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The potential impact of the COVID-19 pandemic on GDP per capita in European countries**

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Abstract

The study simulates the potential impact of the COVID-19 pandemic on gross domestic product (GDP) per capita in European countries for the first half of 2020. It is realized through regression analysis. The dependent variable was GDP per capita (forecast by International Monetary Fund) and the independent variables were five factors that characterize the spread of the COVID-19 pandemic in European countries (total confirmed cases per capita; total confirmed deaths per capita; percentage of recovered in the total confirmed cases on July 1, 2020; total tests per capita; percentage of days from the beginning of the spread of COVID-19 in the total number of days in the first half of 2020). Based on the results of the regression analysis, the regression equation explains 56 % of the changes in the dependent variable. The proposed regression model is recognized as adequate to sample data. The multicollinearity among independent variables is denied. Thus, the proposed regression model can be used to determine the impact of the COVID-19 pandemic on GDP per capita, when information on real GDP per capita becomes known.

Keywords: COVID-19; pandemic; spread; global threat; GDP per capita; simulation; impact; regression analysis; European countries.

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1. Introduction

The number of confirmed cases of COVID-19 in European countries on September 1, 2020, is 3,591,271, which is 1,164,244 more than on July 1, 2020 (2,427,027). Since July 1, 2020, the number of confirmed cases in European countries has increased by 48 %. Daily statistics show disappointing data in order to predict the end of the pandemic. All this causes a situation when it is necessary to understand what negative consequences a pandemic will have and whether it is possible to maintain the normal functioning of human activities in the context of the pandemic.

The collapse in the economy caused by the unexpected COVID-19 pandemic spread has become the subject of many studies that are focused on establishing trends that should be expected in the current year. Even before the start of the COVID-19 pandemic, the scientific community predicted a new global financial crisis due to the fact that the world economy is developing cyclically. Certainly, the exponential spread of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) as a trigger could not have been expected. The COVID-19 pandemic has intensified de-globalization and shifted the focus towards large regions of stability. Currently, most countries are helping to strengthen the domestic market and increase domestic solvency, thus changing the priorities of export, innovation, and monetary policies. To restore economic growth, reduce economic consequences of the pandemic and strict self-isolation, various strengthened measures and instruments of state regulation are used to prevent a wave of mass bankruptcies of companies and layoffs of workers. Carrying out such events requires significant financial investments.

According to the IMF report [4, p. 21], since April 2020 more than two-thirds of governments around the world have expanded budget support measures and announced the size of budget measures at $ 11 trillion globally. The use of strict quarantine measures has led to a global decline in production, the service market, a decrease in consumer demand and investment activity.

In the modern globalized world, unforeseen and poorly controlled transformations have taken place, which have led to a change and violation of the entire security system. The COVID-19 pandemic has become a real challenge to global security and a threat on a global scale, which has led to a negative and even devastating impact on all spheres of life and key institutions for managing and regulating social processes. The most unexpected and dangerous impact was the impact on the economic systems, which suffered billion dollars losses. Therefore, tracking changes caused by the COVID-19 pandemic, including simulation of the potential impact of the pandemic on GDP per capita, is extremely relevant for the research.

2. Literature review

The relevance of studies on the impact of the COVID-19 pandemic on GDP per capita is not in doubt. The lack of publications focused on establishing the impact of the spread of the COVID-19 pandemic on GDP per capita in different countries is due to the fact that not enough time has passed to obtain the necessary analytical information. This circumstance is confirmed by the fact that the pandemic has manifested itself in European countries since the end of January 2020 (the first confirmed cases are dated January 24, 2020, in France and Sweden), and information on the real size of GDP per capita for the first half of 2020 has not yet been officially released. However, some authors are trying to predict the probable or potential impact of COVID-19 on economic situation in different countries and the world in general.

It is hard to assess the depth and the breadth of the pandemic as it is spreading, and to precisely estimate how long it will take countries to return to normal activity levels [Maliszewska et al, 2020]. According to the work of M. Maliszewska, A. Mattoo, and D. Van der Mensbrugghe (dated April 2020), economic models can be used to model the consequences of pandemics, among which the main focus is on the direct impact of a reduction in employment; the increase in costs of international transactions; the sharp drop in travel; the decline in demand for services that require proximity among people. This paper illustrates the transmission channels and heterogeneous impact of COVID-19 on output and trade in different scenarios. The illustrated scenarios indicate that the potential loss of income in affected countries could be significant, with global GDP declining by up to 3,9 %, and developing countries hit the hardest (4 % on average, but some over 6,5 %).

The economic cost of the COVID-19 pandemic can be proxied by GDP forgone, namely the difference between current forecasts and pre-COVID-19 outlook [Boissay & Rungcharoenkitkul, 2020]. The authors of this work (dated April 2020) compare the GDP forecasts of the pre-COVID-19 outlook and Deutsche Bank (March 31, 2020), Goldman Sachs (March 31, 2020), JPMorgan (March 27, 2020), Nomura (March 27, 2020), that were formed after the beginning of the pandemic. The graphs show that the largest decline in GDP is forecasted according to the results of the second quarter of 2020 (in comparison with the results of the fourth quarter of 2019 and the first quarter of 2020) with a subsequent increase in this measure in accordance with the results of the third and fourth quarter of 2020. Under the baseline scenario, annual output loss ranges between 5 and 9 % of pre-COVID-19 estimates for the US, and between 4 and 4,5 % for the global economy. In worse scenarios, these costs could reach 11 % for the US and 8 % for the global economy. The latest IMF (2020) forecasts released on 14 April already inch towards these scenarios, with US and global output losses in 2020 projected at 8 % and 6 % respectively.

The study of W. McKibbin & R. Fernando (dated March 2020) explores seven different scenarios of how COVID-19 might evolve in the current year [McKibbin & Fernando, 2020]. It examines the impacts of different scenarios on macroeconomic outcomes (including GDP) and financial markets in a global hybrid general model, which consists of dynamic stochastic general equilibrium (DSGE) model and computable general equilibrium (CGE) model. These scenarios prove that even a contained outbreak could significantly impact the global economy in the short run. While scenarios 1-3 assume that epidemiological events are isolated in China, scenarios 4–6 are pandemic scenarios where epidemiological shocks occur in all countries to differing degrees. While scenarios 1–6 assume the shocks are temporary, scenario 7 is a case where a mild pandemic is expected to be recurring each year for the indefinite future [McKibbin & Fernando, 2020]. The authors maintain that the COVID-19 pandemic will have a significant impact on the economies of different countries, but preventive measures may reduce economic losses.

It is currently difficult to make a comprehensive review of the literature on the impact of the COVID-19 pandemic on macroeconomic indicators in the world or in some regions. However, the articles above prove that the results of similar research are published, even despite their prognostic nature.

3. The identification of previously unresolved issues and the formulation of research hypotheses

The aggravation of the economic crisis phenomena associated with the exponential rate of spread of the COVID-19 pandemic requires a revision of state policy to stabilize the state of the economy of individual countries and the world as a whole. The volume and speed of recovery of the economies of the countries will be uneven since it depends on the duration of quarantine measures and available financial resources. In conditions of financial and economic turbulence, the share of the shadow economy is growing. Therefore, the need for a balanced and well-grounded policy of de-shadowing of the economy is becoming more urgent.

There is an extra need to study the impact of the COVID-19 pandemic on the global economy as a bacteriological and viral threat. This threat destabilizes national security in the process of geopolitical transformations of the modern world, which can have devastating and insidious consequences for all people around the world.

The routine lifestyle for people worldwide has been disrupted since the beginning of the COVID-19 pandemic. New terms are coming in our life – «social distancing», «self-isolation», «quarantine», «flatten the curve», «person-to-person transmission», «lockdown», «essential workers», «online drinking», «WFH (working from home)», «do masking», «the COVID-19 era», «the post-COVID-19 world», «distance learning» etc. This pandemic is changing not only the lifestyle and terminology that is used in everyday life, but also all systems that ensure countries normal functioning and development.

The COVID-19 pandemic affects all areas of business, production chains, changes in communication between the seller and the buyer. All participants should revise old strategies and modernize them or replace with new ones adapted to the new reality.

According to Shirakawa's work, the biggest problem facing world economy is not inflation or deflation, but low growth [Shirakawa, 2020]. The author emphasizes that the dire situation facing in-person services such as tourism, restaurants, and transport. The ultimate consequence of the coronavirus pandemic is that it should force a deep rethink on how macroeconomic policy is developed.

In support of this line of thought, the COVID-19 pandemic is devastating the travel and tourism industries, which provided some countries with a significant portion of the annual GDP, thereby reducing this macroeconomic indicator in the current period. Italy and Spain are also among the most vulnerable countries to the economic fallout of the pandemic. Both countries rely heavily on travel and tourism, which has come to a screeching halt in the past months and remains very limited to this day despite gradual reopenings [Richter, 2020]. As shown on Figure 1, travel and tourism contributed 14,3 % and 13 %, respectively, to Spain's and Italy's GDP last year, including direct contributions from hotels, travel agents, airlines, restaurants, etc.

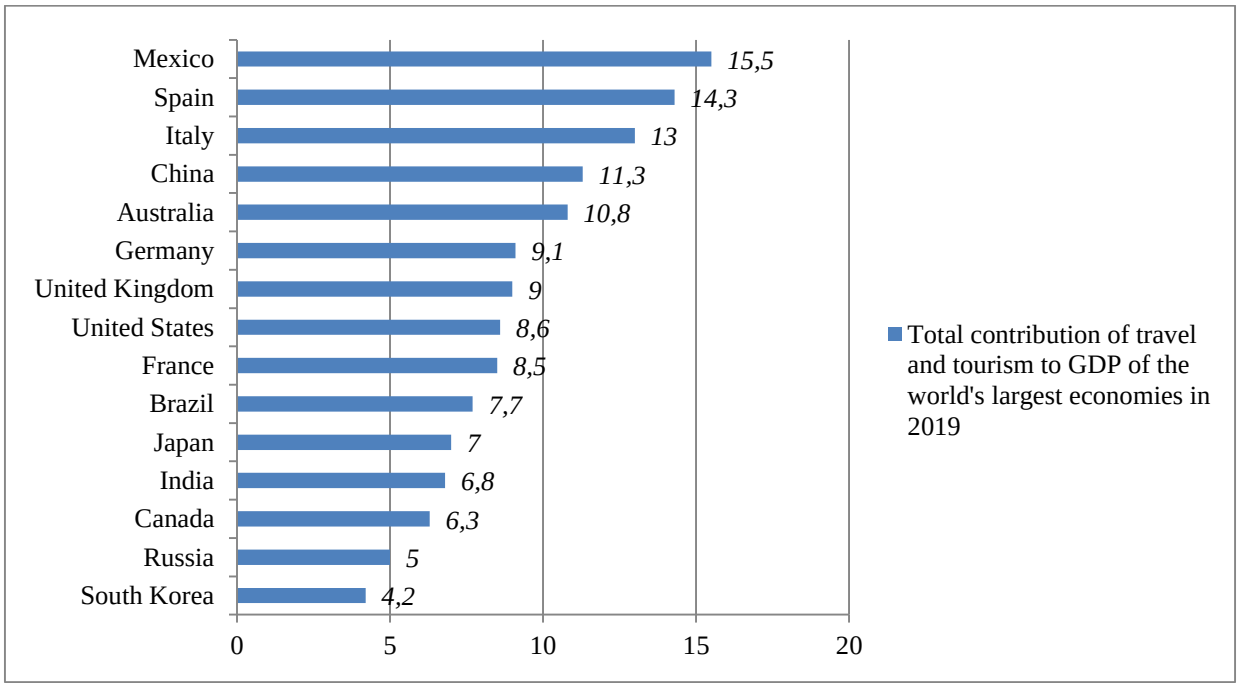


Fig. 1. Total contribution of travel and tourism to GDP of the world's largest economies in 2019, % [Richter, 2020]

According to the World Travel & Tourism Council (WTTC), 2019 was another year of strong growth for the global travel & tourism sector reinforcing its role as a driver of economic growth and job creation. In 2019, travel & tourism provided 10,3 % of global GDP [13].The fall in the travel & tourism sector due to the circumstances of the COVID-19 pandemic will have a destructive effect, especially on tourist-oriented countries, where the contribution of these sectors to GDP is significant (fig. 1).

In the context of the COVID-19 pandemic spread, customer relationship management is coming to the fore in terms of company survivability and predictability of its performance, which makes it necessary to pay close attention to the value-based management of customer capital and implement effective tools to increase customer loyalty. Companies around the world are facing the challenge of reducing consumption. The decrease in demand is followed by a decrease in production and other processes that lead to a decrease in GDP in the country. According to Gourinchas' article, faced with declining demand for their products – and in some sectors such as leisure, travel, or entertainment the collapse in demand is likely to be near total – firms will want to cut costs, shedding workers to avoid a complete collapse. Banks, with a worsening portfolio of non-performing loans, will naturally want to cut lending, further darkening the prospects of the non-financial sector. Suppliers will ask to be paid, etc. Panic or loss of confidence adds another layer. The result would be cascading business failures, with an associated surge in layoffs and a build-up in financial fragilities [Gourinchas, 2020].

Therefore, at the company level, it is important to research the markets and develop effective management of customer capital, and at the country level, it is necessary to clearly understand serious losses from the COVID-19 pandemic to all economic processes, which lead to a decrease in GDP per capita. In general, at macroeconomic level, it is necessary to determine the potential risks by establishing the impact of the COVID-19 pandemic on GDP per capita.

The hypothesis of this study is that the spread of the COVID-19 pandemic affects GDP per capita in European countries. Real data on the spread of the COVID-19 pandemic for the first half of 2020 is available, but the absence of real data on GDP per capita for the same period forces us to use the forecast of GDP per capita as «real», which will be the reason for the potential, probable nature of the research results and only the possibility of simulation such an impact.

4. Research methodology and methods

The aim of the article is to simulate the potential impact of the COVID-19 pandemic on GDP per capita in European countries using the example of the first half of 2020. Using multiple regression model, the relationships between dependent variable (y) and independent variables (x_1, x_2, x_3, x_4, x_5) will be examined.

The potential impact of the COVID-19 pandemic on GDP per capita in European countries is explored by determining a list of factors characterizing the pandemic and, possibly, having a significant impact on the analyzed macroeconomic indicator. These factors for regression analysis are represented by the following:

1) *Total confirmed cases per capita.* The term «per capita» means «per person» and is used in a lot of analytical research to identify trends and links between indicators for the needs of economics, sociology, history, and other social sciences. Exploring the spread of the COVID-19 pandemic in the country, one of the main indicators will be the total number of confirmed cases. To compare the development of the pandemic in different countries, the indicator «Total confirmed cases per capita» will be more appropriate, since it shows confirmed cases relative to the size of the country's population.

2) *Total confirmed deaths per capita.* According to Table 1, the most affected European countries in the first half of 2020 by COVID-19 are the United Kingdom (43,906 confirmed deaths), Italy (34,767 confirmed deaths), France (29,861 confirmed deaths), Spain (28,363 confirmed deaths). This indicator is absolute, since it shows the total number of confirmed deaths for the analyzed period. More efficient for our model would be an indicator that shows the total number of confirmed deaths per capita.

3) *Percentage of recovered in the total confirmed cases on July 1, 2020.*As of July 1, 2020, the total number of confirmed COVID-19 cases in European countries is 2,427,027. The exact number of people who recovered in general for European countries is unknown, since there are no such data for Spain, the United Kingdom, Sweden, and the Netherlands. Information on the proportion of recovered people in the total number of recorded cases of the disease makes it possible to understand how critical the situation in the country is with the number of active cases of the disease. Countries such as Germany, Switzerland, Ireland, Austria, Denmark, Norway, Finland, Luxembourg, Estonia, Iceland, Andorra, San Marino (Table 1) as of July 1, 2020 showed a high percentage of recovered (above 90 %).

4) *Total tests per capita.* Proper organization of population testing is of particular importance for the successful fight against the spread of coronavirus SARS-CoV-2 and the COVID-19 pandemic in the world. Therefore the ratio of the number of tests performed as of July 1, 2020 to the population is certainly an important and necessary factor to take into account.

5) *Percentage of days from the beginning of the spread of COVID-19 in the total number of days in the first half of 2020*. In some countries, the pandemic officially began in late January, in others – in February or March, therefore the first half of 2020 could have different lengths of the COVID-19 pandemic for different countries, measured in days. This moment will undoubtedly have an impact on the general situation of the COVID-19 pandemic in a particular country.

Table 1 provides information on the factors of the spread of the COVID-19 pandemic in 48 European countries/regions, but the regression model will use data for only 33 countries, information for which is available for all factors.

In our model GDP per capita (forecast by IMF) will be dependent variable (y).GDP is one of the most important macroeconomic indicators used to measure the performance of the national economy. GDP per capita shows how the national economy of a country correlates with the level of welfare of its average resident. This figure is obtained by dividing real GDP by population. If the country has a downward trend in GDP per capita, it indicates a crisis in the economy and deteriorating living standards.

Calculating GDP per capita in international dollar is considered one of the most accurate ways to assess and compare economic development. Forecasting GDP per capita in an anti-crisis policy to overcome the effects of a pandemic is very important. GDP forecasting as an element of economic forecasting under certain conditions (influence of endogenous and exogenous factors) is an element of public administration. The obtained forecasting results are used by experts to determine the necessary measures of public policy for the long and short term, outlining its most effective tools and mechanisms to reduce the level of crisis and accelerate their time, while maintaining positive effects.

Table 1
Factors of the spread of COVID-19 by European countries during the 1st half of 2020 *, **

№	Country, other	Total confirmed cases	Total confirmed cases per capita	Total confirmed deaths	Total confirmed deaths per capita	Total recovered	Active cases	Percentage of recovered in the total confirmed cases on July 1, 2020	Total tests	Total tests per capita	Population	The date of the first confirmed cases	Number of days from the date of the first confirmed cases during the first half of 2020	Total number of days during the first half of 2020	Percentage of days from the beginning of the spread of the disease in the total number of days in the first half of 2020
-	-	-	**1st factor**	-	**2nd factor**	-	-	**3rd factor**	-	**4th factor**	-	-	-	-	**5th factor**
-	-	*1*	*1/5*	*2*	*2/5*	*3*	-	*3/1*100 %*	*4*	*4/5*	*5*	-	*6*	*7*	*6/7*100 %*
1	Russia	654405	**0,004484**	9536	**0,000065**	422931	221938	**64,63**	19852167	**0,136033**	145935982	31.01.2020	152	182	**83,52**
2	Spain	296739	**0,006347**	28363	**0,000607**	n/a***	n/a	**n/a**	5448984	**0,116543**	46755218	31.01.2020	152	182	**83,52**
3	United Kingdom	283181	**0,004171**	43906	**0,000647**	n/a	n/a	**n/a**	9662051	**0,142311**	67893830	31.01.2020	152	182	**83,52**
4	Italy	240578	**0,003979**	34767	**0,000575**	190717	15255	**79,27**	5445476	**0,090068**	60459584	31.01.2020	152	182	**83,52**
5	Germany	196324	**0,002343**	9061	**0,000108**	179800	7463	**91,58**	5873563	**0,070099**	83790088	27.01.2020	156	182	**85,71**
6	France	165719	**0,002539**	29861	**0,000457**	76539	59319	**46,19**	1384633	**0,021212**	65276894	24.01.2020	159	182	**87,36**
7	Sweden	70487	**0,006978**	5469	**0,000541**	n/a	n/a	**n/a**	519113	**0,051394**	10100615	24.01.2020	159	182	**87,36**
8	Belarus	62424	**0,006606**	398	**0,000042**	47553	14473	**76,18**	1013056	**0,107210**	9449246	27.02.2020	125	182	**68,68**
9	Belgium	61509	**0,005307**	9754	**0,000842**	17021	34734	**27,67**	1239232	**0,106916**	11590751	04.02.2020	148	182	**81,32**
10	Netherlands	50335	**0,002937**	6115	**0,000357**	n/a	n/a	**n/a**	616376	**0,035970**	17135760	27.02.2020	125	182	**68,68**
11	Ukraine	44998	**0,001029**	1173	**0,000027**	19548	24277	**43,44**	666147	**0,015234**	43726567	03.03.2020	120	182	**65,93**
12	Portugal	42454	**0,004164**	1579	**0,000155**	27798	13077	**65,48**	1190384	**0,116751**	10195939	02.03.2020	121	182	**66,48**
13	Poland	34775	**0,000919**	1477	**0,000039**	21791	11507	**62,66**	1546510	**0,040864**	37845573	04.03.2020	119	182	**83,52**
14	Switzerland	31851	**0,003680**	1965	**0,000227**	29200	686	**91,68**	583928	**0,067460**	8655945	25.02.2020	127	182	**83,52**
15	Romania	27296	**0,001419**	1667	**0,000087**	19314	6315	**70,76**	722697	**0,037574**	19234136	26.02.2020	126	182	**83,52**
16	Ireland	25470	**0,005157**	1734	**0,000351**	23364	372	**91,73**	434261	**0,087928**	4938832	29.02.2020	123	182	**83,52**
17	Austria	17873	**0,001984**	705	**0,000078**	16491	677	**92,27**	620886	**0,068930**	9007513	25.02.2020	127	182	**85,71**
18	Moldova	16898	**0,004189**	549	**0,000136**	9594	6755	**56,78**	98934	**0,024527**	4033723	07.03.2020	116	182	**87,36**
19	Serbia	14836	**0,001698**	281	**0,000032**	12772	1783	**86,09**	409866	**0,046915**	8736440	06.03.2020	117	182	**87,36**
20	Denmark	12794	**0,002209**	606	**0,000105**	11693	495	**91,39**	1071479	**0,184972**	5792667	27.02.2020	125	182	**68,68**
21	Czechia	12046	**0,001125**	349	**0,000033**	7797	3900	**64,73**	555980	**0,051915**	10709450	01.03.2020	122	182	**81,32**
22	Norway	8896	**0,001641**	251	**0,000046**	8138	507	**91,48**	338860	**0,062496**	5422116	26.02.2020	126	182	**68,68**

End of the table 1

23	Finland	7236	**0,001306**	328	**0,000059**	6700	208	**92,59**	246000	**0,044397**	5540924	29.01.2020	154	182	**65,93**
24	North Macedonia	6454	**0,003098**	306	**0,000147**	2598	3550	**40,25**	60773	**0,029170**	2083372	26.02.2020	126	182	**66,48**
25	Bulgaria	5154	**0,000742**	232	**0,000033**	2722	2200	**52,81**	144369	**0,020782**	6946975	08.03.2020	115	182	**65,38**
26	Bosnia and Herzegovina	4606	**0,001404**	188	**0,000057**	2432	1986	**52,80**	94126	**0,028695**	3280258	05.03.2020	118	182	**69,78**
27	Luxembourg	4345	**0,006939**	110	**0,000176**	4003	232	**92,13**	191282	**0,305492**	626145	29.02.2020	123	182	**69,23**
28	Hungary	4157	**0,000430**	586	**0,000061**	2714	857	**65,29**	277750	**0,028753**	9659720	04.03.2020	119	182	**67,58**
29	Greece	3432	**0,000329**	192	**0,000018**	1374	1866	**40,03**	315982	**0,030320**	10421687	26.02.2020	126	182	**69,78**
30	Croatia	2831	**0,000690**	108	**0,000026**	2155	568	**76,12**	80456	**0,019602**	4104572	25.02.2020	127	182	**63,74**
31	Albania	2580	**0,000897**	65	**0,000023**	1516	999	**58,76**	23869	**0,008294**	2877718	08.03.2020	115	182	**64,29**
32	Estonia	1989	**0,001499**	69	**0,000052**	1836	84	**92,31**	107439	**0,080991**	1326557	27.02.2020	125	182	**68,68**
33	Iceland	1847	**0,005412**	10	**0,000029**	1823	14	**98,70**	82094	**0,240540**	341290	28.02.2020	124	182	**67,03**
34	Lithuania	1818	**0,000668**	78	**0,000029**	1524	216	**83,83**	428238	**0,157376**	2721108	28.02.2020	124	182	**69,23**
35	Slovakia	1687	**0,000309**	28	**0,000005**	1466	193	**86,90**	213521	**0,039109**	5459706	06.03.2020	117	182	**84,62**
36	Slovenia	1613	**0,000776**	111	**0,000053**	1384	118	**85,80**	103097	**0,049591**	2078945	04.03.2020	119	182	**69,23**
37	Latvia	1121	**0,000595**	30	**0,000016**	974	117	**86,89**	152778	**0,081025**	1885577	02.03.2020	121	182	**63,19**
38	Montenegro	576	**0,000917**	12	**0,000019**	315	249	**54,69**	13186	**0,020995**	628068	17.03.2020	106	182	**64,84**
39	Andorra	855	**0,011065**	52	**0,000673**	799	4	**93,45**	3750	**0,048532**	77268	02.03.2020	121	182	**67,58**
40	San Marino	698	**0,020570**	42	**0,001238**	656	0	**93,98**	5713	**0,168361**	33933	27.02.2020	125	182	**65,38**
41	Malta	671	**0,001520**	9	**0,000020**	647	15	**96,42**	96266	**0,218008**	441570	07.03.2020	116	182	**69,23**
42	Channel Islands	571	**0,003284**	47	**0,000270**	512	12	**89,67**	21388	**0,122994**	173895	09.03.2020	114	182	**69,78**
43	Isle of Man	336	**0,003951**	24	**0,000282**	312	0	**92,86**	6519	**0,076655**	85043	19.03.2020	104	182	**63,19**
44	Faroe Islands	187	**0,003827**	0	**0,000000**	187	0	**100,00**	16336	**0,334295**	48867	04.03.2020	119	182	**68,68**
45	Gibraltar	178	**0,005283**	0	**0,000000**	176	2	**98,88**	13427	**0,398534**	33691	04.03.2020	119	182	**68,13**
46	Monaco	103	**0,002624**	4	**0,000102**	95	4	**92,23**	16200	**0,412760**	39248	28.02.2020	124	182	**68,13**
47	Liechtenstein	82	**0,002150**	1	**0,000026**	81	0	**98,78**	900	**0,023603**	38131	03.03.2020	120	182	**64,29**
48	Vatican City	12	**0,014981**	0	**0,000000**	12	0	**100,00**	n/a	**n/a**	801	06.03.2020	117	182	**65,38**
	Total	2427027	**0,003246**	192198	**0,000257**	**-**	**-**	**-**	**-**	**-**	0,136033	-	-	-	**-**

* – statistics for columns «Total confirmed cases», «Total confirmed deaths», «Total recovered», «Active cases», «Total tests», «Population» were taken from [14]

** – information for column «The date of the first confirmed cases» was taken from [2]

*** – not available

The COVID-19 pandemic has caused an unprecedented economic shock since the Great Depression. The economic, social and political consequences of the spread of COVID-19 are difficult to predict, but it is clear that all major financial institutions and analytical agencies have revised their economic growth forecasts, which are expected to collapse in all developed and developing economies. The global recession caused by COVID-19 will lead to a contraction of the global economy in 2020. In particular, the growth rate of gross domestic product is projected to decline:

- by 3,0 according to the survey by the International Monetary Fund (IMF), April 2020 [5, p. 7];
- by 5,2 according to the report of the World Bank Group, June 2020 [12, p. 4];
- by 7,6 in accordance with the document of the Organisation for Economic Cooperation and Development (OECD), June 2020 [8, p. 13].

The study used the projected value of GDP per capita, calculated by the International Monetary Fund (IMF) for 2020-2024 in international dollars and published in October 2019 [9], before the beginning of spread of the COVID-19 pandemic. To ensure the relevance and comparability of the model data, the value of GDP per capita for half a year is calculated by dividing the projected value of GDP per capita for the year in half (Table 2).

Table 2
GDP per capita forecast for the 1st half of 2020 (according to IMF), international dollars*

№	*Country*	*GDP per capita forecast**	*№*	*Country*	*GDP per capita forecast**	*№*	*Country*	*GDP per capita forecast**
1	Russia	15409,78	12	Ireland	43494,1	23	Luxembourg	56022,29
2	Italy	20791,09	13	Austria	27585,99	24	Hungary	17970,6
3	Germany	27653,1	14	Moldova	4080,27	25	Greece	15808,14
4	France	24320,02	15	Serbia	9883,73	26	Croatia	14603,56
5	Belarus	10611,87	16	Denmark	27837,34	27	Estonia	18802,81
6	Belgium	25452,34	17	Czechia	20292,39	28	Iceland	28486,84
7	Ukraine	5155,03	18	Norway	39819,03	29	Lithuania	19375,51
8	Portugal	17467,91	19	Finland	24773,94	30	Slovakia	19160,77
9	Poland	17825,59	20	North Macedonia	8688,82	31	Slovenia	20171,97
10	Switzerland	33778,85	21	Bulgaria	13017,16	32	Latvia	16493,26
11	Romania	14777,38	22	Bosnia and Herzegovina	7447,08	33	Malta	24794,73

* – information for column «GDP per capita forecast» was taken from [9]

This forecast may serve as the basis for our model, although it did not take into account such a threat to the economy as a pandemic. It should be noted that the projected data have a fairly high degree of conventionality. Today, one of the main risks is high uncertainty, and therefore the accuracy of forecasts is quite conditional.

In summary, the aim of this study is achieved by using the regression analysis, where the dependent variable is GDP per capita (forecast by IMF) and the independent variables are five factors that characterize the spread of the COVID-19 pandemic in European countries (total confirmed cases per capita; total confirmed deaths per capita; percentage of recovered in the total confirmed cases on July 1, 2020; total tests per capita; percentage of days from the beginning of the spread of COVID-19 in the total number of days in the first half of 2020).

5. Main results

Table 3 shows the analysis performed using the Ordinary Least Squares (OLS) method, more commonly referred to as linear regression. It demonstrates the extent to which the independent variable (or variables) will affect the dependent variable. In the presented regression model, GDP per capita (IMF forecast) is used as a dependent variable (y), and indicators characterizing the spread of COVID-19 in European countries are used as independent variables (x_1, x_2, x_3, x_4, x_5).

Table 3
OLS, using the observations 1–33 (Dependent variable – GDP per capita (IMF forecast))

	Coefficient	*Standard error*	*T-statistics*	*P-value*	*Significance by t-statistics*
const	−8191,23	16556.4	−0,4947	0,6248	
TC per capita	−188462	1,04995e+06	−0,1795	0,8589	
TD per capita	2,56770e+07	1,11965e+07	2,293	0,0298	**
% recovered	283,606	88,2650	3,213	0,0034	***
TT per capita	53033	28538,9	1,858	0,0741	*
% days	15,0524	239,190	0,06293	0,9503	

This model looks like the following regression equation (1.1):

$$\hat{y} = -8191 - 188462x_1 + (2.56770e + 07)x_2 + 284x_3 + 53033x_4 + 15x_5, \quad (1.1)$$

where y – GDP per capita (forecast by IMF);
x_1 – total confirmed cases per capita (TC per capita);
x_2 – total confirmed deaths per capita (TD per capita);
x_3 – percentage of recovered in the total confirmed cases on July 1, 2020 (% recovered);
x_4 – total tests per capita (TT per capita);
x_5 – percentage of days from the beginning of the spread of COVID-19 in the total number of days in the first half of 2020 (% days).

According to the p-value (Table 3), the indicator x_5 (percentage of days from the beginning of the spread of COVID-19 in the total number of days in the first half of 2020) is recognized as the most significant in the presented regression equation (the p-value of P_{days} is 0.9503). The second most significant factor is x1 (total confirmed cases per capita). If in the first case (between x_5 and y) there is a positive correlation, then in the second there is a negative correlation (between x_1 and y). The positive correlation means that an increase in x_5 (percentage of days from the beginning of the spread of COVID-19 in the total number of days in the first half of 2020) will lead to an increase in y (GDP per capita forecast by IMF). The negative correlation means that an increase in x_1 (total confirmed cases per capita) will lead to a decrease in y (GDP per capita forecast by IMF). The p-value of x_2, x_3, and x_4 is less than 0.1, so the significance of the impact of these factors is relatively low.

According to the t-test, three coefficients of the regression equation were recognized by the program as significant (marked with asterisks in Table 3 – *, **, ***). Statistically significant independent variables are the percentage of recovered in the total confirmed cases on July 1, 2020 (% recovered), the total confirmed deaths per capita (TD per capita), and the total tests per capita (TT per capita). The rest of the independent variables were considered statistically insignificant. When accurate data on GDP per capita become available, the proposed model will be tested and improved, and statistically insignificant independent variables will be removed from it. Since the model is simulation, this is not necessary.

The statistical characteristics for all variables (y, x_1, x_2, x_3, x_4, x_5) of the presented regression model are shown in Table 4.

Table 4
Summary statistics, using the observations 1–33

Variable	*Mean*	*Median*	*Standard Deviation*	*Min*	*Max*
GDP per capita	20965	19161	10997	4080	56022
TC per capita	0,00243	0,00164	0,00192	0,000309	0,00694
TD per capita	0,000127	0,000057	0,000182	0,000005	0,000842
% recovered	73,8	79,3	19,8	27,7	98,7
TT per capita	0,0822	0,0625	0,0700	0,0152	0,305
% days	70,2	68,1	7,10	63,2	87,4

Table 4 shows summary statistics for all variables of the analyzed regression model, which generally inform about the values from the sample (e.g. minimal, average (mean) and maximum value for each variable). For example, for a variable such as the total confirmed cases per capita (TC per capita), the maximum value is 0,00694 (Luxembourg), the minimum value is 0,000309 (Slovakia), the standard deviation is 0,00192, the average (mean) value is 0,00243, the median is 0,00164.

The coefficient of determination (R^2) of this model is 0,56, which confirms the practicability of the analyzed regression model. This makes it possible to use this equation to simulate the potential impact of the COVID-19 pandemic on GDP per capita in European countries with a 56 % probability.

The presented regression of 56 % explains the changes in y (GDP per capita forecast by IMF). The remaining 44 % of the changes are due to other factors that are not included in the presented equation as independent variables.

According to the results of F-test (Fisher test), the proposed regression model is recognized as adequate to sample data, because the comparing the observed value of F [5, 27] with the critical value of F [5, 27] shows that $F_{observed}$ is higher than $F_{critical}$ ($F_{critical}$ (2.57) < $F_{observed}$ (7.01) with a probability of error of 0.05), which confirms the basic requirement of this test.

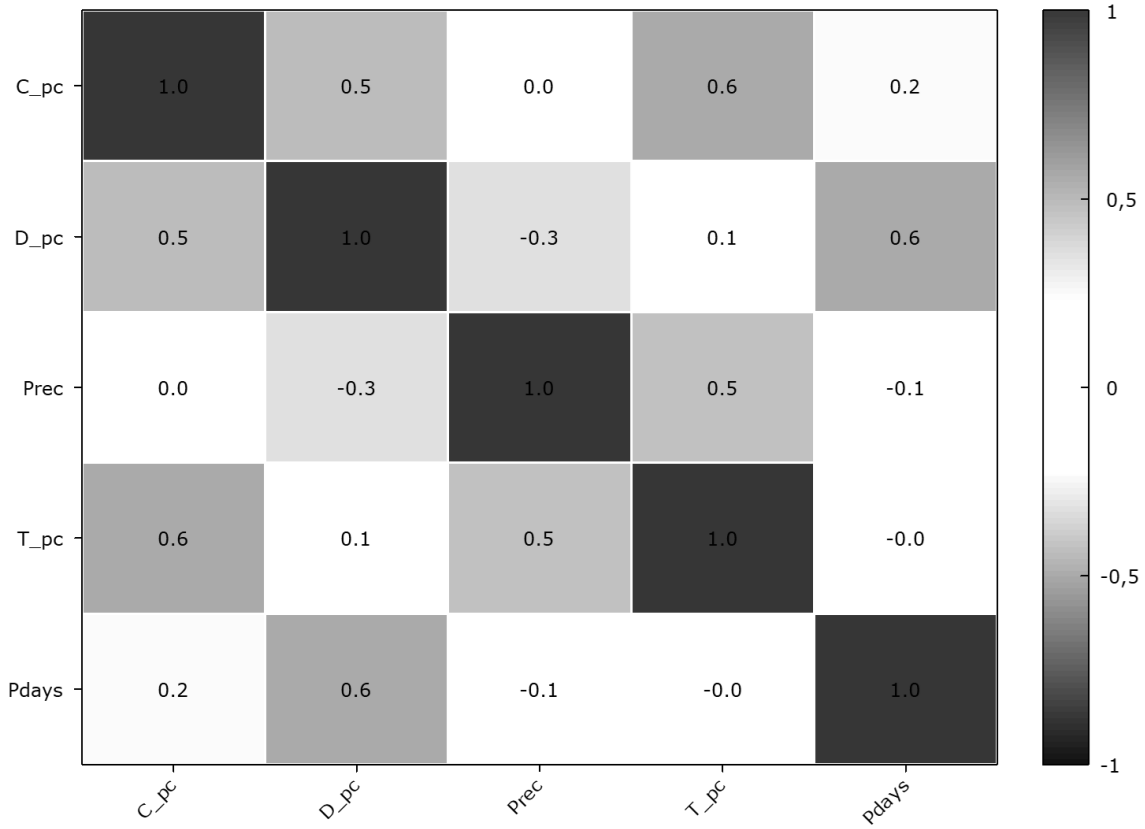
Table 5 shows the correlation coefficients for the independent variables, the values of which confirm the absence of multicollinearity between the presented variables. Exactly the lack of highly correlated independent variables is one of the requirements of multiple regression.

Table 5
Correlation coefficients for independent variables, using the observations 1-33

TC per capita	*TD per capita*	*% recovered*	*TT per capita*	*% days*	*Variables*
1,0000	0,4858	0,0457	0,5538	0,2432	*TC per capita*
	1,0000	–0,3287	0,0546	0,5517	*TD per capita*
		1,0000	0,4639	–0,0954	*% recovered*
			1,0000	–0,0131	*TT per capita*
				1,0000	*% days*

Within our regression model the most significant correlations between independent variables are 0.5538 (between the total tests per capita (TT per capita) and the total confirmed cases per capita (TC per capita)) and 0.5517 (between the percentage of days from the beginning of the spread of COVID-19 in the total number of days in the first half of 2020 (% days) and the total confirmed deaths per capita (TD per capita)).

Figure 2 shows the correlation matrix for visualizing the level of collinearity of the independent variables.



*where C_pc – TC per capita, D_pc – TD per capita, Prec – % recovered, T_pc – TT per capita, Pdays – % days

Fig. 2. Correlation matrix for independent variables, using the observations 1–33*

The above data (Table 5, Figure 2) suggest the absence of multicollinearity of the independent variables, due to the lack of correlation coefficients with a value above 0.7. There are several negative (inverse) correlations, which mean that increasing one variable will decrease another (TD per capita / % recovered; % recovered / % days; TT per capita / % days).

For another variant of testing for multicollinearity is using the regression models, where our independent variables (total confirmed cases per capita; total confirmed deaths per capita; percentage of recovered in the total confirmed cases on July 1, 2020; total tests per capita; percentage of days from the beginning of the spread of COVID-19 in the total number of days in the first half of 2020) will be dependent variables, and all other factors will be independent variables. Thus, the coefficient of determination (R^2) will be known, which allows us to understand the level of collinearity between the independent variables of our regression model (Table 6).

Table 6
Test independent variables for multicollinearity

Dependent variable	*Independent variables*	*Coefficient of determination (R^2)*
TC per capita	TD per capita; % recovered; TT per capita; % days	0,518622
TD per capita	TC per capita; % recovered; TT per capita; % days	0,528831
% recovered	TC per capita; TD per capita; TT per capita; % days	0,362376
TT per capita	TC per capita; TD per capita; % recovered; % days	0,511072
% days	TC per capita; TD per capita; % recovered; TT per capita	0,323698

All values of coefficient of determination (Table 6) are below 0,7, which denies multicollinearity for selected variables.

The results of regression analysis in the form of an equation were used to simulate the potential impact of the COVID-19 pandemic on GDP per capita in European countries. The quality of the proposed regression model (with the appropriate structure of variables) is confirmed by the results of various tests.

6. Concluding remarks

The aim of this article was to simulate the potential impact of the COVID-19 pandemic on GDP per capita in European countries using the example of the first half of 2020. The hypothesis of this study was that the spread of the COVID-19 pandemic affects GDP per capita in European countries.

According to the results of the regression analysis, where the dependent variable was GDP per capita (forecast by IMF) and the independent variables were five factors that characterize the spread of the COVID-19 pandemic in European countries (total confirmed cases per capita; total confirmed deaths per capita; percentage of recovered in the total confirmed cases on July 1, 2020; total tests per capita; percentage of days from the beginning of the spread of COVID-19 in the total number of days in the first half of 2020), the obtained equation can be used to simulate the potential impact of the COVID-19 pandemic on GDP per capita in European countries.

This study has some limitations. Firstly, the lack of information on the real value of GDP per capita for the first half of 2020 makes it impossible to accurately determine the impact of the COVID-19 pandemic on this macroeconomic indicator. On the one hand, this limitation makes it impossible to draw accurate conclusions regarding the impact of the pandemic on GDP per capita, but on the other hand, it allows us to propose the developed regression equation with a set of factors as a simulation model. This model can be used to determine the impact of the COVID-19 pandemic on GDP per capita, when information on real GDP per capita becomes known. Secondly, the proposed model is built on the example of European countries, and not all, but only those for which there are informational data on the factors that were taken into account (the sample included 33 countries). Therefore, the results that were identified in the course of this analysis will not necessarily repeat the trends of the spread of the pandemic and the corresponding impact on GDP per capita in other regions.

The following research prospects are proposed. The proposed model can be used to determine the impact of the COVID-19 pandemic on GDP per capita, when GDP per capita for 2020 is known from official sources. This model should be tested on real values of GDP per capita and, accordingly, it should be concluded whether it is suitable for establishing accurate links between the COVID-19 pandemic and this macroeconomic indicator, but this will be possible after 2021. Similar studies, based on the simulation method, will give rise to subsequent developments in this research area. Geographically, this research topic is urgent and important to the whole world. Therefore, such studies will be relevant both for the world as a whole and for its regions. Of particular interest is the issue of comparative analysis of losses in the structure of GDP from the industries most affected by the pandemic, such as travel and tourism. Also it is necessary to conduct a critical analysis of the impact of the COVID-19 pandemic and strict quarantine measures on the level of shadowing of the economies of Europe and the world.

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