The impact of the pharmaceutical industry on the innovation performance of European countries

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There are significant differences in innovation performance between countries. Additionally, the pharmaceutical sector is stronger in some countries than in others. This suggests that the development of the pharmaceutical industry can influence a country's innovation performance. Using the Global Innovation Index (GII) and selected performance measures of the pharmaceutical sector, this study examines how the pharmaceutical sector influences the innovation performance of countries from the European context. The dataset of 27 European countries was analysed using simple, and multiple linear regressions and Pearson's correlation. The findings show that only three indicators of the pharmaceutical industry – pharmaceutical Research and Development (R&D), pharmaceutical exports, and pharmaceutical employment – explain the innovation performance of a country largely. Pharmaceutical R&D and exports have a significant positive impact on a country's innovation performance, whereas employment in the pharmaceutical industry has a slightly negative impact. Additionally, global innovation performance has been found to positively influence life expectancy. The authors further outline the implications and possible policy directions based on these findings.

Keywords:
pharmaceutical industry,
innovation performance,
Global Innovation Index,
R&D,
Europe,
life expectancy

Introduction

European citizens can expect to live 30 years longer than they did a century ago and have a better quality of life, thanks to advances in science and technology and the research-based pharmaceutical industry (EFPIA 2021). However, some diseases, such as various cancers, rare diseases, and Alzheimer's still cannot be treated or are inadequately treated. Further, the recent emergence of COVID-19 and its mutations has become a major threat today.

Innovation is one of the main drivers of gross domestic product (GDP) growth and a key success factor in global competition. The pharmaceutical industry is one such industry that is highly innovative. According to the 2020 EU Industrial R&D Investment Scoreboard, the pharmaceutical industry has the highest ratio of R&D investment to net sales (15.4%), followed by 'software and computer services' (11.8%) and technology hardware and equipment (9.00%) (Grassano et al. 2020).

However, previous studies have not addressed how the pharmaceutical industry affects the innovation performance of countries; thus, it is timely and crucial to examine the relationship between the key performance indicators of the pharmaceutical industry and country-level innovation performance. We hypothesise that a stronger pharmaceutical industry positively influences a country's innovation performance.

The main objective of this study is to investigate how the pharmaceutical industry affects country-level innovation performance in the European context. To achieve this objective, the relationship between the GII and pharmaceutical industry metrics were examined. This study also analyses the relationship between innovation performance and life expectancy to add to the overall body of academic literature.

Literature review

Innovation and the GII

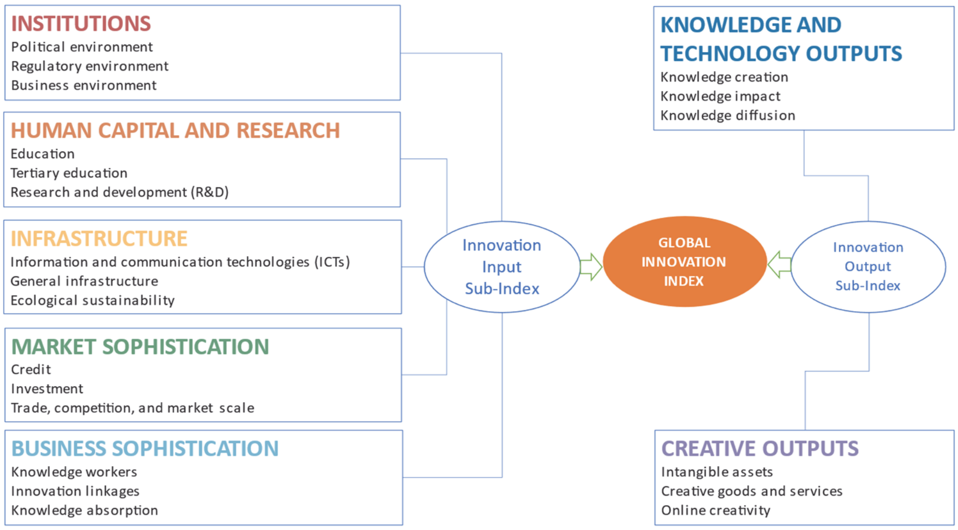
Innovation plays a significant role, contributing to a country's economic growth (Maradana et al. 2017, Pece et al. 2015, Aguilar 2022). The need to assess innovation performance and comparability across countries has led to the development of the GII (Cornell University–INSEAD–WIPO 2020), recognised by the European Union (EU). The GII provides a framework for measuring innovation that enables policymakers to develop their strategies.

The tendency to increase the volume of innovation financing, as one of the strongest engines of the modern economy, is not new (Kuznets 1972). Cornell University, in cooperation with the French business school INSEAD and the World Intellectual Property Organization, developed the GII to determine the relationship and assess the innovativeness of economies. Since innovation is a subjective indicator, the GII approach is promising and relatively objective (Iqbal–Rahman 2020). The annual report assesses the innovation of the economies of all countries based on a number of indicators for compiling the rating. Proxies that may not reflect innovation in their true sense are used because of the lack of data on innovation in some countries. The report also examines leading scientific and technical clusters, which are centres of innovation activity in countries. Each country has its own weaknesses and strengths, determined by the analysis of institutions, human resources and their development, infrastructure, the degree of development of the market and business, and the technological and creative results of innovation activity.

The purpose of this report is to provide meaningful data on innovations that can help countries assess the effectiveness of their innovation activities and make decisions on further development plans (Androschuk 2021). It is possible to combine data from previous years and conduct a trend analysis since the report is published annually (Naqvi 2016). Overall, the index reflects the innovation hierarchy of the world quite well.

Figure 1

Framework of the GII



Source: based on Cornell University–INSEAD–WIPO (2020: 205.).

The GII ranks economies according to their capacity for innovation. The multidimensional index comprises approximately 80 indicators, divided into innovation inputs and outputs. The overall GII score is based on the average of the innovation input and output sub-indices. Both sub-indices have equal weights for the overall GII score. The innovation input sub-index, which captures elements of the economy that enable innovative activities, comprises the following five pillars: institutions, human capital and research, infrastructure, market sophistication, and business sophistication. These elements foster innovation activities in a country. The innovation output sub-index, which shows the outcome of innovative activities within the economy, has two pillars: knowledge, technology, and creative output. Each pillar was divided into three sub-pillars (Figure 1).

In 2020, 131 countries were studied, representing 93.5% of the total population and 97.4% of global GDP. The GII has become both a primary reference for innovation and an 'action tool' for countries to incorporate the GII into their innovation agenda.

The GII 2020 identified six key findings (Cornell University–INSEAD–WIPO 2020). The first key finding is that the pandemic COVID-19 has had a positive effect on innovation (Nyikos et al. 2021, Nagy–Veresné Somosi 2022). Innovation has increased in the pharmaceutical and biotechnology sectors owing to the development of vaccines and advances in education and retail. COVID-19 has also had a positive impact on the pharmaceutical industry in general (Dániel et al. 2021). Governments have sought to mitigate the negative impacts of innovation in sectors affected by the pandemic. Second, the crisis led to a decline in funding for innovation. Venture capital deals have also declined, and initial public offerings (IPOs) and start-ups have grown less. It is predicted that venture capital will take longer to recover than R&D; thus, there may be a shortage of funding for innovation. Innovation diffusion is directed toward health, online education, big data, e-commerce, and robotics. Third, the global innovation landscape is shifting eastward, with China, Vietnam, India, and the Philippines showing an increasing trend in the GII growth. China, as part of the middle-income group of countries, is an innovation leader and stands out for producing innovations that match those of the top ten economies.

Another important insight is that developing countries can excel in certain pillars of innovation. It is worth observing the world's top rankings in certain aspects of innovation in the GII, such as venture capital, R&D, entrepreneurship or high-tech manufacturing. The balance of the innovation system was also assessed in countries with the GII. The GII is also used to determine the innovation performance in relation to the level of economic development. The fifth important finding is the existence of regional differences, with some countries having a great innovation potential. North America and Europe are at the top, followed by Southeast Asia, East Asia, and Oceania. Finally, innovation in some high-income economies, notably China, is concentrated in science and technology clusters. The US has the most clusters (25), followed by China (17), Germany (10), and Japan (5) (Cornell University–INSEAD–WIPO 2020).

It is also important to note that most economies that have moved up the GII over time have benefited greatly from their integration into value chains and innovation networks. Today, international openness and collaboration in innovation pose real risk. However, the joint search for medical solutions during the pandemic showed how powerful collaboration could be. The speed and efficiency of this collaboration show that internationally coordinated R&D missions can effectively counter the tendency toward increased isolationism and address important societal issues.

According to the GII 2020, Switzerland is the most innovative economy in the world, with an index score of 66.1 (Table A1 in the Appendix). Switzerland's success is the result of its production of high-value innovations, knowledge-intensive employment, and high R&D spending. Switzerland was followed by Sweden (62.5) and the United States (60.6). The top ten also include the United Kingdom (59.8), the Netherlands (58.8), Denmark (57.5), Finland (57.0), Singapore (56.6), Germany (56.5), and the Republic of Korea (56.1).

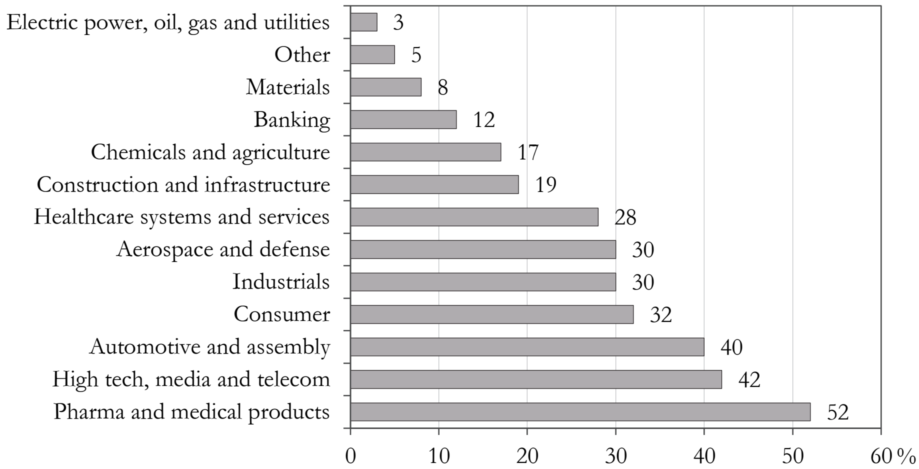
Countries at the bottom of the GII ranking are Zambia (19.4), Mali (19.2), Mozambique (18.7), Togo (18.5), Benin (18.1), Ethiopia (18.1), Niger (17.8), Myanmar (17.7), Guinea (17.3), and Yemen (13.6). In Africa, low scores in the GII can be explained by limited access to innovation systems due to the low level of scientific and technological activities, dependence on government or foreign funders as a source of R&D, low business absorptive capacity, and a difficult business environment (Cornell University–INSEAD–WIPO 2020).

Innovation and the pharmaceutical industry

The pharmaceutical industry has long relied more on research and innovation than other industries (Cardinal 2001, Romasanta et al. 2020). R&D is crucial for the growth and future success of pharmaceutical research companies (Schuhmacher–Kuss 2018). Valuable pharmaceutical innovations should be encouraged, identified, and rewarded. A medicine can only be considered „truly innovative" if it offers additional clinical efficacy and/or effectiveness compared to the current treatment. In addition, it is 'valuable' only if it addresses an unmet medical need (Annemans et al. 2011). Investments in pharmaceuticals are of a long-term nature, making it difficult in assessing the effectiveness of investments since the results of R&D can only be obtained in the distant future. At the same time, methodological disputes continue on accounting for numerous hidden costs that can further increase the cost of research. Even further, the development of new drugs is becoming increasingly expensive; estimates range from USD 1 billion to USD 11 billion (Kumar–Sundarraj 2018). Consequently, the key strategies used in the field of scientific research and innovation in the pharmaceutical industry today are mergers and acquisitions, licensing, and strategic partnerships (Haraszkiewicz-Birkemeier–Hołda 2019). The innovation and investment activities of pharmaceutical companies have a significant impact on the development of society as well as globalisation. With existing and new diseases to fight, if a pharmaceutical company wants to stand out, it has to spend more on R&D (Yildirim–Mestanoğlu 2019). According to McKinsey experts' estimates, the cost of innovation accounts for up to half of pharmaceutical companies' profits, well above for the same indicator in other industries. However, high R&D spending is not restricted to the pharmaceutical industry (Brennan et al. 2020). This is also high in the high-tech, media, and telecom industries, as well as in the automotive and assembly industries (Figure 2).

Figure 2

Global private-sector R&D spending as a share of earnings before interest, taxes, depreciation and amortization (EBITDA) by industry, 2019



Source: Brennan et al. (2020).

At the same time, the pharmaceutical industry is striving to reduce the ever-increasing costs of R&D using artificial intelligence, which provides a better understanding of the relationships between various formulas and parameters (Krishnaveni et al. 2020). However, with rapidly growing development costs, the reduced profitability of new medical organisations and missed breakthrough innovations can negatively affect the future of the pharmaceutical industry (van Vierssen Trip et al. 2017). Therefore, one of the tasks of pharmaceutical companies is to find a compromise between innovation and pricing (Konopielko–Trechubova 2019).

Medical progress is driven by the pharmaceutical industry and vice versa. The aim is to provide patients with innovative treatments that are widely available and accessible by turning fundamental research into new products in the market (EFPIA 2021).

Pharmaceutical industry in Europe

The pharmaceutical industry is one of the most powerful high-tech industries in Europe and is a key asset for the European economy. It is the main driver of current and future growth as well as global competitiveness. The pharmaceutical industry in Europe employs approximately 830,000 people directly and approximately 2.5 million people indirectly (EFPIA 2021). The R&D spend for Europe alone was 39,000 million EUR, a huge investment. However, this industry also has several problems. However, additional regulatory hurdles, rising R&D costs, and the impact of fiscal austerity measures, since 2010 are the biggest challenges currently facing the European pharmaceutical industry (EFPIA 2021). For example, the estimated R&D cost for a new drug in 2014 was 1,926 million EUR, 2.5 times higher than that in the 1990s, and 14.3 times higher than that in the 1970s. (DiMasi et al. 2016) Nowadays, the time to market is also very long, 12-13 years on average. In addition, rapidly developing countries, particularly Brazil, China, and India, pose a serious threat to the fragmented EU pharmaceutical market by siphoning off R&D investment and activity, including the long-standing, strong market dominance of the United States (EFPIA 2021).

Key indicators are presented based on the latest report of the European Federation of Pharmaceutical Industries and Associations (EFPIA 2021) to provide an overview of the European pharmaceutical industry, representing 36 national pharmaceutical industry associations, 39 leading pharmaceutical companies, and 14 small-and medium-sized enterprises (e.g. the research-based pharmaceutical industry operating in Europe). The indicators comprise pharmaceutical industry R&D spending, pharmaceutical production, pharmaceutical employment, pharmaceutical market value, pharmaceutical exports, and pharmaceutical imports. The figures are from 2019.

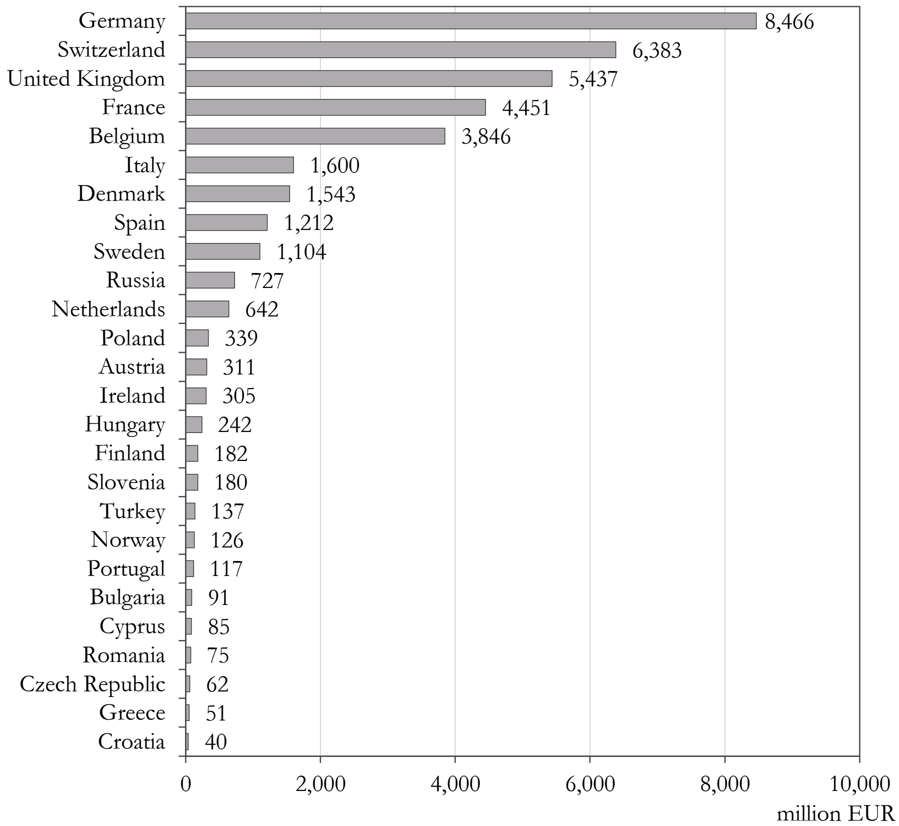
Pharmaceutical R&D

In 2019, the pharmaceutical industry in Europe invested more than 37,700 million EUR into R&D. The distribution of investments is uneven with more than 22.2% of this amount being invested in Germany. Substantial R&D investments also characterise the pharmaceutical sector in Europe, Switzerland, the United Kingdom, France, and Belgium. For example, in Russia, this amount is much lower at only 727 million EUR. In Croatia, at the other end of the spectrum, it is only 40 million; that is, pharmaceutical R&D in Germany is almost 212 times higher than in Croatia (Figure 3).

However, globally far too little has been invested in sustainable R&D to prevent public health crises as the outbreak of the COVID-19 pandemic showed (Eyal-Cohen–Rutschman 2020).

Figure 3

Pharmaceutical industry research & development in Europe, 2019



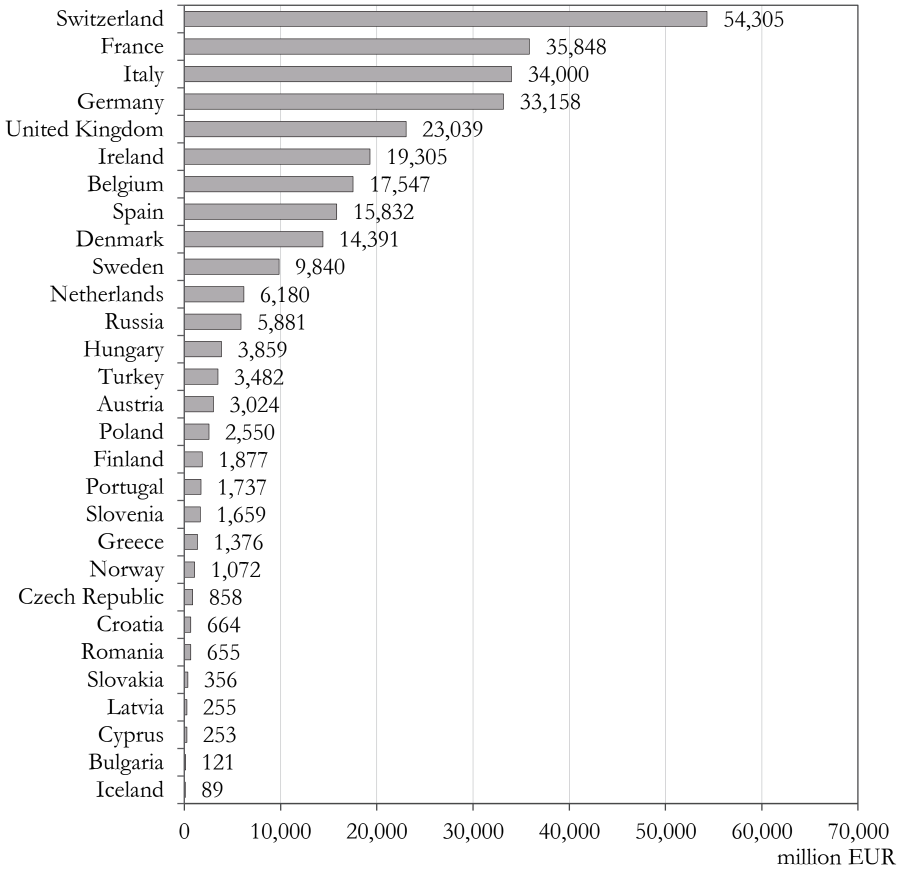
Source: based on EFPIA (2021: 7.).

Pharmaceutical production

Pharmaceutical production is not uniform in Europe. Switzerland is the largest pharmaceutical producer, with an output of 54,305 million EUR, followed by France, Italy, Germany, and the United Kingdom (Tóth–Csomós 2016). These countries are the top five pharmaceutical producers in Europe. By contrast, Iceland, Bulgaria, Cyprus, Latvia, and Slovakia were the smallest European producers (Figure 4).

Figure 4

Pharmaceutical production in Europe, 2019



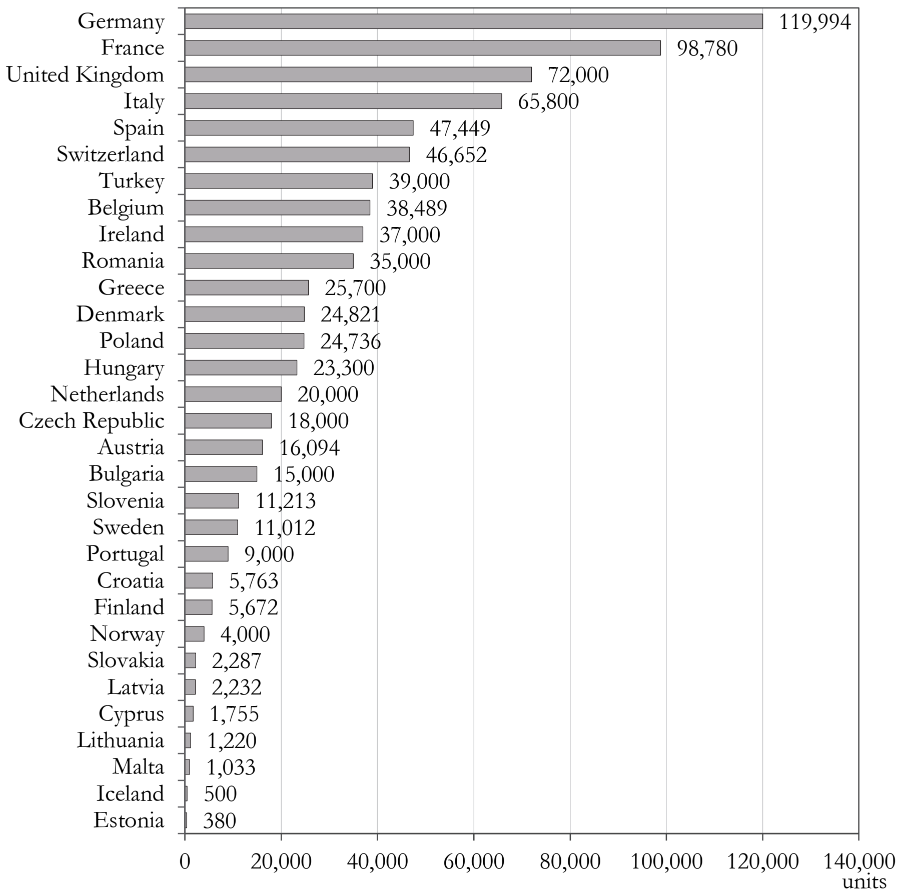
Source: based on EFPIA (2021: 11.).

Pharmaceutical employment

Europe's pharmaceutical industry is a major industrial employer in the high-technology sector. It employs approximately 830,000 people, almost 15% of whom are in Germany alone. France is also a major employer, with almost 99,000 people employed in the pharmaceutical industry. However, United Kingdom, Italy, Spain, and Switzerland also have many people working in this industry. Estonia has the smallest number of employees in Europe, followed by Iceland, Malta, Lithuania, and Cyprus (see Figure 5).

Figure 5

Employment in the pharmaceutical industry, 2019



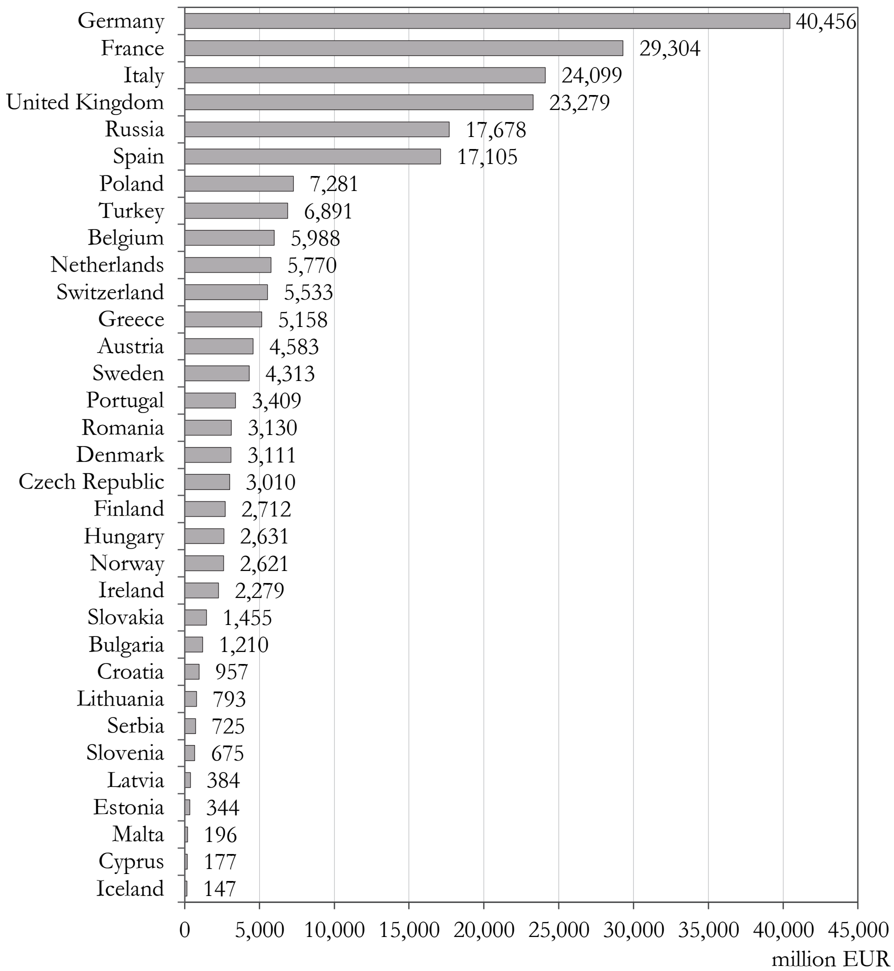
Source: based on EFPIA (2021: 12.).

Pharmaceutical market value

Pharmaceutical market value refers to the sale of medicines for human use at ex-factory prices through all distribution channels (pharmacies, hospitals, dispensing doctors, supermarkets, etc.), whether dispensed on prescription or at the request of the patient. Market value does not include the sales of veterinary medicines. Germany is the largest market in Europe, with a share of 17.79% (Figure 6). This is followed by France (12.89%), Italy (10.60%), the United Kingdom (10.24%), Russia (7.77%), and Spain (7.52%). In contrast, the smallest market in Europe is Iceland, with less than 0.06% share, followed by Cyprus, Malta, Estonia, and Latvia, all with less than 0.20% share (Figure 6).

Figure 6

Pharmaceutical market value (at ex-factory prices), 2019



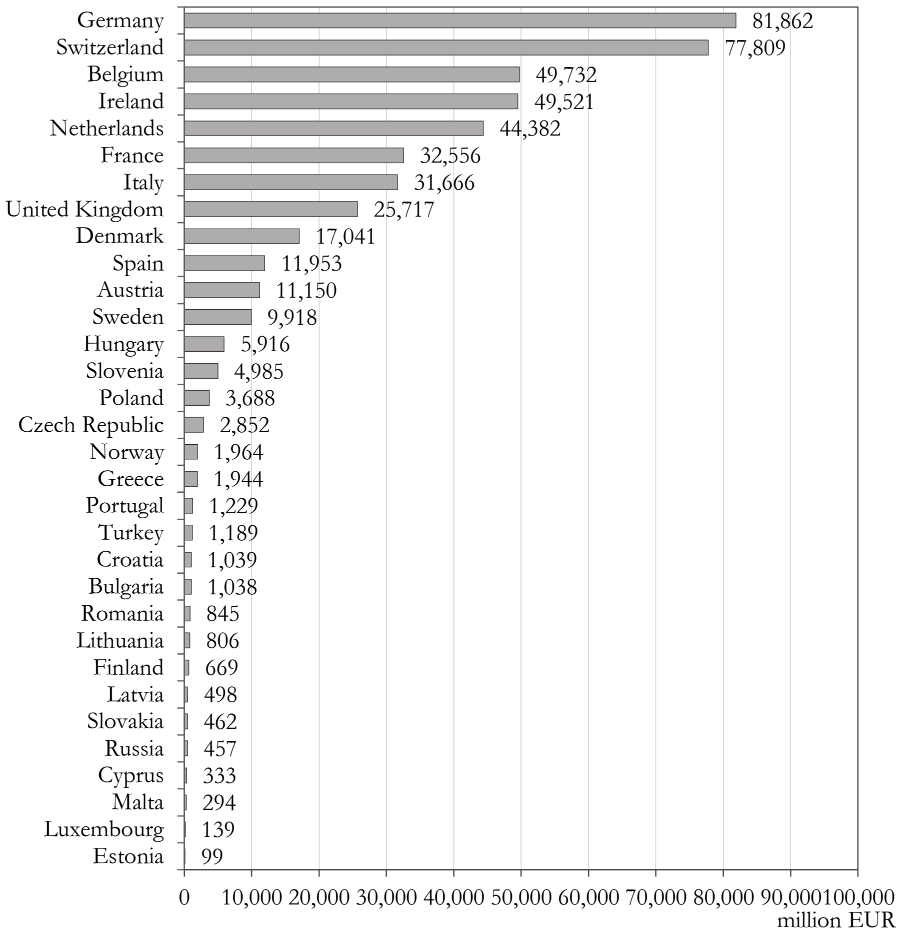
Source: based on EFPIA (2021: 15.).

Pharmaceutical exports

Germany is the largest exporter of pharmaceuticals in Europe, closely followed by Switzerland (Figure 7). The top five exporting countries were Belgium, Ireland, and the Netherlands. Estonia has modest export performance, followed by Luxembourg, Malta, Cyprus, and Russia. These countries had the worst pharmaceutical export performances.

Figure 7

Pharmaceutical exports, 2019



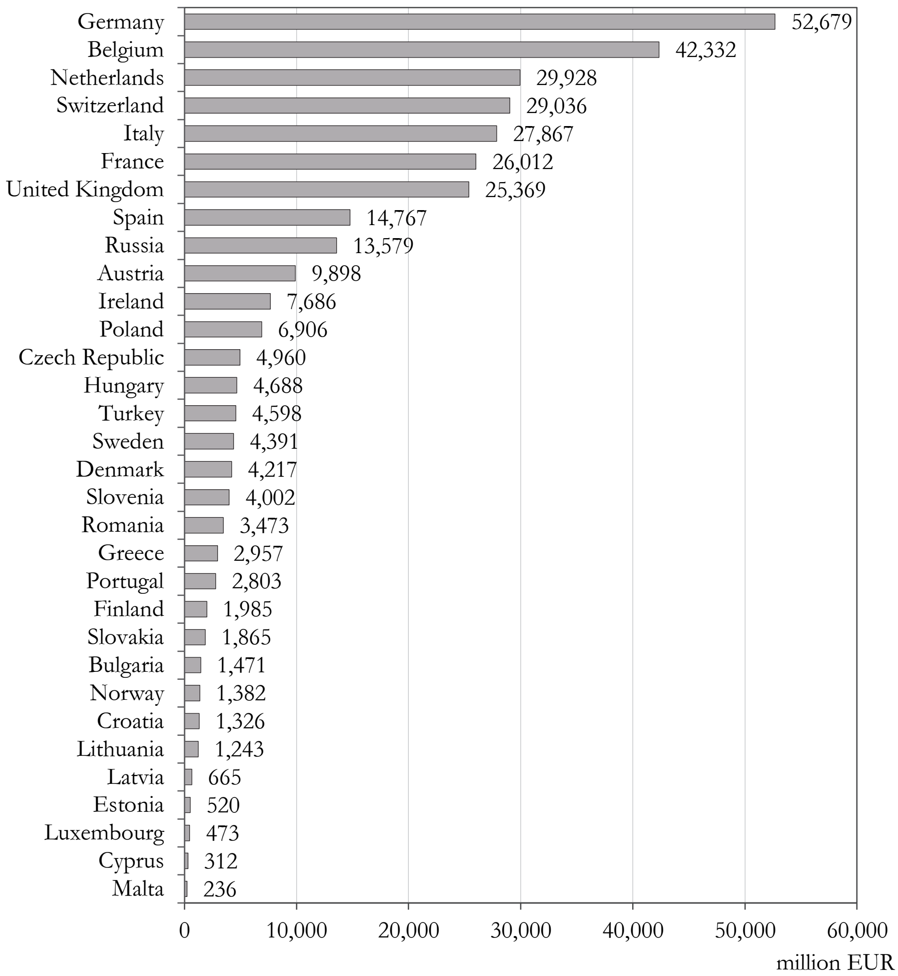
Source: based on EFPIA (2021: 18.).

Pharmaceutical imports

Germany was the largest importer of pharmaceuticals in Europe, followed by Belgium. Figure 8 shows that the Netherlands, Switzerland, and Italy were among the top five EU importers. Malta's pharmaceutical imports were the smallest in Europe, followed by Cyprus, Luxembourg, Estonia, and Latvia.

Figure 8

Pharmaceutical imports, 2019



Source: based on EFPIA (2021: 19.).

Research methodology and sample

We analysed the relationship between the GII and the key performance indicators of the pharmaceutical industry to achieve the research objectives. The GII measures the innovation performance of 131 countries (Cornell University–INSEAD–WIPO, 2020). The study of the European Federation of Pharmaceutical Industries and Associations contains pharmaceutical industry data of 32 countries (EFPIA 2021). It must be noted that the GII does not contain any sub-indices specific to the pharmaceutical industry.

Data were missing for some indicators (R&D, production, and employment) in EFPIA (2021). Therefore, countries with missing data (Estonia, Iceland, Latvia, Lithuania, Malta, and Slovakia) were excluded from the analysis. Employment data for Russia were not available in EFPIA (2021) and were taken from Statista (2017).

The raw dataset for the remaining 27 countries can be found in Table A2 in the Appendix. The sample consisted of 27 European countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom. The relatively small sample size of 27 was one of the limitations of this study. Another limitation is that the results can only be interpreted in a European context, and the data refer to only one year (2019), since only the most recent EFPIA figures were used for the analysis.

We used multiple linear regression (MLR) to test the working hypothesis that a more developed pharmaceutical sector positively affects a country's innovation performance. In the simple linear regression, the GII score was the dependent variable, while pharmaceutical R&D, pharmaceutical production (PROD), pharmaceutical employment (EMP), pharmaceutical market value (MV), pharmaceutical export (EXP), and pharmaceutical import (IMP) were the independent variables. The relationship between innovation performance and life expectancy was analysed using Spearman's correlation.

Results and discussion

First, the data were cleaned to test the linear regression conditions and the descriptive statistics of the variables examined to detect erroneous values (Table 1). Missing and/or erroneous values were not included in the raw dataset.

Table 1

Descriptive statistics, 2019

Denomination	GII	R&D	PROD	EMP	MV	EXP	IMP	Life expec-tancy
Valid	27	27	27	27	27	27	27	27
Missing	0	0	0	0	0	0	0	0
Mean	47.663	1,399.704	10,847.000	32,779.259	8,326.481	15,662.741	11,980.296	80.488
Std. Deviation	9.009	2,259.674	14,153.496	29,849.172	10,170.120	23,247.149	14,194.740	2.953
Shapiro-Wilk	0.953	0.654	0.760	0.858	0.719	0.699	0.769	0.887
P-value of Shapiro-Wilk	0.252	<.001	<.001	0.002	<.001	<.001	<.001	0.007
Minimum	34.900	38.000	121.000	1,755.000	177.000	333.000	312.000	73.200
Maximum	66.100	8,466.000	54,305.000	119,994.000	40,456.000	81,862.000	52,679.000	84.000

The independent variables were not normally distributed as the P-values in the Shapiro-Wilk test as shown in Table 1; thus, the log transformation was used to transform skewed data to close to 'normal' and augment the reliability of the analyses. Table 2 shows the descriptive statistics of the new independent variables, which are now normally distributed.

Table 2

Descriptive statistics, 2019

Denomination	logR&D	logPROD	logEMP	logMV	logEXP	logIMP
Valid	27	27	27	27	27	27
Missing	0	0	0	0	0	0
Mean	2.594	3.580	4.314	3.638	3.648	3.754
Std. Deviation	0.7273	0.7268	0.4762	0.5343	0.7639	0.5799
Shapiro-Wilk	0.9346	0.9664	0.9629	0.9640	0.9335	0.9635
P-value of Shapiro-Wilk	0.090	0.510	0.428	0.454	0.084	0.441
Minimum	1.580	2.083	3.244	2.248	2.522	2.494
Maximum	3.928	4.735	5.079	4.607	4.913	4.722

The boxplots showed that there were no outliers in the database. Due to the strong correlation with pharmaceutical R&D, pharmaceutical production was removed from the model. Pharmaceutical MV was also not included in the final model because it is highly correlated with pharmaceutical employment (Table 3). The third variable not included is pharmaceutical import because it is highly correlated with pharmaceutical export. As a result, only three independent variables remained in the final model (pharmaceutical R&D, pharmaceutical EMP, and pharmaceutical EXP).

Table 3

Pearson's correlations, 2019

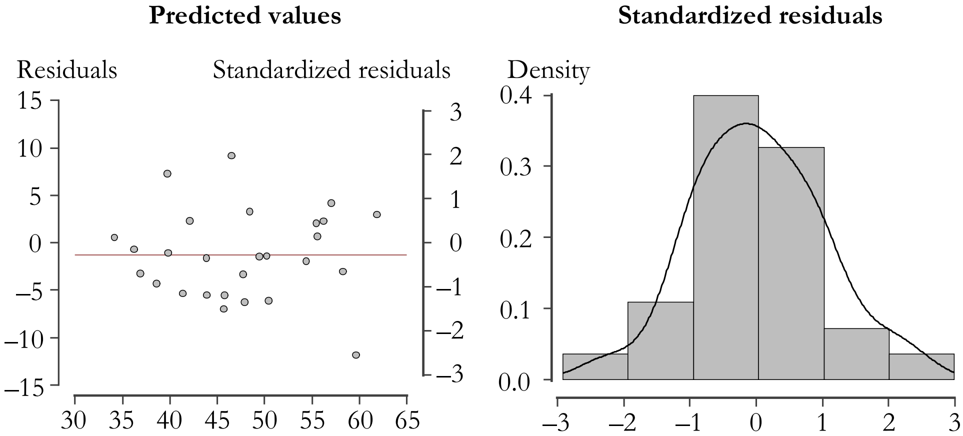
Variable		logR&D	logPROD	logEMP	logMV	logEXP	logIMP
1. logR&D	Pearson's r	–	–				
2. logPROD	Pearson's r	**0.899*** **	0.752***				
3. logEMP	Pearson's r	0.707***	0.746***	–			
4. logMV	Pearson's r	0.709***	0.723***	**0.837*** **	–		
5. logEXP	Pearson's r	0.740***	0.701***	0.541**	0.428*	–	
6. logIMP	Pearson's r	0.694***	–	0.703***	0.621***	**0.850*** **	–

* p <.05, ** p <.01, *** p <.001

The scatter plot of residuals vs. predicted and the standardised residual histogram (Figure 9) imply that the linear relationship and homoscedasticity conditions are satisfied.

Figure 9

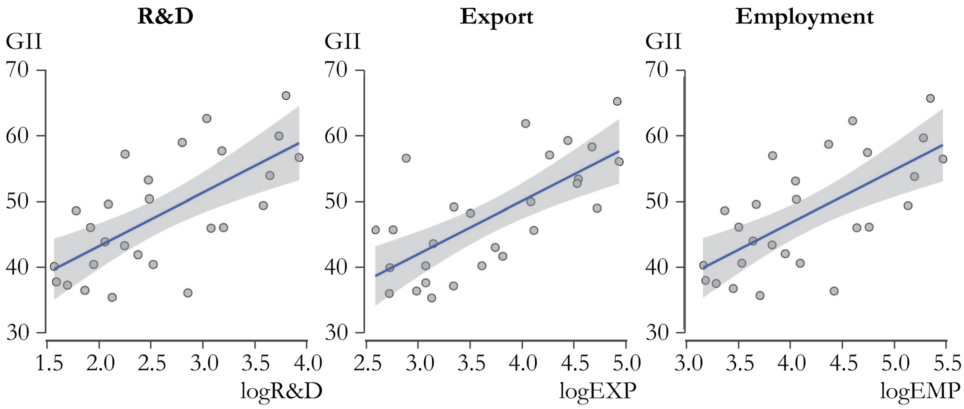
Scatter plot residuals vs predicted, and the standardised residual histogram, 2019



The Durbin-Watson d value of 1.761, which is close to the ideal value of 2.0, signals no disturbing autocorrelation in the sample. Figure 10 shows the positions of the countries, determined by their scores on the GII and their logarithmical scores of pharmaceutical R&D, pharmaceutical exports, and pharmaceutical employment data.

Figure 10

Scree-plot of the countries (GII and pharmaceutical R&D, pharmaceutical export and pharmaceutical employment), 2019



The ANOVA table (Table 4) shows that the model is significant, and therefore generalisable to the population.

Table 4

ANOVA table, 2019

Model		Sum of squares	df	Mean square	F	p
H_1	Regression	1,549.021	3	516.340	21.166	<.001
	Residual	561.082	23	24.395		
	Total	2,110.103	26			

Note: The intercept model is omitted since no meaningful information can be shown.

As shown in Table 5, R^2 value of 0.734 indicates that the resulting model is robust, with 73.4% of the variance in the output variable (GII) explained by the predictor variables (logR&D, logEXP, and logEMP). The adjusted R^2 indicates that the explanatory power of the model for the population is also very high (69.9%). It suggests that only three pharmaceutical indicators could explain the innovation performance of a country.

This supports the findings of Duenas-Gonzalez–Gonzalez-Fierro (2020) that pharmaceutical innovation leads to economic growth and is a sign of a country's innovation efforts.

Table 5

Model summary – GII, 2019

Model	R	R^2	Adjusted R^2	RMSE	Durbin-Watson		
					autocorrelation	statistic	p
H_0	0.000	0.000	0.000	9.009	0.203	1.522	0.202
H_1	0.857	0.734	0.699	4.939	0.108	1.761	0.560

Table 6 shows that the global innovation performance of a country can be estimated using the following formula:

$$GII = 53.805 + 9.389 * logR\&D - 11.819 * logEMP + 5.616 * logEXP$$

Standardised beta coefficients suggest that pharmaceutical R&D, pharmaceutical employment, and pharmaceutical exports strongly influence innovation performance; therefore, the research hypothesis is accepted.

Table 6

Coefficients, 2019

Model		Unstandar-dised	Standard error	Standardised	t	p
H_0	(Intercept)	47.663	1.734		27.491	<.001
H_1	(Intercept)	53.805	10.031		5.364	<.001
	logR&D	9.389	2.359	0.758	3.980	<.001
	logEMP	–11.819	2.880	–0.625	–4.104	<.001
	logEXP	5.616	1.887	0.476	2.976	0.007

Pharmaceutical R&D and pharmaceutical exports have a positive effect on innovation performance, while higher employment in the pharmaceutical industry has a negative effect on it. This means that in countries where pharmaceutical R&D spending is high and pharmaceutical export is significant, we can generally expect high innovation performance, especially when pharmaceutical labour intensity is low. In other words, per capita value-added in the pharmaceutical sector should be high for a country to perform better in global innovation competition. Highly skilled labour and automated R&D activities supported by artificial intelligence in the pharmaceutical sector have a positive impact on a country's global innovation performance.

The relationship between innovation performance and life expectancy is also examined. Since the life expectancy variable has a non-normal distribution, Spearman correlation was used to indicate the direction of the relationship between the two variables. The Spearman correlation coefficient (rs=0.661) indicates a strong positive relationship between the GII and life expectancy (Table 7). Therefore, we can assume that when a country's innovation performance increases, life expectancy also increases; that is, innovation positively influences life expectancy. Understanding this relationship is particularly important for Hungary, where life expectancy is among the lowest in OECD countries (Uzzoli 2016, Pál et al. 2021).

Table 7

Spearman's correlations, 2019

Variable		Life expectancy	GII
1. Life expectancy	Spearman's rho	–	
2. GII	Spearman's rho	0.661***	–

* p <.05, ** p <.01, *** p <.001

As shown by both the MLR and Spearman's correlation results, the development of the pharmaceutical industry in a country has a positive impact on innovation performance and life expectancy. Our findings support previous research that innovation (Khullar et al. 2019), particularly pharmaceutical innovation (Omachonu–Einspruch 2010, Lichtenberg 2012), has a positive impact on life expectancy. Pharmaceutical innovation is particularly important because Lichtenberg (2012), in a study that examined 30 developing and developed countries between 2000 and 2009, found that it was responsible for 73 percent of the increase in life expectancy. Pharmaceutical innovation, the introduction and use of cost-effective new medicines, significantly increased cancer survival rates in New Zealand and significantly reduced premature cancer mortality in the period to 1998–017 (Lichtenberg 2021).

Conclusions

Due to the pandemic, the role of the pharmaceutical industry has never been more important. More specifically, new treatments have not been developed in such a short time, as in the last two years. This suggests that the pharmaceutical industry needs to become increasingly innovative, with practical examples to show, such as the development of genetically engineered state-of-the-art RNA and DNA vaccines for COVID-19. Therefore, innovation and R&D are becoming increasingly critical in this sector. At the same time, our results indicate that an innovative pharmaceutical industry has a strong positive impact on a country's overall innovation performance. It creates a knowledge-based ecosystem that has a positive impact on innovation in other industries. Based on our research findings, we recommend that economic policymakers who want to improve a country's innovation performance use all possible means to promote the establishment and development of an innovative pharmaceutical industry. In particular, the promotion of pharmaceutical R&D and exports play an important role in the development of an innovation ecosystem. Our results also show that the number of employees in the pharmaceutical industry negatively impacts innovation performance. Therefore, we can assume that innovation performance improves in countries where a smaller number of employees create more added value in the pharmaceutical industry. In this respect, Europe, in particular, lags far behind North America, where the indicator of gross value-added per employee in the pharmaceutical industry is 2.16 times higher (Statista 2012). This indicates a more distant prospect and calls for conscious development of knowledge using the latest technology (e.g. with the help of artificial intelligence). Finally, the development of an innovative pharmaceutical industry has a positive impact on life expectancy. Since our research results focused on the European context, our future research direction is to extend this research to other countries around the world.

Appendix

Table A1

Global Innovation Index ranking, 2019

Ranking	Country	GII	Ranking	Country	GII
1	Switzerland	66.1	34	United Arab Emirates	41.8
2	Sweden	62.5	35	Hungary	41.5
3	United States	60.6	36	Latvia	41.1
4	United Kingdom	59.8	37	Bulgaria	40.0
5	Netherlands	58.8	38	Poland	40.0
6	Denmark	57.5	39	Slovakia	39.7
7	Finland	57	40	Lithuania	39.2
8	Singapore	56.6	41	Croatia	37.3
9	Germany	56.5	42	Viet Nam	37.1
10	Republic of Korea	56.1	43	Greece	36.8
11	Hong Kong. China	54.2	44	Thailand	36.7
12	France	53.7	45	Ukraine	36.3
13	Israel	53.5	46	Romania	36.0
14	China	53.3	47	Russian Federation	35.6
15	Ireland	53.0	48	India	35.6
16	Japan	52.7	49	Montenegro	35.4
17	Canada	52.3	50	Philippines	35.2
18	Luxembourg	50.8	51	Turkey	34.9
19	Austria	50.1	52	Mauritius	34.4
20	Norway	49.3	53	Serbia	34.3
21	Iceland	49.2	54	Chile	33.9
22	Belgium	49.1	55	Mexico	33.6
23	Australia	48.4	56	Costa Rica	33.5
24	Czech Republic	48.3	57	North Macedonia	33.4
25	Estonia	48.3	58	Mongolia	33.4
26	New Zealand	47.0	59	Republic of Moldova	33.0
27	Malta	46.4	60	South Africa	32.7
28	Italy	45.7	57	North Macedonia	33.4
29	Cyprus	45.7	58	Mongolia	33.4
30	Spain	45.6	59	Republic of Moldova	33.0
31	Portugal	43.5	60	South Africa	32.7
32	Slovenia	42.9	61	Armenia	32.6
33	Malaysia	42.4	62	Brazil	31.9

(The table continues next page.)

(Continued.)

Ranking	Country	GII	Ranking	Country	GII
63	Georgia	31.8	98	Trinidad and Tobago	24.1
64	Belarus	31.3	99	Ecuador	24.1
65	Tunisia	31.2	100	Cabo Verde	23.9
66	Saudi Arabia	30.9	101	Sri Lanka	23.8
67	Iran	30.9	102	Senegal	23.7
68	Colombia	30.8	103	Honduras	23.0
69	Uruguay	30.8	104	Namibia	22.5
70	Qatar	30.8	105	Bolivia	22.4
71	Brunei	29.8	106	Guatemala	22.4
72	Jamaica	29.1	107	Pakistan	22.3
73	Panama	29.0	108	Ghana	22.3
74	Bosnia and Herzegovina	29.0	109	Tajikistan	22.2
75	Morocco	29.0	110	Cambodia	21.5
76	Peru	28.8	111	Malawi	21.4
77	Kazakhstan	28.6	112	Côte d'Ivoire	21.2
78	Kuwait	28.4	113	Lao PDR	20.6
79	Bahrain	28.4	114	Uganda	20.5
80	Argentina	28.3	115	Madagascar	20.4
81	Jordan	27.8	116	Bangladesh	20.4
82	Azerbaijan	27.2	117	Nigeria	20.1
83	Albania	27.1	118	Burkina Faso	20.0
84	Oman	26.5	119	Cameroon	20.0
85	Indonesia	26.5	120	Zimbabwe	20.0
86	Kenya	26.1	121	Algeria	19.5
87	Lebanon	26.0	122	Zambia	19.4
88	Tanzania	25.6	123	Mali	19.2
89	Botswana	25.4	124	Mozambique	18.7
90	Dominican Republic	25.1	125	Togo	18.5
91	Rwanda	25.1	126	Benin	18.1
92	El Salvador	24.8	127	Ethiopia	18.1
93	Uzbekistan	24.5	128	Niger	17.8
94	Kyrgyzstan	24.5	129	Myanmar	17.7
95	Nepal	24.4	130	Guinea	17.3
96	Egypt	24.2	131	Yemen	13.6
97	Paraguay	24.1			

Table A2

Raw dataset for analysis, 2019

Country	GII	R&D	Production	Employment,	Market value	Export	Import	Life expectancy, years
	0–100	million EUR		units	million EUR			
Austria	50.1	311	3,024	16,094	4,583	11,150	9,898	82.0
Belgium	49.1	3,846	17,547	38,489	5,988	49,732	42,332	82.1
Bulgaria	40.0	91	121	15,000	1,210	1,038	1,471	74.96
Croatia	37.3	40	664	5,763	957	1,039	1,326	78.07
Cyprus	45.7	85	253	1,755	177	,333	312	80.38
Czech Republic	48.3	62	858	18,000	3,010	2,852	4,960	79.3
Denmark	57.5	1,543	14,391	24,821	3,111	17,041	4,217	81.5
Finland	57.0	182	1,877	5,672	2,712	669	1,985	82.1
France	53.7	4,451	35,848	98,780	29,304	32,556	26,012	82.9
Germany	56.5	8,466	33,158	119,994	40,456	81,862	52,679	81.4
Greece	36.8	51	1,376	25,700	5,158	1,944	2,957	81.7
Hungary	41.5	242	3,859	23,300	2,631	5,916	4,688	76.4
Ireland	53.0	305	19,305	37,000	2,279	31,666	27,867	82.8
Italy	45.7	1,600	34,000	65,800	24,099	498	665	83.6
Netherlands	58.8	642	6,180	20,000	5,770	44,382	29,928	82.2
Norway	49.3	126	1,072	4,000	2,621	1,964	1,382	83.0
Poland	40.0	339	2,550	24,736	7,281	3,688	6,906	78.0
Portugal	43.5	117	1,737	9,000	3,409	1,229	2,803	81.8
Romania	36.0	75	655	35,000	3,130	845	3,473	75.36
Russia	35.6	727	5,881	66,523	17,678	457	13,579	73.2
Slovakia	39.7	38	356	2,287	1,455	462	1,865	77.8
Slovenia	42.9	180	1,659	11,213	675	4,985	4,002	81.6
Spain	45.6	1,212	15,832	47,449	17,105	11,953	14,767	83.9
Sweden	62.5	1,104	9,840	11,012	4,313	9,918	4,391	83.2
Switzerland	66.1	6,383	54,305	46,652	5,533	77,809	29,036	84.0
Turkey	34.9	137	3,482	39,000	6,891	1,189	4,598	78.6
United Kingdom	59.8	5,437	23,039	72,000	23,279	25,717	25,369	81.3

Source: based on Cornell University–INSEAD–WIPO (2020), EFPIA (2021), Statista (2017).

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REFERENCES

AGUILAR, E. C. (2022): Regional systems of entrepreneurship in 2017–2018: An empirical study in selected regions of South America *Regional Statistics* 12 (1): 51–76. https://doi.org/10.15196/RS120103

ANDROSCHUK, G. (2021): Global Innovation Index 2020: who will finance innovations? *Law and Innovations* 1 (33). 7–13. https://doi.org/10.37772/2518-1718-2021-1(33)-1

ANNEMANS, L.–CLEEMPUT, I.–HULSTAERT, F.–SIMOENS, S. (2011): Stimulating pharmaceutical innovation in the EU *Expert review of Pharmacoeconomics & Outcomes Research* 11 (3): 235–239. https://doi.org/10.1586/erp.11.19

CARDINAL, L. B. (2001): Technological innovation in the pharmaceutical industry: The use of organizational control in managing research and development *Organization Science* 12 (1): 19–36. http://dx.doi.org/10.1287/orsc.12.1.19.10119

CORNELL UNIVERSITY–INSEAD–WIPO (2020): *The Global Innovation Index 2020*: *Who will finance innovation?* 13th edition. Ithaca, Fontainebleau and Geneva.

DÁNIEL, Z. A.–MOLNÁRNÉ BARNA, K.–MOLNÁR, T. (2021): Koronavírus-járvány a V4-országokban – Társadalmi, gazdasági hatások, regionális összefüggések, kormányzati beavatkozások *Területi Statisztika* 61 (5): 555–576. https://doi.org/10.15196/TS610501

DIMASI, J. A.–GRABOWSKI, H. G.–HANSEN, R.W. (2016): Innovation in the pharmaceutical industry: New estimates of R&D costs *Journal of Health Economics* 47: 20–33. https://doi.org/10.1016/j.jhealeco.2016.01.012

DUENAS-GONZALEZ, A.–GONZALEZ-FIERRO, A. (2020): Barriers for pharmaceutical innovation with focus in cancer drugs, the case of Mexico *Therapeatic Innovation and Regulatory Science* 54 (2): 342–352. https://doi.org/10.1007/s43441-019-00062-w

EYAL-COHEN, M.–RUTSCHMAN, A. S. (2020): Tax policy and pharmaceutical innovation *Saint Louis U. Legal Studies Research Paper* No. 2020-34, November 18, 2020. http://dx.doi.org/10.2139/ssrn.3732567

IQBAL, B. A.–RAHMAN, M. N. (2020): The economics and econometrics of global innovation index. In: LEAL JAMIL, G.–FERREIRA, J. J. P.–PINTO, M. M.–PESSOA, C. R. M.–XAVIER, A. (eds.): *Handbook of research on strategic innovation management for improved competitive advantage* pp. 1375–1385., IGI Global. http://dx.doi.org/10.4018/978-1-5225-9273-0.ch066

KHULLAR, D.–FISHER, J.–CHANDRA, A. (2019): Trickle-down innovation and the longevity of nations *The Lancet* 393 (10187): 2272–2274. http://dx.doi.org/10.1016/s0140-6736(19)30345-9

KONOPIELKO, L.–TRECHUBOVA, A. (2019): R&D effectiveness in the pharmaceutical industry. In: STUDZIENIECKI, T.–KOZINA, M.–ALILOVIC, D. S. (eds.): *33rd International Scientific Conference on Economic and Social Development* pp. 287–297., Varazdin Development and Entrepreneurship Agency, Varazdin.

KRISHNAVENI, C.–ARVAPALLI, S.–SHARMA, J. V. C.–DIVYA, K. (2020): Artificial intelligence in pharma industry – a review *International Journal of Innovative Pharmaceutical Sciences and Research* 7 (10): 37–50. http://dx.doi.org/10.21276/IJIPSR.2019.07.10.506

KUMAR, V.–SUNDARRAJ, R. P. (2018): The societal value of pharmaceutical innovation. In: *Global Innovation and Economic Value* pp. 147–187., India Studies in Business and Economics. Springer, New Delhi. https://doi.org/10.1007/978-81-322-3760-0_4

KUZNETS, S. (1972): Innovations and adjustments in economic growth *The Swedish Journal of Economics* 74 (4): 431–451. https://doi.org/10.2307/3439284

LICHTENBERG, F. R. (2021): The impact of pharmaceutical innovation on the longevity and hospitalization of New Zealand cancer patients, 1998–2017 *Expert Review of Pharmacoeconomics & Outcomes Research* 21 (3): 476–477. https://doi.org/10.1080/14737167.2021.1871330

MARADANA, R. P.–PRADHAN, R. P.–DASH, S.–GAURAV, K.–JAYAKUMAR, M.–CHATTERJEE, D. (2017): Does innovation promote economic growth? Evidence from European countries *Journal of Innovation and Entrepreneurship* 6 (1): 1–23. http://dx.doi.org/10.1186/s13731-016-0061-9

NAGY, SZ.–VERESNÉ SOMOSI, M. (2022): The relationship between social innovation and digital economy and society *Regional Statistics* 12 (2): 3–29. https://doi.org/10.15196/RS120202

NAQVI, S. R. (2016): Global Innovative Index and India: Current trends and opportunities *International Journal of Science Technology and Management* 5 (9): 138–146. https://ssrn.com/abstract=3480949

NYIKOS, GY.–SOHA, B.–BÉRES, A. (2021): Entrepreneurial resilience and firm performance during the COVID-19 crisis – Evidence from Hungary *Regional Statistics* 11 (3): 29–59. https://doi.org/10.15196/RS110307

OMACHONU, V.K.–EINSPRUCH, N. G. (2010): Innovation in healthcare delivery systems: A conceptual framework *The Innovation Journal* 15 (1): 1–20.

PÁL, V.–LADOS, G.–ILCSIKNÉ MAKRA, ZS.–BOROS, L.–UZZOLI, A.–FABULA, SZ. (2021): Concentration and inequality in the geographic distribution of physicians in the European Union, 2006–2018 *Regional Statistics* 11 (3): 3–28. https://doi.org/10.15196/RS110308

PECE, A. M.–SIMONA, O. E.–SALISTEANU, F. (2015): Innovation and economic growth: An empirical analysis for CEE countries *Procedia Economics and Finance* 26: 461–467. https://doi.org/10.1016/s2212-5671(15)00874-6

ROMASANTA, A. S.–VAN DER SIJDE, P.–VAN MUIJLWIJK-KOEZEN, J. (2020): Innovation in pharmaceutical R&D: Mapping the research landscape *Scientometrics* 125: 1801–1832. https://doi.org/10.1007/s11192-020-03707-y

SCHUHMACHER, A.–KUSS, M. (2018): The future of pharma R&D: how external innovation changes pharma R&D *Pharma Focusasia* 32: 14–19.

TÓTH, G.–CSOMÓS, GY. (2016): Mapping the position of cities in corporate research and development through a gravity model-based bidimensional regression analysis *Regional Statistics* 6 (1): 217–220. https://doi.org/10.15196/RS06111

UZZOLI, A. (2016): Health inequalities regarding territorial differences in Hungary by discussing life expectancy *Regional Statistics* 6 (1): 139–163. http://dx.doi.org/10.15196/RS06108

VAN VIERSSEN TRIP, F. W.–NGUYEN, N. C.–BOSCH, O. (2017): R&D productivity in the pharmaceutical industry. In: *Decision Management: Concepts, Methodologies, Tools, and Applications* pp. 302–320., IGI Global. http://dx.doi.org/10.4018/978-1-5225-1837-2.ch014

YILDIRIM, H. H.–MESTANOĞLU, M. (2019): Competitiveness in Turkey the pharmaceutical industry *IBAD Journal of Social Sciences* Special Issue: 340–352. http://dx.doi.org/10.21733/ibad.612571

INTERNET SOURCES

BRENNAN, T.–ERNST, P.–KATZ, J.–ROTH, E. (2020): *Building an R&D strategy for modern times.* https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/building-an-r-and-d-strategy-for-modern-times (downloaded: 11 August 2021)

European Federation of Pharmaceutical Industries and Associations (EFPIA) (2021): *The Pharmaceutical Industry in Figures. Key Data 2021.* https://www.efpia.eu/media/602709/the-pharmaceutical-industry-in-figures-2021.pdf (downloaded: 8 August 2021)

GRASSANO, N.–HERNÁNDEZ, H.–TÜBKE, A.–AMOROSO, S.–DOSSO, M.–GEORGAKAKI, A.–PASIMENI, F. (2020): *The 2020 EU Industrial R&D Investment Scoreboard* http://dx.doi.org/10.2760/655526 https://op.europa.eu/en/publication-detail/-/publication/73e624aa-406c-11eb-b27b-01aa75ed71a1/language-en (downloaded: 7 August 2021)

HARASZKIEWICZ-BIRKEMEIER, N.–HOŁDA, A. (2019): Current perspectives and challenges in the pharmaceutical, life science and healthcare sectors *Biotechnology eJournal* http://dx.doi.org/10.2139/ssrn.3427035

LICHTENBERG, F. R. (2012): *Pharmaceutical innovation and longevity growth in 30 developing and high-income countries*, 2000-2009. National Bureau of Economic Research (NBER) Working Paper No. 18235, July 2012. https://www.nber.org/system/files/working_papers/w18235/w18235.pdf (downloaded: 11 August 2021)

STATISTA (2012): *Gross value added per employee in global pharmaceutical industry in 2012, by region* https://www.statista.com/statistics/418701/pharmaceutical-value-added-per-employee-worldwide-by-region/ (downloaded: 12 August 2021)

STATISTA (2017): *Top countries by pharmaceutical industry employment 2014* https://www.statista.com/statistics/418051/leading-countries-by-employment-in-pharmaceutical-industry/ (downloaded: 12 August 2021)