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The Impact of investment in Research and Development on the Economic Growth in Serbia[5]

Abstract: The main objective of this paper is to examine the impact of investment in research and development on economic growth in the Republic of Serbia, expressed through the correlation of this and other macroeconomic aggregates. A variety of statistical and econometric techniques of variables and time series analysis are employed. In order to quantify the contribution of investments in research and development to the GDP real growth, initially data series at current prices are converted in real terms, applying previously calculated composite deflator for research and development. Based on these data, estimated for the period 1995-2015, the contribution of R&D investments to the GDP real growth is explicitly shown and expressed in percentage points. Also, the latest available data since 2016. up to 2018. have been presented in order to show the trend in this area. The empirical results achieved in the study reveal a strong interdependence among the R&D expenditures and economic performance at the national level in Serbia. Based on these findings, a statistically significant causality relationship

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oriented from GDP real growth to research and development activity is confirmed. As real economic activities and growth rate increase, R&D must also increase for sustainability. However, the causality in the opposite direction cannot be verified.

Keywords*: GDP, GERD, research and development, economic growth, statistical and econometric analysis; Serbia.*

Uticaj ulaganja u istraživanje i razvoj na ekonomski rast u Republici Srbiji

Apstrakt*: Cilj ovog naučnog rada je da istraži uticaj ulaganja u istraživanje i razvoj na ekonomski rast u Republici Srbiji, kroz njihovu korelaciju ali i u korelaciji sa drugim makroekonomskim agregatima. Koriste se različite statističke i ekonometrijske tehnike kao i analiza vremenskih serija. U cilju kvantifikovanja doprinosa ulaganja u istraživanje i razvoj rastu bruto društvenog proizvoda, incijalne serije podataka po tekućim cenama su konvertovane u realne iznose primenom prethodno izračunatog kompozitnog deflatora za istraživanje i razvoj. Bazirano na ovim podacima, procenjenim za vremenski period od 1995. do 2015, doprinos ulaganja u I&R rastu realnog bruto društvenog proizvoda je prikazan eksplicitno u procentnim poenima. Takođe, prikazani su i najnoviji dostupni podaci u peridou od 2016. do 2018. godine u ovoj oblasti. Empirijski podaci studije otkrivaju jaku međuzavisnost između troškova za istraživanje i razvoj i ekonomske performanse na nacionalnom nivou. Zasnovano na ovim nalazima, potvrđena je značajna statistička zavisnost između rasta realnog bruto društvenog proizvoda i istraživanja i razvoja. Sa rastom ekonomskih aktivnosti i povećavanjem stope rasta, I&R se mora takođe povećavati kako bi rast bio održiv. Međutim, uzročnost u obrnutom pravcu se ne može verifikovati.*

Ključne reči*: BDP, troškovi za istraživanje i razvoj, istraživanje i razvoj, ekonomski rast, statistička i ekonometrijska analiza, Srbija*

1. Introduction

In the knowledge society, the culture of knowledge creation based on developed educational system and infrastructure is supported by a wide application of information and communication technologies (ICT) (Britz et al., 2005). There are numerous studies, theoretical and empirical, which prove crucial role of research and innovation (R&I) as engines of employment growth and competitiveness. Hence, the support for R&I is considered a key driver for strategy of the European Council adopted in Lisbon in March 2000,

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which main goal should be that the EU by 2010 becomes a dynamic knowledge-based economy, the most competitive in the world, with sustainable economic growth, numerous and better jobs and greater social cohesion - the so-called "Lisbon Strategy" (European Council-Lisbon 2000). The direct consequence of such a strategy is adopted requirements that member states should have reached a level of gross expenditure for research and development (GERD) of 3% of gross domestic product (GDP) by 2010 - the so-called. "Barcelona target" (European Council-Barcelona, 2002). Although this goal was not realized in 2010, investment in research and development (R&D), and investment in education and training of human resources is also the backbone of EU policies in the second decade of the XXI century. These areas are essential for economic growth and development of knowledge-based economy. The strategy "Europe 2020" sets out a vision of the European market economy for the 21st century, which aims to create a smart and sustainable economy with high levels of employment, productivity and social cohesion. Innovation activities are the driver of economic progress and are a key element of the strategy "Europe 2020" (EC, 2010).

Indicators of investment in R&D and innovation indicators are the basic instruments for monitoring the objectives of the EU Initiative (Innovation Union, Europe 2020) and the European Research Area (ERA). The strategy "Europe 2020" determines the direction of development of the European market economy of the 21st century investing in R&D amounting to 3% of GDP, which is one of the five priorities that EU should achieve by 2020.In addition, IUS (Innovation Union Scoreboard) report and other key reports of the European Commission are stressing necessity that countries of the EU and other countries should develop a broad set of indicators of R&D and innovation activities (European Commission Innovation Union Scoreboard, 2016).

Analysis of different modules of R&D activities are the subject of this paper, in order to, for the first time in Serbia, examine the impact of investment in R&D on the macroeconomic aggregates, which provides the basis for decision-making in this area. The main objective of this paper is to examine the impact of investment in R&D on economic growth in the Republic of Serbia, expressed through the correlation of this and other macroeconomic aggregates.

Further specification of concepts and treatment of R&D costs as a fixed asset, as well as improving the compilation of this aggregate should enable better evaluation of R&D activities and provide background information for a wide

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range of users, primarily for policy makers in this field. This paper consists following chapters:

- Analysis of the literature, related to the topic of the article;
- Selected R&D indicators in the Republic of Serbia;
- Research and development expenditures in volume terms in Serbia;
- R&D investments by industries and effect of their allocation on economic performance in Serbia.

2. Literature review

Insufficient funding of research and innovation is a common concern of scientific communities worldwide. This attitude is directly opposed to positions of decision-makers in science and innovation management, both in the public and private sector, emphasizing, at the same time, the question of the extent to which research and innovation contribute to the growth and development of companies, sectors and the economy as a whole. The theory of economic growth is a scientific approach which aims to answer this question. The analysis of the literature leads to several approaches to the empirical research on the contribution of science and innovation to economic growth. One group of empirical studies of endogenous growth models examined the effects of variables that represent science and innovation in the growth of total factor productivity (TFP). Jones (1995) used a time series of growth rates of TFP and increase of the number of scienists and engeneeers in France, Germany, Japan and the US, to examine the validity of the model of growth based on R&I. The author did not achieve evidence that these variables were positively related, and, therefore, proposed that, instead of the number of scientists and engineers, the share of investment in R&I in the total GDP should be introduced in the analysis, in order to take into account, the size of the economy. Zachariadis (2003) provided strong evidence that the investment in R&I of the US economy and the growth of TFP are positively correlated.

The positive relationship between research and productivity growth in the national economy was confirmed in the studies which used panels of international data (Frantz, 2000, Griffith et al., 2002). They also identified strong evidence that the transfer and diffusion of R&D from industrialized countries to developing countries have positive effects on the growth of TFP in developing countries (Griffith et al., 2002).

A particular problem in these studies is the quality of data on R&I. To study the determinants of innovation, which are at the core of endogenous growth

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theory, it is necessary to provide reliable data on inputs for R&D, as well as on the results of innovation activities. One of the first studies which used data on patents at the aggregate level in order to examine the determinants and effects of innovation, was the work of Porter & Stern (2000). This study showed that innovation is positively related to the human capital in R&D sector and national accumulation of knowledge, but, also, that there is a significant relationship between innovation and the growth of TFP.

Using the techniques of panel data for 20 OECD and 10 non-OECD countries for the period 1981-1997, Ulku (2004) examined the following hypotheses of R&I in a model of endogenous growth: (1) investment in R&I will increase innovation, and there is a constant yield of innovation; (2) innovation leads to an increase in GDP per capita. The results indicated a positive relationship between GDP per capita and innovation in OECD and non-OECD countries, but the effect of accumulated research on innovation is significant only in the OECD countries with large markets. Although these results support the endogenous growth model, they do not provide evidence for the continued contribution of innovation and research, which further implies that innovation does not lead to a permanent increase in economic growth. This, however, does not suggest a rejection of the model of growth based on research, because neither information on patents nor data on R&D do not fully complies research and innovation activities.

Savvides and Zachariadis (2003) showed that the national R&D and foreign direct investment increase domestic productivity and increase added value. Zachariadis (2003) compared the effects of R&D on the performance of the sectors and the economy as a whole, and concluded that the effect of the R&D is much more pronounced for the economy as a whole than for the manufacturing sector.

The issue of the contribution of R&I to economic growth is a subject of interest of researchers in the countries of the Western Balkans as well. Attempts on quantification of this contribution, using econometric analysis of available indicators of research and innovation, are presented in the studies of Aralica & Redžepagić (2012) for Croatia and Kutlača et al. (2012) for Serbia. The results of these studies suggest some positive effects of R&I on GDP in Croatia and Serbia, as well as the negative correlation of indicators of human resources in R&D and the growth of GDP in Serbia.

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3. Selected R&D indicators in the Republic of Serbia

The main data sources for the R&D activity are the regular annual statistical surveys on R&D organizations and on GBAORD (Government Budget Appropriations on Reseaarch and Development) conducted by the Statistical Office of the Republic of Serbia (SORS) on the bases of the Law on Official Statistics ("Official Journal of the RS", number 104/2009). R&D organizations and their activities are classified according to the type, size class and scientific field. Employees in the R&D sector are shown by occupation, scientific qualifications, type of employment and working hours, as well as by full-time equivalent (FTE). For calculation of the key indicators, methodological recommendations of international institutions (OECD, Eurostat) – Frascati Manual (FM) were used.

The adoption of the updated conceptual framework of new European System of National and Regional Accounts (ESA, 2010) entails a different treatment of expenditures for research and development in national accounts. The major change is treating these expenses as gross fixed capital formation, instead of the previous treatment as intermediate consumption. The influence of treatment of costs in R&D is coherent in the calculation of GDP, both by production and expenditure approach. It is, also, the most important methodological change in the conducted audit of GDP, and its full implementation requires continued improvement and regular updating.

In the period 2008 to 2015, there is a trend of growth of gross expenditure on R&D, but also a decrease in investments from the Government budget during the last year (Fig. 1 and 2). In recent years, the total funds invested in R&D (GERD) are characterized by constant fluctuation. The share of total budget funds that were spent on R&D is around 0.45% of GDP during the last five years. The soecific situation exsists in 2009, when the considerable expansion of R&I activities is identified. This is the year in which the accreditation of higher education institutions and programs is conducted, as well as the selection of a significant number of employees in teaching and scientific positions.

Figure 1. Share of total spending on R&D in GDP
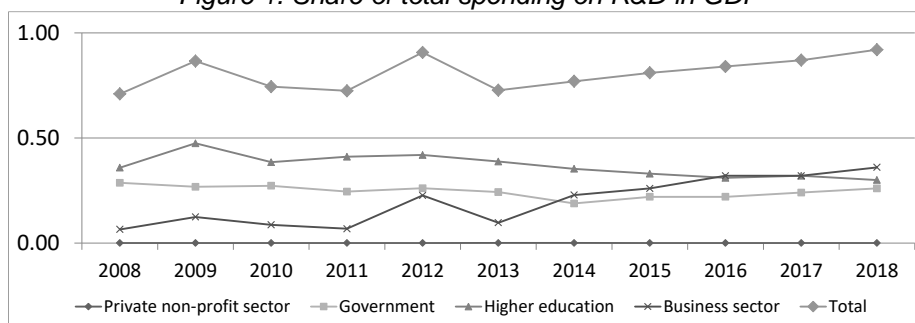
Figure 2. Share of budget funds for R&D in GDP Employees in R&D activities
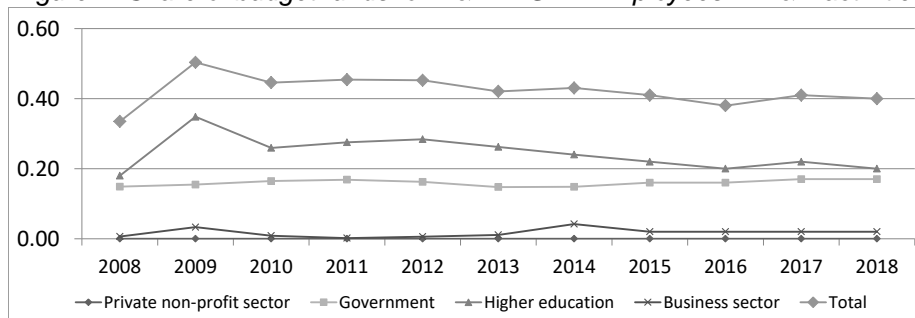
Table 1. Basic indicators of investment in research and development, in %

	2008	2009	2010	2011	2012	2013	2014	2015
Total resources/GDP	0.71	0.87	0.74	0.72	0.91	0.73	0.77	0.88
Budget resources/GDP	0.33	0.50	0.45	0.45	0.45	0.42	0.43	0.44
Business sector/GDP	0.06	0.12	0.09	0.07	0.23	0.10	0.23	0.28
Government sector/GDP	0.29	0.27	0.27	0.24	0.26	0.24	0.19	0.24
Higher education/GDP	0.36	0.47	0.38	0.41	0.42	0.39	0.35	0.36
Private non-profit setor/GDP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Expenditures of private and public enterprises / Total expenditures for RD	7.8	8.3	8.6	9.1	5.8	7.5	8.2	12.8
Expenditures of the	60.2	62.9	59.4	63.4	51.3	59.5	53.5	50.7

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state and local administration / total expenditures for RD								
Expenditures of the higher education / total expenditures for RD	22.3	20.9	28.4	21.8	33.7	25.1	25.9	23.9
Expenditures of non-profit organizations / Total expenditures for RD	0.7	0.8	0.0	0.1	0.1	0.1	0.0	0.0
Expenditures from abroad/ Total expenditures for RD	5.1	6.2	3.6	5.5	9.2	7.8	12.5	12.6
Researchers per 1000 inhabitants	1.57	1.64	1.73	1.88	1.84	2.04	2.13	2.29
Number of employees in RD / total employees	0.93	1.01	1.02	1.06	1.05	1.13	1.08	1.15
Number of researchers / total number of employees in RD	59.70	59.83	65.34	68.93	67.44	69.58	69.30	69.13
Total expenditures for RD / per capita in thous. RSD	1.39	3.41	3.13	3.41	4.51	3.93	4.22	4.93
Total expendituresfor RD / per researcher in thousands. RSD	887.9	2077.7	1806.5	1813.8	2453.4	1924.2	1984.1	2149.3

Source: SOR

R&D system in the Republic of Serbia in the observed period 2008-2015, is improved with increased financial support for R&I from public sources, and since 2012, also from international sources and loans. The number of researchers has increased from 11,534 in 2008 to 16,338 in 2015, with particularly meaningful participation of young researchers. According to the Statistical Office of the Republic of Serbia, in 2015, there were 23,629 employees in 279 institutions and organizations engaged in research activities in Serbia, of which 69.13% were researchers.

The latest available data for 2018 has shown that the total resources/GDP has reached its peak since 2008, by slightly overcoming the highest level reached in 2012 (observer for the period 2008-2015). This indicates that Serbian economy has also been recovered from the negative effects of the global economic crises. Another positive trend is recorded in expenditures from abroad, which has been more than doubled in 2018 (21,56%) compared

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to 2012 (9,2%) when it has reached its peak in the period from 2008-2015. The result in 2018 is caused mostly by the available resources from the Horizon 2020 EU funded program of projects.

Table 2. Basic indicators of investment in research and development, in %, period 2016-2018.

	2016	2017	2018
Total resources/GDP	0.84	0.87	0.92
Budget resources/GDP	0.38	0.40	0.40
Business sector/GDP	0.31	0.32	0.36
Government sector/GDP	0.22	0.24	0.26
Higher education/GDP	0.31	0.32	0.30
Private non-profit setor/GDP	0.00	0.00	0.00
Expenditures of private and public enterprises / Total expenditures for RD	16.45	18.12	20.39
Expenditures of the state and local administration / total expenditures for RD	45.55	46.55	43.14
Expenditures of the higher education / total expenditures for RD	25.03	15.42	14.91
Expenditures of non-profit organizations / Total expenditures for RD	0.0	0.0	0.0
Expenditures from abroad/ Total expenditures for RD	12.97	19.91	21.56
Researchers per 1000 inhabitants	2.35	2.3	2.32
Number of employees in RD / total employees	1.17	1.10	1.08
Number of researchers / total number of employees in RD	70.48	71.03	70.58
Total expenditures for RD / per capita in thouands. RSD	5.38	5.92	6.68
Total expendituresfor RD / per researcher in thousands RSD	2287.63	2566.50	2875.20

Source: SORS

4. Research and development expenditures in volume terms in Serbia

The basic methodological framework for the estimation of R&D investments is based on the principles and definitions provided by the System of National Accounts 2008 (SNA, 2008), European System of National and Regional Accounts (ESA, 2010) and internationally recognised standards and

recommendations for the estimation in volume terms, as defined in the Eurostat publication "Handbook on price and volume measures".

In this paper, for calculations at constant prices, the method of calculations at previous year prices is applied, which means that for each year, the previous year is taken as a base year. In order to ensure comparable data series for growth rate estimations, the chain-linking method needs to be applied and, thereby, data are reduced to a selected referent year.

Gross domestic expenditures on R&D encompass wide range of different types of costs, which are integrated by category into three subgroups:
- compensation of employees,
- material costs (material and other current expenses),
- investment costs (gross expenditures on fixed assets used in the R&D, such as land and buildings, instruments and equipment, computer software, etc.).

Each of those three groups is further broken into various components which embody the complex input cost structure of R&D activity in the country. Computation of R&D expenditures in volume terms is done by applying the input-cost and deflation methods. Measuring R&D in volume terms is not the straightforward exercise due to specific nature of R&D activity - products of R&D are, in most cases, unique and produced for internal use. When it does not seem feasible to measure market value, the use of input price change, as a proxy for output price change, is a standard approach.

R&D expenditures at constant prices are calculated by deflating the components at current prices. Since the total input structure for R&D includes: costs of raw materials, energy, costs of machinery and equipment and other fixed assets, salaries and wages for employees, and a number of other elements, the deflator used for R&D - composite price index for R&D - is estimated as the weighted average of the respective producer price indices of industrial products for: domestic market, consumer price indices, implicit deflator of gross fixed capital formation and index of average gross salaries and wages in R&D division 72 of NACE Rev. 2. Experimental R&D calculation at constant prices is performed in two stages:
- calculations of each costs component at previous year prices using appropriate indicator;
- calculations of chain-linked volume measures (referent 2010 year).

Determining the appropriate deflators and preparation of price index series for each cost category is the starting point of the estimation. Deflation is carried out at the lowest level of details available. Table 3. provides an overview of the deflators used by main types of R&D expenditures.

Table 3. Deflators applied for the R&D constant price estimates

Gross expenditures on R&D	Deflators
Investment costs	**Composite deflator for R&D investment expenditures**
Land and construction works	Composite price index for construction works
Domestic machinery and equipment	Composite price index for domestic equipment
Imported machinery and equipment	Composite price index for imported equipment
Patents, licenses, studies and projects	Consumer price index for education
Software	Composite deflator for software
Computers	Composite deflator for ICT equipment
Other	GFCF implicit price index
Current material costs	**Composite deflator for R&D current material costs**
Material costs for research and development activity	
Energy	Producer price indices of industrial products for domestic market for energy
Other material costs	Producer price indices of industrial products for domestic market for intermediate products
Payments based on contracts and copyright contracts	Consumer price index for education
Per diems, travel expenses, etc.	Consumer price index for services
Other operating costs and expenses	Consumer price index for services
Labour costs and compensation of employees in R&D	**Average gross salary index in R&D division**

Source: Authors

Afterwards, the respective weights, which were the basis for calculating the composite deflators, are obtained from statistical surveys. For labour costs deflation, the index of gross salaries has been selected. The labour cost index covers wages and salaries for all persons employed in the R&D (division 72 of NACE Rev. 2). For material costs, deflator is obtained as a weighted average

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of PPIs and CPIs related with the integral cost elements. These weights are obtained based on very detailed data from the regular R&D survey conducted by SORS. Investments in buildings, machinery, software, etc. are deflated by the composite price index for capital expenditure, defined by specific technical structure in R&D activity. The composite price index is calculated as the weighted average of applied producers' price indices of industrial products for domestic market, the consumer price index, GFCF implicit deflator and composite deflators for relevant parts of gross fixed capital formation related to R&D. Besides available indices, the new price indices, such as composite price index for ICT equipment and the composite price index for computer programs (software), are computed in this paper as well.

Gross domestic expenditures on R&D at constant prices are obtained by summing up estimated data on investment costs, material costs and gross salaries, in volume terms. The data on research and development at previous year prices within every section level (NACE Rev. 2) are obtained by deflating each cost component separately (the same deflator is applied for all activities by type of cost).

The following cumulative dynamics diagram reveals the underlying structure of the R&D input costs and their interaction in a time perspective. This chart (Fig.3) cumulatively displays the current totals of these three different series of expenditures in a comparative visual model. The space between curves indicates changes in the R&D cost structure during the observed period.

Figure 3. Gross domestic expenditures in R&D and the structural cost changes
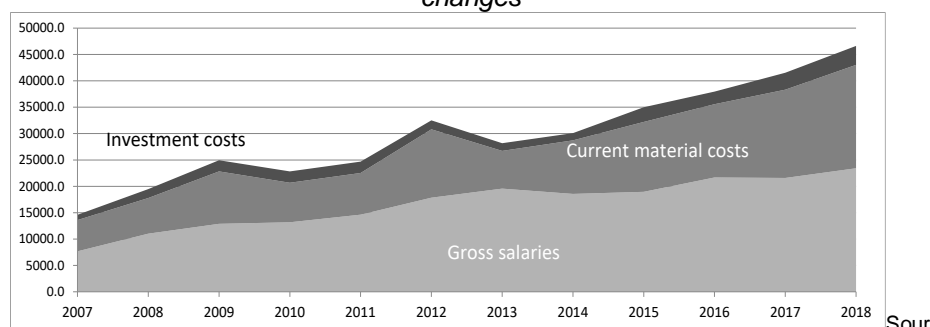
Source: Authors, SORS

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The dynamics of substantial parts of research and development gross expenditures in the Republic of Serbia is presented in the Table 4

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Table 4. GDP and R&D gross domestic expenditures, real growth rates, 2008-2015

	Cumulative real growth rate, %	Average annual real growth rate, %
Gross domestic expenditures on R&D	24.6	5.2
R&D gross salaries	19.2	5.1
Current material R&D expenses	32.1	4.3
Investment costs on R&D	23.0	9.3
GDP	*-0.8*	*-0.1*

Source: Authors, SORS

5. R&D investments by industries and effect of their allocation on economic performance in Serbia

In order to calculate current R&D expenditures, the following general rule was applied: all expenditures on purchases of R&D or on R&D production by market producers classified to division 72 NACE rev. 2 should be recorded as intermediate consumption. When those units perform their activities as sub-contractors to other units performing R&D, there is a possibility of double counting of the capital formation value. To elude this, acquisition of the intermediate R&D product, produced by the sub-contractor, is scored as intermediate consumption (as a component of the final product rather than a capital asset). In order to avoid double counting of capital goods value at the national economy level, it is necessary to make an adjustment related to the distribution of that part of R&D investments by section level of the Classification of Activities. Likewise, in order to avoid double counting, the following items of the fixed assets are subtracted from intramural expenditures on R&D:
- capital expenditures (gross expenditures on fixed assets used in the R&D such as land and buildings, instruments and equipment, computer software, etc.),
- payments for licences to use intellectual products (principally R&D assets, such as patents)
- expenditures on own-account production of software used in R&D
Preliminary estimation of investments in R&D by section level of NACE rev. 2 is calculated at current and constant prices.

The percentage distribution of the R&D investments by activities is presented inTable 5.

Table 5. Economic allocation of the R&D investments in Serbia, %

Sectors (NACE rev. 2)	2009	2010	2011	2012	2013	2014	2015
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**
A	0.0	1.3	0.0	0.2	0.0	0.5	0.5
B, C, D, E	12.2	9.4	11.5	21.5	22.7	21.2	19.6
F - Construction	0.8	0.5	0.2	0.4	0.8	0.3	0.6
G, H, I	2.3	4.1	2.0	1.2	1.4	1.5	0.8
J	0.6	0.8	0.2	0.3	0.5	4.4	1.4
K	0.3	4.0	3.8	0.0	1.9	0.6	0.1
L	0.0	0.0	0.0	0.1	0.0	0.0	0.0
M, N	3.5	6.2	7.6	17.3	4.6	4.4	3.0
O, P, Q	79.9	72.9	73.6	58.5	67.8	66.6	73.5
R, S	0.4	0.7	1.0	0.4	0.4	0.4	0.4

Source: Authors

The most substantial part of the investments in R&D in the period 2009 - 2015 was realized in the sections *O, P and Q* – in average 70.4% of the total R&D investments. Computation of R&D investments in volume terms is done by applying the input-cost and deflation method. able 6. provides an overview of the deflators used by main R&D investment components.

Table 6. R&D investment components and related deflators

R&D investments components	Deflators
R&D material costs	R&D material costs composite deflator
Wages and salaries in R&D	Average wages and salaries index in R&D activity
R&D export	R&D output composite deflator
R&D import	Composite deflator for R&D import
Own-account software in R&D	Composite deflator for own-account software
Patents and licences in R&D	Consumer price index for education
Other	R&D output composite deflator

Source: Authors

Composite deflator for output of R&D activities is obtained as the weighted average of the deflators of three basic inputs (material costs, investments costs and compensation of employees). Composite deflator for imported R&D is derived as the weighted average of the R&D implicit deflators in the

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countries from which the R&D products are mainly imported, adjusted with changes of exchange rates of respective currencies in RSD.The R&D investment level is significantly affected by the R&D net exports changes. Deflators for other R&D investment inputs (own-account software, patents and licenses, taxes and subsidies, consumption of fixed capital and net operating surplus) are obtained from the price statistics.

Table 7. R&D Investments, real growth rates, 2009-2015

Sectors (NACE rev. 2)	Average annual real growth rate, %	Cumulative real growth rate, %
Total	**2.0**	**12.4**
A	53.9	1,230.0
B, C, D, E	9.8	74.8
F	-4.7	-25.1
G, H, I	-15.2	-62.9
J	18.9	183.2
K	-16.8	-66.7
L	-17.5	-68.4
M, N	-0.9	-5.5
O, P, Q	0.8	5.0
R, S	-0.6	-3.4

Source: Authors, SORS

Over the period 2009 - 2015, the cumulative growth of the investment in R&D amounted to 12.4% (with an average annual real growth rate of 2.0%). The most significant positive changes in the level of the R&D investments are realized in the sectors A, B, C, D, E *(*Table 7*)*. Observing at the A36 level, the expansion of R&D activity was recorded in 2012, resulting from the significant contribution of the growing R&D investments of the manufacturing industries (13.6 percentage points). Contribution of R&D investments real growth to the GDP by economic sectors (A3) is presented in Table 8.

Table 8. Contribution of R&D investments to the GDP real growth by sectors (A3), percentage points

	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Total	**-0.051**	**-0.027**	**0.048**	**0.133**	**-0.162**	**0.008**	**0.086**
Agriculture	0.000	0.009	-0.009	0.001	-0.001	0.003	0.001
Manufacturing industries	0.026	-0.027	0.020	0.103	-0.021	-0.014	0.007
Services	-0.077	-0.009	0.037	0.029	-0.139	0.020	0.079

Source: Authors, SORS

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[6] According to the ESA 2010 Transmission programme of data, activities are aggregated into 3 aggregates: (A);(B,C,D,E,F); (G,H, I, J,K, L,M, N, O,P, Q, R,S,T).

In addition, beside the explicitly calculated R&D impact on the GDP real growth, for the purposes of planning and economic decision-making, it is necessary to investigate whether there is an interdependence between the R&D and other macroeconomic variables by sections (NACE rev. 2). As the main indicators of comprehensive economic and R&D activity in the country, the following macroeconomic aggregates have been identified and scrutinized by industries: GVA, output and investments in research and development. To enable comparison and analysing development of the selected phenomena through different time periods, the data series are chain-linked with the reference 2010 year.

Potential interconnections between these indicators are tested by applying correlation analysis techniques. First of all, it is necessary to calculate the appropriate lagged value in order to examine the long-term relationship between affected data series. To that end, the optimal lagged length is selected as 1 by considering the Akaike (AIC) and Schwarz (SC) information criterions. Correlation coefficients calculated between the pairs of indicators are shown in Table 9.

Table 9. Correlation coefficients between R&D investments and macroeconomic indicators, by industries, 2009-2015

Sectors (NACE rev. 2)	Correlation coefficients between R&D investments and selected indicators:			
	Output	**Output (-1)**	**GVA**	**GVA (-1)**
A	0.08	0.44	0.19	0.13
B, C, D, E	0.67	0.54	0.85	0.61
F	-0.16	0.51	-0.16	-0.20
G, H, I	-0.67	-0.26	-0.46	-0.19
J	0.26	0.46	-0.15	0.44
K	0.50	0.65	0.54	0.63
L	-0.19	-0.22	0.06	-0.25
M, N	0.00	0.31	0.55	-0.30
O, P, Q	-0.32	0.09	-0.24	0.08
R, S	-0.08	-0.21	0.12	0.73

Source: Authors, SORS

The values of the correlation coefficients presented in Table 9 indicate potential interdependencies between the selected indicators. However, the value of correlation coefficient can describe the direction and strength of connections between variables, but it is not a sufficient condition to establish a causal relationship (in either direction). The absolute values above 0.5 can be considered as indicators of relatively strong interdependence between two variables.

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A strong positive correlation was identified between the value of the R&D and GVA in the section B, C, D, E expressed in volume terms (r = 0.85), as well as between the real R&D investments in the section R, S and value of the corresponding GVA with lag 1 (r = 0.73) for the period observed. Furthermore, the positive and moderately strong correlation is also discovered between R&D in the section of financial and insurance activities and output with lagged length selected as 1 in the same section (r = 0.65). On the other hand, R&D investments in O, P, Q, which count on the largest share in total investments for research and development, do not show a link among the economic aggregates inspected by the section, whereas, in some industries the negative correlation has been identified.

As already mentioned, even a very strong correlation does not imply causation. Therefore, based solely on correlation analysis, the existence (positive or negative) or the absence of R&D investment influence upon the indicators observed by activities can't be confirmed. Consequently, the nature of these relationships should be further examined by applying the more appropriate statistical and econometric techniques of variables and time series analysis. Contemporary allocation of gross fixed capital formation in the Republic of Serbia is moving towards the increasing share of intellectual property products, in which the prevailing part belongs to the R&D investments. Changes in the economic structure and country's specialization for specific activities inevitably lead to R&D expenditures increase in respecting sectors. Industries that have reached an average annual R&D investment real growth rate above the 15%, recorded a remarkable share increase in the total R&D investment structure. Tendencies of these structural economic changes should be based on long-term sustainability.

5. Relationship between R&D Investments and Economic Growth in Serbia

In this article, the relationship between R&D expenditures and economic growth was scrutinized in Serbia for the period of 1995 to 2015. Experimental results of the analysis are based on the data set obtained from relevant surveys conducted in the SORS. The interdependence among economic and R&D performances in the country is tested on numerous indicators summarized in Table 10.

Table 10. R&D and relevant macroeconomic indicators

Variable	Description
R&D parametars	
R&D	R&D GFCF, chain-linked volume measures (reference 2010 year)
R&Dcop	R&D GFCF, constant prices (previous year prices)
R&Dcs	R&D capital stock, chain-linked volume measures (reference 2010 year)
IRuBDP	R&D GFCF, % of GDP
R&Dpc	R&D GFCF, chain-linked volume measures (reference 2010 year), per capita
R&Dgrate	R&D GFCF real growth rate
R&Dlc	R&D labour costs, chain-linked volume measures (reference 2010 year)
R&Dmc	R&D material costs, chain-linked volume measures (reference 2010 year
Macroeconomic	**Indicators**
GDPcup	Gross domestic product, current prices
GDPcop	Gross domestic product, constant prices (previous year prices)
GDP	Gross domestic product, chain-linked volume measures (reference 2010 year)
GDPgrate	GDP real growth rate
GDPpc	GDP, chain-linked volume measures (reference 2010 year), per capita
GDPpcgrate	Real GDP per capita, growth rate
GFCF	Gross Fixed Capita Formation, chain-linked volume measures (reference 2010 year)

In order to investigate the existence of causality between the selected indicators, the appropriate econometric methods of contemporary time series analysis are applied. These statistical techniques are effectively applicable to economic disciplines, primarily because the majority of economic phenomena can be presented in a form of the vector time series model. Basic methodological framework for modeling macroeconomic time series is the concept of co-integration. The precondition of co-integration technique application is stationarity of individual non-stationary time series linear combination.

Two non-stationary series are co-integrated or they converge toward the long-run steady state, if they are integrated of the same order and if their deviation from equilibrium path is stationary. Based on Granger's theorem, these variables can be represented in the form of error correction model (ECM).

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ECMs represent a theoretically-driven approach useful for estimating both short-term and long-term effects (the latter one by so-called error correction mechanism) of one time series on another. The term error-correction relates to the fact that last-periods deviation from a long-run equilibrium, the error, influences its short-run dynamics. Thus, ECMs directly estimate the speed at which a dependent variable returns to balance after a change in other variables. In testing of the co-integration relationships between the selected data series in this research, the following tests are applied: unit root test, co-integration test, Granger's causality test, information criterions and standard statistical tests for the assessment of the linear regression model assumptions. The results obtained in this study are derived using EViews software package, which proved to be an excellent tool for a complex statistical data analysis, econometric model simulations, time series analysis, forecasting, etc.

Table 11. Contribution of R&D investments to the GDP real growth, in percentage points

	R&D real growth rate, %	GDP real growth rate, %	R&D, % of GDP	R&D contribution to the GDP real growth rate, percentage points
1996	-4,7	2,4	0,4	-0,02
1997	25,5	7,2	0,5	0,10
1998	11,2	2,4	0,5	0,05
1999	1,2	-12,1	0,5	0,01
2000	3,7	7,8	0,5	0,02
2001	-10,9	5,0	0,5	-0,05
2002	-3,4	7,1	0,5	-0,02
2003	-5,1	4,4	0,5	-0,03
2004	11,6	9,0	0,6	0,06
2005	4,5	5,5	0,6	0,03
2006	16,1	4,9	0,7	0,10
2007	-4,2	5,9	0,7	-0,03
2008	19,1	5,4	0,8	0,13
2009	-6,7	-3,1	0,7	-0,05
2010	-3,6	0,6	0,7	-0,03
2011	6,6	1,4	0,8	0,05
2012	17,7	-1,0	0,9	0,13
2013	-17,8	2,6	0,7	-0,16
2014	1,2	-1,8	0,7	0,01
2015	11,8	0,8	0,8	0,09

Source: Authors, SORS

In order to quantify the contribution of investments in research and development to the GDP real growth, initial data series at current prices are converted in real terms, by applying previously calculated composite deflator for R&D. Based on these data, estimated for the period 1995-2015, the contribution of R&D investments to the GDP real growth is explicitly shown and expressed in percentage points (Table 11).

Depending on the R&D share in GDP, as well as on value of R&D real growth rate, the contribution ranges from - 0.16 to 0.13 percentage points in the reporting period. Besides the explicitly calculated R&D impact on the real GDP growth, for the purposes of planning and economic decision-making, it would be worthwhile to examine whether there is an interdependence between the R&D and GDP real growth. Potential connections between observed indicators are examined by applying correlation analysis. The values of the correlation coefficients indicate potential interdependencies between the selected indicators. The absolute values above 0.5 can be considered as relatively strong interdependence between the two variables. Nature of this relationship is further investigated by applying diverse statistical and econometric methods.

A strong positive correlation was identified between the value of the GDP and R&D expressed in volume terms (r = 0.83), as well as between the share of investments in research and development in GDP and value of the real GDP (r = 0.92) for the period observed. Furthermore, the positive and moderately strong correlation is also discovered between R&D and gross fixed capital formation (r = 0.79). This may mean that higher innovation activity could cause intensive development of the economy and higher productivity expressed through the changes of main macroeconomic aggregates (GDP and GFCF). On the other hand, higher investments in R&D could be the result of a higher GDP level.

Assuming that GDP at volume terms is dependent variable, then, in relation to the R&D performance, it is best exemplified by R&D indicator taken as a percentage of gross domestic product, considering that the value of correlation coefficient of this indicators pair is closest to 1. In this research, the dependency between R&D expenditures and economic growth, shown through the GDP, is scrutinized having in mind that both selected aggregates represent the comprehensive measure of economic and innovation activities in the country. The R&D data are first calculated in current prices, and then deflated by appropriate prices indices. The analyses are performed by taking the logarithms of the given series expressed in volume terms. Since the variables are in log form, the interpretation of the results shows the elasticity

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of the phenomenon measured. The data set used in this research comprises of annual observations, and relates to the period from 1995 to 2015.

The stationarity of series included in the analyses is explored as well. In the process, expanded Dickey-Fuller's unit root test is employed to check whether the series are I(1) or I(0). The null hypothesis is stated assumption of the non-stationarity against the alternative hypothesis that the observed process is stationary. The results of test show that the null hypothesis of a unit root in each time series were failed to reject at 5 percent significance level but strongly rejected at their first difference. This implies that our two variables, GDP and R&D, have unit root at level but after first differencing they become I(1), what allows testing assumptions about the existence of co-integration.

In addition, the appropriate lagged values have to be calculated in order to examine the long-term relationship between R&D and GDP series via the Johansen co-integration test. To that end, the optimal lagged length is selected as 1 by considering the Akaike (AIC) and Schwarz (SC) information criterions. Furthermore, testing is performed by using the Johansen-Juselius procedure that provides a complete integration analysis of macroeconomic time series: determination of the number of co-integrating vector(s), identification of related parameters, division into endogenous and exogenous variables, identification of sources of non-stationary, etc.

The system of equations in which the series that are found stationary at the same order in co-integration test are included is based on Vector Auto-Regressive (VAR) model. In this test, the trace and maximum eigenvalue statistics are used in order to investigate the existence of a co-integration relationship between the series examined. The obtained results indicate that there is a unique long-term or equilibrium relationship between variables. Both trace statistics and max-eigen statistics confirm that there is one cointegrating vector at 5% significance level. Once confirmed the existence of co-integrating vector, the relationship between the two variables in the short term and long term can be evaluated with error correction models (ECM). Upon further investigation, the parameters obtained from vector error correction model are estimated and analysed.

In order to determine the direction of cause and effect relationship between the series examined in the research, the causality test is employed. To that end, Granger causality test is applied by using stationary DLOGR&D and DLOGGDP series. It is verified that R&D series adapts to the equilibrium path, i.e. LOGGDP Granger cause LOGR&D. On the other hand, testing the R&D impact on GDP, it was not conceivable to reject the null hypothesis (p =

0.2601). Accordingly, it could be concluded that LOGR&D does not Granger cause LOGGDP. The model estimated has passed several commonly used diagnostic tests regarding that the residuals have no evidence of serial correlation and heteroscedasticity and have multivariate normal distributions.

7. Concluding remarks

Among economists and policymakers, but also in general public, there is consensus that R&D is a key prerequisite for the sustainable long-term economic growth and rising of living standard and social welfare. By subtracting the impact of price fluctuation, the R&D real growth becomes visible, providing a potential background for policymakers and insight for implementing an adequate development strategy that will eventually lead to a sustainable economic system. The experimental calculation of R&D in real terms, applied in this paper, relies on the recommended input-cost and deflation methods in price and volume measurement. Even though input-cost measures are commonly used, a deflator obtained this way reflects only the influence of the price fluctuations of R&D costs, without allowing changes in productivity to affect the real measures of R&D output. Considering that R&D expenditures are an important source for the increase of productivity, it is necessary to improve quality-adjusted volume measures of R&D and prepare of consistent time series in compliance with the international practices and standards.

The empirical results achieved in the study reveal a strong interdependence among the R&D expenditures and economic performance at the national level in Serbia. Based on these findings, a statistically significant causality relationship oriented from GDP real growth to R&D activity is confirmed. As real economic activities and growth rate increase, R&D must also increase for sustainability. However, the causality in the opposite direction cannot be verified.

Having in mind that future economic progress will be driven by the invention and application of new technologies and that R&D is one category of spending that develops these advanced technologies, it is of utmost importance for developing economies to continuously encourage increasing investments in research and innovation. In brief, R&D activities are generally accepted as the underlying driving force of economic goals achievement. Therefore, strategic orientation on this issue should be turned towards the reaching an adequate "profitability threshold" regarding the R&D percentage share in GDP, where the benefits of investments deployed in research and

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development area would be recognizable and their impact on economic growth visible.

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