COVID-19 pandemic outcomes in Brazil – Electoral choices, demography, economic and social status

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Abstract

We discuss the relationships between the outcome of the COVID-19 pandemic in Brazil at the municipal level and different health, social, demographic, and economic indices. We obtain strong Spearman correlations between the data gathered for each of the 3079 municipalities with at least 10,000 inhabitants and the proportion of cases and deaths by COVID-19 and the results by municipality of the 2018 Brazilian presidential election. We thoroughly discuss the historical, economic, and social origins of such correlations, evidencing a profoundly segregated society.
I. INTRODUCTION

The outcome of a democratic election is expected to have a strong impact on the immediate future of a country. This is especially true in polarized contexts like the United States in the 2020 presidential election, where a populist right-wing president was defeated by a more traditional politician representing the long-standing liberal democracy, or the recent French presidential election, where the current president was re-elected, after running against an openly far-right candidate in the second round of the election. A similar electoral dispute occurred in Brazil in 2018 (and it is again as this work is written), where the country had to choose between the far-right candidate Jair Messias Bolsonaro, a former army captain and a congress deputy, who eventually won the election, and the left-wing candidate Fernando Haddad, a university teacher and former minister of education.

Amid the different issues resulting from the policies implemented by different ideologies when operating in a central government, the capacity to deal with crisis is certainly the one with the most overreaching consequences. This was staunchly demonstrated with the advent of the COVID-19 pandemic, caused by the SARS-CoV-2 virus. According to official reports [21], since its first detection in Wuhan (China) in December 2019 to the present date, the virus has been responsible for six and a half million deaths and 615 million cases. Although these figures are sadly impressive in and of themselves, the real numbers are much worse, with cases significantly under-reported [22] and under-reported deaths proportionately smaller but still significant [27]. The estimated real number of deaths in the world is approximately 18 million [19], with under-reporting varying significantly among countries and regions. This only shows that the burden of COVID-19 is by far the worst planetary health crisis in more than a century.

A recent report by the Lancet Commission on lessons for the future from the COVID-19 pandemic [30] addresses both the correct measures and failures in the mitigation of the COVID-19 pandemic and its social and economic consequences. Among different analysis, the report points out that most governments, and the World Health Organization, were too slow to react to the new pandemic; that many mitigation measures were hindered by wide sectors of the population; and that trust in communities acted as an important fighting tool against the pandemic. Some authors have addressed the consequences of pandemic mitigation policies according to government choices based on the prevailing ideology in
the government and its public discourse. Based on surveys from the initial stages of the pandemic, Pickup and collaborators discussed the effects of political partisanship in attitudes and perceptions of government policies in mitigating the pandemic in the US and Canada [29], with evidence that partisanship guided the assessment of central government policies against COVID-19 in both countries. Bennouna et al. studied the great variations of COVID-19 mitigation policies in Brazil, Mexico and the US and the importance of central (presidential) and state (governors) coordination, or its absence, in the adoption of public policies [2]. The effect of political partisanship on adherence to social distancing in each US state was studied using mobility statistics, and found to be closely related to the respective governor’s political party, with recommendations being more effective in Democratic than in Republican counties [17]. A comparison of public health emergency measures and social policies in Brazil, Germany, India and the US demonstrated that their simultaneous implementation succeeded in confronting the pandemic, as was the case in Germany; that social policies without associated health interventions failed to result in an effective mitigation, as occurred in Brazil and the US; while in India, public health policies simply failed due to the absence of social interventions [16]. Today, among different public policies the most effective against COVID-19 is mass vaccination, that if properly planned can significantly reduce the burden in lost lives [11], a fact many times denied in anti-scientific speeches by some public authorities. In Brazil non-adherence to vaccination was responsible for the great majority of death by COVID-19 during the period from January to March 2022, when vaccine were widely available in the country [25]. These studies put forward the need for strong coordinated actions between different levels of government for the simultaneous adoption of social and health policies for an efficient mitigation of the current and future pandemics [39].

Here we investigate the correlations between the outcomes of the COVID-19 pandemic, the electoral choices for the 2018 second round of the Brazilian presidential election, and a series of social, economic, and demographic indicators. All data is considered at the municipal level, the smallest administrative division in Brazil. The present work is heavily based on a large and representative set of data, and thus significantly expands on previous studies focusing on the COVID-19/Election relationships. We will discuss the picture that emerges from such analysis and its social and historical roots, and hope to shed more light on an important and intricate country that manifests many difficulties faced by many other nations.
II. DATA AND SOURCES

The Federate Republic of Brazil is divided in 26 states plus the Federal District, and each state is divided in municipalities (5570 in total), with a number of inhabitants ranging from 10,004 to 12,228,009 (2022 estimates), and area from 3,656 km\(^2\) for Santa Cruz de Minas in the state of Minas Gerais, up to 159,533,730 km\(^2\) for Altamira in the state of Pará (northern region). A municipality usually, but not always, corresponds to a city or a small conglomerate of cities. In order to have statistical significance for the COVID-19 data we considered in the present analysis the 3079 municipalities with an estimated population of at least 10,000.

The following data and respective sources were used in our analysis:

- Total number of COVID-19 cases and deaths by Brazilian municipality [3]. The proportion of the population already infected by the SARS-CoV-2 virus is called the attack rate.

- Number of COVID-19 vaccine by dose and type as a function of time for each municipality [28].

- Number of votes received by each candidate at the second round of the 2018 Brazilian election [38].

- Budget from the federal government for the public health structure received during the year of 2021 [28].

We also used the following social, economic and demographic data for the year of 2010, when the last official Census in Brazil was completed:

- Illiteracy rate by municipality, for individual with 18 years of age or more [20].

- Proportion of individuals in each municipality with 25 years or more having completed their primary education [20].

- GINI index by municipality [20].

- Percentage of extremely poor individuals [20].

- Average income in each municipality [20].
• Human Development Index in each municipality [20].

• Population by self-declared race (skin color) in each municipality [36].

We used the following estimates for the population in each municipality:

• Estimated population in 2022 in each municipality [14].

Although the census data is a decade old as the 2020 census was postponed due to the pandemic, we do not expect a significant change in the rates and proportions used here, but we recognize it as a source of error in the analysis to be presented below. The list of all variable considered in the correlation analysis is summarized in Table I.

| Data Variable | Variable |
|---------------|----------|
| Election result | $E_r$ |
| COVID-19 attack rate | $A_r$ |
| COVID-19 mortality rate | $M_r$ |
| Vaccine coverage (2 doses) in the population | $V_c$ |
| Adult illiteracy rate | $I_r$ |
| GINI coefficient | $G_i$ |
| Percentage of population in extreme poverty | $P_p$ |
| Average income | $A_I$ |
| Human development index | $HDI$ |
| Per capita public health budget | $H_b$ |
| Percentage of black and indigenous population | $BI$ |

TABLE I. Variables considered in the analysis.

III. METHODS AND DATA ANALYSIS

In order to determine the intrinsic relations between each pair of variables listed in Table I, we use the Spearman rank-order correlation $r_s(A, B)$ between two ordered series $A = (A_1, \ldots, A_{N_{\text{data}}})$ and $B = (B_1, \ldots, B_{N_{\text{data}}})$ each composed by $N_{\text{data}}$ values. It is given by the Pearson
correlation between their rank values, and for the special case that the ranks are all distinct by [26]:

\[ r_s[A, B] = 1 - 6 \frac{\sum_{i=1}^{N_{\text{data}}} d_i^2}{N_{\text{data}}(N_{\text{data}}^2 - 1)}, \] (1)

with \( d_i \) the difference in paired ranks of the two data sets \( A \) and \( B \) given by the difference in position of the \( i \)-th data point in the two data sets in ascending order. The Spearman correlation satisfies \(-1 \geq r_s \geq 1\) and is a measure for how two variables are monotonically related, by an increasing or decreasing relation if \( r_s > 0 \) or \( r_s < 0 \), respectively. The statistical significance of the Spearman correlation is determined from a Monte Carlo procedure as explained in the appendix.

The results for the 2018 presidential election in Brazil (second round) are represented in each municipality by an index defined as

\[ E_r = \frac{V_1 - V_2}{P_m}, \] (2)

where \( V_1 \) and \( V_2 \) are the votes received by Fernando Haddad and Jair Bolsonaro, respectively, and \( P_m \) is the population in the given municipality. Visual representations for relations among some pairs of the variables in Table I are given by the scatter plots in Fig. 1 where strong correlations are easily visible. The values of the Spearman correlation \( r_s \) for all pairs of the data values are given in in Fig. 2. The statistical significance, as given by the p-value for each pair is given in Table II of the appendix. We note that the correlation values have a strong statistical significance and are certainly not due to pure chance.

IV. DISCUSSION AND CONCLUSIONS

Needless to say, but always good to remember, correlation is not causation. As we discuss below, the adherence to a dubious view of science and its achievements is correlated to the choice to vote for a right-wing populist candidate, but not a consequence of it. In fact, they are both consequences of a conservative dominant social structure. Before all, it is important to recognize that it is a central element of the ethos of some social segments in Brazil to diffuse alleged conspiratorial contexts with attacks on modern and liberal values. The current Brazilian president, Jair Messias Bolsonaro, elected in 2018, reinforces discourses from an autocratic historical past, marked by the absence of individual and collective liberties and guarantees, common in countries with a lasting democratic tradition [1, 4, 23]. This
is reinforced by an internal and subjective connection between the speech of allies and the president himself. In order to go deeper into the analysis to explain the far from negligible relationship between a worse outcome from the COVID-19 pandemic and the vote for president in each Brazilian municipality, we show how this inherently unequal society becomes evident from a number of variables representing social, demographic, and economic data,
FIG. 2. Heatmap and values of Spearman correlations $r_s$ between the variables in Table I.

and compare them with the outcomes of policies for mitigating the COVID-19 pandemic. This will allow us to better understand the reasons why the latter also correlates with the presidential vote.

The values for the Spearman correlation $r_s$ between all indices and rates in Table I demonstrate a strong tendency for municipalities with a majority of votes in Bolsonaro to have a worse pandemic outcome, i.e., the higher the proportion of votes in Bolsonaro, the higher the attack rate and the proportion of deaths in the population (see also Figs. 1A, 1B, and 1C). In the same way, a higher human development index and higher average income strongly correlate with a vote for Bolsonaro. On the other hand, the left-wing candidate Haddad received a higher proportion of votes in municipalities with higher adult illiteracy, higher inequality as measured by the GINI index, a higher proportion of extreme poverty and a higher proportion of black and indigenous population. Those are signs of a highly segregated social structure, that translates into electoral choices and the expression of not of prossocial behaviors relevant to the mitigation of a crisis, such as the current pandemic.

The evidence of historical racial injustice is reinforced in the present analysis by the strong correlation between the proportion of black and indigenous populations and data related to economic inequality. Nevertheless both the attack rate (proportion of cases in the population) and the mortality by COVID-19 have a significant negative Spearman correlation with the proportion of black and indigenous population, which also tended to vote in the left-wing candidate. This does not imply that black and indigenous populations were less affected by the pandemic. For instance, the most populous of all municipalities, the city of
São Paulo, with more than twelve million inhabitants, voted significantly for Bolsonaro and was heavily hit by the pandemic and counts as a single entity in the present analysis. It was estimated that the number of deaths among black individuals is significantly higher than in white individuals in Brazil, as it is also in the United States, for the period from January to July 2020 [7]. It is noteworthy that localities where Haddad obtained the majority of votes are also those that have a higher expenditure in the public health sector per inhabitant (by 2021), despite having a lower average income, which may be related to local governments (mayors and municipal parliaments) being more prone to finance public structures and not having to rely on a very present health private sector.

The negative correlation between Haddad’s vote and vaccination rate may appear to be a contradictory result, but it can be explained by a closer look at the scatter plot in Fig. [1], where no tendency for higher or smaller vaccination can be detected except for a number of municipalities in the lower right portion of the plot (a lower vaccination rate and higher voting in Haddad). By inspecting the vaccination data we observe that there are 188 municipalities with less than 30% of fully vaccinated individuals, with 140 of them from the state of Ceará. This is either due to a local problem in data gathering or some other issue specifically present in this state. With this observation, we conclude that there is no clear difference in vaccination rates between municipalities that voted for either candidate.

Behaviors for preventing the dissemination of the SARS-CoV-2 virus, based on scientifically sound and effective measures [12, 30], such as personal hygiene measures, mask wearing, social distancing, avoiding crowds and quarantining when ill, are linked to trust in government [18]. President Bolsonaro delivered many speeches to cast doubt on scientific evidence on the efficacy of such non-pharmaceutical interventions [13]. At the height of the pandemic, with more than four thousand deaths in a single day, no awareness campaigns were deployed by the central federal government (and barely timid ones by state governments) to properly guide the general population. In fact, considerable effort was expended in calling into question the efficacy of all valid mitigation measures, which were implemented in the majority of countries where public policies are dictated democratically. Nevertheless, his speeches didn’t have a homogeneous reach across the country, as shown here. Counter-intuitively prosocial behavior at the municipality level is a proxy for worse economic and social indicators, as richer localities fared worse against the pandemic. In Brazil, economic status does not correlate with healthy stances, with a conservative attitude being associated
with a denial of basic scientific facts.

As the data synthesized here demonstrates, the majority of votes lean away from the existing social order in each locality. Municipalities with lower economic indices and a higher proportion of marginalized people tend to vote left, while those with higher indices tend to vote right-conservative. Our analysis show that the outcomes of the COVID-19 pandemic demonstrates the intensity of political, social, and economic relations in Brazilian society, either in a democratic or an authoritarian framework [1], displaying structures similar to those of its colonial pre-independence version, which is still manifest after a few centuries of the arrival of Portuguese and other Europeans, and that help explain how the country fought against the pandemic. Democracy in Brazil has a troubled history, with its present incarnation initiated in 1989 by the first democratically elected president after the last military regime. Brazilian democracy has contradictory roots, stemming from the tensions between liberal and authoritarian tendencies, both aiming at an economic liberal regime [10, 33]. For most of the 20th-century, democracy in Brazil was a fictional landscape, having gone through different autocratic regimes: the Getúlio Vargas “Estado Novo” (new state) from 1937 to 1945 and a military dictatorship from 1964 to 1985, both with strong support from economic elites and the urban middle class [6, 8]. Prior to Vargas, the country was ruled by oligarchies with a semblance of democracy [34].

True political and institutional stability was attained only in 2002 by the first presidential transition from an elected president to a new and also elected president, from Fernando Henrique Cardoso to Luís Inácio da Silva. This stability was short-lived as president Dilma Rousseff, who succeeded Lula da Silva, was deposed by a legal impeachment process in 2016 based on dubious accounting and fiscal issues. As a consequence, the office was passed by Michel Temer, Rousseff’s vice president, to Jair Messias Bolsonaro, the elected current president. It is worth mentioning that Lula da Silva tried to run for the presidency but was prevented by his arrest on charges later dropped by the Brazilian Supreme Court. This turmoil evinces the interplay of the judiciary and the executive agents and a dubious independence among them leading to a context of questioning the rule of law, the basis of a modern liberal democracy. As a young democracy, Brazil still faces issues related to its colonial and slave exploitation past, demonstrating a difficulty in linking itself to liberal democratic values.

The effect of the rise of candidate Bolsonaro, and its counterparts in states and munici-
palities, demonstrates the return of a debate that seemed surpassed in the last century: the vaccine as a way to prevent and eradicate frequent endemic diseases in tropical countries. It would not be an exaggeration to say that the vaccination structure in Brazil surpasses that of many rich and developed countries, with a long history of more than a century. An important episode in this history, that took place in 1904, when Oswaldo Cruz, one of the greatest sanitarians in recent history, as Director General of Public Health in the federal capital at the time, Rio de Janeiro, decided to fight three major diseases that plagued the city: smallpox, fever, and bubonic plague. Teams were created to fight the proliferation of mosquitoes that transmit yellow fever (at the time, Stegomyia Fasciata, now Aedes Aegypti), also called mosquito killers. Those teams entered the residences abruptly, without any previous warning or clarification, carrying out inspections and ordering renovations and even demolitions, which resulted in panic and public unrest. To deal with the bubonic plague, authorities even encouraged the hunting of rats by monetary reward for those who brought them in dead. Regarding the third disease, smallpox, a mandatory vaccination campaign was organized, approved and implemented in the year 1904. Two situations were presented as unsatisfactory for the population: one of a moral order, where women needed to be touched and raise their sleeves to carry out the vaccination; and one of a political nature, which would be the imposition of vaccination as mandatory. Oswaldo Cruz maintained the order for a mandatory vaccination card for hiring in jobs and trips and some other instances, resulting in riots and, eventually, the well-known Vaccine Rebellion [35]. This episode exemplifies the ethereal relationship between the authoritarian past, characterized by relationships based on the “Pater Familiae” (common in rural societies) and the present, a country where an accelerated phase of urbanization and in search of more equitable and egalitarian relationships merges into a schizophrenic network of actions. Bolsonaro ascension was poised to act as an eloquent figure and spokesperson for the national oligarchic elites, a good portion of the middle class, economic heirs, and of the moral framing of past oligarchic elites. On the other hand, Fernando Haddad’s candidacy was seen as an effort to break with this hierarchical, segregated, and unequal history of the country, a view consistent with the data and its analysis as presented above. Its voters, even those who are illiterate or have low schooling, demonstrate what educator Paulo Freire named the reflective capacity, typical of modern citizens of societies organized under social classes and not states, with parent-child relationships in homes being a surrogate of the objective-cultural conditions of the totality
in which they participate. And, if the latter are authoritarian, rigid, dominating conditions, they penetrate the homes and increase the feeling of oppression [15].

All of this puts in evidence the contradictory foundations of the Brazilian democracy, struggling with an evaluative ground based on a moral framework excluding women, indigenous people, blacks, the LGBTQIA+ population, and other segments of society that do not fit into a worldview commonly associated with the political orientations of candidates who support right-wing and far-right values and proposals [37]. The strife with scientific values alongside those that are the foundations of a more liberal and modern society in Brazil is not new, but in fact, an “eternal return”. However, the administration of Bolsonaro and his vice-president, former General Mourão, updates some elements, such as the use of social networks and other media strategies based on fake news [5], to conduct a political project that has cannot be qualified as new, but uses technological advances for instant dissemination, causing an institutional and social imbalance. Not surprisingly, this is very similar to what has occurred in other countries, including rich and developed ones, where individuals with a far-right rhetoric were able to seize control of the government.

The political, economic, social, and environmental projects put in place by the current Brazilian central government favor an increasing income concentration, and is clearly reflected at the electoral results as seen in Figs. 1E and 1I, and the corresponding values in Table 2. This has a strong negative impact on the structural values of modernity, among which the modernization of the country’s economy, the implementation of a fair taxation structure, gender equality and opportunity, access to good quality public goods and services. In this context, it is important to highlight the creation of mishaps and stratagems to reduce transparency and the access of citizens to government spending and the execution of the public budget through the imposition of one hundred years of secrecy in some official documents, including telephone messages from national authorities, that could compromise the performance of the current presidential administration. All those issues are transported to the municipal level by local authorities of same political beliefs and practices as the central government.

As to the mitigation of the COVID-19 pandemic, federal authorities in Brazil failed to recognize how serious the situation was, and even propagated false beliefs and irresponsible attitudes, such as denying the existence of efficient therapies in favor of scientifically proven inefficient medications, and even delivering public speeches against mass vaccina-
tion. Therefore, it comes as no surprise that the burden of the pandemic was higher in those municipalities where authorities sympathized and supported such policies, as a sad consequence of a divided society between modernity and a colonial past. The mandatory use of masks, which was implemented by the state governments despite the opposition of the federal government, and other non-pharmaceutical measures, were dependent on the willingness and conformity of local authorities, as well as individual behavior, closely influenced by the dominant beliefs. We also observe that municipalities with worse social and economic indicators tended to vote for the left-wing candidate, an intellectual from the middle class, and not for the right-wing candidate that boasted of its identity to the people. This is at variance with what was observed at local elections with a preference for candidates having the same “descriptive representation” [9]. This shows that, for elections at the national level, a significant part of the Brazilian electorate identify itself with one of two opposing ideological views [31, 32], and that social class, economic, and racial realities are determinants of this choice.

We conclude by stressing that the election of President Bolsonaro, which impacted to not properly fight the dissemination of the SARS-CoV-2 virus, is not the cause of many mishaps in Brazil, but a symptom of an underlying contradictory social and economic structure that, among other consequences, hinders the development and evolution of a stable, modern, democratic and inclusive society in Brazil.

**APPENDIX: STATISTICAL SIGNIFICANCE OF CORRELATIONS**

In the present appendix we explain the statistical significance of the Spearman correlation values obtained in the present work, i.e. what are the odds that the value is due to pure chance. We employ a Monte Carlo method by shuffling the order of the data in each series a thousand times, and computing the value of $r_s$ in each case. This results in a distribution of values that is sufficiently close to a Gaussian distribution, which is then used to obtain the $p$-value, i.e. the probability of the null hypothesis [24]. In order to illustrate this procedure, figure 3 shows the normalized distributions obtained from the randomized samples and the actual value of $r_s$ for the correlation between $N_b$ and $AI$ and for $E)r$ and $M_r$. The numerical results for all possible pairings are shown in Table II.
FIG. 3. Distribution of values for the Spearman correlation $r_s$ using the randomization procedure, between (A) the public health per capita expenditure $H_b$ and the average income $AI$ with $p = 1.05 \times 10^{-2}$, and (B) the electoral result coefficient $E_r$ and the COVID-19 mortality rate $M_r$ with $p = 1.06^{-39}$. The black vertical line indicate the value of $r_s$ for the original data.

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| Variable | Variable | p-value  | Variable | Variable | p-value  | Variable | Variable | p-value  |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| $E_r$    | $A_r$    | $2.1 \times 10^{-19}$ | $E_r$    | $M_r$    | $1.06 \times 10^{-39}$ | $E_r$    | $V_c$    | $3.51 \times 10^{-32}$ |
| $E_r$    | $I_r$    | $1.35 \times 10^{-66}$ | $E_r$    | $G_i$    | $2.80 \times 10^{-31}$ | $E_r$    | $P_p$    | $5.28 \times 10^{-66}$ |
| $E_r$    | $A_I$    | $4.52 \times 10^{-51}$ | $E_r$    | $HDI$    | $1.73 \times 10^{-53}$ | $E_r$    | $H_b$    | $1.45 \times 10^{-7}$  |
| $E_r$    | $B_I$    | $7.33 \times 10^{-73}$ | $A_r$    | $M_r$    | $2.18 \times 10^{-10}$ | $A_r$    | $V_c$    | $4.35 \times 10^{-11}$ |
| $A_r$    | $I_r$    | $8.11 \times 10^{-17}$ | $A_r$    | $G_i$    | $2.84 \times 10^{-10}$ | $A_r$    | $P_p$    | $1.83 \times 10^{-12}$ |
| $A_r$    | $A_I$    | $4.88 \times 10^{-13}$ | $A_r$    | $HDI$    | $1.08 \times 10^{-11}$ | $A_r$    | $H_b$    | $1.59 \times 10^{-2}$  |
| $A_r$    | $B_I$    | $2.89 \times 10^{-22}$ | $M_r$    | $V_c$    | $5.55 \times 10^{-17}$ | $M_r$    | $I_r$    | $2.32 \times 10^{-51}$ |
| $M_r$    | $G_i$    | $2.71 \times 10^{-20}$ | $M_r$    | $P_p$    | $1.26 \times 10^{-34}$ | $M_r$    | $A_I$    | $7.57 \times 10^{-39}$ |
| $M_r$    | $HDI$    | $1.46 \times 10^{-28}$ | $M_r$    | $H_b$    | $2.59 \times 10^{-5}$  | $M_r$    | $B_I$    | $3.84 \times 10^{-49}$ |
| $V_c$    | $I_r$    | $4.18 \times 10^{-45}$ | $V_c$    | $G_i$    | $2.09 \times 10^{-15}$ | $V_c$    | $P_p$    | $1.17 \times 10^{-41}$ |
| $V_c$    | $A_I$    | $1.19 \times 10^{-23}$ | $V_c$    | $HDI$    | $5.33 \times 10^{-27}$ | $V_c$    | $H_b$    | $1.06 \times 10^{-5}$  |
| $V_c$    | $B_I$    | $1.99 \times 10^{-31}$ | $I_r$    | $G_i$    | $1.79 \times 10^{-23}$ | $I_r$    | $P_p$    | $1.96 \times 10^{-74}$ |
| $I_r$    | $A_I$    | $4.04 \times 10^{-61}$ | $I_r$    | $HDI$    | $2.31 \times 10^{-44}$ | $I_r$    | $H_b$    | $4.96 \times 10^{-6}$  |
| $I_r$    | $B_I$    | $1.97 \times 10^{-78}$ | $G_i$    | $P_p$    | $3.98 \times 10^{-29}$ | $G_i$    | $A_I$    | $6.10 \times 10^{-30}$ |
| $G_i$    | $HDI$    | $3.40 \times 10^{-20}$ | $G_i$    | $H_b$    | $3.50 \times 10^{-2}$  | $G_i$    | $B_I$    | $1.60 \times 10^{-36}$ |
| $P_p$    | $A_I$    | $8.91 \times 10^{-67}$ | $P_p$    | $HDI$    | $7.03 \times 10^{-58}$ | $P_p$    | $H_b$    | $3.42 \times 10^{-6}$  |
| $P_p$    | $B_I$    | $5.18 \times 10^{-77}$ | $A_I$    | $HDI$    | $4.95 \times 10^{-64}$ | $A_I$    | $H_b$    | $1.05 \times 10^{-2}$  |
| $A_I$    | $B_I$    | $3.00 \times 10^{-69}$ | $HDI$    | $H_b$    | $4.89 \times 10^{-5}$  | $HDI$    | $B_I$    | $2.45 \times 10^{-69}$ |

TABLE II. Statistical significance p-value for the Spearman correlation $r_s$ between each pair of variable in Table I from $N_r = 1000$ randomizations for each pair of variables.

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