Innovation and competitiveness in the European Union countries

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Abstract: This paper examines innovation performance in association with competitiveness development in the European Union (EU) countries. The innovation factor indicators are linked to the global competitiveness index (GCI). The two set hypotheses are tested: first, that expenditure for research and development (R&D) in a company, and university-industry collaboration in researches affect GCI. Second, that the relationships exist between the GCI and innovation factor indicators, but there is a different strength of the connection. A special focus of the analysis is on the two sub-periods: during the economic crisis in the years 2008–2013 and the post-economic crisis in the years 2014–2017. The research contributes to a better understanding of the relationships between expenditures for R&D in a company, university-industry collaboration in researches, and the GCI. The results also confirmed a positive correlation, but different strength of the connection between the GCI and other analysed innovation factor variables such as innovation capacity, quality of research institutions, availability of scientists, a number of registered patents applications, and government procurement of advanced technology products. The results suggest that gross domestic product per capita is positively correlated with innovation factor indicators and the GCI.

Keywords: competitiveness; innovation performance; global competitiveness index; GCI; European Union.

Reference to this paper should be made as follows: Marčeta, M. and Bojnec, Š. (2021) 'Innovation and competitiveness in the European Union countries', *Int. J. Sustainable Economy*, Vol. 13, No. 1, pp.1–17.

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1 Introduction

In the age of globalisation, the European Union (EU-28) countries are increasingly concerned with the issue of global competitiveness and economic growth (Marčeta and Bojnec, 2020). An important task for the EU-28 countries is the increasing cohesion of economies and openness in the world and the pursuit of higher levels of competitiveness and economic growth. An important role in this process is expected from innovation. Innovation might be linked to industry and university collaboration as a driver for competitiveness and economic growth.

The disparities and heterogeneity between the EU-28 countries in terms of the level of economic development, which is measured by gross domestic product (GDP) per capita, and innovation activities, have motivated the research on their global competitiveness. Breuss (2018) argued that the new EU member states, although they are growing continuously faster than the old EU member states, they still need to go a long way until the catching-up with the richest ones. The EU's objective is to reduce disparities between EU countries, as they have become a threat to income inequality and economic progress. Governmental policy is needed to underpin income inequality and global competitiveness. There are differences between the EU-28 countries in terms of the innovation factor related to the performance of universities, research activities, scientists, and patents. The key differences between EU-28 countries lie primarily in the pillar of innovation.

The Europe 2020 strategy sets out recommendations for improving competitiveness and economic development with the following priorities (European Commission, 2010): the development of knowledge and innovation-based economy and promoting a more resource-efficient competitive economy. Other incentives include research and development (R&D) funding, innovative ideas for new products and services that generate growth and jobs; improving the education system and ensuring that young people enter the labour market; improving the business environment and supporting industry, with the important link between companies and research organisations and institutions and EU competition policy makes markets work better and brings tangible benefits to Europe.

We aim to present that are available and appropriate innovation factor indicators for analysing the competitiveness of the EU-28 countries. These indicators are: innovation capacity, quality of research institutions, expenditures for R&D in a company as business research on the extent to which companies invest for R&D, university-industry collaboration in research or to what extent companies and universities participate in research, availability of scientists, number of registered patents applications, and government procurement of advanced technology products. In addition, GDP per capita as a level of economic development indicator is included in the analyses.

Innovation can be an important factor in policy-making that can help to improve economic growth and competitiveness.

The main objective of the study is to measure innovation performance in the EU-28 countries using innovation factor indicators of the global competitiveness index (GCI). More specifically, this paper aims to examine and evaluate the effects of innovation on competitiveness, the innovation factor indicators that affect competitiveness. The impact of innovation is examined from various perspectives, considering GDP per capita due to the heterogeneity of the EU-28 countries. It is significant to understand the competitiveness of the EU-28 countries and diverse driving factors enhancing global competitiveness.

The study contributes to the impact of innovation on the competitiveness of the EU-28 countries based on individual innovation factor indicators defined by the World Economic Forum (WEF) concept. The study addresses two issues: first, the relationships among the GCI variables and second, the impact of innovation factor indicators on GCI.

The rest of the paper is structured as follows. The second section provides a review of the literature. We define innovation and principal innovation factor variables for measuring GCI. In the third section methodology and data are explained. In the fourth section there are analysed trends in GCI in the period 2008–2017. The EU-28 country's performance is assessed and compared using correlation and regression analyses for two sub-periods: during the economic crisis in the years 2008–2013 and the post-economic crisis in the years 2014–2017. The fifth section presents results and discussion. The final section concludes and provides some implications.

2 Review of literature

Global competitiveness requires new products and innovations in the global market from countries and enterprises. Universities can be important producers of knowledge. Innovation, technology diffusion, and globalisation have modified the nature of competition.

There are different approaches and findings regarding competitiveness measurement. Karman (2019) investigated the relations between the flexibility and agility of human resources and achieving sustainable competitiveness at the micro-level. Comparative advantage theory says that trading allows specialisation for any location that specialises in products in which it has competitive advantages. According to Porter (2000), the basis for national competitiveness is productivity, which in the long run is the main determinant of each country's standard of living. According to Porter (2008) comparative advantage influences on productivity and competitiveness. Productivity is a measure of efficiency and represents the key to economic growth. High productivity means that the economy creates high added value or high-tech products with important links with research and innovation.

Schumpeter (1934) defines innovation as introducing new products and improving quality, new methods in production based on technology and scientific discoveries, opening new markets, providing new sources of raw materials and new market structures in an industrial organisation. Fagerberg (1988) developed a model of competitiveness in domestic and foreign markets, which depends on the ability to compete in technology, the ability to compete in delivery (capacity), and the ability to compete in price. According to Fagerberg et al. (2010), innovation is frequently driven by a highly educated workforce in R&D firms closely linked to leading scientific centres of excellence.

The respectable source of global competitiveness is WEF. The global competitiveness of countries is a set of institutions, policies, and factors that determine the level of country productivity (WEF, 2014). A central objective of the global competitiveness report is to assess the capacity of the world economy to achieve sustained economic growth (Mcarthur and Sachs, 2002). According to WEF (2014), the development and maintenance of competitiveness depend mainly on the well-functioning of 12 pillars of competitiveness which are organised into three stages of economic development: basic, efficiency-driven, and innovation. Out of the 12 pillars, a statistically significant relationship with the GCI indicator of Slovakia was confirmed for 7 pillars, but not proved for the following pillars: 4th Pillar: Health and primary education, 5th Pillar: Higher education and training, 7th Pillar: Labor market efficiency, 9th Pillar: Technological readiness and 10th Pillar: Market size (Sofrankova et al., 2017). The relationships between all pillars and the GCI do not exist. Our focus is on factors of innovation that can identify challenges in improve the GCI.

Most competitive countries obtain the highest scores for innovation factors. In Lithuania, there is a significant relation between country competitiveness and innovation factors embracing R&D activities, technological readiness, and business sophistication (Pilinkus and Boguslauskas, 2007). Lithuanian national education and innovation system are viable because of its strong science and technology research tradition and engineering orientation. New technology investments are bringing together different actors such as universities, research institutes, business enterprises, and governmental institutions with the aim to shape and implement both short-term and long-term strategies. Scientists and engineers in companies contribute to research capacity, project work, patents and innovation helping to transfer the results of university research to local businesses or industry.

Universities are the engine of research and innovation that can lead to new ideas, projects, innovations and patents (Lester and Sotarauta, 2007; Florida, 2006; Goddard and Vallance, 2013; Smith, 2017; Breuss, 2018), which can improve global competitiveness and level of economic development. The importance of a globally competitive university in research and education has been argued by several studies because knowledge and human capital are key factors in prosperity and development (Harisson and Turok, 2017). Improvements in technology (both new goods and better ways of producing goods) can be achieved by technological innovation creating a truly new technology, or by technological diffusion adopting (and adapting) a technology that has been developed globally (Mcarthur and Sachs, 2002; Abad-Segura et al., 2020). Innovation is the substantial investment in R&D to create new products and offers better methods of production and distribution (Loo, 2018).

The cooperation of companies and universities or networks represent a response to the processes of globalisation and, in the light of spatial-temporal compression, at the same time also the drivers to increase competitiveness in the local, national and international environment. A competitive environment should be ensured since the cooperation of universities with industry is an important source of competitive advantage. University management needs to be aware of changes and transformations in the increasing importance of linking universities, knowledge and technology institutions to ensure greater cooperation with the local environment, to promote the crucial role of scientists, knowledge transfer and also the emergence of innovations and new businesses at local and international level (Florida and Cohen, 1999).

The concept for promoting university-industry collaboration has been reinforced by the application of Porter's (2007) cluster concept and of Triple-Helix model to innovation-led economic competitiveness. Etzkowitz (2003) developed a Triple-Helix concept pointing to interactions between institutions, industry, universities and government which fosters entrepreneurship, innovation and economic growth. Universities play a central role in contributing to the creation and transfer of knowledge or human capital, and to enhance research activities and the flow of knowledge into the economy. The Triple-Helix approach was applied to study collaboration between university-industry-policies to identify competitive advantages and to pursuit innovation activities in the Slovenian forestry value chain (Malek et al., 2015).

The expansion of tertiary education can have positive effects for the individual and the economy because the economic development of the country is positively correlated with the number of students enrolled in tertiary education and also with the quality of education (Čepar and Bojnec, 2013, 2014).

The links were found between total factor productivity and R&D expenditure (Nekrep et al., 2018) and universities (Drucker and Goldstein, 2007). In 2017, the EU-28 countries spent around 2.1% of GDP on R&D (Eurostat, 2019). Sofrankova et al. (2017) pointed out the link between R&D expenditures and innovation in businesses. The statistically significant relationship among the R&D expenditure and the score of individual pillars within the overall GCI indicator was confirmed for each of the four Višegrad countries: Slovakia and Poland with 5 pillars, Hungary with 7 pillars, and the Czech Republic with 3 pillars.

Public policies and strategies to achieve the country's competitiveness are different from the conventional approach to promoting the university's role in economic development through intellectual property, technology and enterprise incubators (Lester, 2007). Government policy and strategic direction in research are important for promoting education, modernising the university system and public procurement.

Our research focus is on analysing selected innovation factor indicators and the evolution of GCI across the EU-28 countries. The specific focus is on the role of different technological innovation indicators that determine the competitiveness based on the WEF concept of innovation. The main thesis is innovation factor indicators affect competitiveness in the EU-28 countries. We aim to identify technological innovation factor indicators, differences and patterns in the development of GCI in assessing competitiveness. We also analyse the correlation between different variables of the innovation environment and assess the impact of innovation factor indicators on the global competitiveness of the EU-28 countries by testing the following two hypotheses:

H1 The level of competitiveness and different innovation factor indicators are positively correlated and exist in heterogeneous relationship strength within the EU-28 countries.

H2 Different combinations of innovative factor indicators, the involvement of universities- industry collaboration in research and expenditures for research in a company are positively associated with the GCI.

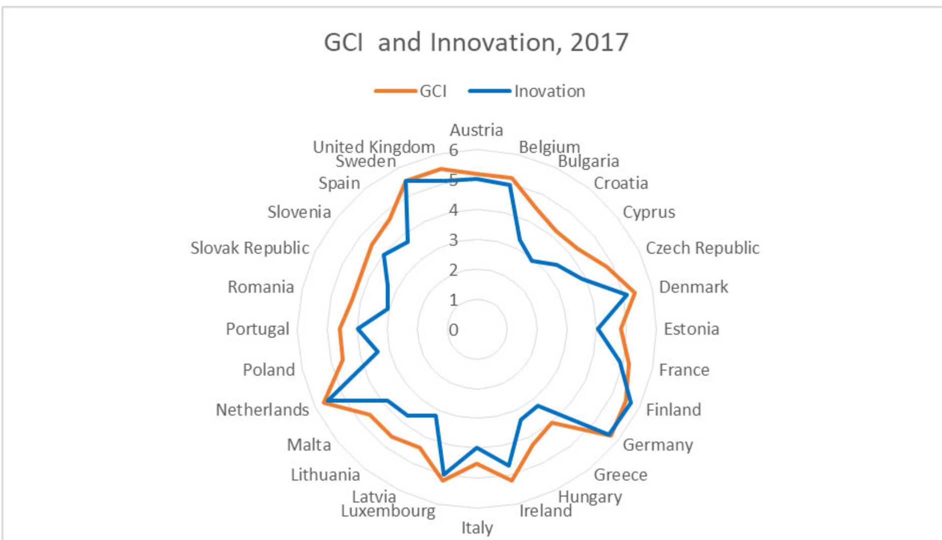
To measure the strength of correlation between different innovation factor indicators and the level of competitiveness or the GCI in the EU-28 countries, has to be motivated with the structure of the innovation factor indicators. They may be correlated with the GCI, but the strength of correlation and its significance can be different. Therefore, it is interesting to test both strength and significance of correlation. Furthermore, we estimate the dependence to establish their impacts on the GCI. Countries with higher expenditures for business research can be also countries with high innovation capacity and global competitiveness. We can expect that if a country has good capacity in terms of universities-industry collaboration in researches it can have a greater impact on global competitiveness and vice versa.

3 Data and methodology

3.1 Data

The empirical analysis is based on data from the WEF reports for the EU-27 countries in the period 2008–2013 and the EU-28 countries, including Croatia, in the period 2014–2017. The descriptive analysis, correlation and regression analyses provide insights on the relations between competitiveness and innovation. The links between innovation environment and GCI indicator in the EU-28 countries are different as can be seen from Figure 1 using a spider chart for the year 2017. Differences are also in the development of the GCI indicator in the period 2008–2017 (Table 1).

Figure 1 Comparison of GCI and innovation in the EU-28 countries, 2017 (see online version for colours)



Source: Authors' presentation based on WEF (2017)

In 2017, according to the innovation factor indicator, Finland was on the top with the highest value of 5.69, followed by Germany 5.65, and the Netherlands 5.55. The lowest value is noticed for Croatia (2.94), Romania (3.08), Latvia (3.22) and Slovakia (3.32). Mostly higher values are for the non-Mediterranean old EU member states and average or lower values are for the old Mediterranean and new EU member states from Central, Mediterranean and Eastern Europe.

Table 1 presents the development of GCI indicator in 10-years interval from 2008 to 2017 for the EU-28 countries. We can see the highest score of GCI for Germany, the Netherlands, Sweden, Finland, Denmark, the UK, France, Ireland, Austria, and Belgium. The lowest score values of GCI were found for new EU member states from transition countries such as Bulgaria, Romania, Croatia, Hungary, Slovakia, and Cyprus as well as Greece from the group of the old EU member states. Over time some improvements among new EU member states can be noticed for Poland, Malta, Romania, and Bulgaria. Despite some improvements, new EU member states have not caught up the developed EU member states (Breuss, 2018).

Table 1 Development of GCI indicator for the EU-28 countries during the period 2008–2017

Country	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Austria	5.23	5.13	5.09	5.14	5.22	5.15	5.16	5.1	5.2	5.2
Belgium	5.14	5.09	5.07	5.20	5.21	5.13	5.18	5.2	5.3	5.2
Bulgaria	4.03	4.02	4.13	4.16	4.27	4.31	4.37	4.3	4.4	4.5
Croatia	4.22	4.03	4.04	4.08	4.04	4.13	4.13	4.1	4.1	4.2
Cyprus	4.53	4.57	4.50	4.36	4.32	4.30	4.31	4.2	4.0	4.3
Czech Republic	4.62	4.67	4.57	4.52	4.51	4.43	4.53	4.7	4.7	4.8
Denmark	5.58	5.46	5.32	5.40	5.29	5.18	5.29	5.3	5.3	5.4
Estonia	4.67	4.56	4.61	4.62	4.64	4.65	4.71	4.7	4.8	4.8
France	5.50	5.43	5.37	5.47	5.55	5.54	5.50	5.1	5.2	5.2
Finland	5.22	5.13	5.13	5.14	5.11	5.05	5.08	5.5	5.5	5.5
Germany	5.46	5.37	5.39	5.41	5.48	5.51	5.49	5.5	5.6	5.7
Greece	4.11	4.04	3.99	3.92	3.86	3.93	4.04	4.0	4.0	4.0
Hungary	4.22	4.22	4.33	4.36	4.30	4.25	4.28	4.2	4.2	4.3
Ireland	4.99	4.84	4.74	4.77	4.91	4.92	4.98	5.1	5.2	5.2
Italy	4.35	4.31	4.37	4.43	4.46	4.41	4.42	4.5	4.5	4.5
Luxembourg	4.26	4.06	4.14	4.24	4.35	4.40	4.50	5.2	5.2	5.2
Latvia	4.45	4.30	4.38	4.41	4.41	4.41	4.51	4.5	4.4	4.4
Lithuania	4.85	4.96	5.05	5.03	5.09	5.09	5.17	4.5	4.6	4.6
Malta	4.31	4.30	4.34	4.33	4.41	4.50	4.45	4.4	4.5	4.6
Netherlands	5.41	5.32	5.33	5.41	5.50	5.42	5.45	5.5	5.6	5.7
Poland	4.28	4.33	4.51	4.46	4.46	4.46	4.48	4.5	4.6	4.6
Portugal	4.47	4.40	4.38	4.40	4.40	4.40	4.54	4.5	4.5	4.6
Romania	4.10	4.11	4.16	4.08	4.07	4.13	4.30	4.3	4.3	4.3
Slovak Republic	4.40	4.31	4.25	4.19	4.14	4.10	4.15	4.2	4.3	4.3
Slovenia	4.50	4.55	4.42	4.30	4.34	4.25	4.22	4.3	4.4	4.5
Spain	4.72	4.59	4.49	4.54	4.60	4.57	4.55	4.6	4.6	4.7
Sweden	5.53	5.51	5.56	5.61	5.53	5.48	5.41	5.4	5.5	5.5
UK	5.30	5.19	5.25	5.39	5.45	5.37	5.41	5.4	5.4	5.5

Source: Authors' compiled based on WEF (2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017)

The following eight indicators are included in the WEF estimates of the GCI indicator:

- innovation capacity (*capac.of inov)*
- quality of research institutions (q*ual.research)*
- expenditures for R&D in a company as business research on the extent to which companies invest for R&D (*expend. for research)*

- university-industry collaboration in researches or to what extent companies and universities participate in research (*coll.univ)*
- government procurement of advanced technology products (*gov.proc)*
- availability of scientists *(scientists)*
- number of registered patents applications *(patent)*
- GDP per capita as a level of economic development indicator (*gdpp).*

A descriptive statistical analysis is used to compare the position of the EU-28 countries based on eight variables of GCI innovation factor indicators. Table 2 presents descriptive statistics for innovation factor indicators for two sub-periods: during the economic crisis 2008–2013 and post-economic crisis 2014–2017. Data for the former do not cover Croatia. In addition, standard deviation of the variables and variance is presented. The standard deviation is the highest for registered patents and GDP per capita. Standard deviation and variance reflect differences in indicators across the EU-27 countries in the first period and across the EU-28 countries for the second period.

Table 2 Descriptive statistics for innovation factor indicators for the EU-27 countries in the period 2008–2013 and for the EU-28 countries in the period 2014–2017

2008–2013	*Mean*	*Std. deviation*	*N*	*2014–2017*	*Mean*	*Std. deviation*	*N*
GCI	4.715	.490	82	GCI	4.763	.450	112
Gdpp	98.900	41.549	82	gdpp	98.804	42.706	112
capac.of inov	4.134	.924	82	capac.of inov	4.620	.767	112
qual.research	4.717	.835	82	qual.research	4.882	.782	112
expend. for research	3.916	.985	82	expend. for research	4.049	.913	112
coll.univ	4.229	.855	82	coll.univ	4.258	.874	112
gov.proc	3.674	.580	82	gov.proc	3.383	.561	112
Scientists	4.582	.617	82	scientists	4.447	.594	112
Patent	50.601	67.466	82	patent	81.876	90.757	112

Source: Authors' calculations based on WEF reports (2008, 2010, 2013, 2014, 2015, 2016, 2017)

The number of observations for the first period is 82 and for the second period 112. The average value of innovation factor indicator estimates is the highest in the observed periods for patents, while the lowest is for government procurement of advanced technologies. The standard deviation is the highest for the patent indicator, showing the dispersion of the value of the variable with respect to the arithmetic mean. Big variations in mean values suggest that changes are needed, especially in improving the capacity of innovation, patents and thus achieving greater competitiveness.

3.2 Methodology

As methods of analyses, we use correlation and regression analyses. A correlation matrix reveals key factors strongly related to the GCI according to the underlying hypothesis. To analyse the impact of independent variables on GCI, we use panel data over two different time periods. We want to find out how the GCI depends on innovation factor indicators. The purpose of the regressions analysis is to identify key associations between variables based on multiple regression analysis by individual factors.

In multiple regression analysis GCI is the dependent variable, β_0 is regression constant, β_n is multiple regression coefficient showing the expected changes, I_n is the independent variable, where n is the number of innovation factor indicators/explanatory variables, which in our case is 8, and ε error term. The model is determined by the equation:

$$GCI = \beta_0 + \beta_1 I_1 + \beta_2 I_2 + \ldots + \beta_n I_n + \varepsilon$$

4 Results

4.1 Correlation analysis

Using SPSS, the Pearson correlation coefficients are shown in Table 3.

The correlation matrix shows that the correlation between the innovation factor variables and the GCI is statistically significant and shows positive associations for several variables in both analysed periods. The correlation coefficient is significant for the variables expenditures for research in a company (0.88 and 0.92), university-industry collaboration in researches ((0.82 and (0.87) and innovation capacity (0.84 and 0.90). There is also a strong correlation between the GCI and the following innovation factor indicators: quality of research institutions (0.83 and 0.88) and the number of registered patents application (0.68 and 0.83). However, it shows a weak correlation between the GCI and the number of scientists (0.534 and 0.485) and the GCI and GDP per capita (0.476 and 0.508). Our hypothesis H1 is confirmed by strong relationships between the GCI variable and different combinations of innovation variables. The EU-28 countries can improve their GCI mainly by strengthening innovation factor indicators, except for the number of scientists. GDP per capita has explored instabilities even during the post-crisis period for some EU-28 countries.

The most important are the links between the GCI and expenditures for research in a company followed by innovation capacity, university-industry collaboration in researches, and quality of research institutions. We found statistically significant relationships of the GCI with the seven innovation factor indicators, except for the number of scientists. From Figure 3 we can see the correlation between the innovation capacity and the GCI.

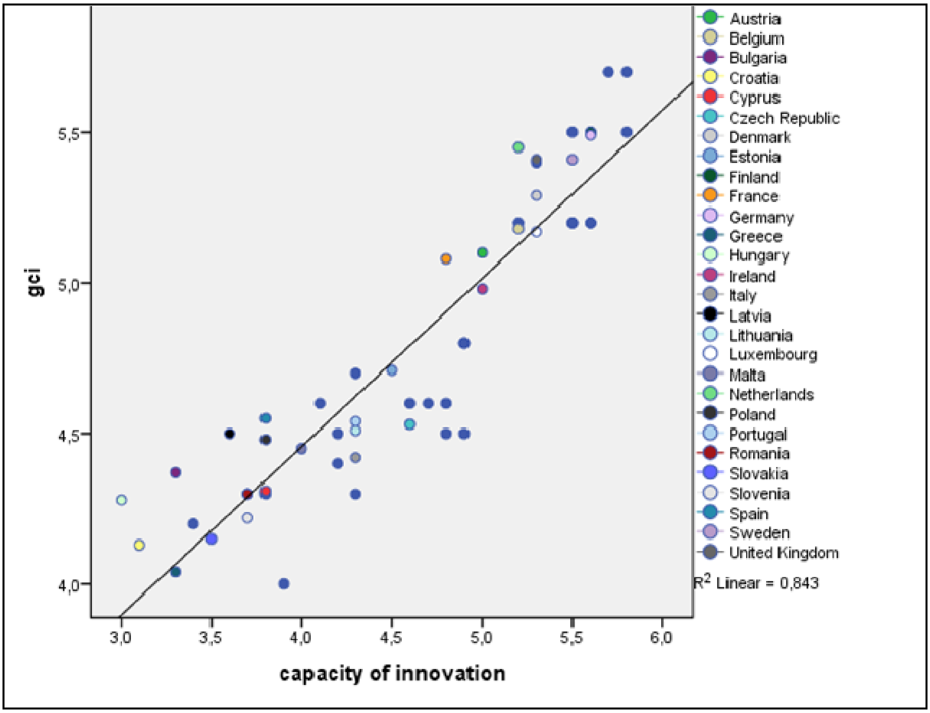
There is a high positive linear correlation between the GCI and the innovation capacity. The division into two groups of the EU-28 countries is noticeable, and lines show its goodness of fit $R^2 = 0.843$.

Table 3 Correlation between GCI and innovation factor indicators for the EU-27 countries in the period 2008–2013 and for the EU-28 countries in the period 2014–2017

2008–2013	*GCI*	*gdpp*	*capac.of inov*	*qual.research*	*expend.for research*	*coll.univ*	*gov.proc*	*scientists*	*patent*
GCI	1.000	0.476	0.840	0.826	0.882	0.819	0.637	0.534	0.681
gdpp	0.476	1.000	0.655	0.438	0.651	0.557	0.569	0.279	0.516
capac.of inov	0.840	0.655	1.000	0.821	0.947	0.814	0.633	0.556	0.778
qual.research	0.826	0.438	0.821	1.000	0.836	0.903	0.538	0.542	0.636
expend. for research	0.882	0.651	0.947	0.836	1.000	0.835	0.691	0.590	0.757
coll.univ	0.819	0.557	0.814	0.903	0.835	1.000	0.603	0.504	0.698
gov.proc.	0.637	0.569	0.633	0.538	0.691	0.603	1.000	0.408	0.470
scientists	0.534	0.279	0.556	0.542	0.590	0.504	0.408	1.000	0.492
patent	0.681	0.516	0.778	0.636	0.757	0.698	0.470	0.492	1.000
2014–2017	*GCI*	*gdpp*	*capac.of inov*	*qual.research*	*expend.for research*	*coll.univ*	*gov.proc*	*scientists*	*patent*
GCI	1.000	0.508	0.900	0.880	0.919	0.870	0.721	0.485	0.828
gdpp	0.508	1.000	0.502	0.396	0.517	0.454	0.592	0.221	0.389
capac.of inov	0.900	0.502	1.000	0.851	0.954	0.827	0.695	0.477	0.795
qual.research	0.880	0.396	0.851	1.000	0.876	0.904	0.635	0.548	0.736
expend. for research	0.919	0.517	0.954	0.876	1.000	0.870	0.731	0.538	0.876
coll.univ	0.870	0.454	0.827	0.904	0.870	1.000	0.742	0.588	0.777
gov.proc	0.721	0.592	0.695	0.635	0.731	0.742	1.000	0.358	0.608
scientists	0.485	0.221	0.477	0.548	0.538	0.588	0.358	1.000	0.587
patent	0.828	0.389	0.795	0.736	0.876	0.777	0.608	0.587	1.000

Source: Authors' calculations based on WEF reports (2008, 2010, 2013, 2014, 2015, 2016, 2017)

Figure 2 Correlation between innovation capacity and GCI, 2017 (see online version for colours)



Source: Authors' presentation based on WEF (2017)

4.2 Regression analysis

The purpose of the regression analysis is to identify key associations between the GCI and innovation factor variables based on multiple regression analysis. We use a regression model for the EU-27 countries during the crisis 2008–2013 period with 82 observations and for the EU-28 countries during the post-crisis 2014–2017 period with 112 observations. Table 4 presents the quality fit of the model at $p<0.001$. There is a linear relationship between the dependent variable GCI and the explanatory independent innovation factor variables for patents, the number of scientists, government procurement of technology, innovation capacity, university-industry collaboration in researches, expenditures research in business, and GDP per capita.

In Table 4, for the period 2008–2013, the value of the correlation coefficient ($R = 0.908$), the coefficient of determination ($R^2 = 0.825$), and the adjusted coefficient of determination (adjusted $R^2 = 0.806$), are high and show a strong correlation between the GCI dependent variable and 8 independent variables: patents, the number of scientists, government procurement of advanced technologies, quality of research institutions, innovation capacity, university and industry collaboration in research, expenditures for research in a company, and GDP per capita.

Table 4 Summary model for the EU-27 countries in the period 2008-2013 and for the EU-28 countries in the period 2014–2017

Model 2008–2013	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*	*Change statistics*		
					R square change	*F change*	*df1*
1	.908[a]	.825	.806	.2162	.825	42.96	8
Model 2014–2017	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*	*Change statistics*		
					R square change	*F change*	*df1*
1	.946[a]	.895	.887	.1683	.895	109.61	8

Notes: [a]Predictors: (Constant), patent, gdpp, scientists, gov.proc, qual.research, capac. Of inov, coll.univer, expend. for research
[b]Dependent Variable: GCI

The correlation coefficient (R = 0.946), the coefficient of determination ($R^2 = 0.895$) and the adjusted coefficient of determination (adjusted $R^2 = 0.887$) show a strong linear dependence for the period 2014–2017. That is, 88.7% of the variance of the GCI and can be explained by the variability of 8 explanatory variables.

Using analysis of variance (ANOVA) F-test, we determine the quality of the regression model and test the null hypothesis. Based on the results of ANOVA and F test, we reject the null hypothesis; $p < 0.001$ suggests that the regression model has a significant fit to the data since at least one regression coefficient is significant.

Table 5 presents the regression model results. We find that not all regression coefficients show a level of significance less than 0.05. The regression coefficients are statistically significant, $p < 0.05$, for the expenditures for R&D in a company as business research on the extent to which companies invest for R&D during the period 2008–2013. On the other hand, GDP per capita as a level of economic development indicator is statistically significant, but with a negative sign. In the period 2014–2017, there is a significant quality of research institutions, innovation capacity, and the number of registered patent applications with a positive sign, and the number/availability of scientists with a negative sign. However, government procurement of advanced technology products, GDP per capita and university-industry collaboration in researches are not significant at less than 5% of significance level. Therefore, we cannot completely reject the null hypothesis of the set H2.

The quality of research institutions, the capacity of innovation and patents applied may increase while the number/availability of scientists may reduce the GCI score.

The calculated regression equation for the EU-27 countries in the period 2008–2013 can be written:

$$GCI = 2.585 - 0.002\beta 1 + 0.317\beta 4 \quad (1)$$

GCI increased by 0.317 if the company research expenditures increased by one estimate.

The calculated regression equation for the EU-28 countries in the period 2014-2017 can be written:

$$GCI = 2.525 + 0.189\beta 2 + 0.210\beta 3 - 0.070\beta 7 + 0.001\beta 8 \quad (2)$$

The regression coefficients indicate that GCI increased by 0.189 if the capacity of innovation increased by one estimate. GCI increased by 0.210 if the quality of research institutions increased by one estimate.

Table 5 Unstandardised and standardised regression coefficients for the EU-27 countries in the period 2008–2013 and for the EU-28 countries in the period 2014–2017

Model 2008–2013	*Unstandardised coefficients*		*Standardised coefficients*	*t-test*	*sig.*
	B	*Std. error*	*Beta*		
(Constant)	2.585	.264		9.799	.000
gdpp	–.002	.001	–.182	–2.482	.015
capac.of inov	.024	.088	.046	.273	.785
qual.research	.067	.081	.114	.823	.413
expend.for research	.317	.089	.637	3.559	.001
coll.univ	.107	.076	.187	1.403	.165
gov.proc	.082	.060	.097	1.364	.177
scientists	–.017	.050	–.022	–.353	.725
patent	.000	.001	.019	.234	.816
Model 2014–2017	*Unstandardised coefficients*		*Standardised coefficients*	*t–test*	*sig.*
	B	*Std. error*	*Beta*		
(Constant)	2.525	.217		11.647	.000
gdpp	.001	.000	.060	1.456	.148
capac.of inov	.189	.073	.290	2.595	.011
qual.research	.210	.057	.328	3.661	.000
expend.for research	.003	.087	.006	.036	.971
coll.univ	.053	.053	.093	1.001	.319
gov.proc	.067	.050	.075	1.350	.180
scientists	–.070	.035	–.083	–1.994	.049
patent	.001	.000	.259	3.486	.001

Table 6 Residuals Statistics for the EU-27 countries in the period 2008–2013 and the EU-28 countries for the period 2014–2017

2008–2013	*Minimum*	*Maximum*	*Mean*	*Std. deviation*	*N*
Predicted value	3.946	5.574	4.715	.445	82
Residual	–.535	.504	.000	.205	82
Std. predicted value	–1.725	1.930	.000	1.000	82
Std. residual	–2.474	2.330	.000	.949	82
2014–2017	*Minimum*	*Maximum*	*Mean*	*Std. deviation*	*N*
Predicted value	3.990	5.606	4.763	.473	112
Residual	–.682	.526	.000	.162	112
Std. predicted value	–1.633	1.784	.000	1.000	112
Std. residual	–4.052	3.124	.000	.963	112

Note: [a]Dependent variable: GCI

Table 6 presents a residual statistic, namely the analysis of residuals to determine the deviations from the actual values and the calculated values according to the dependent variables. The standard deviation is used as a measure of the representability of the arithmetic mean. The smaller the standard deviation compared to the arithmetic mean, the smaller the difference between the actual values of the variable and its arithmetic mean and vice versa.

5 Discussion

The results based on the correlation matrix confirmed a strong correlation and interdependence of the considered indicators. The GCI is measured through 8 different innovation factor indicators. At first glance, these results can be predictable because the GCI can be highly correlated with those indicators through which it is measured. However, it is less predictable, which innovation variable is more, and which is less strongly correlated with the GCI. In the field of innovation, the most important are the expenditures for R&D in a company. There is a significant positive correlation between the innovation factor variables and the GCI in the EU-28 countries. The correlation coefficient is very high for the selected innovation factor variables except for the number/availability of scientists and GDP per capita. The highest positive correlation of the GCI is with the expenditures for R&D in company, university-industry collaboration in researches, innovation capacity, quality of research institutions and the number of registered patents application. The use of innovative components can contribute to achieve new products and services in the market that increase productivity. GCI is particularly enhanced by improving innovation capacity and improving the quality of research institutions.

The regression analysis confirmed only a few significant indicators: in the period 2008–2013, these are expenditures for R&D in a company but do not show statistical significance in the period 2014–2017, when the most important variables were found in innovation capacity and the quality of research institutions and the number of registered patents applications, while the number/availability of scientists with a negative sign. In addition to GDP per capita, university-industry collaboration in research show less significant impact on the GCI.

Considering the research for developed and developing countries, our results, findings and implications are largely consistent and in accordance with the previous results, findings and recommendations. Pilinkus and Boguslauskas (2007) found that the most competitive countries are leaders in gross domestic expenditure on R&D, leaders in generating skilled members of society, leaders in issuing patent applications, and leaders in information-communication technology expenditure as a percentage of GDP. This is in line with the investment of companies and businesses in research, which can result in higher value-added innovations, products and services. Loo (2018) made recommendations for Canada, for a greater collaboration among the academia, government and business communities to investigate the relationship between GCI and international business opportunities. Placido and Hwang (2019) argued on the important role of government in the innovation pillar score improvements in the Philippines and that GCI is strongly positively associated with investments into innovation and innovative institutions. Finally, similar to Zinnes et al. (2001), it would be useful to include a broader number of different groups of innovation and non-innovation factor indicators to explain drivers of global competitiveness and not only a narrow number of indicators that are the constitution component of the GCI when it is somehow expected higher correlation with those indicators through which it is measured.

6 Conclusions

This study contributes to the investigation of drivers of the GCI in the EU-28 countries during the periods 2008-2013 and 2014-2017. The focus was on the innovation pillars of the GCI indicator and relationships with 8 innovation factor variables. The correlation analysis confirmed significant relationships of the GCI with innovation factor variables. This finding confirmed H1 on the existence of the relationship between the level of GCI and different innovation factor variables in the EU-28 countries. However, the regression analysis only partly confirmed the set H2 particularly for the significant impact of expenditures for R&D in a company as business research and the GCI. As a striking finding, the results differ for the period of economic crisis and the period of post-economic crisis or economic recovery. More significant results were found for the latter.

The relationship between innovation factor indicators, GCI and level of economic development in the EU-28 countries confirmed differences in the performance of innovation factor indicators. The results can be relevant for innovation and global competitiveness policymakers. The empirical analysis provides insights to a better understanding of the relationships between the GCI and innovation factor indicators in the EU-28 countries. The strengthening of innovation systems in countries requires both transparent institutions and findings for innovative components that increase productivity and global competitiveness.

This study is limited to the innovation factor indicators of the GCI measure, the EU-28 countries and two sub-periods 2008-2013 and 2014-2017. An issue for the future research could be to include updated variables in the relationships between GCI and some other indicators such as for information-communication technology, scientific publications, expenditure on R&D as % of GDP, and particularly the role of institutions and governance indicators on GCI.

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