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The socio-economic catalysers of COVID-19 pandemic

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Abstract
The COVID-19 pandemic was triggered on December 2019 in the city of Wuhan, China, spreading across the world causing global economic crisis and public health emergency. One could ask: what are the socio-economic factors that catalyse the spread of the disease and why are some countries more affected by the COVID-19 pandemic. Therefore, the goal of this paper is to investigate these socio-economic catalysers of the COVID-19 spread. For that purpose, a cross-country regression analysis was conducted at three time points (April 1st, 2020, April 15th 2020 and April 29th, 2020) using OLS, Tobit and PPML estimators. The results of the analysis have shown that countries with higher gross domestic product per capita, population, HDI and HFI indices have been hardely hit with the global COVID-19 pandemic. When some variables were transformed with by dividing it with the population variable, POPDEN and TOUR variables appeared to be significant. The AGE variable was important in the model taking into account total deaths due to the COVID-19 infection. The limitations of the paper are related to data unavailability for some variables in the most recent year. The results obtained from this analysis should be repeated, taking into account other time points and additional COVID-19 socio-economic catalysers.

Keywords: COVID-19, PPML, socio-economic catalysers, Tobit.

JEL classification: C38, I19.
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Introduction
The COVID-19 outbreak was triggered in December 2019 in the city of Wuhan, Hubei province in China. Since then the virus spread across the world, McKibbin and Roshen (2020a). The countries take actions to limit the spread of the virus in the form of social isolation policies, limiting work and restricting the mobility of people, Maliszewska et al. (2020). The economic consequences of the COVID-19 spread were detrimental not only to public health systems but to trade and travel, agriculture and food industry, retail chains, finance sector and others as well, Evans (2020). According to McKibbin and Roshen (2020b) a contained outbreak could significantly impact the global economy in the short run. Investment in public health systems, especially in less developed economies, where health care systems are less developed and population density is high, could avoid greater scale of costs. One

could ask: what are the socio-economic factors that catalyse the spread of the disease and why are some countries more heavily affected by the COVID-19 pandemic. Various authors have investigated these factors. Most often mentioned in recent empirical literature are population and population density (Žmuk and Jošić, 2020), containment measures, reducing mobility and other restrictions, (Deb et al., 2020), international tourism (Folinas and Metaxas, 2020), lower yearly average temperatures, higher economic openness and stronger political democracy (Hossain, 2020), air travel (Hubert, 2020; Keita, 2020), international trade, travel and common borders (Krisztin et al., 2020; Ranasinghe et al., 2020), wearing face masks (Mitze et al., 2020), immigrant stock (Sirkeci and Yucesahin, 2020), GDP per capita and personal freedom (Vigdorovits, 2020) and others.

The goal of this paper is to investigate the socio-economic catalysers of the COVID-19 spread based on previous investigations. The variables that are chosen in the analysis are gross domestic product per capita (GDPPC), population density (POPDEN), population (POP), international tourism expressed in the number of tourist arrivals (TOUR), air transport expressed in the number of passengers carried (AIR), median age (AGE), Human Development Index (HDI) and Human Freedom Index (HFI). The impact of various factors influencing the COVID-19 spread (represented with the Total cases of infection variable) will be investigated using the cross-country regression analysis conducted at three time points (April 1st, 2020, April 15th, 2020 and April 29th, 2020) which is the novel approach in regards to the previous research in this field. Cross-country regression models will be then estimated using the OLS, Tobit and PPML estimators. It is expected that the results will show that aforementioned socio-economic factors are having positive and significant impact on the spread of the COVID-19 disease.

The paper is structured in five sections. After the introduction, in literature review empirical investigations on determinants of the COVID-19 spread have been discussed and elaborated. In the methodology and data section a cross-country regression analysis conducted at three time points and estimated using OLS, Tobit and PPML estimators has been explained. The data sources for total cases of the COVID-19 disease across the world as well as independent variables representing the COVID-19 determinants, based on the previous investigation, have been used. In the results and discussion section the main results of the analysis have been displayed. The final section contains the conclusion, presents the limitations of the paper and recommendations for future research.

Literature review

Žmuk and Jošić (2020), on a sample of 209 countries, found that variable population is statistically significant in regression models for total cases, total deaths and tests variables whereas the population density variable is not. In the case of Italian, French and United Kingdom's regions, the results have shown that the population density variable also positively affects the spread of COVID-19. According to Deb et al. (2020) containment measures, by reducing mobility, restrictions on gatherings and public events, school and workplace closings as well as stay-at-home orders have been very effective in flattening the pandemic curve. The spread of the COVID-19 disease particularly affected the globalised nature of international tourism which is perhaps the main industry most negatively impacted by it, Folinas and Metaxas (2020). Hossain (2020) found that the number of confirmed cases of the COVID-19 infection is higher in countries with lower yearly average temperatures, higher economic openness and stronger political democracy. Air travel caused 8-9% percent of all confirmed cases on average in two waves in March, Hubert (2020).

Therefore, it is important to adopt social and spatial distancing to effectively tackle the COVID-19 spread. Keita (2020) came to similar conclusions. More connected countries registered first cases of infection earlier than the less connected countries with the effect being reinforced by direct flight connections to China.

Krisztin et al. (2020) used spatial econometric specification to model daily infection rates of Covid-19 across countries focusing on the number of flight connections, relationships in international trade and common borders. In early stages of the infection international flight linkages have shown to be the main transmission channel. Mitze et al. (2020) used the synthetic control method to analyse the effect of face masks on the spread of Covid-19 in Germany. They found that wearing masks reduced the number of confirmed Covid-19 cases between 2.3% and 13% in a period of 10 days after they became compulsory. International travel is one of the key contributors to spreading the COVID-19 disease around the globe. This exerted tremendous pressure on international tourism and airline industry, Ranasinghe et al. (2020). Sirkeci and Yucesahin (2020) argued that monitoring immigrant stock and travel data could help contain the spread of COVID-19. Stojkoski et al. (2020) investigated the potential of 29 socio-economic determinants explaining the COVID-19 pandemic spread. However, the true empirical model behind the COVID-19 spread is made up of only a few determinants. Each determinant is able to provide a most credible explanation for a particular individual country due to their heterogeneous socio-economic characteristics. Vigdorovits (2020) used a gravity model to express the time to a first case of infection as a function of various socioeconomic factors. The largest effect on lowering the survival time had the personal freedom variable. Higher GDP per capita and larger population in a country also reduced the survival time. On the other side, a greater distance from the outbreak source increased it.

Data and methodology

In this section, data and research methodology used in the analysis will be explained and elaborated. In order to estimate the impact of various factors on the COVID-19 spread, a cross-country regression analysis will be conducted at three time points (April 1st, 2020, April 15th, 2020 and April 29th, 2020). The spread of the COVID-19 disease will be approximated with the total cases of COVID-19 variable which will be the dependent variable in the model. The data for this variable are provided from the EU Open Data Portal (2020) webpage.

In Figure 1 the total number of cases and deaths due to the COVID-19 disease worldwide in the period from January 1st 2020 to May 1st 2020 is displayed. At the end of April there were 3,137,334 cases of infection and 227,763 deaths due to the COVID-19 disease. In Figures 2 and 3 total cases and deaths due to the COVID-19 infection in the top 15 countries with the highest number of cases and fatalities are presented.

It can be noticed that the United States are the country with the highest number of cases (1,069,826) and deaths (63,006) due to the COVID-19 disease (Figure 2). Other most infected countries are mainly from the European continent (Spain, Italy, United Kingdom, France, Germany).

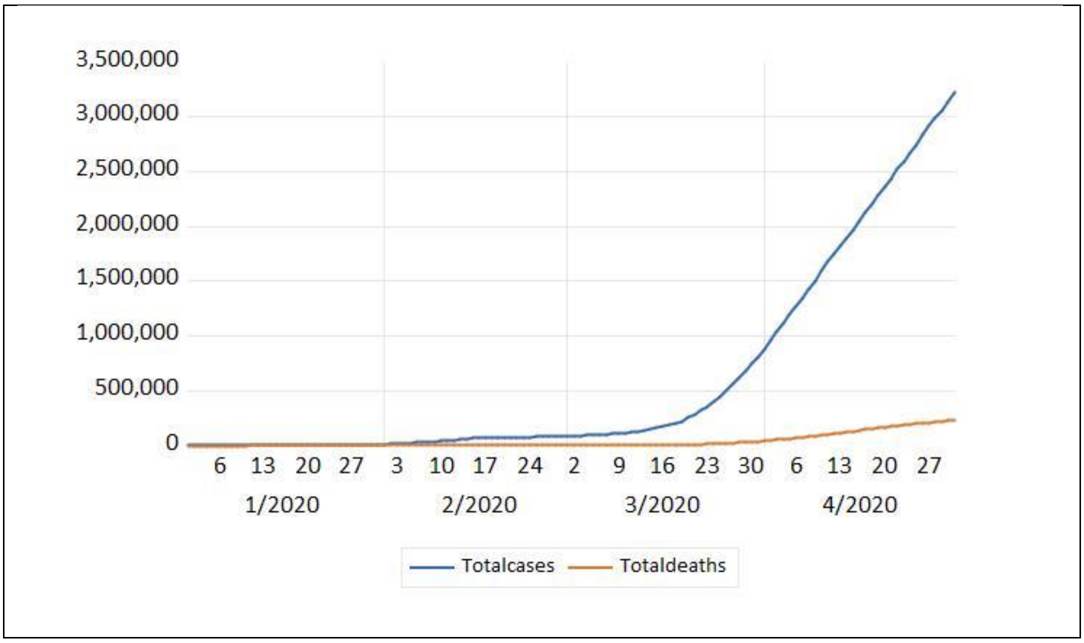

Figure 1 Total cases and total deaths due to COVID-19 worldwide, from January 1st 2020 to May 1st 2020

Source: Author's according to the EU Open Data Portal (2020)

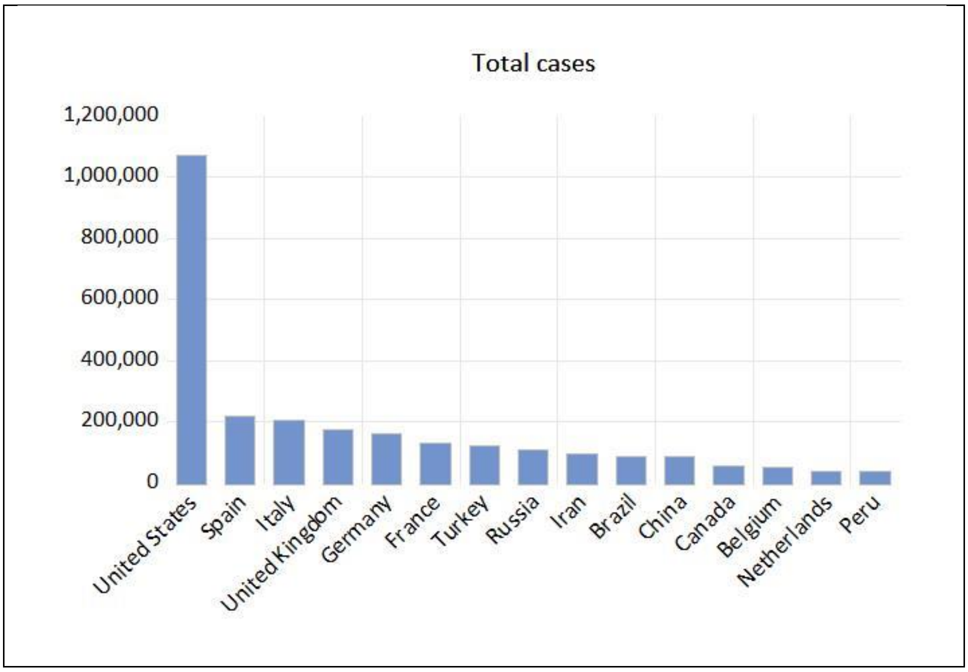

Figure 2 Total cases of infection due to COVID-19 worldwide, top 15 countries, May 1st 2020

Source: Author's according to the EU Open Data Portal (2020)

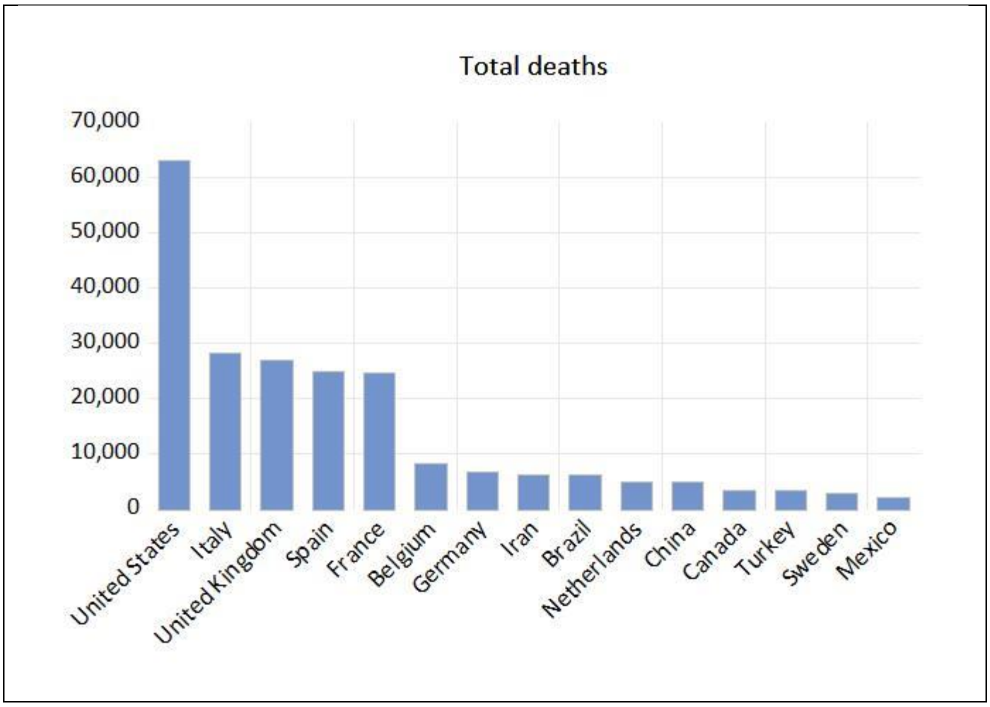

Figure 3 Total deaths due to COVID-19 infection worldwide, top 15 countries, May 1st 2020

Source: Author's according to the EU Open Data Portal (2020)

According to the previous literature research, the following independent variables can be seen as representing: gross domestic product per capita (GDPPC), population density (POPDEN), population (POP), international tourism, number of arrivals (TOUR), air transport, passengers carried (AIR), median age (AGE), Human Development Index (HDI) and Human Freedom Index (HFI). The data for the gross domestic product per capita were available from the World Bank for the year 2018, (World Bank, 2020b) as well as for the air transport (World Bank, 2020a), international tourism (World Bank, 2020c), population density (World Bank, 2020d) and population in total (World Bank, 2020e). In addition, the data sources for the median age, Human Development Index (HDI) and Human Freedom Index (HFI) variables were available from the Global Change Data Lab (2020), Human Development Report Office (2020) and Cato Institute (2020) respectively. The data were collected for 111 countries worldwide for the most recent years and presented in Table A1 in Appendix. In most cases, it was the year 2018 for non-COVID-19 variables. In Equation 1 a cross-country regression model for the estimation of the COVID-19 spread is presented.

$$\mathrm{Totalcases}_i = \alpha + \beta_1\mathrm{GDPPC_i} + \beta_2\mathrm{POPDEN_i} + \beta_3\mathrm{POP_i} + \beta_4\mathrm{TOUR_i} + \beta_5\mathrm{AIR_i} + \\ + \beta_6\mathrm{AGE_i} + \beta_7\mathrm{HDI_i} + \beta_8\mathrm{HFI_i} + \varepsilon_I \quad (1)$$

It is expected to obtain a positive sign of the regression coefficient for all observed variables in the estimated regression model. The spread of COVID-19 is thought to be positively correlated with an increased GDP per capita, population and population density, the number of tourists and air arrivals in a country as well as with the higher median population age, Human Development Index (HDI) and Human Freedom Index (HFI). In Equation 2 a cross-country regression model for the estimation of the COVID-19 spread in a logarithmic form is displayed.

$$\log(\mathrm{Totalcases_i}) = \alpha + \beta_1(\log \mathrm{GDPPC_i}) + \beta_2 \log(\mathrm{POPDEN_i}) + \beta_3 \log(\mathrm{POP_i}) + \\ + \beta_4 \log(\mathrm{TOUR_i}) + \beta_5 \log(\mathrm{AIR_i}) + \beta_6 \log(\mathrm{AGE_i}) + \beta_7 \log(\mathrm{HDI_i}) + \beta_8 \log(\mathrm{HFI_i}) + \varepsilon_i \quad (2)$$

For some countries, there are values of zero for the Total cases variable at the observed time-points. In those cases, the value of this variable was set to 1 because the logarithmic value of zero is not defined. However, that can lead to significant biases. In order to take into account these cases of zero infection, the Poisson Pseudo Maximum Likelihood (PPML) model will be estimated (Equation 3). Santos Silva and Tenreyro (2011) showed that the PPML model could perform very well in situations when the proportion of zeroes in data is quite large. Alongside with the PPML model, the censored Tobit model (Tobin, 1958) will be also employed in the analysis. The Tobit model is often used to analyse data for which the substantial fraction of the observations is equal to zero and the part of the observations on the dependant variable is left censored. In Equation 3 a cross-country regression for the PPML model is presented.

$$\mathrm{Totalcases_i} = \exp[\alpha + \beta_1(\log \mathrm{GDPPC_i}) + \beta_2 \log(\mathrm{POPDEN_i}) + \beta_3 \log(\mathrm{POP_i}) \\ + \beta_4 \log(\mathrm{TOUR_i}) + \beta_5 \log(\mathrm{AIR_i}) + \beta_6 \log(\mathrm{AGE_i}) + \beta_7 \log(\mathrm{HDI_i}) \\ + \beta_8 \log(\mathrm{HFI_i})]\varepsilon_i \quad (3)$$

In Figures A1 and A2, in the Appendix, total cases and fatalities due to the COVID-19 infection, per 100,000 citizens, for the most infected countries in the world are presented. The most infected countries in the world, per 100,000 citizens, are Luxembourg, Iceland, Spain and others displayed. On the other side, countries with the most fatalities due to the COVID-19 disease, per 100,000 citizens, are Belgium, Spain, Italy and France. The common feature for these countries is the higher median age of the population, with the value of 40 years old and above. In order to take this important fact into consideration, total cases, total deaths, the number of arrivals (TOUR), air transport, passengers carried (AIR) variables will be transformed by dividing its value with the population variable (POP), displayed in Equations 4 and 5.

$$\left(\frac{\mathrm{Totalcases}}{\mathrm{POP}}\right)_i = \alpha + \beta_1 \mathrm{GDPPC_i} + \beta_2 \mathrm{POPDEN_i} + \beta_3 \mathrm{POP_i} + \beta_4 \left(\frac{\mathrm{TOUR}}{\mathrm{POP}}\right)_i + \beta_5 \left(\frac{\mathrm{AIR}}{\mathrm{POP}}\right)_i \\ + \beta_6 \mathrm{AGE_i} + \beta_7 \mathrm{HDI_i} + \beta_8 \mathrm{HFI_i} + \varepsilon_i \quad (4)$$

$$\left(\frac{\mathrm{Totaldeaths}}{\mathrm{POP}}\right)_i = \alpha + \beta_1 \mathrm{GDPPC_i} + \beta_2 \mathrm{POPDEN_i} + \beta_3 \mathrm{POP_i} + \beta_4 \left(\frac{\mathrm{TOUR}}{\mathrm{POP}}\right)_i + \beta_5 \left(\frac{\mathrm{AIR}}{\mathrm{POP}}\right)_i \\ + \beta_6 \mathrm{AGE_i} + \beta_7 \mathrm{HDI_i} + \beta_8 \mathrm{HFI_i} + \varepsilon_i \quad (5)$$

By transforming these variables of interest, the real state of the infection worldwide will be determined, which is important when investigating the socio-economic catalysers of the COVID-19 spread.

Results and discussion

The basic descriptive results for the observed variables are given in Table 1. There are 111 countries included in the analysis. TC represents total cases of infection recorded on April 1st, April 15th and April 29th, 2020. On April 1st countries with the highest number of infections were the United States of America with 189,618 cases, Italy with 105,792, then follows Spain with 94,417, China 82,295 and Germany with 67,366 cases of infection. On the other side, observed countries with the lowest number of infections were Malawi and Papua New Guinea with only one case of infection recorded. Countries having the highest median age or oldest population are Japan

(48.2 years) and Italy (47.9 years) while countries having the lowest median age population are Angola (16.8 years) and Gambia (17.5 years). The country having the densiest population is Singapore (7,953 per square kilometre) while countries having the least dense population are Mongolia (2.04) and Australia (3.24).

Table 1 Descriptive statistics of observed variables, n=111

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Sum	Sum Sq. Dev.
TC (1.4.)	7,065.91	533.	189,618.	1	24,578.82	5.18	33.01	4,663.96	784,316.	6.65E+10
TC (15.4.)	16,436.74	1,373.	609,516.	2	64,134.04	7.564786	67.84	20,507.81	1,824,478.	4.52E+11
TC (29.4.)	25,770.19	2,131.	1,012,583.	7	102,319.40	8.343725.	79.61	28,438.67	2,860,491.	1.15E+12
HDI	0.76	0.79	0.94	0.43	0.13	-0.71	2.72	9.91	84.98	1.87
HFI	7.12	6.93	8.88	4.50	0.97	-0.103999	2.29	2.51	790.53	103.37
AGE	33.23	32.60	48.20	16.80	8.48	-0.218123	2.04	5.10	3689.50	7,911.16
AIR	37,002,028	5,365,261.	8.89E+08	8,904.	1.06E+08	6.192905	45.74	9,161.60	4.11E+09	1.24E+18
TUR	11,392,046	3,939,000.	89,322,000	140,000.	17,335,566	2.657974	10.44	386.89	1.26E+09	3.31E+16
POP	55,084,185	10,629,928	1.39E+09	96,762.	1.86E+08	6.495075	45.95	9,313.78	6.11E+09	3.82E+18
POPDEN	226.38	83.22	7952.99	2.04	783.87	8.891176	86.91	34,032.71	25,129.08	67,590,569
GDPPC	18,515.77	9272.62	116,639.90	389.39	21,767.05	1.807948	6.52	117.88	2,055,25	5.21E+10

Source: Author's calculations.

In Table 2, the results of correlation testing between the independent variables in the analysis are presented. It can be noticed that there is a positive linear relationship between some pairs of variables (AGE-HDI) and (GDPPC-HDI). There could be potential multicollinearity problem, referring to a situation when two or more explanatory variables in a multiple regression model are highly linearly related.

Table 2 Correlation matrix

	HDI	HFI	AGE	AIR/POP	TUR/POP	POP	POPDEN	GDPPC
HDI	1	0.66960	0.86786	0.35736	0.42795	-0.05827	0.16548	0.71252
HFI	0.66960	1	0.68778	0.25790	0.35726	-0.12091	0.12259	0.61023
AGE	0.86786	0.68778	1	0.19489	0.39668	0.00920	0.14095	0.55003
AIR/POP	0.35736	0.25790	0.19489	1	0.43128	-0.07383	0.13992	0.57512
TUR/POP	0.42795	0.35726	0.39668	0.43128	1	-0.16333	0.26557	0.38966
POP	-0.05827	-0.12091	0.00920	-0.07383	-0.16333	1	-0.00609	-0.07491
POPDEN	0.16548	0.12259	0.14095	0.13992	0.26557	-0.00609	1	0.23344
GDPPC	0.71252	0.61023	0.55003	0.57512	0.38966	-0.07491	0.23344	1

Source: Author's calculations.

In Table A2, the results of a cross-country regression analysis for the COVID-19 spread are presented. The regressions were made for three time points (April 1st, April 15th and April 29th, 2020) using the OLS and PPML estimators and the Tobit model. All three models were estimated in a logarithmic form. There are 111 observations in total for all three models at observed time points. The adjusted R-square for the OLS model is on a satisfactory level around 0.8, meaning that the estimated model is very well explained with its explanatory variables. The values of Durbin-Watson statistics are a little higher than 2. The rule of thumb says that D-W test statistic values in the range of 1.5 to 2.5 indicate that there is no autocorrelation detected in the sample but the values outside of this range could be cause for concern, especially under 1 or more than 3. The results of a cross-country regression analysis for the COVID-19 spread are similar for all three models. The GDPPC, POP and HDI variables have been positively significant in the majority of regression models and time points. In addition, the HFI variable was positively significant in a regression model related to April 1st and April 15th time points. This result was highly expected according to the economic theory. On the other hand, the POPDEN, TOUR, AIR and AGE variables have not been proven to be significant in the analysis. However, further investigation in this important field of research should be made. The TOUR and AIR variables could be considered crucial at the beginning of the COVID-19 spread, when the first cases of infection have appeared. Later on, other factors such as anti-epidemic measures are more important. According to Žmuk and Jošić (2020) population density can also catalyse the spread of COVID-19 alongside with the population variable. There is a methodology issue that the reported number of cases is lower than the real number of infected people respectively. Some countries such as India, Brazil and the majority of African countries have not experienced the spread of the disease yet, so that fact can significantly affect the overall results of the analysis.

Table 3 Cross-country regression for COVID-19 spread, total cases of infection, population transformed

Dependent variable	Totalcases/POP (1st April 2020)		Totalcases/POP (15th April 2020)		Totalcases/POP (29th April 2020)	
Independent variable/ Model	OLS	Tobit	OLS	Tobit	OLS	Tobit
Constant	62.49017 (39.95864)	62.49017 (38.30445)	56.05520 (62.86108)	56.05520 (60.25879)	83.42896 (79.58166)	83.42896 (76.28718)
GDPPC	0.002412*** (0.000277)	0.002412*** (0.000266)	0.003762*** (0.000436)	0.003762*** (0.000418)	0.004625*** (0.000552)	0.004625*** (0.000529)
POPDEN	-0.015256*** (0.004615)	-0.015256*** (0.004424)	-0.021566*** (0.007260)	-0.021566*** (0.006960)	-0.003274 (0.009191)	-0.003274(0.008811)
POP	3.83E-09 (1.91E-08)	3.83E-09 (1.83E-08)	3.17E-09 (3.00E-08)	3.17E-09 (2.87E-08)	-1.22E-08 (3.80E-08)	-1.22E-08 (3.64E-08)
TOUR/POP	9.91E-05*** (3.14E-05)	9.91E-05*** (3.01E-05)	0.000111** (4.94E-05)	0.000111** (4.74E-05)	2.82E-05 (6.25E-05)	2.82E-05 (6.00E-05)
AIR/POP	-1.59E-05 (1.11E-05)	-1.59E-05 (1.06E-05)	8.38E-07 (1.74E-05)	8.38E-07 (1.67E-05)	3.38E-05 (2.20E-05)	3.38E-05 (2.11E-05)
AGE	1.278848 (0.919813)	1.278848 (0.881736)	2.045310 (1.447008)	2.045310 (1.387106)	2.646268 (1.831901)	2.646268 (1.756065)
HDI	-189.3794*** (64.82725)	-189.3794*** (62.14357)	-243.9634** (101.9832)	-243.9634** (97.76139)	-205.8434 (129.1100)	-205.8434* (123.7652)
HFI	2.348530 (5.365945)	2.348530 (5.143809)	5.465575 (8.441457)	5.465575 (8.092002)	-4.036350 (10.68682)	-4.036350 (10.24441)
Adjusted R-sq.	0.591686		0.642333		0.660414	
S.E. of regress.	36.00061	36.47594	56.63449	57.49475	71.69884	73.08578
Prob. (F-stat.)	0.0000000		0.0000000		0.0000000	
Mean dep. var.	24.81702	24.81702	51.72346	51.72346	77.63595	77.63595
S.D. dep. var.	56.33946	56.33946	94.69822	94.69822	123.0374	123.0374
Log likelihood		-550.5817		-600.8739		-627.0539
Avg. log likelihood		-4.960196		-5.413278		-5.649134
Durbin-Watson	2.042893		2.139438		2.018426	
Observations	111	111	111	111	111	111

*Standard errors in parentheses, * denotes significance under 10%, ** significance under 5% and *** significance under 1%, Swamy and Arora estimator of component variances, GML (Newton-Raphson/Marquardt steps)*

Source: Author's calculations.

In Table 3, the results of a cross-country regressions for the COVID-19 spread when total cases of infection (population transformed), are presented. The PPML model could not be displayed. The PPML model may has problems when the dependant varaible have many zeroes, this is the case when it is populaion transformed. The GDPPC variable has a positive and significant effect in the regression models meaning that COVID-19 spreads easily in more developed countries. The TOUR/POP variable was also positively significant in the regression models, indicating that the inflow of tourists in the early stage of the epidemic had significant impact on the spread of the disease. The POPDEN and HDI variables were significant in some regression models but the regression coefficient was negative which is contrary to the expected positive sign according to the theory. This can be explained by the fact that not all countries worldwide have been equally affected by the spread of disesase. For example, India, China, Brasil and other South American countries have not been hard hit by the epidemic at the time of writing this paper.

Table 4 Cross-country regression for COVID-19 spread, total deaths, population transformed

Dependent variable	Totaldeaths/POP (1st April 2020)		Totaldeaths/POP (15th April 2020)		Totaldeaths/POP (29th April 2020)	
Independent variable/ Model	OLS	Tobit	OLS	Tobit	OLS	Tobit
Constant	0.478029 (2.841605)	-2.352345 (3.277655)	-3.033736 (6.756909)	-3.033736 (6.477190)	-8.516008 (10.13918)	-10.00499 (9.827249)
GDPPC	5.12E-05** (1.97E-05)	5.19E-05** (2.19E-05)	0.000147*** (4.69E-05)	0.000147*** (4.49E-05)	0.000208*** (7.03E-05)	0.000202*** (6.79E-05)
POPDEN	-0.000282 0.000328)	-0.000251 (0.000356)	-0.000847 (0.000780)	-0.000847 (0.000748)	-0.001317 (0.001171)	-0.001308 (0.001128)
POP	-3.47E-10 (1.36E-09)	1.14E-10 (1.47E-09)	-5.71E-10 (3.22E-09)	-5.71E-10 (3.09E-09)	-4.99E-10 (4.84E-09)	-4.14E-10 (4.66E-09)
TOUR/POP	-7.71E-07 (2.23E-06)	-2.16E-06 (2.51E-06)	-3.67E-06 (5.31E-06)	-3.67E-06 (5.09E-06)	-1.03E-05 (7.97E-06)	-1.04E-05 (7.67E-06)
AIR/POP	-9.28E-07 (7.87E-07)	-9.97E-07 (8.55E-07)	-2.11E-06 (1.87E-06)	-2.11E-06 (1.79E-06)	-6.51E-07 (2.81E-06)	-6.40E-07 (2.70E-06)
AGE	0.150931** (0.065411)	0.142732* (0.073037)	0.286264* (0.155538)	0.286264* (0.149099)	0.383519 (0.233395)	0.371639* (0.224898)
HDI	-7.616937 (4.610103)	-2.446789 (5.315724)	-13.79812 (10.96213)	-13.79812 (10.50833)	-16.91653 (16.44940)	-14.07280 (15.98386)
HFI	0.064833 (0.381592)	-0.110607 (0.425753)	0.664872 (0.907368)	0.664872 (0.869806)	1.444305 (1.361566)	1.409625 (1.311203)
Adjusted R-sq.	0.121687		0.196874		0.222340	
S.E. of regress.	2.560135	2.665070	6.087616	6.396163	9.134867	9.567750
Prob. (F-stat.)	0.0000000		0.0000000		0.0000000	
Mean dep. var.	0.760841	0.760841	2.442516	2.442516	4.002792	4.002792
S.D. dep. var.	2.731733	2.731733	6.792904	6.792904	10.35875	10.35875
Log likelihood		-230.1616		-353.3037		-395.8954
Avg. log likelihood		-2.073528		-3.182916		-3.566625
Durbin-Watson	2.115108		2.156885		2.153498	
Observations	111	111	111	111	111	111

*Standard errors in parentheses, * denotes significance under 10%, ** significance under 5% and *** significance under 1%, Swamy and Arora estimator of component variances, GML (Newton-Raphson/Marquardt steps)*

Source: Author's calculations.

The results from Table 4, related to cross-country regressions for the COVID-19 spread when total fatalities have been observed, also population transformed, indicate that the GDPPC variable is positively significant as a determinant of the COVID-19 spread. Another variable having a positive and significant effect on the spread of the disease, and fatalities in particular, is median age. That means that countries with higher median age or older population structure had relatively more fatalities due to the COVID-19 disease.

From the aforementioned analysis it can be concluded that various factors have an impact on the spread of the disease but in certain time periods and under different conditions. The GDPPC, POP and HDI variables have been positively significant in the majority of regression models and time points while the HFI variable was positively significant in regression models related to the April 1st and April 15th time points. On the other hand, when the regression models were estimated with the transformation in some variables regarding the countries' population, the GDPPC variable was positively significant in the regression models. In addition, the inflow of tourists in the early stages of the epidemic had a significant impact on the spread of the disease while the median age variable had positive and significant impact on the excess number of fatalities due to the COVID-19 disease.

Conclusions

The goal of paper was to investigate the determinants of the COVID-19 spread. The results of the analysis have shown that the GDPPC, POP, HDI and HFI variables, at some time points, have a positive and significant effect on the spread of the disease. When the model was modified by transforming some variables by dividing their value by the population variable, the POPDEN and TOUR/POP variables appeared to be significant also. On the other hand, the AGE variable was important in the models taking into account total deaths due to the COVID-19 infection. The limitations of the paper are related to the fact that data for most of the independent variables were not available for the year 2020 but were collected for the most recent year. Countries implement various containment and mitigation measures directed to limit the spread of the COVID-19 disease and are in different stages of epidemic curve, so the results of this analysis should not be taken as conclusive. Furthermore, the reported number of cases is lower than the real number of infected people while some countries have still not yet experienced the full spread of the disease. Recommendations for future research could include making a detailed analysis of individual countries at additional time points. Other COVID-19 variables could be investigated, such as new cases and new deaths due to the COVID-19 infection. The results presented in this paper can be relevant for economic and health policy makers in order to facilitate implementing public health-policy decisions.

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Appendix

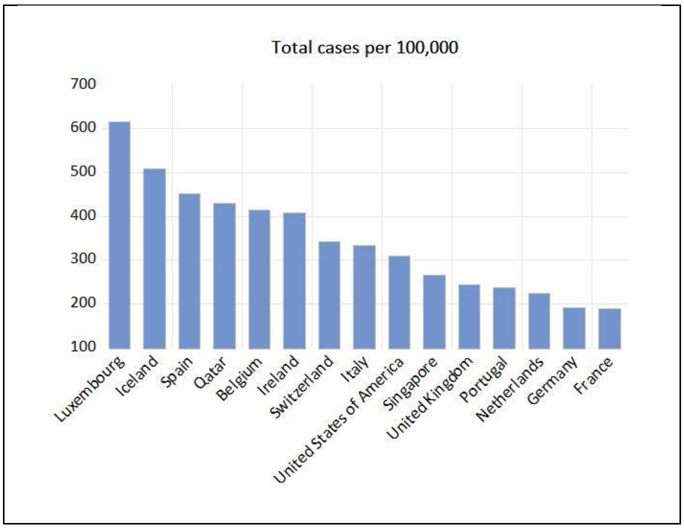

Figure A1 Total cases of COVID-19, country per 100,000 citizens, as of April 29th 2020
Source: Author's calculations.

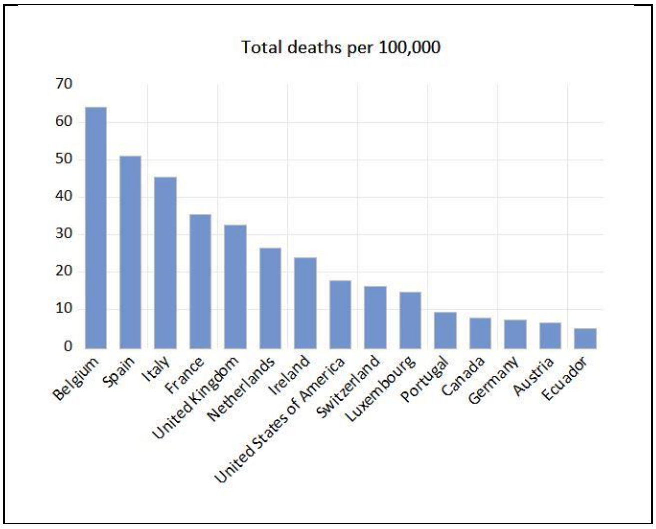

Figure A2 Total deaths due to COVID-19, country per 100,000 citizens, as of April 29th 2020

Source: Author's calculations.

Table A1 Determinants of COVID-19 spread by country

Country	HDI	HFI	POPDEN	POP	AGE	GDPPC	TUR	AIR
Albania	0.79	7.84	104.61	2,866,376	38.0	5,268.84	5,340,000	303,137
Algeria	0.76	4.99	17.73	42,228,429	29.1	4,114.71	2,657,000	6,442,442
Angola	0.57	5.40	24.71	30,809,762	16.8	3,432.38	218,000	1,516,628
Argentina	0.83	6.86	16.26	44,494,502	31.9	11,683.95	6,942,000	18,081,937
Australia	0.94	8.62	3.25	24,982,688	37.9	57,373.68	9,246,000	75,667,645
Austria	0.91	8.48	107.21	8,840,521	44.4	51,461.95	30,816,000	12,935,505
Azerbaijan	0.75	6.22	120.27	9,939,800	32.4	4,721.17	2,633,000	2,279,546
Bahamas	0.81	7.56	38.53	385,640	34.3	32,217.87	1,633,000	1,197,116
Bahrain	0.84	6.63	2017.27	1,569,439	32.4	24,050.75	12,045,000	5,877,003
Belarus	0.82	6.65	46.73	9,483,499	40.3	6,289.93	11,501,600	2,760,168
Belgium	0.92	8.29	377.21	11,433,256	41.8	47,518.63	9,119,000	13,639,487
Belize	0.72	6.95	16.79	383,071	25.0	4,884.74	489,000	1,297,533
Bhutan	0.62	6.53	19.78	754,394	28.6	3,243.23	274,000	275,849
Bolivia	0.70	6.61	10.48	11,353,142	25.4	3,548.59	1,142,000	4,122,113
Brazil	0.76	6.48	25.06	209,469,333	33.5	8,920.76	6,621,000	102,109,977
Brunei_Darussalam	0.85	5.69	81.40	428,962	32.4	31,628.32	278,000	1,234,455
Bulgaria	0.82	7.79	64.70	7,025,037	44.7	9,272.62	9,273,000	1,022,645
Burkina_Faso	0.43	6.73	72.19	19,751,535	17.6	715.12	144,000	151,531
Cambodia	0.58	7.13	92.06	16,249,798	25.6	1,510.32	6,201,000	1,411,059
Canada	0.92	8.65	4.08	37,057,765	41.4	46,232.99	21,134,000	89,380,000
Cape_Verde	0.65	7.45	134.93	543,767	25.7	3,635.40	710,000	140,429
Chile	0.85	8.15	25.19	18,729,160	35.4	15,923.35	5,723,000	19,517,185
China	0.76	6.17	148.35	1.393E+09	38.7	9,770.84	62,900,000	611,439,830
Colombia	0.76	6.93	44.75	49,648,685	32.2	6,667.79	3,904,000	33,704,037
Congo	0.61	5.80	15.36	5,244,363	19.0	2,147.76	156,000	333,899
Costa_Rica	0.79	7.70	97.91	4,999,441	33.6	12,027.36	3,017,000	1,948,546
Cote_dIvoire	0.52	6.59	78.83	25,069,229	18.7	1,715.53	1,965,000	779,482
Croatia	0.84	7.86	73.08	4,087,843	44.0	14,909.69	16,645,000	2,093,577
Cyprus	0.87	7.93	128.71	1,189,265	37.3	28,689.69	3,939,000	401,408
Czechia	0.89	8.34	137.60	10,629,928	43.3	23,078.57	10,611,000	5,727,200
Ecuador	0.76	6.82	68.79	17,084,357	28.1	6,344.87	2,535,000	5,365,261
Egypt	0.70	4.50	98.87	98,423,595	25.3	2,549.13	11,196,000	12,340,832
El_Salvador	0.67	6.89	309.88	6,420,744	27.6	4,058.25	1,677,300	2,545,105
Estonia	0.88	8.46	30.39	1,321,977	42.7	23,266.34	3,234,000	31,981
Ethiopia	0.47	5.25	109.22	109,224,559	19.8	772.31	849,000	11,501,244
Fiji	0.72	7.17	48.36	883,483	28.6	6,266.96	870,000	1,670,216
Finland	0.93	8.53	18.16	5,515,525	42.8	50,152.34	3,224,000	13,364,839
France	0.89	8.02	122.34	66,977,107	42.0	41,463.64	89,322,000	70,188,028
Gambia	0.47	5.94	225.31	2,280,102	17.5	716.11	552,000	53,735
Georgia	0.79	7.74	65.28	3,726,549	38.7	4,717.14	4,757,000	516,034
Germany	0.94	8.53	237.37	8,290,5782	46.6	47,603.02	38,881,000	109,796,202
Greece	0.87	7.33	83.22	10,731,726	45.3	20,324.25	30,123,000	15,125,934
Guatemala	0.65	7.07	160.95	17,247,807	22.9	4,549.01	1,781,000	145,795
Guyana	0.67	6.74	3.96	779,004	26.3	4,979.00	287,000	26,069
Hungary	0.85	7.65	107.91	9,775,564	43.4	16,161.98	17,552,000	31,226,848
Iceland	0.94	8.41	3.53	352,721	37.3	73,191.11	2,343,800	7,819,740
India	0.65	6.64	454.94	1.353E+09	28.2	2,009.97	17,423,000	164,035,638
Indonesia	0.71	6.83	147.75	267,663,435	29.3	3,893.59	15,810,000	115,154,101
Ireland	0.94	8.52	70.45	4,867,309	38.7	78,806.43	10,926,000	167,598,633
Israel	0.91	7.61	410.53	8,882,800	30.6	41,715.02	4,121,000	7,404,373
Italy	0.88	8.04	205.45	60,421,760	47.9	34,483.20	61,567,200	27,630,436
Jamaica	0.73	7.20	270.99	2,934,855	31.4	5,354.23	2,473,000	180,951
Japan	0.92	8.28	347.07	126,529,100	48.2	39,289.95	31,192,000	126,387,527
Jordan	0.72	6.84	112.14	9,956,011	23.2	4,241.78	4,150,000	3,383,805
Kazakhstan	0.82	6.90	6.77	18,272,430	30.6	9,812.60	8,789,000	7,143,797
Kuwait	0.81	6.19	232.17	4,137,309	33.7	33,994.40	8,508,000	6,464,847
Kyrgyzstan	0.67	6.98	32.93	6,322,800	26.3	1,281.36	423,000	709,198
Laos	0.60	6.20	30.60	7,061,507	24.4	2,542.48	3,770,000	1,251,961
Latvia	0.85	8.29	30.98	1,927,174	43.9	17,860.61	1,946,000	4,058,762
Lebanon	0.73	6.74	669.49	6,848,925	31.1	8,269.78	1,964,000	2,981,937
Lithuania	0.87	8.32	44.53	2,801,543	43.5	19,153.40	2,825,000	26,031
Luxembourg	0.91	8.56	250.09	607,950	39.7	116,639.89	1,018,000	2,099,102
Madagascar	0.52	6.32	45.14	26,262,368	19.6	527.50	291,000	541,290
Malawi	0.49	6.60	192.44	18,143,315	18.1	389.39	871,000	10,545
Malaysia	0.80	6.52	95.96	31,528,585	29.9	11,373.23	25,832,000	60,481,772
Malta	0.89	8.37	1511.03	484,630	42.4	30,098.28	2,599,000	2,576,898
Mauritius	0.80	7.52	623.30	1,265,303	37.4	11,238.69	1,399,000	1,745,291
Mexico	0.77	6.65	64.91	126,190,788	29.3	9,673.44	41,313,000	64,569,640
Moldova	0.71	6.93	123.52	2,706,049	37.6	3,227.31	160,000	1,135,999
Mongolia	0.74	7.61	2.04	3,170,208	28.6	4,121.73	529,000	670,360
Montenegro	0.82	7.43	46.27	622,227	39.1	8,844.23	2,077,000	565,522
Morocco	0.68	6.18	80.73	36,029,138	29.6	3,222.20	12,289,000	8,132,917
Mozambique	0.45	6.24	37.51	29,495,962	17.7	498.95	2,743,000	540,124
Myanmar	0.58	5.44	82.24	53,708,395	29.1	1,325.95	3,551,000	3,407,788
Nepal	0.58	6.51	195.94	28,087,871	25.0	1,033.91	1,173,000	3,296,953
Netherlands	0.93	8.50	511.46	17,231,624	43.2	53,024.05	18,780,000	43,996,045

Table A1 Determinants of COVID-19 spread by country - continued

Country	HDI	HFI	POPDEN	POP	AGE	GDPPC	TUR	AIR
New_Zealand	0.92	8.88	18.55	4,841,000	37.9	41,945.33	3,686,000	17,249,050
Oman	0.83	5.98	15.60	4,829,483	30.7	16,415.15	2,301,000	10,438,241
Panama	0.80	7.69	56.19	4,176,873	29.7	15,575.07	1,785,000	12,939,350
Papua_New_Guinea	0.54	6.60	19.00	8,606,316	22.6	2,730.27	140,000	964,713
Paraguay	0.72	6.90	17.51	6,956,071	26.5	5,821.81	1,181,000	560,631
Peru	0.76	7.55	24.99	31,989,256	29.1	6,941.23	4,419,000	17,758,527
Philippines	0.71	6.88	357.69	106,651,922	25.2	3,102.71	7,168,000	43,080,118
Poland	0.87	7.78	124.04	37,974,750	41.8	15,420.91	19,622,000	9,277,538
Portugal	0.85	8.27	112.24	10,283,822	46.2	23,407.90	16,186,000	17,367,956
Qatar	0.85	6.15	239.59	2,781,677	31.9	68,793.78	1,819,300	29,178,923
Romania	0.82	8.11	84.64	19,466,145	43.0	12,301.18	11,720,000	4,908,235
Russia	0.82	6.34	8.82	144,478,050	39.6	11,288.87	24,551,000	99,327,311
Saudi_Arabia	0.86	5.42	15.68	33,699,947	31.9	23,338.96	15,334,000	39,141,660
Serbia	0.80	7.30	79.83	6,982,604	41.2	7,246.73	1,711,000	2,262,703
Seychelles	0.80	7.16	210.35	96,762	36.2	16,433.93	362,000	455,201
Singapore	0.94	8.11	7953.00	5,638,676	42.4	64,581.94	14,673,000	40,401,515
Slovenia	0.90	7.97	102.64	2,073,894	44.5	26,123.97	4,425,000	1,094,762
South_Africa	0.71	7.08	47.63	57,779,622	27.3	6,374.02	10,472,000	23,921,748
South_Korea	0.91	8.20	529.65	51,606,633	43.4	31,362.75	15,347,000	88,157,579
Spain	0.89	8.12	93.53	46,796,540	45.5	30,370.89	82,773,000	80,672,105
Sri_Lanka	0.78	6.41	345.56	21,670,000	34.1	4,102.48	2,334,000	5,882,376
Switzerland	0.95	8.82	215.52	8,513,227	43.1	82,796.54	10,362,000	28,857,994
Thailand	0.77	6.55	135.90	69,428,524	40.1	7,273.56	38,178,000	76,053,043
Togo	0.51	6.31	145.05	7,889,094	19.4	679.25	573,000	566,295
Trinidad_and_Tobago	0.80	6.62	270.93	1,389,858	36.2	17,129.91	375,000	2,525,130
Tunisia	0.74	6.08	74.44	11,565,204	32.7	3,447.50	8,299,000	4,274,199
Turkey	0.81	6.21	106.96	82,319,724	31.6	9,370.17	45,768,000	115,595,496
Ukraine	0.75	6.26	77.03	44,622,516	41.4	3,095.17	14,104,000	7,854,842
United_Arab_Emirates	0.87	6.13	135.61	9,630,959	34.0	43,004.95	21,286,000	95,533,069
United_Kingdom	0.92	8.47	274.83	66,460,344	40.8	42,943.90	36,316,000	165,388,610
United_Republic_of_Tanzania	0.53	6.26	63.58	56,318,348	17.7	1,060.99	1,378,000	1,481,557
United_States_of_America	0.92	8.46	35.77	326,687,501	38.3	62,794.58	79,745,920	889,022,000
Vietnam	0.69	6.29	308.13	95,540,395	32.6	2,566.59	15,498,000	47,049,671
Zambia	0.59	6.49	23.34	17,351,822	17.7	1,539.90	1,072,000	8,904
Zimbabwe	0.56	5.65	37.32	14,439,018	19.6	2,146.99	2,580,000	282,539

Source: Author's calculations.

Table A2 Cross-country regression analysis for COVID-19 spread

Dependent variable	log(Totalcases) 1.4.2020.			log(Totalcases) 15.4.2002.			log(Totalcases) 29.4.2020.		
Independent variable/ Model	OLS	PPML	Tobit		PPML	Tobit	OLS	PPML	Tobit
Constant	-21.35033*** (4.687901)	-0.998832 (1.862181)	21.07841*** (4.575112)	-16.68047*** (4.676046)	-0.200833 (1.696355)	- 16.68047*** (4.482469)	-13.72504*** (4.896507)	0.185341 (1.619734)	-13.72504*** (4.693804)
LOG(GDPPC)	0.689392*** (0.246170)	0.036374 (0.101701)	0.675859*** (0.240222)	0.494597** (0.245548)	0.016537 (0.092399)	0.494597* (0.235383)	0.475002* (0.257124)	0.022070 (0.088148)	0.475002* (0.246480)
LOG(POPDEN)	0.097019 (0.085485)	0.020207 (0.030975)	0.095918 (0.083385)	0.080752 (0.085269)	0.015035 (0.028958)	0.080752 (0.081739)	0.090504 (0.089289)	0.015139 (0.028057)	0.090504 (0.085593)
LOG(POP)	0.808804*** (0.129503)	0.125000** (0.052169)	0.799312*** (0.126340)	0.830636*** (0.129176)	0.112955** (0.047907)	0.830636*** (0.123828)	0.896586*** (0.135266)	0.116226** (0.045963)	0.896586*** (0.129666)
LOG(TOUR)	0.105131 (0.139057)	0.017872 (0.056864)	0.110410 (0.135751)	0.113568 (0.138705)	0.016404 (0.051973)	0.113568 (0.132963)	0.107622 (0.145245)	0.014678 (0.049763)	0.107622 (0.139232)
LOG(AIR)	0.008699 (0.092641)	0.000521 (0.038361)	0.015644 (0.090573)	0.026799 (0.092407)	0.002122 (0.035072)	0.026799 (0.088581)	0.003353 (0.096763)	-0.002793 (0.033491)	0.003353 (0.092758)
LOG(AGE)	0.610271 (0.975801)	0.029303 (0.383302)	0.589213 (0.952179)	0.285930 (0.973333)	-0.020215 (0.350743)	0.285930 (0.933040)	-1.20E-09 (4.72E-09)	-0.081184 (0.335764)	-0.171418 (0.977030)
LOG(HDI)	3.631600* (2.143296)	1.605257* (0.938207)	3.765530* (2.093041)	5.056383** (2.137876)	1.421840* (0.840991)	5.056383** (2.049374)	5.803368** (2.238671)	1.327986* (0.796356)	5.803368*** (2.145995)
LOG(HFI)	2.400923** (1.116788)	0.166721 (0.426809)	2.363362** (1.088628)	1.853565* (1.113964)	0.113869 (0.391179)	1.853565* (1.067849)	1.286550 (1.166484)	0.052795 (0.374211)	1.286550 (1.118195)
Adjusted R-sq.	0.814434			0.812569			0.794931		
S.E. of regress.	1.131053		1.133184	1.128193		1.133130	1.181384		1.187119
Prob. (F-stat.)	0.0000000			0.0000000			0.0000000		
Mean dep. var.	5.981609	5.981609	5.981609	6.973442	6.973442	6.973442	7.507644	7.507644	7.507644
S.D. dep. var.	2.625632	2.625632	2.625632	2.605931	2.605931	2.605931	2.608799	2.608799	2.608799
Prob(Quasi-LR stat)	0.0000000	523.6572			0.0000000			0.0000000	
Quasi-LR statistic	108.1566	577.7355			90.69687			82.29983	
Durbin-Watson	2.312459			2.260391			2.121099		
Observations	111	111	111	111	111	111	111	111	111

Standard errors in parentheses, * denotes significance under 10%, ** significance under 5% and *** significance under 1%.
Source: Author's calculations.