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Cultural and Institutional Factors Predicting the Infection Rate and Mortality Likelihood of the COVID-19 Pandemic

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Abstract: The spread of COVID-19 represents a global public health crisis, yet some nations have been more effective at limiting the spread of the virus and the likelihood that people die from infection. Here we show that institutional and cultural factors combine to explain these cross-cultural differences. Nations with efficient governments and tight cultures have been most effective at limiting COVID-19's infection rate and mortality likelihood. An evolutionary game theory model suggests that these trends may be partly driven by variation in adherence to cooperative norms across nations. We summarize basic and policy implications of these findings.

The COVID-19 pandemic represents a global health crisis. The virus has quickly spread from its epicenter in Wuhan, China, across the planet. As of March 2020, COVID-19 has infected over 650,000 people and killed over 30,000 people worldwide. There have been over 130,000 cases and close to 2,500 deaths in the United States alone, and both figures have surpassed Chinese rates and are growing exponentially by the day. Yet certain countries have had far more success in slowing the number of COVID-19 cases and the likelihood that infected individuals will die from the virus. Singapore, Hong Kong, Taiwan and South Korea have each been able to effectively contain the virus, and despite controversy around its early handling of the virus, China has recently been able to vastly reduce new infections. By contrast, Italy, Spain, and the U.S., have experienced more pronounced growth in prevalence and death rates than other countries. Scientists, policy makers, journalists and lay people alike are all urgently trying to understand the mechanisms that have produced such national variation in order to learn how to curtail the spread of COVID-19.

Here we present data on how societal institutions and culture could critically contain COVID-19. Our analyses are based on the premise that the COVID-19 pandemic is a global threat that requires effective and rapid cooperation and coordination to solve. Based on this premise, we propose that nations with efficient governments that are able to quickly allocate revenue and coordinate with private sector industries may be able to slow the trajectory of the virus and reduce its morality rate compared with nations with less efficient governments. Additionally, tighter cultures that have strong norms and little tolerance for deviance (1, 2) may be better able to adopt new norms (e.g. social distancing, effective handwashing) that contain the virus compared to looser cultures. Our predictions are consistent with models of cultural evolution which show that, in the face of acute ecological threat, human groups require strict norms to maintain high levels of cooperation and coordination (3). When nations combine efficient government with tight cultures, they should be able to rapidly introduce and regulate these cooperative norms, increasing their ability to slow the spread and impact of an ecological threat such as COVID-19.

Building on this theoretical foundation, we predict that cultural tightness and government efficiency should combine to predict the infection rate and mortality likelihood associated with COVID-19, such that the nations that fare the best may have both culturally tight norms and efficient governments and the nations that fare the worst may have culturally loose norms and inefficient governments. Here we test this prediction using data on 528,019 confirmed cases of COVID-19 (including 23,672 deaths) across 141 world nations to examine how governmental efficiency and cultural tightness together can radically impact the spread and death rates of COVID-19 above and beyond economic and demographic differences between countries. All data and code associated with these analyses are available from OSF at https://osf.io/pc4ef/ for reproduction and examination. We retrieved and updated these data between March 21st and March 30th, 2020.

We retrieved data on COVID-19 around the world from the European Center for Disease Control, which provides daily updates of the number of COVID-19 documented cases and the number of documented deaths due to COVID-19. We downloaded these data for 161 world nations. In order to avoid confounding these COVID-19 data with nations' population sizes, we downloaded data on cases per million citizens, and indexed death rate through the number of mortalities divided by the number of total cases.

We measured government efficiency using the World Bank's *Government Efficiency Index,* which assesses the public sector's performance in managing/regulating the political economy. According to this metric, efficient governments score highly on 5 dimensions: they are efficient in spending public revenue, they do not place strong compliance burdens on the private sector, they are able to efficiently settle legal and judicial disputes in the private sector, they are receptive to challenges from the private sector, and they offer transparent information about changes in government policies and regulations affecting private sector activities. The 2017 measure captures the government efficiency of 126 nations. We measured *cultural tightness* using the index from Gelfand and colleagues (1), who measured tightness through 6 items, including “There are many social norms that people are supposed to abide by in this country,” and “In this country, if someone acts in an inappropriate way, others will strongly disapprove.” This measure was originally gathered by Gelfand (1) across 33 nations, and then expanded to 57 nations by Eriksson and colleagues (4). The measure captures the strength of norms in a nation and the tolerance for people who violate norms.

The rate of COVID-19 over time showed an exponential growth curve, which is typical for the early stages of pandemic and epidemic outbreaks (5). We focused on the rate of cases after the number of cases exceeded 1 per million people, a CDC metric intended to track growth rates as the disease posed a risk to increasing numbers of people. We predicted that cultural tightness and government efficiency would predict slower growth rates of COVID-19 and lower mortality likelihoods, and that nations with high cultural tightness *and* high government efficiency would show especially slow growth rate and mortality likelihood. We captured infection rate by fitting regression equations for each nation, log-transforming the outcome variable (cases per million people) and the predictor variable (days) to account for the exponential growth rate of the virus. Log-transformation converts exponential growth rates into linear growth rates, which can be predicted in a general linear model. These linear growth rates for each nation are displayed in Figure 1.

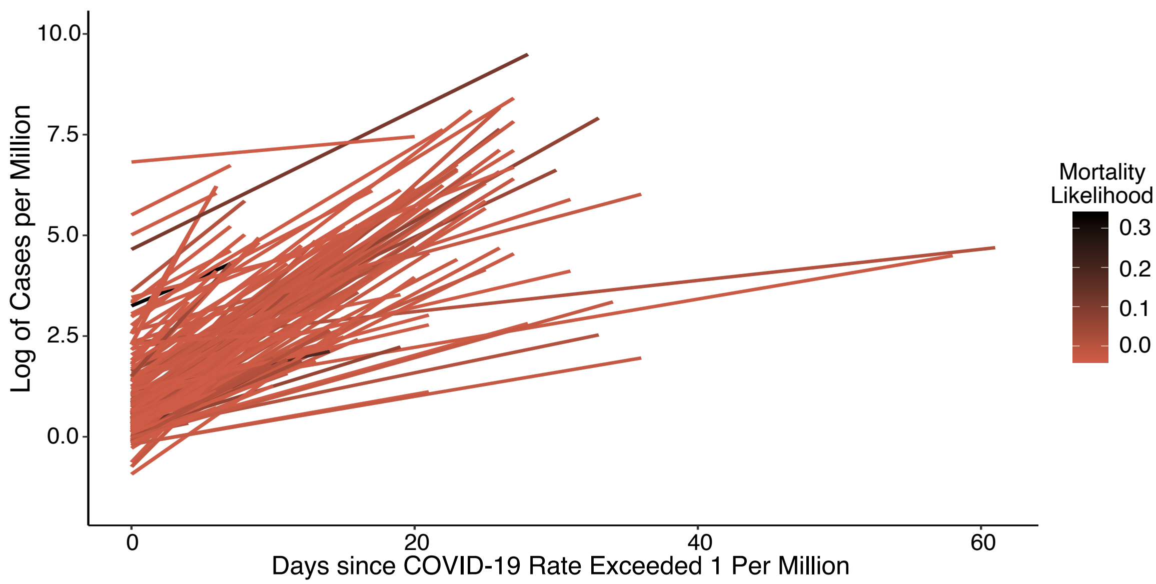

Figure 1. The Log-transformed growth curve of COVID-19 cases per million people. Each line is the rate of COVID-19 infection growth over time. The lines are colored based on the mortality likelihood (the probability of mortality for every COVID-19 case) for each nation.

We next conducted a second set of regressions using the estimates from our initial general linear models to predict cross-cultural variation in the infection rate of COVID-19. We note that general linear models do not account for the error inherent in estimating growth curves. To address this limitation, we weighted cases in our second set of regressions by number of observations across nations, so that nations with high numbers of observations (and more reliable estimates) would be weighted over and above nations with low numbers of observations (and less reliable estimates). We also predicted mortality likelihood, which we measured through the number of deaths from COVID-19 divided by the number of COVID-19 cases in a nation. While these models did not estimate change over time, they still captured a critical variable, since it is important to minimize the likelihood that people will die from COVID-19 once they have contracted the illness.

To make our models more robust, we controlled for factors that may be strongly related to the spread of COVID-19, such as economic development, inequality, and median age. We included these variables in all of our regressions, and our Supplemental Materials explore other factors such as population density. Economic development was indexed through GDP per capita, which we retrieved from the International Monetary Fund's 2019 release. Inequality was indexed through the nations' Gini coefficients, which we retrieved from the most recent World Bank estimate for each nation. We retrieved data on nations' median ages from the 2018 CIA World Factbook, the most recent release where we could locate this information. These covariates were standardized prior to model estimation. Finally, we also examined the distribution of rate of cases and mortality likelihood prior to fitting our models. These distributions revealed that the growth rate of cases was normally distributed, but the mortality likelihood was highly skewed (see Supplemental Materials). Therefore, we used an ordinary least squares regression with gaussian distribution to predict rate of cases but a logistic function with exponential distribution to predict mortality likelihood.

Our models examining infection rate revealed that cultural tightness and government efficiency were each related to the rate of new cases across nations. Culturally tight nations and nations with higher levels of government efficiency each had significantly slower COVID-19 infection rates. Figure 2 illustrates these relationships, and Table 1 lists the model coefficients.

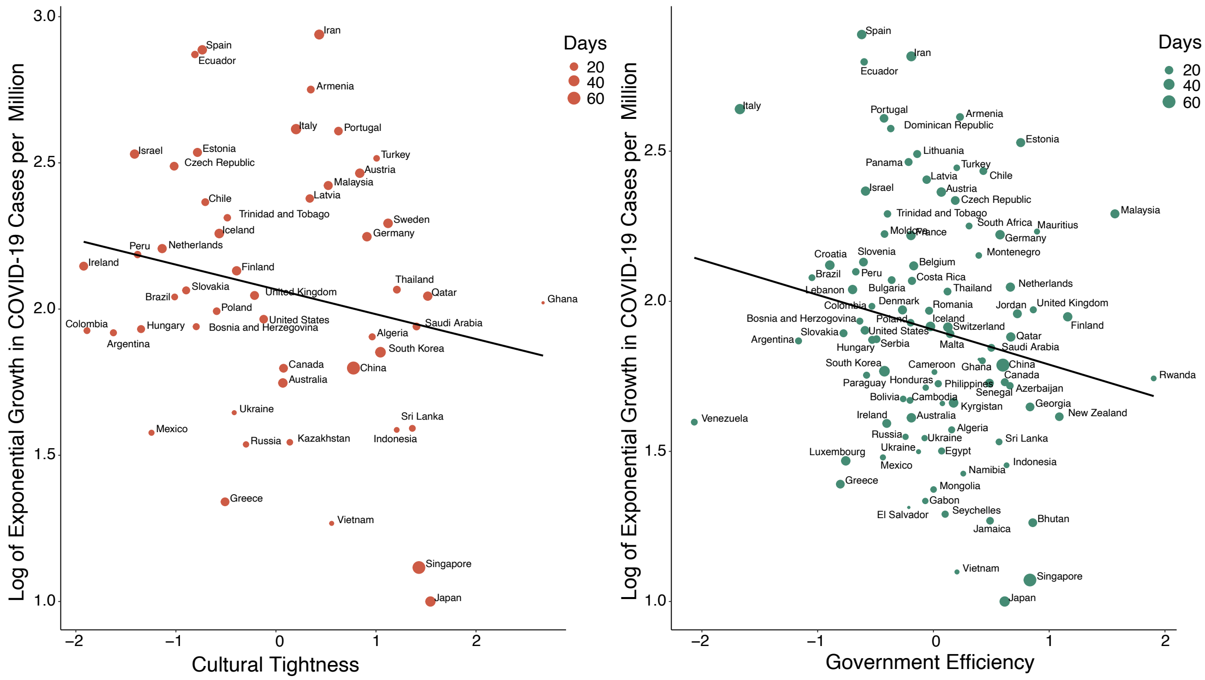

Figure 2. The bivariate relationships between COVID-19 exponential infection rate and cultural tightness (left) and government efficiency (right). All variables have been residualized based on GDP, Gini coefficients, and median age. Node size connotes the number of days available in our analysis, with larger nodes indicating more days.

Table 1. COVID-19 Rate of Cases by Cultural Tightness and Government Efficiency

Predictor	***DF***	***b***	***SE***	***t***	***p***
Model 1	45				
Cultural Tightness		-.15	.07	-2.15	.037
GDP Per Capita		.25	.07	3.84	< .001
Gini		-.10	.09	-1.08	.288
Median Age		.03	.17	.19	.852
Model 2	88				
Government Efficiency		-.19	.07	-2.79	.006
GDP Per Capita		.38	.05	7.40	<.001
Gini		-.10	.05	-1.83	.071
Median Age		.0002	.05	.004	.997

We next tested the interaction of cultural tightness and government efficiency on growth rates of COVID-19. This model found a significant interaction between tightness and efficiency, $b = -.17$, $SE = .07$, $t(41) = -2.23$, $p = .031$, such that cultural tightness significantly predicted slower rates of COVID-19 cases amongst governments with relatively high (1 SD above the mean) efficiency, $b = -.19$, $SE = .08$, $t(41) = -2.28$, $p = .028$, but not with governments with relatively low (1 SD below the mean) efficiency, $b = .08$, $SE = .12$, $t(41) = .68$, $p = .499$. Conversely, government efficiency predicted a slower rate of COVID-19 cases for nations that had relatively high (1 SD above the mean) cultural tightness, $b = -.36$, $SE = .16$, $t(41) = -2.35$, $p = .024$, but not nations with relatively low (1 SD below the mean) cultural tightness, $b = -.03$, $SE = .12$, $t(41) = .23$, $p = .818$.

To put this interaction into context, our models predicted that nations with mean levels of cultural tightness and government efficiency would have a log-transformed rate of 1.41 new cases per million people per day. Nations with low cultural tightness and low government efficiency would have a similar log-transformed rate of 1.45 new cases per million. However, nations with high cultural tightness and high government efficiency would have a much lower log-transformed rate of 1.06 new cases per million. Re-converting these log-transformed values through exponentiation suggests that, in the month (30 days) following the first COVID-19 case per million people, a tight nation with high government efficiency would have 103.21 fewer cases per million people than a loose nation with low government efficiency. For a nation the size of the United States (327.2 million), this would translate to approximately 33,770 fewer cases. These estimated trajectories are displayed in Figure 3.

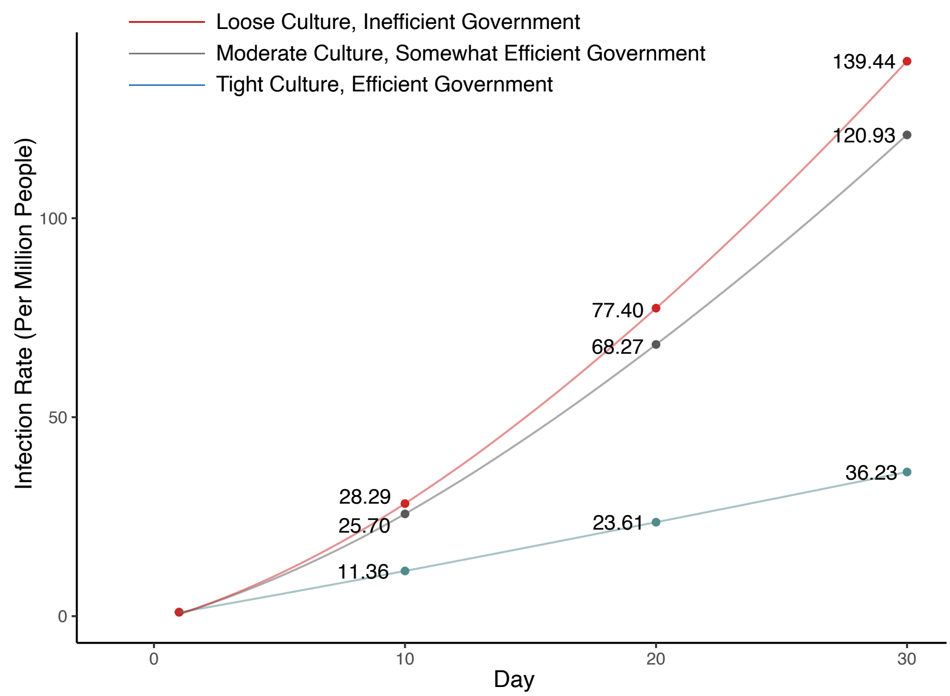

Figure 3. The estimated infection rate curves for nations with loose and inefficient governments (red), nations with moderately tight cultures and somewhat efficient governments (gray), and nations with tight cultures and efficient governments (blue). The estimates are derived from our efficiency x tightness regression coefficients, through exponentiating the coefficients from these coefficients to account for the initial log transformation.

We next replicated these analyses for estimates of mortality likelihood. Because mortality likelihood followed an exponential distribution, we performed logistic regression with an exponential distribution, with the number of days since the first confirmed case as a weight variable as with our infection rate analysis. Culturally tight nations and nations with higher levels of government efficiency each had significantly lower death rates of COVID-19, suggesting that both national institutions and national culture play an important role in the infection rate and death toll of the COVID-19. Nations with more efficient governments may be better able to contain the spread of the virus, and to reduce the probability that virus victims die. Likewise, culturally tighter nations appear to be better equipped to slow the rate of COVID-19 and prevent large-scale mortality from the virus. Table 2 lists the coefficients from these main effect models.

Table 2. COVID-19 Mortality Likelihood by Cultural Tightness and Government Efficiency

Predictor	***DF***	***B***	***SE***	χ^2	***p***
Model 1	51				
Cultural Tightness		-0.17	0.02	41.92	<.001
GDP Per Capita		-0.26	0.02	88.39	<.001
Gini		-0.21	0.04	24.73	<.001
Median Age		0.31	0.07	26.26	<.001
Model 2	89				
Government Efficiency		-0.43	0.03	227.63	<.001
GDP Per Capita		0.07	0.02	8.44	.004
Gini		-0.14	0.02	22.39	<.001
Median Age		0.03	0.03	0.90	.34

We next tested the interaction of cultural tightness and government efficiency. This model found a significant interaction between tightness and efficiency, $b = -0.30$, $SE = .03$, $t(50) = 66.30$, $p < .001$. This interaction was similar to the interaction we observed on infection rates, such that the mortality likelihood was similar for nations with low cultural tightness and government efficiency (2.91%, 95% CI = [2.64, 3.21]) and for nations with moderate cultural tightness and government efficiency (2.72%, 95% CI = [2.58, 2.86]), but was much lower for nations with high tightness and high government efficacy (1.48%, 95% CI = [1.39, 1.58]). If we combine these estimates with our infection rate estimates for our first set of models, this would suggest that 1.43 more people per million will die every month in loose nations with low governmental efficiency than in tight nations with high government efficiency. For a nation the size of the United States, this would translate to 467.90 total deaths, or 14.7% of the total number of deaths due to COVID-19 (N=3,170) in March in the United States.

We suggest that these findings may be crucially related to variance in individuals' proclivity to cooperate in tight versus loose cultures under conditions of threat. To illustrate this mechanism, we draw from past game theory models of cultural tightness and the evolution of cooperation. These models do not aim to fully explain our observed data, but they do offer a potential mechanism for why tightness might be related to more adaptive responses to COVID-19 and why this effect may be strongest in nations with high government efficiency.

Previous evolutionary game theory models have shown that under conditions of high threat—where payoffs are reduced for a population of agents—mutual cooperation becomes essential for the population's survival (3). When threat is high and agents are connected in a fixed network (6), clusters of cooperative agents survive whereas individual defectors quickly die off, and cooperation spreads across the network. In the current geopolitical context, reduced payoff rates represent the survival pressures of COVID-19, and the demand for cooperation represents a heightened need for behaviors such as frequent hand-washing or social distancing that may sometimes be costly to the individual but allow the group as a whole to survive (7).

We suggest that cultural tightness, which can be operationalized by stronger norms and a higher rate of individual-level conformity, accelerates a population's responsiveness to threats such as COVID-19 by allowing agents to more efficiently conform to popular neighboring strategies. When there is no threat, this heightened conformity is not necessarily functional, since agents may conform to successful individual defectors as well as successful groups of cooperators. But in the context of threat, group-based cooperation emerges as essential (3), and conformity will allow cooperation to quickly spread across a population of agents.

We illustrate this dynamic in an evolutionary model of agents playing prisoner's dilemmas in a 20 x 20 toroidal grid, with agents' payoff over time determining their fitness (i.e. their likelihood of dying and reproducing). Agents received a standard prisoner's dilemma payoff in this model (8) in addition to a base payoff, but their total payoff was reduced according to a level of threat τ which escalated over time (3). One hundred runs represented a loose culture in which agents have a low probability c of conforming to their neighbors' strategies (c = .05), whereas another 100 runs represented a tight culture in which agents have a higher probability of conforming (c = .20).

Figure 4 shows that, in the early stages of the model where threat is low, tight and loose cultures are similarly likely to cooperate. However, as time passes and threat levels escalate, mutual cooperation becomes more essential and agents in tight cultures are able to mimic the behavior of cooperative groups more rapidly than agents in loose cultures. Since mutually cooperative agents received higher joint payoffs than defecting agents, agents in tight cultures were able to survive for longer than agents in loose cultures. Our supplemental materials summarize this model in more depth and perform additional robustness checks and exploratory runs that suggest that strong normative conformity can be an effective evolutionary strategy during periods of intense threat.

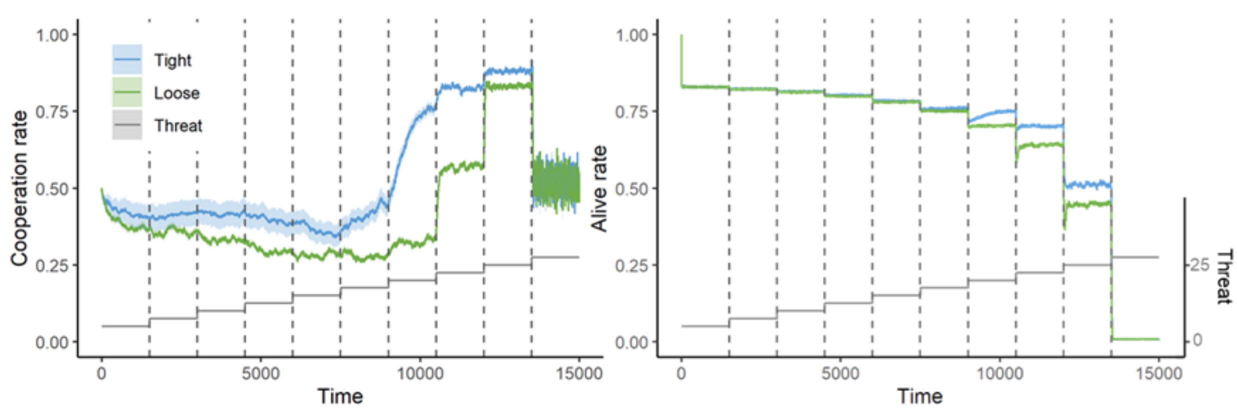

Figure 4. The results of an evolutionary game theory model of cooperation in the face of a threat such as COVID-19. The figure depicts 200 runs of the model, with each run containing 15,000 iterations. The shadow shows standard error. In 100 "tight" runs, agents had a high likelihood (c = .20) of conforming to their neighbors' prisoner's dilemma decisions. In 100 "loose" runs, agents had a lower likelihood (c = .05) of conforming to neighbors' decisions. The model also included a level of threat τ which started at a low level (5) and escalated every 1,500 iterations and reached its maximum value (27.5) in the 13,500th iteration of the model. The left panel of the plot displays cooperation rates over time, and the right side displays survival rates over time. At the highest level of threat, all agents die out, but at moderate-to-severe levels of threat, tightness bolsters agents' cooperation and survival rates.

While this model does not explicitly incorporate government efficiency, it implies that tightness should be most effective when populations can rapidly introduce—and allocate resources to enforce—cooperative norms following a global threat such as COVID-19. If institutions do not supply agents with information about cooperative norms during a pandemic, or do not invest resources to help agents follow these norms, conformity may not be sufficient to counteract the effects of threat.

Our empirical and theoretical data make a number of basic and applied contributions. We show that, during a global pandemic, cultural and institutional factors can combine to influence nations' responses. Nations with strict norms and efficient governments may be able to quickly introduce, support, and disseminate cooperative norms that increase a population's survival. These findings may also contain several important lessons for nations around the world. For example, governmental policies that increase communication between the public and private sectors may be able to put recommendations into action on a widespread scale. Loose cultures such as Spain and the United States should emphasize the importance of complying with social norms in mass communication about COVID-19, since individuals in these cultures have generally experienced less ecological threat (1) and may therefore be more likely to underestimate the risk of the virus and have reactance to having increased constraint. We emphasize that, while temporarily tightening norms is likely key to reducing the threat from COVID-19, groups can loosen norms once threat subsides. These recommendations should complement existing behavioral insights into how people and groups should manage the economic and health impacts of the pandemic (9).

We note several important caveats in our analysis. First, our data are correlational, which means we cannot infer causation from these findings. Nevertheless, we do take several steps to address this limitation, including controlling for important covariates (e.g. societal wealth, inequality, average age), employing a longitudinal design, and building an evolutionary game theory model with causal dynamics. Second, government efficiency and cultural tightness are not the only other factors that are important for curtailing COVID-19, and our own analyses suggest that more developed countries are also at risk for high infection rates. Third, our data focus on the early spread of COVID-19. Since loose cultures have higher creativity than tight cultures (1,10), they may be able to develop more innovative long-term methods of countering the virus. Indeed, it may be that cultural tightness is more effective in the early stages of threats such as the current pandemic whereas cultural looseness is more effective at the later stages, after threats have been initially contained.

Finally, we note that strong norms to fight COVID-19 do not imply that governments should become autocratic. Autocratic responses to COVID-19 may actually exacerbate its effects. Indeed, some research suggests that extreme levels of tightness can negative affect the well-being of individuals in a nation (11) and can impair group creativity (10). While it is important for governments to introduce and regulate beneficial norms (e.g. social distancing, effective handwashing) and coordinate social action (e.g. distribution of testing kits and ventilators), authoritarian responses to COVID-19 may do long-term damage to the autonomy and well-being of a nation's citizens.

COVID-19 has already reshaped our world, and if we are to effectively combat the virus, we must reshape our cultures and institutions. Here we offer two factors—cultural tightness and government efficiency—that predict the spread of the COVID-19 virus and determine whether the virus has a high mortality rate. While these factors are rooted in cultural evolutionary studies of human history, they make important predictors for our future. Our findings suggest that strong norms and efficient leadership may be the keys to saving millions of lives in the months to come.

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Supplemental Materials

1. Distribution of Dependent Variables

Prior to estimating our models, we examined the distributions of infection rate and mortality likelihood. These models found that infection rate was relatively normally distributed, whereas mortality likelihood had an exponential distribution. In other words, some nations had a far higher rate of recorded mortalities than most nations. For regression, this implied that a traditional OLS approach with gaussian distribution would be appropriate for modeling infection rate, whereas a generalized linear model with an exponential distribution would be better suited to analyze mortality likelihood. We adopted these models in our hypothesis tests.

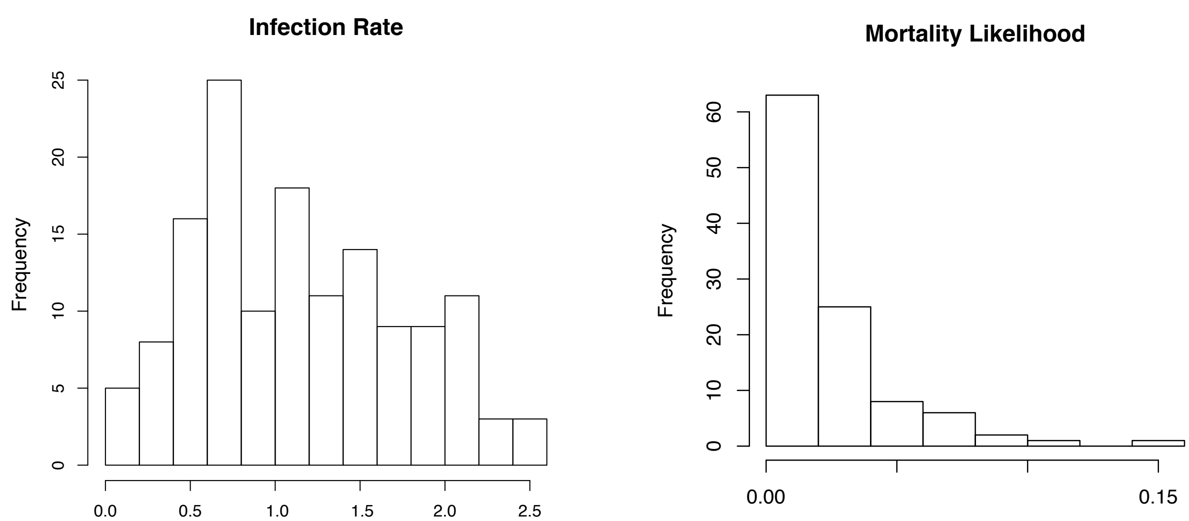

Figure S1. The distribution of infection rate and morality likelihood across nations. Infection rate was normally distributed, whereas mortality likelihood was highly skewed.

2. Other Potential Factors Related to the COVID-19 Rate of Infection.

Our models also included several important covariates, including GDP per Capita, Gini coefficient, and median age of each nation. Surprisingly, of these three predictors, only GDP was significantly related to the infection rate of COVID-19. We also investigated population density, which could theoretically lead to more rapid rates of infections. However, population density was not significantly related to infection rate, and was actually non-significantly *negatively* related to infection rate, $r = -.07$, $p = .38$. Nevertheless, we confirmed that, when population density was modeled along GDP per capita—the only control which significantly predicted COVID-19 infection rates, tightness ($b = -.14$, $p = .048$) and government efficiency ($b = -.20$, $p = .003$) both remained significant predictors of infection rate, and their interaction remained significant ($b = -.15$, $p = .031$).

3. Theoretical Model Details and Robustness Checks.

Agents are embedded in a 20 × 20 toroidal (i.e., wrap-around) grid. Each agent has a strategy, which is either *cooperate* or *defect*. The simulation starts with a grid that is fully occupied by agents whose strategies are chosen randomly, with both strategies being equally likely. Then the simulation repeatedly performs the following sequence of updating steps:

1) *Immigration*: At a randomly chosen empty site, a new agent appears whose strategy is equally likely to be *cooperate* or *defect*.

2) *Interaction*: In each iteration, each agent gets a *base payoff* = 30 from the environment, independent of payoffs it gets from interactions. Each agent also plays typical cooperation games (Table S1) with all of its alive neighbors on the grid, and receives *interaction payoffs* from the games. Agents' actions are chosen according to their strategies, which is either cooperate of defect. All the pairs in the grid play the games in a random order.

Table S1. Payoff of matrix of the cooperation game.

	Action of Agent Y	
	Cooperate	Defect
Action of Agent X		
Cooperate	(X: 2, Y: 2)	(X: -1, Y: 3)
Defect	(X: 3, Y: -1)	(X: 0, Y: 0)

In addition, agents are subject to a specific level of threat that is implemented as a deduction of τ from everyone's total payoff. Thus, an agent's final payoff, π, in each iteration is as defined in Eq. 1. These payoffs are not cumulative across iterations.

$$\pi = \textit{base payoff} + \textit{interaction payoff} - \tau. \tag{1}$$

This final payoff is transformed into an agent's fitness, $f(\pi)$, based on the well-established principle of diminishing marginal utility, as shown in Eq. 2.

$$f(\pi) = \begin{cases} 1 - e^{-0.1\cdot\pi}, \text{if } \pi \geq 0; \\ 0 \qquad\quad\;\; , \text{if } \pi < 0. \end{cases} \tag{2}$$

3) *Reproduction*: Each agent is chosen in a random order and given a chance to reproduce with a probability equal to its fitness. Reproduction means creating an offspring in a randomly selected adjacent empty site, if there is any. The offspring is a new agent that usually will have the same strategy and group tag as its parent, but there is a small probability $\mu = 0.05$ that it will instead have a randomly selected strategy, chosen in the same way as in Step 1 earlier.

4) *Death*: In each iteration, an agent has a probability d to die. The death probability of an agent is a function of its fitness, $f(\pi)$, defined by Eq. 3. As an agent's fitness increases, the death probability of the agent decreases as shown in Figure S2. If an agent dies, it will be removed from the grid.

$$d = e^{-2.3\cdot f(\pi)} \tag{3}$$

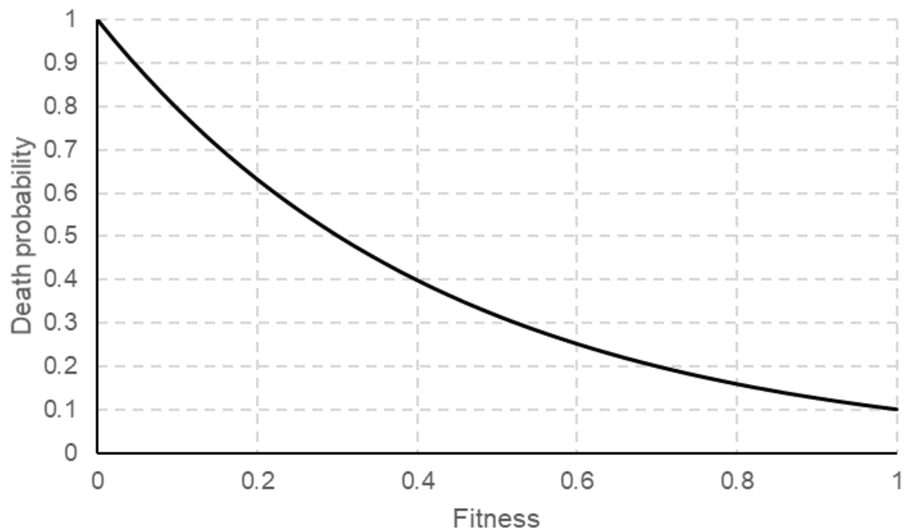

Figure S2. Death probability as a function of an agent's fitness.

5) *Conform*: In each iteration, after Step 4, each agent has a conforming rate of c to adopt the mode strategy among all of its alive neighbors. If there are multiple mode strategies among the neighbors (i.e., there are equal number of cooperators and defectors among all the alive neighbors), the agent randomly selects one of the multiple mode strategies.

The key parameters of this model intended to represent ecological threat, manipulated by τ, and cultural tightness, manipulated by c. Consistent with past work (3), we operationalized ecological threat via payoff structure, such that highly threatening environments reduced the maximum payoff that agents received. Culture tightness is operationalized by conforming rate c, which denotes the pressure to conform with the local norm.

Note that in Figure 4, in the tight culture, the standard error on the left panel is high. This is because in some of the single runs, most of the population cooperate while in some other runs, the majority defect (see Figure S3).

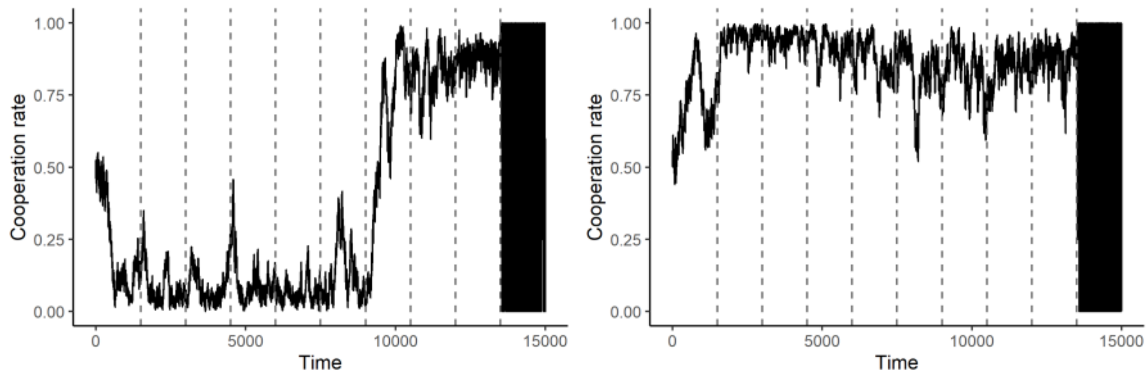

Figure S3. Example of the cooperation rate in two different single runs in tight culture. On the left, the majority defect when threat is low while on the right, the majority cooperate.

We also ran the models under a variety of other levels of tightness. Figure S4 shows the results when c = [0.1, 0.15, 0.3, 0.4, 0.5]. The results are replicated. At moderate-to-severe levels of threat, tightness bolsters agents' cooperation and survival rates.

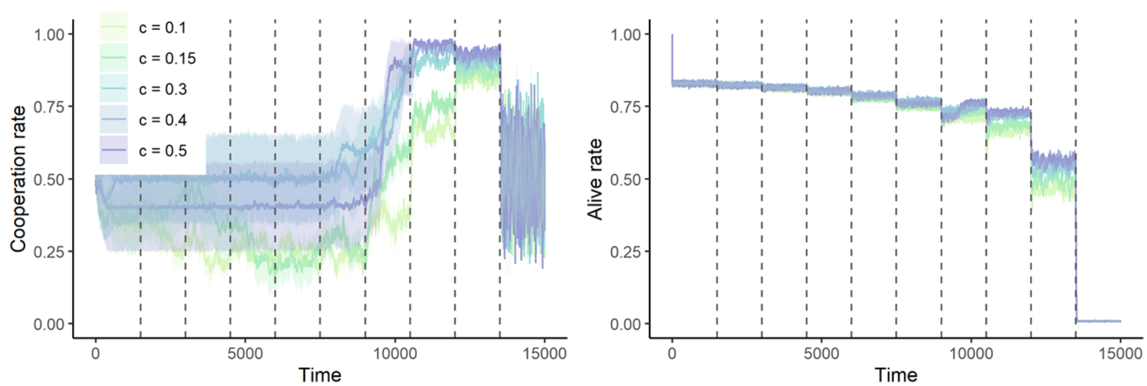

Figure S4. The figure depicts 10 runs under each level of tightness c. Each run containing 15,000 iterations. The shadow shows standard errors. Threat τ started from a low level (τ = 5) and escalated every 1,500 iterations and reached its maximum value (c = 27.5) in the 13,500th iteration.