educational and practical activities.

I wish you pleasant reading!

Eva Vávrová

Chairwoman of the Program Committee

CONTENTS

An Empirical Analysis of the Impact of R&D on Productivity in EU Countries

[1]O. Mykolenko , [2]S. Strapchuk, [3]O. Kozyrieva

[1]National University of Pharmacy,
Faculty of Pharmaceutical Technology and Management,
Department of Management and Administration
Pushkinska Str. 53, 61000, Kharkiv, Ukraine
E-mail: mykolenkohelen@gmail.com

[2]National University of Pharmacy,
Faculty of Pharmaceutical Technology and Management,
Department of Management and Administration
Pushkinska Str. 53, 61000, Kharkiv, Ukraine
E-mail: baysvetlana@gmail.com

[3]National University of Pharmacy,
Faculty of Pharmaceutical Technology and Management,
Department of Management and Administration
Pushkinska Str. 53, 61000, Kharkiv, Ukraine
E-mail: yakakos74@gmail.com

***Abstract**: The research investigates the question whether research and development expenditures contribute to productivity growth and depend on the particular countries' capacity and industries' technological level. The paper deals with the analysis of the impact of R&D on the companies' productivity on the industry level in EU countries based on panel data and the stochastic frontier production function approach. We estimate the production function separately for six different sectors and one industry. The results indicate that distribution of production and other relevant factors, such as physical capital per employee, labour force with tertiary education, ICT goods exports etc., vary significantly across industries, reflecting different absorption and diffusion capability of economies and their potential to structural changes. The findings have the practical value for strategic development of Ukrainian economy in the course of integration into EU market, and suggest the design of R&D policy based on the experience of EU countries, structure of the national industries, their technological level and future perspectives.*

Keywords: R&D; productivity, technological level

JEL classification codes: O32; O39

1 Introduction

There is widespread understanding that innovation is a trigger for economic growth, especially in the long run (Fagerberg et al., 2010; Mairesse and Mohnen, 2010). However, the conceptual and empirical links between innovation and growth on different levels are complex. Innovation is not a linear process, and there is no direct impact of investments in innovation on economic development. Moreover, metrics for the analysis suffer from limitations. This makes it difficult to establish new perspectives on future policy on innovation development, and research and development (R&D) spending Thus, strengthening innovation is a fundamental challenge for European countries in their quest for greater prosperity and better lives, including Ukraine with its developing market.

According to the Global Innovation Index Ukraine has ranked highest in the last seven years (43th), having improved position mostly due to high coefficient of innovation efficiency – knowledge and technology outputs (GII, 2018). The strengths of the country are knowledge creation, results of scientific research, ratio of patents by origin to GDP, ratio of useful utility models by origin to GDP, computer software spending (% GDP), ICT services export in percent of total trade (GII, 2018). Nevertheless, Ukrainian economy has a weak basis for innovatory technology-based development. The number of enterprises that carried out research into innovation in 2017 decresed by 9 % compared to 2016. Investments in intangible assets during the last fifteen years have not exceeded 4% of capital investments, and the share of high-tech and medium-tech production amounted to 11.3% of all manufacturing sector (SIA, 2018). In addition, according to statistics, R&D expenditures have not reached 0.5 % of GDP in 2018 that is not comparable with data of EU countries and their targets (SIA, 2018). After EU countries didn't reach 3 % of R&D expenditure in GDP by 2010, the renewed 3 % goal was set as one of the main five targets of the Europe 2020 strategy adopted in 2010 (Liik, 2014). Thus, the strategic development of Ukraine should be based on balanced R&D policy that absorbs best practices and experience of developed EU countries in innovation and R&D activities on different levels.

Thus, the aim of the paper is to analyse the contribution of research and development to the efficiency (productivity) of industries with various technological levels in EU countries. In order to perform the analysis stochastic frontier production function approach was employed. There are plenty of scientific researches that deal with the stochastic frontier analysis as the basis for measuring technical efficiency (Aigner et al., 1977; Coelli et al., 2005; Belotti et al., 2013; Liik, 2014). Aditionally, stophastic frontier analisys allows to estimate a much wider range of time-varying inefficiency based on the inefficiency effects model of Battese and Coelli (1995) and the 'true' fixed and random-effects models developed by Greene (2005). We conduct our analysis in order to investigate whether production efficiency are influenced by various factors of production (physical capital, R&D capital) on the one hand, and the various factors external to the enterprises in order to identify the perspectives on R&D policy in Ukraine. The industry-level data are from OECD STAN (indicators of labour, capital, etc.) and ANBERD (R&D expenditures) databases for 21 EU countries for the period of 2009–2016. In addition, the variables for various external factors are derived from the World Development Indicators database.

Desining the policy goals on R&D one needs to consider the industrial specialization of the economy and the respective technological levels of industries in sectors. For instance, Kumbhakar et al. (2012) linked R&D to higher effeciency primarily in high-tech industries and not in low-tech industries based on data collected from the biggest European R&D performers. Therefore, the targets for R&D expenditures have to be differentiated with regard to the technological level of particular industry. The other research suggests that EU firms are more likely to achieve productivity gains through capital-embodied technological change at least in medium and low-tech sectors (Castellani, 2016). And Ortega-Argilés et al. (2014) point to a lower capacity of European companies to transform R&D investment into productivity gains due to a sort of modern Solow's (1987) paradox. They conclude that there might be an effect due to both level and productivity impact of R&D spending within European firms, irrespective of their sectoral belonging. Since there is a variety of research results, we will focus on sectoral differences in technological capacity of absorbtion and diffusion.

2 Methodology and Data

The study is based on industry-level (by International Standard Industrial Classification of All Economic Activities (ISIC) Rev. 4) data from 21 EU countries, over 8-year period from 2009 to 2016, forming an unbalanced panel. Two datasets were combined, OECD STAN (for measures of output, labour input, and capital) and OECD ANBERD (for research and development expenditures). We have used the OECD data as it includes most of the EU countries. The study also includes data from countries like the USA, Japan, and South Korea. Additionally, in order to construct the efficiency frontier we utilized data from countries with the highest levels of productivity in the respective industries.

Model Specification

Based on econometric theory pre-specified functional form is estimated and inefficiency is modeled as an additional stochastic term. The Stochastic frontier production function model (single Cobb-Douglas form for panel data) is as follows (Coelli et al., 2005):

$$\ln Y_{it} = \beta_0 + \beta_1 \times \ln K_{it} + \beta_2 \times \ln R\&D_{it} + \delta_i \ln z_{ti} + t + v_{it} - u_i, \quad (1)$$

where:

Y_{it} – value added per employee;

K_{it} – physical capital per employee;

$R\&D_{it}$ – R&D capital per employee;

t – time trend; .

z_{ti} – efficiency covariates (external factors); .

v_{it} – random variables of i-th unit in year t reflecting effect of statistical noise;

u_i – non-negative time-invariant random variables capturing time-invariant technical inefficiency.

Table 1 presents the description of individual variables.

Table 1. Descriptive statistics

Variable	Description	No. of obser	Mean	SD	Min	Max
LF	Labour force with tertiary education (% of total)	4163	29.5	6.2	15.3	41.5
ICTEx	ICT goods exports (% of total goods exports)	4200	6.58	4.06	1.07	26
ICTIm	ICT goods imports (% total goods imports)	4200	7.8	2.73	2.75	15.69
Y	Y = VA/ NEM*	4200	217977	590873	1533	11841500
K	Physical capital* / NEM	4163	68622	232165	110	3630000
R&D	$R\&D_{capital}$* / NEM	3453	2384	6825	0.006	86348

Source: authors' calculations based on ANBERD, OECD STAN, World Development Indicators database
* the currency is euro

The following variables from the Table 1 are used in our model:

- NEM – number of employees;
- GFCF – gross fixed capital formation at current prices; .
- VA – value added at current prices;
- $R\&D_{exp}$ – R&D expenses (at current prices).

According to widely used perpetual inventory method (Hall, Mairesse et al., 2010) $R\&D_{exp}$ and investments into physical capital must be capitalized in order to provide R&D and physical capital stock variables. R&D capital in time period *t* is calculated as follows:

$$R\&D_{capital_t} = R\&D_{capital_{t-1}}(1-\delta) + R\&D_{\exp_t}, \quad (2)$$

where δ is the depreciation rate.

We base our analysis on the following depreciation rates for R&D capital (Kumbhakar et al., 2012): high-tech – 20%; medium-tech – 15%; low-tech – 12%. The depreciation rates for physical capital equal 8%, 6%, and 4% respectively. Different depreciation rates are explained by relevant technological level of the corresponding sector and its life cycle.

In order to produce adequate efficiency estimation a common production frontier is a necessary condition (Koop, 2001). Thus, considered sectors should share a common frontier. To utilize these samples, sectors are grouped into manufacturing (high-tech 21, 26-28, 72; medium-tech 05-25, 29-33, 58-63,69-75, 84-88; and low-tech 15–37); services (45-47,49-53,55-56,58-66,68-75,77-82,84-88,90-99), primary (01–03). A pharmaceutical industry (21) was derived due to its strategic importance for Ukrainian economy. Manufacturing is divided by technological level according to ISIC Rev. 4. Therefore, we estimate the production function separately for six different sectors and one high-tech industry. Also we concern the possible problem of multicollinerity between two types of capital that needs to be reduced. Per capita specification is one of the remedial measures to overcome this problem.

Fixed and random effect models are used for different sectors (test results in Table 2). Since our models don’t include time-invariant covariates heterogeneity is not reflected in the fixed-effects SFA model.

3 Results

Table 2 presents the results of seven different models: six of them are fitted across sectors, including whole sample, and one is estimated for a pharmaceutical industry. All models are based on Equation (1). The estimates are derived from multiple tests of a number of options, including combinations of external factors (LF, ICTEx, ICTIm). We consider both fixed- and random effect models (the choice is based on the random-effects test).

One industry (21) as a part of the high-tech sector is represented separetly, firstly, to show the differences between sector- and industry-based productivity, secondly, to shed the light on a strategic perspective on innovation development of Ukrainian economy. As a result, mean efficiency of high-tech sector as a whole differs from pharmaceutical industry. Thus, averaging the values over sectors may create significant differeces and result in models’ inaccuracy due to indistinguishable heterogeneity.

Table 2 also shows that outlined external factors being significant in sector-based models, are non-significant in the whole sample model. For instance, tertiary education appares to have the capacity for developing new technologies, when the innovation becomes the basis of development (Acemoglu et al., 2006). The factor has a positive influence on productivity in high and medium-tech manufacturing, as well as in services. It has even higher elasticity than R&D capital respectively, in both high and medium-tech sectors. In pharmaceutical industry, the impact of educated labour on productivity is even more stronger than in all other sectors, which points to heterogeneity within sectors. The specified factor are generally under government control, so policy-makers are not restricted in stimulating labour market. The other variables that we consider are ICT goods exports and ICT import. In contrast to ICT goods exports (% of total exports), imports has a positive impact on production efficiency. This could be diffusion effect (spread of technology). However, it is significant only in case of services. In medium-tech manufacturing it has a lowest effect among all factors within this sector.

In addition, production input estimates are also significant, and some general conclusions can be made. Physical capital appares to be statistically significant in all sectors. In manufacturing sectors, the effect of physical capital depends on a technological level of sector. It decreases with a rising technological level. In all sectors, physical capital has a significant influence, being the highest in the primary sector However; the differences in the impact of the variable between sectors’ are not so visible. In turn, R&D capital shows the opposite trend. It increases with a rising technological level. And the differences between values are much more visible (0.12 versus 0.05). R&D capital also looks more elastic than the other capital. The R&D effect increases if a particular industry moves closer to the efficiency frontier (Acemoglu et al., 2006). Exactly in that case the innovation becomes an important source of development, while for the industries located out of the efficiency frontier the effect may be lower.

A time trend of technological change is also present mostly due to the high-tech sector and its progress, however, it has a weak effect on effeciency in all industries. Only primary sector shows no progress in technological level on a year-by-year basis. However, built on our analisys the primary sector is the one with time-varying decreasing inefficiency. Therefore, the primary sector is moving closer to the efficiency frontier.

The results are generally in accordance with other studies of a similar type (Kumbhakar et al., 2012; Hall et al., 2010). However, this study is based on stochastic frontier production function approach that includes inefficiency analisys across sectors, but not countries.

The study is not without limitations that are mostly connected with the outlined factors. For instance, R&D capital as a part of innovation process is not a comprehensive variable, but it is easily available. As a result, we base our investigation on the assumption that technological level relates to R&D intensity, which is not always the case. There may be indistinguishable heterogeneity across industry. And the last but not the least, additional efficiency covariates (external factors) should be considered. For instance, Jaumotte and Pain (2005) show that the availability of scientists and engineers, industry-academia knowledge exchange and others would increase the R&D activities of entreprises.

Table 2. Models' parameters for different sectors

Variable	Whole sample	High-tech	Pharmaceutical industry	Medium-tech	Low-tech	Primary sector	Services
lnK	0.248***	0.189***	0.718***	0.311***	0.526***	0.823***	0.496***
lnR&D	0.101**	0.121**	0.242***	0.111**	0.056***	-	0.038*
Time	0.004***	0.018***	-	0.078***	0.013***	-	0.043***
lnLF	-	0.181**	0.426**	0.214**	-	-	0.143**
lnICTEx	-	-	-	-	-	-	-
lnICTIm	-	-	-	0.058*	-	-	0.112*
constant	-91.12***	-37.89***	1.14*	-103.28***	-148.15***	9.41**	-94.56***
RE test	*F*(4.321)=24.3	*F*(4,349)=3.89	-	*F*(6.318)=0.98	*F*(3.428)=9.12	*F*(4.412)=1.46	*F*(2.389)=0.85
p-value	0.0000	0.0563	-	0.3258	0.0008	0.4112	0.0000
Hetero-skedasticity	$\chi^2(8) = 139.55$	$\chi^2(1) = 18.94$	-	$\chi^2(6) = 76.93$	$\chi^2(3) = 64.45$	$\chi^2(3) = 8.75$	$\chi^2(3) = 108.4$
p-value	.0000	.0004	.0000	.0000	.0031	.3698	.0058
Mean effeciency	0.19	0.42	0.71	0.39	0.39	0.56	0.35

Source: authors' calculations

4 Conclusions

The analysis contributes to the literature by the developing the ideas of Kumbhakar et al. (2012) with industry-level data on a wider set of countries. Based on the previous literature and the analysis the importance of R&D is highlighted. It is concluded that the growth of R&D capital prominently contributes to enhancing effect more in high-tech industries, such as pharmaceutical and ICT. Both industries are of strategic importance to Ukrainian economy. Therefore, R&D investments in the development of these industries will contribute to the increased level of value added according to our results. And the experience of EU countries proves our assumption.

A contribution to economic productivity may also result from technological progress embodied in physical capital. We identified that physical capital is the only one variable that positively influences productivity in all industries. Investment in more advanced machinery or in new computers are beneficial for any industry. According to our analysis, it has a strong effect on pharmaceutical and primary sector. What is more important is that primary sector includes agriculture that also will benefit in Ukraine from investing in a new technology and machinery after the land market becomes opened for sale.

We also contribute by investigating how the link between production efficiency and R&D is influenced by various external factors like ICT good exports or imports (% of total).

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