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ON THE IMPACT OF THE COVID-19 HEALTH CRISIS ON GDP FORECASTING: AN EMPIRICAL APPROACH

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Abstract. Statistical dependence between the GDP growth projection adjustments for the end of 2020 and the health impact of the Covid-19 pandemic is detected and quantified for a broad set of countries. A `rate` that captures this health impact for each country is contrasted to the difference in GDP growth projections for the end of 2020 released in two subsequent times: 2019 (pre-pandemic) and early 2020 (post-pandemic). The difference of this two variables exhibited a significant rank correlation with the `rate`, and a linear model was successfully fitted, concluding that at the beginning of the pandemic health conditions played a significant role in the GDP projections.

1. **Introduction.** Immediately after the Covid-19 health crisis was declared in January 2020, the general financial and economic conditions deteriorated, greatly affecting the world's economic activities. The lack of knowledge regarding the consequences of the pandemic led the authorities to impose severe restrictions on social and economic activities along different countries. Some of the imposed measures were: social distancing, border closure and stoppage of different economic activities. These policies produced an unprecedented shock having a high impact on the countries overall economical activities. Due to these facts and to the prevailing high uncertainty, in March 2020 some key financial indicators fell to levels similar to those seen in the Great Recession of 2008-2009.

In this scenario of great uncertainty, several financial institutions published their Gross Domestic Product (GDP) growth projections. These projections are crucial for countries' economies. Not only do they generate expectations about the economic future of each country, but, for example, they are a relevant input in the analysis of investment and spending policies. In this study we consider the projections published by two of the most established international economic institutions: the International Monetary Fund (IMF) and the World Bank (WB). These two institutions produce annual forecasts of several relevant economic variables in their publications of the *World Economic Outlook* and the *Global Economic Prospects*

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respectively. It is important to note that both institutions' methodologies share some characteristics and make global forecasts for the world economy based on the forecasts of individual countries. However, they use different models and macroeconomic variables to develop their respective projections.

The problem of predicting the GDP growth is a very relevant and difficult one. There is an extensive literature on the performance of GDP growth forecasts for different financial institutions, for both developed and emerging countries. Among those are [1], [2] and [9]. This difficulty is exacerbated in the context of an economic crisis. In [8], the authors analyzed the financial institutions' forecasting performance during the 2008-2009 Great Recession. In 2007, growth projections for 2008 suggested no major deceleration of the global economy; in the beginning of 2008, growth projections for 2008 showed negative growth mostly for developed countries. In this work, it is shown that the prediction error for 2008 was close to 3% for the main international economic institutions, whereas the prediction error is around 1% in years when there is no economic crisis.

With this in mind, in the context of the Covid-19 economic crisis, a higher variance of the GDP prediction errors was to be expected, due to the immediate negative impact that this crisis had in the economy and health of the population in most countries. It is clear that there existed strong methodological limitations in the beginning of the pandemic, that could lead to a decrease of the accuracy of GDP growth projections. It is crucial for institutions modeling GDP growth projections during this crisis to be able to distinguish transitory from persistent shocks in each sector of the economy, and to fully understand their interactions. It was of paramount importance to have access to up-to-date economic information during the early stages of the pandemic so that financial institutions could capture the effects of shocks to various economic policies and activities.

Once the IMF and the WB published the GDP growth projections in April and June 2020 respectively, it was possible to compare the different GDP growth projections for 2020: the ones produced in 2019, previous to the pandemic, and the ones corresponding to the beginning of 2020, once the pandemic was established. Both financial institutions, in their reports, quantify the impact of the Covid-19 pandemic in most of economic activities related to GDP growth, for each country, and then interpret the results ([6],[11]). The greater the perception of the impact of the Covid-19 pandemic is on any country, the more it will affect the projection of its economic development; and thus, in average, that perception is what really matters in order to adjust the GDP growth projections.

In the present paper we investigate to what extent the adjustment of the GDP growth projections for the end of 2020 (from the ones published in 2019 to the ones made in 2020) is explained by the health impact of the pandemic in each country or region. In other words, we want to know if those countries where the infection rate and deaths per capita were higher, a larger decrease on GDP growth projections for the end of 2020 was predicted. To this end, we tested if the orders induced in the list of all countries by the GDP growth decrease and by the Covid-19 relative impact were correlated. Furthermore, as this rank correlation showed significant, we quantify the existing dependency by the adjustment of linear models.

The rest of the paper is organized as follows. In section 2 we present the data sets used, we define the variable `rate` that captures the relative health impact of the pandemic in each country, and we describe the methodology used to detect and quantify dependencies between this variable and the growth projection variations

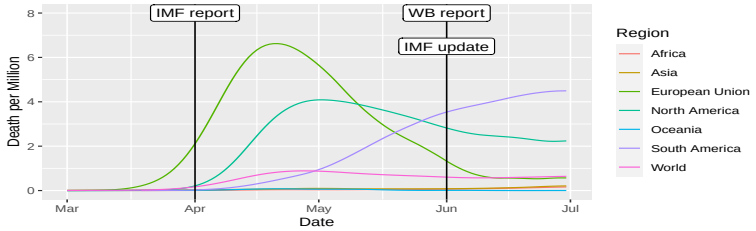


FIGURE 1. Smoothed deaths per one million population (03/01/2020 - 12/31/2020).

before and after the pandemic was declared. In section 3 we present the obtained results, and discuss their most relevant aspects. In section 4 we present the final conclusions.

2. Data and methods.

2.1. **Evolution of the pandemic around the world.** In the last 70 years, the world did not endure a worldwide crisis of a similar magnitude to the Covid-19 pandemic. The pandemic impacted in different ways, moments, and regions of the world. Figure 1 shows the smoothed daily dynamics of the deaths per one million population in each of the continents. Due to the variability and noisiness of the data, we first smooth the data using a 7-day average, and then we again smooth the results using a 14-day average, following the methodology of the World Health Organization [14]. It is worth mentioning that the focus of the pandemic changed from one continent to another during the first months of 2020, and the most affected continents were Europe, Asia and America. For more detailed information about the evolution of the pandemic, we refer for instance to *Timeline of the Coronavirus* [16] or *COVID-19 pandemic* page at Wikipedia [17].

2.2. **Data.** The IMF and the WB regularly analyze different macroeconomic variables for a large amount of countries. In the case of the IMF, the data set includes 193 countries. It includes the GDP growth projections for 2020 made in April 2019 (`Apr2019_IMF`) and April 2020 (`Apr2020_IMF`); the latter were published shortly after the beginning of the Covid-19 pandemic, in a scenario of great uncertainty. During March and April 2020, Europe was struggling with the pandemic, whereas the Americas were not very affected yet (see Fig. 1). In June 2020, the IMF published update GDP growth projections for 2020 for 30 representative countries around the world (`Jun2020_IMF`). The data is available in the *World Economic Outlook* [11] and [12] respectively. In the case of the WB, the data set comprises 127 countries, not including developed countries. It includes the GDP growth projections for 2020 made in December 2019 (`Dic2019_WB`) and June 2020 (`Jun2020_WB`). The data is available in the *Global Economic Prospects* [5] and [6] respectively. We assume the former were made without considering the Covid-19 pandemic, and the latter when the pandemic already had a large impact in most countries of the world.

The Covid-19 database, obtained from *Our World in Data* [15], includes relevant variables for 208 countries and regions. From this daily updated data set we extracted the following variables: population, total daily positive cases, and total daily deaths. Notably, several countries included in this dataset have no pandemic deaths in March and May 2020. This countries are mostly African countries or

small islands. In Figure 1 we observe that the virus hit Africa months after Asia, Europe and America. In addition, it is easier for island states to protect their borders from the virus, which is why several island and isolated territories remained several months without cases or deaths.

2.3. **Quantification of the depth of the pandemic across different countries.** Using the available data, to quantify the relative cumulative impact of the pandemic, we propose an indicator denominated `rate`, that summarizes the status of the pandemic at a certain time in certain country, through the simple formula:

$$\texttt{rate} \ = \log\left(1 + \frac{Deaths \times 10^6}{Population} \times \frac{365}{Duration}\right),$$

which can be thought off as

$$\texttt{rate} \ = \log\left(1 + \frac{\text{Deaths per million people}}{\text{Duration of the pandemic (in years)}}\right).$$

Although the deaths reported by the countries are possibly affected by biases, we consider deaths instead of positive cases to avoid the larger bias introduced by the different testing capacities of each country. To take into account the size of each country, we count the number of deaths per million population. It is important to take into account in the variable the fact that the epidemic begins on each country at a different time, therefore we annualized the count from the moment of the beginning of the epidemic (the date of the first reported case), introducing the *Duration* of the epidemic in each country, multiplying by the number of calendar days of a year. Relevant features in the construction of these `rate` are the fact that it is always positive, assigns a zero to the countries with zero deaths, and applying logarithm is an adequate transformation to compare `rate` with GDP growth using linear models in Section 3.2.

Figure 2 (left) shows the evolution of the variable `rate` between April 2020 and June 2020. For June 2020, we observe a larger mean but a smaller variance. Figure 2 (right) shows the growth projections made by the IMF and WB before and after the world pandemic was declared.

In order to better understand the impact of the duration of the pandemic and death rate in the variable `rate` we refer to figure 3. We consider the data in April and June 2020 for 30 reference countries which will be studied in section 3; we can observe how the increase of 2 months of the duration of the pandemic, and the increase of deaths-per-million people, impact on the variable `rate`. It is important to keep this in mind when analyzing the `rate` boxplot in figure 2, because a small increase in `rate` might imply a large increase in deaths-per-million people, specially when the duration of the pandemic is small.

2.4. **Detection and quantification of statistical dependencies.** Our first objective is to detect if there exist decreasing dependencies between the difference in growth projections that occurred during the pandemic and the variable `rate` defined in subsection 2.2. For this purpose, we will perform a Spearman's rank correlation test:

$$\begin{cases} H_0: & \text{Differences in growth projections and } \texttt{rate} \text{ are independent,} \\ H_1: & \text{There exist negative dependencies between the differences in} \\ & \text{growth projections and } \texttt{rate}. \end{cases}$$

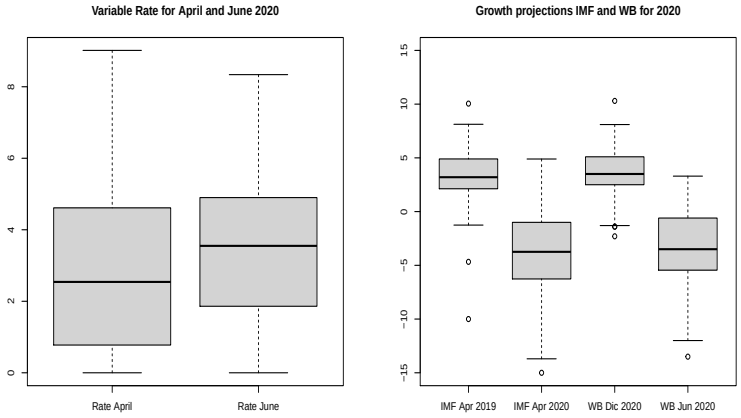


FIGURE 2. Boxplots of the variables. Left: `rate`. Right: GDP growth projections for 2020.

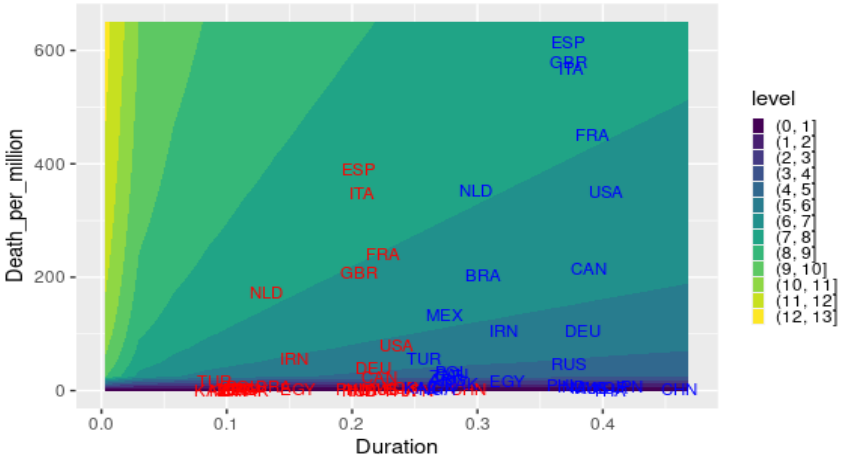


FIGURE 3. Relation of the duration (in years) of the pandemic, deaths per million people due to Covid-19, and the levels of the variable *rate* for 30 reference countries. Data for April 2020 is shown in red, whereas data for June 2020 is shown in blue.

This classical test studies the similarity of the rank vectors of each sample ([4], [10]). As usual, we set the significance level of the test as $\alpha = 0.05$. This test has two main advantages: it does not make any assumptions on the sample distributions; it detects both linear and non-linear dependencies. The main disadvantage is that the test works best for continuous distributions, and the `rate` has many observations equal to 0 (the ones corresponding to countries without deaths); thus, we will obtain only an approximation of the p-value of the test. If the test does not reject the null hypothesis, we conclude that the `rate` does not help to predict the differences in growth projections, and it is not possible to fit any model (linear or not).

If dependencies between GDP growth projections and `rate` are detected, the next step is quantifying them. As a first step, we are interested in the *linear* dependencies, so we consider the model

$$Y = a_1 X_1 + a_2 X_2 + b,$$

where Y represents the growth projections made during the pandemic, X_1 represents the projections made before the pandemic, and X_2 represent the `rate`. If the rank correlation test rejects the null hypothesis but the linear model coefficient for the variable `rate` is not significant, it means that there exist a more complex, non-linear dependency between the variables. For more details about linear regression models we refer to [7].

The intercept b can be interpreted as a *global impact* of the pandemic in the growth projections. We are interested in assessing if a_1, a_2 and b are significantly different to zero, as this will show if there exist a linear dependency between Y and (X_1, X_2). We are also interested in verifying that $a_1 = 1$ -the projections made before the pandemic should act as a baseline for the projections during the pandemic- and that the sign of a_2 should be negative -the larger the impact of the pandemic for a given country, the greater the decrease of the growth projection should be-. Under the assumption that Y is a normal random variable and X_1, X_2 are not random, then the parameters a_1 and a_2 are random variables with normal distribution. Using that, we can quickly check our hypotheses regarding a_1 and a_2. To check if $a_1 = 1$, it is enough to measure how many standard deviations away the estimated coefficient $\hat{a}_1$ is from 1: more than two should be enough to reject the null hypothesis. When comparing if a_2 is the same for two different models, we sum the standard deviations of each parameter; if the difference between the estimated coefficients is greater than twice the sum of standard deviations, it should be enough to rejecto the null hypothesis. These ideas depend on strong assumptions, so they should only be taken as approximations, and we will consider them only to shed some light on the intricacies of the models. For more details, we refer to [3].

When studying the variable `rate`, we observe an atom in zero. This atom corresponds to all the countries without deaths due to the Covid-19 pandemic, and makes the linear regression analysis more complicated. That is why we split the data in countries with and without deaths due to Covid-19, and compare the resulting models. Of course, the parameter a_2 is discarded when considering countries without deaths. This is also relevant to our working hypothesis, as countries without deaths should be less affected in the GDP growth projections published by the IMF and WB. We are interested in observing if their GDP growth projections behave similarly, and if the parameter b is the same for both models, as it represents a constant world impact quantity.

3. **Results.**

3.1. **Visualization.**

Let us start with the IMF data set. As established in subsection 2.4, we split the countries without deaths from the countries with deaths, and show the relationship between the GDP growth projections both before and during the pandemic, and the `rate`. In particular, in Figure 4 we observe that the countries whose GDP growth projections decreased the least, are also the ones whose `rate` is the lowest. This indicates a possible negative correlation between GDP growth projections decrease and the `rate`.

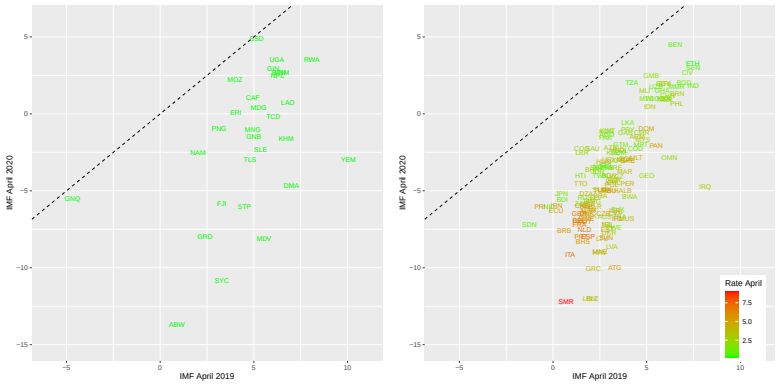


FIGURE 4. Scatter plot of the IMF GDP growth projections for 2020 generated in April 2020, and the `rate`. Left: countries without deaths due to the pandemic. Right: countries with positive `rate`. Countries are represented by their alpha-3 ISO 3166 code.

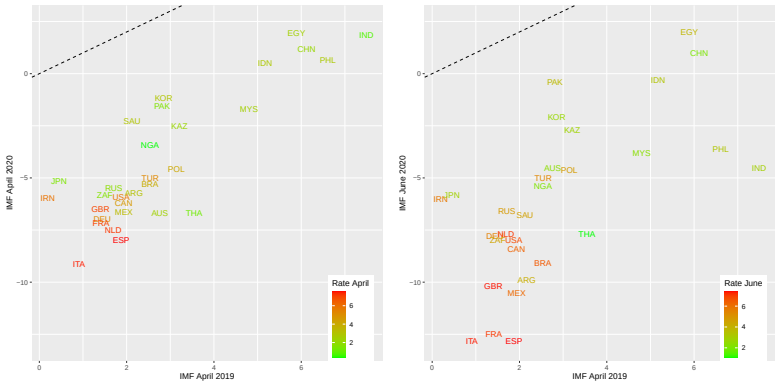


FIGURE 5. Scatter plot of the IMF GDP growth projections for 2020 generated in April and June 2020, and the `rate`. Only the 30 reference countries selected by the IMF are considered. Left: Data set for April 2020. Right: Data set for June 2020.

Figure 5 shows the GDP growth projection evolution for 2020. This analysis is made only for the 30 reference countries that the IMF has updated the projections, belonging to all the different continents. We observe that most countries behave as we expected, that is, negative correlation between GDP growth projections decrease and `rate`. Countries in the Americas show a GDP growth projection strong decrease for 2020 when comparing the projections made in April and June 2020. The same behaviour is observed in the most affected European countries. This matches the fast evolution of the pandemic between April and May 2020 in those regions.

We now perform the same analysis made in this section for the WB data. It is important to observe that these projections were made in June, that is, 3 months after the World Health Organization (WHO) declared a world pandemic [13]. We consider that this data set does not require to split countries with and without

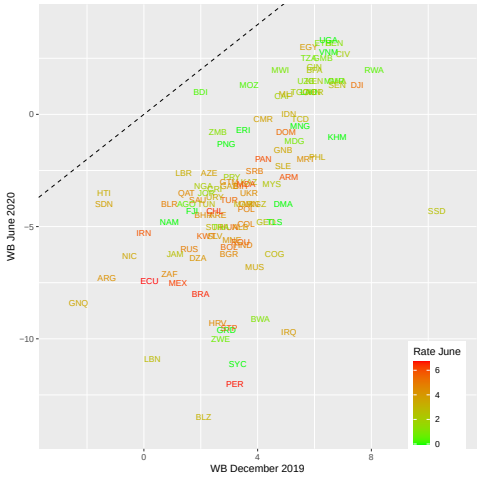


FIGURE 6. Scatter plot of the WB GDP growth projections for 2020 generated in June 2020, and the `rate`.

deaths, as most of the countries had already reported deaths due to Covid-19. The observed behaviour in Figure 6 is similar to the one observed in Figure 4.

3.2. **Detection and quantification of dependencies.** The next step is to detect decreasing dependencies between the differences in GDP growth projections and `rate`. Table 1 shows the results for both IMF and WB data sets. For the IMF data set, we consider the data for April (most of the countries) and June (30 reference countries). In all cases, we observe a statistically significant negative correlation, as it was expected.

Growth projection difference	Variable	r_s	p-value
`Apr2020_IMF − Apr2019_IMF`	`Rate April`	-0.423	2.4e-09
`Jun2020_IMF − Apr2019_IMF`	`Rate June`	-0.554	8.8e-04
`Jun2020_WB − Dic2019_WB`	`Rate June`	-0.37	2.0e-05

TABLE 1. Spearman rank correlation r_s.

We conclude that there are decreasing dependencies between health data and GDP growth projection differences. Therefore, the higher relative impact the Covid-19 had in a country, the greater downfall of the GDP growth projection.

Our objective now is to quantify the dependency between the GDP growth projections change and the `rate`, using linear regressions, as detailed in subsection 2.4.

3.2.1. *IMF data for April 2020.* We first consider the IMF data for April 2020. In our work hypothesis, countries without Covid-19 deaths in April 2020 should exhibit a similar GDP growth projection change. For this countries, the `rate` is equal to zero. The results are shown in table 2. As expected, the coefficient $\hat{a}_1$ is significant and less than 1 standard deviation from 1. The intercept is significant, which can be interpreted as the main impact in GDP growth decrease for these countries. We now consider countries with at least 1 death due to Covid-19 in April 2020. The

	Par.	Estimate	Std. Error	t-value	$\mathbf{Pr}(>\|t\|)$	Signif. codes
`Intercept`	$\hat{b}$	-5.77	1.62	-3.60	0.00140	**
`Apr2019_IMF`	$\hat{a}_1$	0.83	0.30	2.79	0.00948	**

TABLE 2. IMF data set for April 2020, countries without deaths due to Covid-19. Residual standard error: 4.102; Adjusted R-squared: 0.1954. Significance codes: 0 '***'; 0.001 '**'; 0.01 '*'; 0.05 '·'; 0.1 ' '.

results are shown in table 3. The coefficient $\hat{a}_2$, related to `rate`, is significant and negative. Also, the intercept and the coefficient $\hat{a}_1$ exhibit the same behaviour as in the model for countries without deaths, and the intercepts are less than 1 standard deviation from each other.

	Par.	Estimate	Std. Error	t-value	$\mathbf{Pr}(>\|t\|)$	Signif. codes
`Intercept`	$\hat{b}$	-5.43	0.63	-8.65	1.34e-14	***
`Apr2019_IMF`	$\hat{a}_1$	1.12	0.20	10.22	2.0e-16	***
`Rate April`	$\hat{a}_2$	-0.65	0.10	-6.21	6.16e-09	***

TABLE 3. IMF data set for April 2020, countries with deaths due to Covid-19. Residual standard error: 2.079; Adjusted R-squared: 0.6417.

3.2.2. *IMF data for June 2020.* We now study the IMF reference countries. We are interested in the temporal evolution of the GDP growth projections under the uncertainty due to the Covid-19 pandemic, so we analyze the GDP growth projections for the 30 reference countries generated in April and June 2020, and compare them. The results for April are shown in table 4. It is worth noting that, for April, we observe residuals with larger variance than the model that considers all countries shown in table 3. This is probably due to the smaller sample size.

	Par.	Estimate	Std. Error	t-value	$\mathbf{Pr}(>\|t\|)$	Signif. codes
`Intercept`	$\hat{b}$	-6.39	0.99	-6.47	6.16e-07	***
`Apr2019_IMF`	$\hat{a}_1$	1.25	0.18	6.86	2.28e-07	***
`Rate April`	$\hat{a}_2$	-0.37	0.16	-2.35	0.0262	*

TABLE 4. IMF data set for April 2020, only 30 reference countries. Residual standard error: 1.568; Adjusted R-squared: 0.7522.

Table 5 shows the results for June 2020. We observe a worse fit of the model. Although the coefficients $\hat{a}_1$ and $\hat{a}_2$ are significant, the intercept b is not. Moreover, the coefficients $\hat{a}_2$ for April and June are different, but it is hard to conclude because of the poor fit of the model for the data of June. However, $\hat{a}_1$ is less than 2 standard deviations from 1, so it can still be regarded as equal to 1, in accordance with our working hypothesis.

3.2.3. *WB data for June 2020.* The results obtained in table 6 for the WB data set in June are similar to the ones obtained in table 3 .

	Par.	Estimate	Std. Error	t-value	$\mathbf{Pr}(>\|t\|)$	Signif. codes
`Intercept`	$\hat{b}$	-3.91	2.15	-1.82	0.08016	
`Apr2019_IMF`	$\hat{a}_1$	0.82	0.32	2.52	0.01813	*
`Rate June`	$\hat{a}_2$	-0.99	0.31	-3.15	0.00402	**

TABLE 5. IMF data set for June 2020, only 30 reference countries. Residual standard error: 2.625; Adjusted R-squared: 0.5478.

	Par.	Estimate	Std. Error	t-value	$\mathbf{Pr}(>\|t\|)$	Signif. codes
`Intercept`	$\hat{b}$	-4.92	0.98	-5.01	2.84e-06	***
`Dic2019_WB`	$\hat{a}_1$	1.02	0.15	6.79	1.39e-09	***
`Rate June`	$\hat{a}_2$	-0.56	0.18	-3.03	0.00322	**

TABLE 6. WB data set for June 2020, all countries. Residual standard error: 2.674; Adjusted R-squared: 0.4546.

4. **Conclusions.** The great global uncertainty produced in the main economic variables during the onset of the Covid-19 pandemic resulted in severe restrictions in many aspects of economic activity around the world. The objective of the present work is to study to what extent the adjustments to GDP growth projection for the end of 2020 (the difference between those made in 2019 and those made in 2020) can be explained by the heath situation due to pandemic in the different countries. In order to answer this question, we construct a `rate`, that summarizes the cumulative relative disease impact of the Covid-19 pandemic in each country at a given time. On the other hand, we consider GDP growth projection data sets generated by two international economic organizations, the International Monetary Fund and the World Bank.

The statistical analysis was carried in two steps. First, we conducted a rank correlation statistical test that showed, in the three cases considered, strong dependencies between the `rate` and adjustments to GDP growth projections for the end of 2020. Our first conclusion is then that the greater the impact of the Covid-19 pandemic in each country, the lower the projection adjustment of its economic development. Secondly, we explored dependencies adjusting a linear model. This quantification analysis showed consistent results regarding the coefficient of the 2019 GDP growth projections (statistically equal to 1 in all scenarios), and statistically equal values of the intercept in two of the three scenarios (indicating a global impact of the pandemic in the GDP decrease). Moreover, the coefficients related to the `rate` are statistically smaller than zero in all cases, as expected.

Our results lead us to believe that the international economic institutions had a conservative approach at the beginning of the Covid-19 pandemic, penalizing countries that were unable to contain the spread of the virus and that showed greater health impacts. Finally, we mention that the question of the accuracy of projections is always relevant, and can only be judged when economic indicators become available.

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