Presentation

What Makes States More Effective at Containing the Spread of the Pandemic? A Theoretical Approach

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Abstract

This paper attempts to explore what makes a state effective at containing the spread of a pandemic such as COVID 19. Despite the unprecedentedly rapid and extensive spread of the disease at the global level, we also witness variation in the dispersal and frequency of this pandemic across the world, leading us to pose a question, “Why are some states more successful at containing the spread of the pandemic disease, while others are not?” By way of answering the question raised above, this study focuses on the fact that a state’s effort to cope with the infectious disease requires individual citizens’ cooperative behaviors such as wearing masks, visiting a medical institution when suspected to get infected, avoiding social gatherings, etc., most of which are costly to each and every individual. This implies that a state’s effort to contain the spread of the pandemic will bear fruit only when citizens are willing to comply with the prevention guidelines provided by the government. Using a simple game theoretical model, this study attempts to analyze what incentivizes citizens to align themselves with their governmental effort to stop the spread of the disease. By analyzing the game theoretic model, this study finds two subgame perfect equilibria (SPE), labelled as *No Request Equilibrium* and *Cooperation Equilibrium*. The equilibrium analysis, producing eight testable hypotheses, suggests that a state’s administrative power to penetrate the society and the state’s ability to have their citizens hold a firm, positive belief about the effectiveness of their cooperative behaviors matter.

Introduction

Since the outbreak of the coronavirus in late December 2019 in China, we have witnessed the spread of an infectious disease at an unprecedented level in terms of its geographical scope and rapidity. But we also witness variation across countries in terms of the number of confirmed cases and deaths. What causes these differences among countries? That is, what makes states more successful at stopping or slowing the spread of the pandemic and resultingly protecting their own citizens more effectively?[1] To answer this question, this study looks more closely at how the government and citizens interact to contain the spread of the pandemic. In particular, this research is primarily intended to figure out what incentivizes citizens to comply voluntarily with recommendations or guidelines offered by the government,[2] central or local, that may help, if observed, curb the spread of the disease but are also costly, with varying degrees, for citizens to follow. Given the nature of the problem, the infectious disease, it would be impossible for the government, no matter what and how much effort it makes, to address this problem effectively, without support or cooperation on the side of citizens.

To this end, this study employs a simple game theoretic model to investigate the strategic interaction between the government and citizens. What I mean by "strategic" suggests the following: First of all, this means that I do not assume that citizens simply comply with the government's recommendations based on a moral principle such as that they should observe the guidelines not to do harm to others. Obviously, we cannot rule out the possibility that some people follow the recommendations for a moral reason, and, in reality, the underlying motives for observing the prevention guidelines recommended by the government are highly likely to be mixed, egoistic and altruistic. Nonetheless, this paper focuses on the former aspect. Second, and related to the first, it is assumed that citizens' decisions on whether to follow the recommendations or not, will hinge on the result of cost-benefit analysis; if they find it too costly to comply with the government guidelines, they may decide not to do so. Similarly, whether the government offers prevention guidelines and requests citizens to follow them will also depend on its cost-benefit analysis because asking for cooperation also entails costs. Thus, if the government finds it costly to request cooperation from its citizens, it will give up asking citizens for cooperation from the outset. In this regard, the game theoretic model may be instrumental in capturing and analyzing the strategic aspect of the citizen-government interaction. By analyzing the game theoretic model, this study finds two subgame perfect equilibria (SPE), labelled as *No*

1 Of course, all the records on the pandemic at the national level are not necessarily attributed to the performance of the government. Several other factors unrelated to the government performance may influence the spread of the pandemic, but the focus of this study is on the administrative aspect that allows states to cope effectively with the disease.

2 These recommendations and guidelines provided by the government are primarily aimed at preventing citizens from getting infected with the coronavirus or if suspected of getting infected, from spreading to other citizens. These recommendations include social distancing, wearing masks, reporting to the disease control center if suspected of getting infected, self-isolating if suspected or confirmed, refraining from all kinds of social gatherings, etc.

Request Equilibrium and *Cooperation Equilibrium*. The equilibrium analysis, producing eight testable hypotheses, suggests that a state's administrative power to penetrate the society and the state's ability to have their citizens hold a firm, positive belief about the effectiveness of their cooperative behaviors matter.

The remainder of this paper proceeds as follows. In the next section, I present a game theoretic model for analyzing the citizen-government interaction. In the third section, I present the two subgame perfect equilibria and analyze these two equilibria to draw out testable hypotheses. In the final section, I conclude with a summary of this research and a few policy suggestions.

The Model

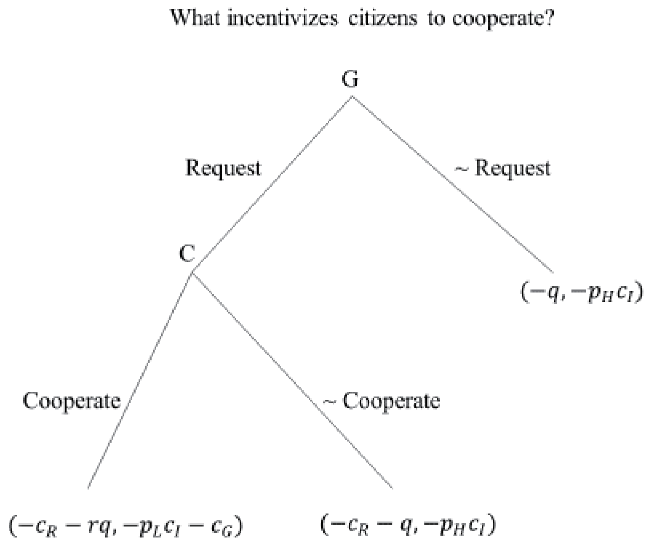

Figure 1
What Incentivizes Citizens to Cooperate?

Table 1. Notations, Assumptions and Meaning

Notations	Assumptions	Meaning
c_R	$c_R > 0$	The cost that the government incurs when requesting cooperation from the citizen
c_G	$c_G > 0$	The cost that the citizen incurs when she cooperates
c_I	$c_I > 0$	The cost that the citizen incurs when getting infected with the disease
q	$q > 0$	The cost of quarantine[3] that the government bears
p_H	$p_H \in [0,1]$	The probability that the citizen gets infected when she cooperates
p_L	$p_L \in [0,1]$	The probability that the citizen gets infected when she refuses to cooperate
$p_H - p_L$	$p_H - p_L > 0$	The probability of infection is lower when the citizen cooperates
r	$r \in (0,1)$	r is a ratio associated with the effect of cooperation; the larger the effect of cooperation, the smaller r becomes.

3 Here I use the term "quarantine" in a broader sense. In a narrow sense, it means almost the same as isolation. But here by the term quarantine I mean encompassing activities carried out by the government to deal with an infectious disease.

Figure 1 presented above illustrates the game theoretic model used here and Table 1 offers a brief summary of the assumptions and meanings of the notations used in the game. In what follows, I describe how this game unfolds.

The game is composed of two stages and two players, the government and the citizen.[4] At the first stage, the game starts with the first move by the government, which decides whether to request cooperation from the citizen or not. If the government decides not to ask for cooperation, the game ends, with the government bearing the full cost associated with the spread of a pandemic, $q > 0$. Here it is assumed that no request for cooperation by the government exposes the citizen to a higher probability of infection to the disease, denoted by p_H, because no request for cooperation is likely to leave the citizen more vulnerable to infection to the disease.[5] Then, the total payoff that the citizen earns can be calculated by choosing a lottery,[6] $p_H \times (-c_I)+(1 - p_H) \times 0= -p_H c_I$. Here c_I (> 0) denotes the cost that the citizen incurs when she gets infected with the disease,[7] and the expression shown above indicates that if the citizen gets infected with the disease, with probability p_H, her corresponding payoff is $-c_I$, but if she does not contract the virus, with probability $1-p_H$, she does not pay any cost, 0, resulting in the final payoff, $-p_H c_I$.

If the government decides to request the citizen to cooperate, the game proceeds to the second stage. At this stage, the citizen decides whether to cooperate or not. Here cooperation means observing the government's prevention guidelines and the citizen's cooperative behaviors include−and may not be limited to−a set of behaviors such as social distancing, wearing masks, reporting to the disease control center if suspected of getting infected, self-isolating if suspected or confirmed, refraining from all sorts of social gatherings, etc. It is worth pointing out that abiding by the preventive measures entails cost to the citizen, and thus her decision on whether to follow them or not may depend on how much cost she is willing to pay. Here the citizen's cost to pay when following the instructions is denoted by c_G (> 0). If she decides to cooperate, then her

4 Here I assume that the citizen represents a typical one in a country and most of the other citizens in the country follow the behavior of the typical citizen.

5 Some might argue that this could be too strong an assumption because people would take protective measures without the government recommendations or guidelines. It must be true that some people are ready to protect themselves from the coronavirus without the government recommendations or guidelines. But their efforts to do so, without the government's subsequent support, would be highly limited, and entail higher costs, making those efforts less sustainable and prompting them to give up on them earlier than with the government's support. In this regard, definitely, I do not deny the possibility of self-protection measures by citizens, but also believe that this assumption still holds.

6 With regard to the notion of a lottery in a game theoretic model, refer to Nolan McCarty and Adam Meirowitz, *Political Game Theory: An Introduction*, Cambridge University Press, 2007, pp. 27-38.

7 In actuality, the cost that citizens bear when getting infected with the infectious disease may vary among individuals from suffering from light symptoms even to death. But for the sake of simplicity, I assume that c_I is an exogenously given value. This may sound a strong assumption. But if we assume that c_I follows a normal distribution, for example, then the actual c_I can be considered a mean value from the distribution because we assume that the citizen is a typical person in the country. However, afterwards this assumption will be a little bit relaxed.

payoff is equal to $-p_L c_I - c_G$. Here I assume that observing the guidelines reduces the probability of getting infected with the disease and this lower probability is denoted by p_L. Evidently, it is assumed that $p_L < p_H$; that is, those who follow the government recommendations are exposed to a lower risk of infection than those who do not. The final payoff, $-p_L c_I - c_G$, can be obtained in a similar way we did right above: $p_L \times (-c_I) + (1-p_L) \times 0 - c_G = -p_L c_I - c_G$. In words, if she gets infected with the disease with probability pL, then she incurs the cost, cI; otherwise, she does not pay any cost; but in this case, the cost of cooperation, cG, is subtracted from the lottery, resulting in the final payoff $-p_L c_I - c_G$.

By contrast, if the citizen refuses to cooperate, she does not need to bear the cost of cooperation, c_G, but becomes more vulnerable to infection as higher probability p_H indicates. As a result, the payoff from no cooperation is assumed to be equal to the payoff that she earns when the government does not request cooperation in the first place, $-p_H c_I$.

Finally, let me describe what happens to the government's payoff, depending on the citizen's decision on cooperation. The government's payoff accruing from the citizen's cooperation is equal to $-c_R - rq$. Here I denote by c_R the administrative costs that the government must bear when requesting cooperation from the citizen. Administrative measures that encourage or help citizens to follow the government's instructions may include the following: reporting the number of confirmed cases on a relevant time basis and releasing information about the confirmed patients' contacts and paths; broadcasting or advertising the prevention guidelines on TV or other social media; developing mobile apps that enable the government to manage self-isolating people; distributing free face masks, etc. Here I assume that these administrative measures that are intended to promote citizens' participation in cooperative behaviors contribute to reducing the cost of quarantine, q, to some extent. To represent the reduction in the cost of quarantine, let $r \in (0,1)$ denote a ratio for the quarantine cost.[8] This implies that the government strongly prefers the citizen's cooperation to non-cooperation once it asks for it because it is self-evident that $-c_R - rq > -c_R - q$.

There are three outcomes in this game. One outcome occurs when the government decides not to make any request for cooperation, and in this case, the government and the citizen ends up with earning the payoffs, $-q$, and $-p_H c_I$, respectively. A second outcome takes place when the citizen responds positively to the government's request for cooperation with the government and the citizen receiving the payoffs, $-c_R - rq$, and $-p_L c_I - c_G$, respectively. The final outcome emerges when the citizen responds negatively to the government's request for cooperation, and the government and the citizen receive the payoffs $-c_R - q$, and $-p_H c_I$.

So far, I have described how this game plays out with additional explanations for the notations used in this game and assumptions applied to this game. In the next section, I proceed

8 The size of r is determined by the effect of cooperation. The more effective at curbing the expansion of the pandemic, the smaller r becomes. For example, $r \approx 0$, the government does not need to pay for the quarantine because $rq \approx 0$.

with the analysis of the model, presenting two subgame perfect equilibria and looking closely at each equilibrium in turn.

Equilibrium and Analysis

This is a simple extensive form game with the assumption of perfect and complete information. Thus, I employ Subgame Perfect Equilibrium (SPE) as a solution concept, which requires backwards induction to solve the game.[9] There are two equilibria in this game depending on the parameter condition.[10] I label one as *No Request Equilibrium* and the other as *Cooperation Equilibrium*. In the former equilibrium, as the name suggests, the government makes no request for cooperation from the citizen in the first place, and in the latter equilibrium, the government requests cooperation, and the citizen responds favorably to the request. Note that there is no subgame perfect equilibrium where the citizen makes a negative response to the government's call for cooperation.[11] In what follows, I analyze each equilibrium in turn in more detail.

No Request Equilibrium

No request equilibrium simply appears to suggest that the government makes no request for cooperation. But a closer examination of this equilibrium reveals that there are two different reasons why the government does so. One reason for no request stems from the citizen's response: the inability of the citizen to cooperate with the government because her cost for cooperation outweighs the benefit from it: $\mathrm{c_G} > (\mathrm{p_H}-\mathrm{p_L})\, \mathrm{c_I}$. Under this condition, the government has no reason to ask the citizen for cooperation because it is simply a waste of time and money given that it *knows* that the citizen does not participate in cooperation.

However, it is important to note that this lack of an ability of the citizen to respond favorably to the government's request may be due to the government's failure to provide an incentive for the citizen to cooperate. Let me elaborate this point clearly below. Here I assume that two things may incentivize citizens to comply with government recommendations: First, following the recommendations reduces the risk of infection, which is suggested by the lower probability of infection, p_L. The greater the difference between p_H and p_L, the more likely the citizen is to follow the guidelines recommended or instructed by the government. Second, the citizen favors conforming to the government recommendations if the cost of complying with the recommendations is not severe. More precisely, only when the cost of the compliance does not exceed the cost they have to pay, given the reduced probability of infection, does the citizen follow the recommendations provided by the government. That is, $\mathrm{c_G} > (p_H-p_L)\, c_I$. Of these two

9 Ibid, pp. 171-184.

10 A brief mathematical proof is provided in the Appendix.

11 It is highly probable in the real world that the citizen does not accept the government's request for cooperation. But this combination of strategies (request, ~cooperate) does not constitute a subgame perfect equilibrium here primarily because all the payoffs are assumed to be common knowledge. Therefore, if the government *knows* that the citizen is not willing to cooperate, it does not make any request for cooperation in the first place to save its resources.

incentives, the government might find it more effective to offer some incentive for the latter, i.e., to reduce the cost of cooperation, c_G, than for the former (p_H–p_L) because for the government the former is less tractable than the latter.

Let me take a couple of examples from South Korea where the government policy helped cut down the cost for cooperation on the part of citizens. In South Korea, individuals who are suspected of contracting the disease are recommended to report voluntarily to the local disease control center and are subject to diagnostic testing once judged by the control center to be a suspect case for COVID 19. Once a person is classified as a suspect case by the disease control center, then the person gets tested for the coronavirus for free, which was definitely a way of reducing the cooperation cost. In addition, the well-known drive-through testing method was an innovative way of enabling time-saving. These examples suggest that the failure on the government side to offer an incentive to lower the cost of cooperation may lead to a negative response from its citizens, and this anticipation ultimately leads to no request for cooperation.

The other reason for the government not requesting cooperation from the citizen may have something to do with the government's lack of resources and/or administrative inefficiency.[12] Even though the citizen is ready to accommodate the demand for cooperation from the government (i.e. $c_G < (p_H - p_L)\ c_I$), the government itself is unable to bear the cost of requesting cooperation (i.e. $c_R > (1-r)\ q$).[13] Given that the quarantine cost is generally substantial, it is less likely, albeit often possible, that the cost of cooperation is higher than the quarantine cost even if it is discounted by (1−r). But if this were the case, it could be interpreted in two ways. First, this problem may arise primarily from a lack of fiscal resources available. That is, a national government may suffer from such a severe lack of resources that it cannot afford to allocate sufficient resources to promote cooperation from civil society. In particular, this lack-of-resources situation most likely occurs in a poor country at an early stage of the outbreak when there are relatively a small number of confirmed cases. Despite the relatively low quarantine cost at the initial stage, the poor government may not be able to finance the expenditure for asking for cooperation. Second, this problem may also arise from the inefficiency of administration. That is, if a state's infrastructural power to penetrate the society is lacking, no doubt it will struggle in vain to cope with this pandemic situation. For example, in South Korea, the disease control centers collect information about confirmed cases, and distribute the collected information instantly to each and every individual with a mobile phone by using the mobile phone text message service, not only alerting citizens so that they can avoid the paths and contacts that confirmed patients visited, but also promoting their self-reporting if they suspect themselves of getting infected. Therefore, this established infrastructural power that enables the government to

12 For the concept of administrative power, refer to Michael Mann, *States, War and Capitalism: Studies in Political Sociology*, Basil Blackwell, 1988, Ch. 1.

13 Here let me set aside the effect of cooperation reflected in r for the time being, assuming that r is fixed at a certain level.

reach out to its citizens, if necessary, must be one of the essential factors that makes a state effective at fighting against the pandemic.

Before proceeding to the next equilibrium, it is worth pointing out that no request on the side of the government for cooperation from its citizens may by itself have a side effect of accelerating the spread of the disease.[14] The silence of the government could send out a wrong signal, albeit unintentional, to their citizens that the disease is not a serious problem, and might precipitate citizens' moral hazard, making them more absent-minded and consequently vulnerable to the infectious disease. Again, this reminds us of the importance of administrative power to support its citizens' cooperative behaviors.

Cooperation Equilibrium

Now, let us look at *Cooperation Equilibrium*. Conceivably, this equilibrium must be closely related to *No Request Equilibrium*, although the former equilibrium is not exactly the opposite of the latter. Thus, in the following, I will analyze the nature of this equilibrium with the possibility of redundancy in mind.

Most of all, it is important to note that $c_G < (p_H - p_L)\, c_I$ is not a sufficient condition for *Cooperation Equilibrium*. Even if $c_G < (p_H - p_L)\, c_I$, the government fails to ask the citizen to comply with the guidelines if $c_R > (1-r)\, q$. That is, if the cost of taking administrative measures that could facilitate citizens' cooperative behaviors were high enough to exceed the reduced quarantine expenditure, the government would decide not to request cooperation from their citizens. As discussed above, this may take place primarily because the government suffers from a lack of fiscal resources available and/or of administrative power. Therefore, *Cooperation Equilibrium* results only when two conditions are met: (i) $c_G < (p_H - p_L)\, c_I$ and (ii) $c_R < (1-r)\, q$.

The first condition implies that the cooperation cost that the citizen incurs must be smaller than the cost she has to bear given the reduced probability of getting infected. The second condition implies that the government cost generated by requesting cooperation must be smaller than the reduced quarantine cost resulting from citizens' voluntary support. These two prerequisites for *Cooperation Equilibrium* suggest that the desirable outcome might not be easy to attain. As the conditions for *Cooperation Equilibrium* suggests, the creation of a virtuous circle requires efforts on both sides. Then, let us consider in more detail what is to be done.

Earlier, we already discussed issues related to c_G and c_R. But when it comes to the citizen's cooperation cost, c_G, we focused on the supply side; that is, we were concerned with how the government can support individuals to reduce the cooperation cost. But it is also necessary to look at this issue from the citizen's perspective by focusing on conditions under which the citizen

14 If this is the case, and the effect of no request for cooperation on the quarantine cost is severe, I have to revise the game model offered here. I mean, the quarantine cost, q, in the first stage must be different from that in the second stage. If I denote the second stage quarantine cost by q', then $q > q'$. But for the sake of convenience, I do not take this likely difference into consideration.

is incentivized to participate in cooperation or discouraged from doing so. Thus, in the following I focus on how the probability difference, and the cost of infection affect the citizen's motivation to cooperate.

The first condition suggests two things. First, *ceteris paribus*, the larger the difference between the probability of getting infected when they cooperate and when they do not, the more incentive citizens have to comply with government recommendations.[15] The larger difference means that following the recommendations really works and helps prevent the citizen from getting infected with the disease. Here we have assumed that this probability (both p_H and p_L) is exogenously given and is common knowledge. But relaxing this assumption, to some extent, and assuming that this probability has something to do with the citizen's belief,[16] we can say that when the citizen believes that the difference (p_H–p_L) is substantially significant, she has a strong incentive to follow the government recommendations. However, if she believes otherwise, it may prompt her to lessen her willingness to comply. In an extreme case where she believes that there is little difference in the probability of getting infected, for example, whether you wear a face mask or not, she finds it totally a waste of time and effort to observe the recommendations because $c_G < (p_H - p_L)\, c_I \approx 0$.[17] Of course, this is a highly extreme situation, but a situation close to this may exacerbate the moral hazard problem, and everyone may find protective measures ineffective and useless, causing the pandemic to spread at an exponential rate. This implies that how citizens form a belief about the effect of complying with the recommendations really matters, and thus it is imperative for the government to inform citizens in a timely manner of successful cases showing that following the government instructions really helps so that they can hold a firm, positive belief about the effectiveness of their protective behaviors.

Second, *ceteris paribus*, the larger the cost of infection, c_I, the stronger the incentive for citizens to cooperate.[18] That is, as the cost of infection increases, the citizen finds complying with the guidelines relatively cheap, and is motivated to cooperate. However, the government should obviously not exaggerate the cost of infection to encourage citizens to comply, but nor should it *downplay* the cost of infection. If citizens believe that $c_I \approx 0$ (i.e., getting infected with the coronavirus is not costly at all), they will switch quickly to defectors because their effort to protect themselves turns out to be nothing more than a waste of time and money.[19] Nowadays we often hear the news about the development of new vaccines for the coronavirus pandemic. This

15 Actually, this statement can be drawn from comparative statics analysis. For example, holding both c_G and c_I constant, raising p_H–p_L generates the effect of lowering c_G. That is, a larger difference between p_H and p_L is associated with a lower cost of cooperation, c_G.

16 By the term "belief" I mean that the probability reflects one's perception of the outside world rather than the reality of the outside world itself.

17 Definitely, $c_G < 0$ is a nonsense because it contradicts the assumption that $c_G > 0$. The inequality above actually means that the citizen switches quickly to a defector as p_H–p_L converges to 0.

18 Note that we have assumed, as with the probability of infection, that this cost is exogenously given, with a typical citizen in mind. But I relax this assumption a little bit at this point for comparative statics analysis.

19 Refer to fn. 16.

must be good news. It is worth pointing out, however, that this good news may embolden citizens to lower their guard against the coronavirus and precipitate their moral hazard, with the result that people start to consider the cost of infection almost equal to zero.

In sum, by analyzing the first condition, $c_G < (p_H - p_L)\ c_I$, we draw out two policy implications: First, the government should promote the effectiveness of cooperative, or protective measures so that citizens have a firm belief that their protective measures make a difference, and second, the government must make sure that their citizens keep alert about the seriousness of the disease. Considering these two implications drawn out from the first condition, it turns out that what U.S. President Donald Trump did was the exact opposite of what this research suggests. He laughed at those who wear masks, and said that contracting the coronavirus is just like catching the seasonal flu, although he seems to have changed his position afterwards.[20] Given his position and influence, this study suggests, his public reluctance to wear masks and downplay of the seriousness of the coronavirus must have had a serious, negative effect on containing the spread of the pandemic in the U.S. at its early stage.

So far, we have examined the first condition. Now let us turn our attention to the second condition, $c_R < (1-r)\ q$, and see what implications we can draw from it. Since we discussed the issue about q and c_R with reference to administrative power right above, here I focus on the effect of r. Here r denotes a ratio associated with the effect of cooperation among citizens, and is assumed to be caused by the citizen's cooperation. Note that r is introduced to the game with the citizen's decision to accommodate the government's request for cooperation. Without cooperation on the part of the citizen, r would not come into being. Therefore, for the government, r is *the rationale* behind its demand for cooperation.[21] The more effective the quarantine effort, the lower r because it is associated with the reduced cost of quarantine by $1-$r.[22] Therefore, the larger $1-$r, the better off the government. Let us label this $1-$r an effectiveness ratio. Then, this ratio is highly likely to be positively correlated to the probability difference, $p_H - p_L$ because in some sense the latter also represents the effectiveness of cooperation

20 Daniel Victor et al., "In his own words, Trump on the coronavirus and masks," *New York Times*, October 2, 2020. https://www.nytimes.com/2020/10/02/us/politics/donald-trump-masks.html (accessed December 2, 2020); Brad Brooks, "Like the flu? Trump's coronavirus messaging confuses public, pandemic researchers say," *Reuters*, March 14, 2020. https://www.reuters.com/article/us-health-coronavirus-mixed-messages-idUSKBN2102GY (accessed December 2, 2020).

21 In a similar vein, for citizens, it is the difference between p_H and p_L that serves as the rationale behind their cooperation.

22 For a more intuitive understanding, let me take a numerical example. Let us assume that r=0.9 and q=10. This means that following the guidelines recommended by the government makes the quarantine cost equal to 0.9x10=9. Note that in the game the payoff for the government was $-c_R$-rq when the citizen cooperates. Now let us assume that r=0.1 with q remaining intact. Then the government quarantine cost is equal to 1. This illustrates that the lower r, the lower the quarantine cost (rq). In addition, note that the reduced quarantine cost is equal to (1-r) q. In the former example, it was (1-0.9)10=1, and in the latter example, it was (1-0.1)10=9. Therefore, when r=0.1, it reduced the quarantine cost as much as 9.

and quarantine efforts.[23] In addition, it can be said that while 1−r overall represents a degree of the effectiveness of quarantine measures on the government side, $p_H - p_L$ stands for a degree of the effectiveness of cooperation on the civil-society side. Both indicators, if observed, may exhibit the extent to which the government and citizens are willing to continue with their efforts to fight against the pandemic.

Testable Hypotheses

In the following, I advance a set of testable hypotheses drawn from the equilibrium analysis. Since the hypotheses listed below are already explained in the previous sections and all of them are straightforward and clear enough, I do not elaborate on them.

H1. A poor country whose fiscal resources are lacking is less likely to take measures to promote cooperative behaviors from its citizens even at an early stage of a pandemic.

H2. A country whose infrastructural power is weak (regardless of the availability of fiscal resources) is less likely to take measures to promote cooperative behaviors from its citizens.

H3: The larger the difference between $p_H - p_L$, the more likely citizens are to comply with government recommendations.

H4: The stronger citizens' belief that the difference between $p_H - p_L$ is large, the more likely citizens are to comply with government recommendations.

H5: The higher the cost of infection, c_I, the more likely citizens are to comply with government recommendations.

H6: The stronger citizens' belief that the cost of infection is high, the more likely citizens are to comply with government recommendations.

H7: The larger the effectiveness ratio, 1−r, the government is more likely to continue requesting cooperation from citizens.

H8: The effectiveness ratio, 1−r, is likely to be positively correlated to the probability difference in infection, $p_H - p_L$.

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23 As suggested earlier, $p_H - p_L$ also predicts the likelihood of cooperation among citizens. The higher $p_H - p_L$, the more likely citizens are to cooperate.

Conclusion: By Way of Policy Implications

This study was intended to ascertain what makes a state more effective at containing the spread of the pandemic such as COVID 19, with a focus on incentives for citizens to comply with the government recommendations aimed at curbing the spread of the disease among citizens. To that end, this research employed a simple game theoretic model to analyze the strategic interaction aspect between the government and citizens. In particular, the analysis of the two equilibria, labelled as *No Request Equilibrium* and *Cooperation Equilibrium*, allowed us to obtain the theoretical findings expressed in the form of testable hypotheses as listed above. For example, one of the interesting hypotheses, I suppose, is that a country where infrastructural power is weak (regardless of the availability of fiscal resources) is less likely to take measures to promote cooperative behaviors from its citizens (H2). Another interesting hypothesis might be that the stronger citizens' belief that the cost of infection is high, the more likely citizens are to comply with government recommendations (H6).

Then, let me return to the key question that motivated this study in the first place, "What makes a state more effective at containing the spread of the pandemic?" The answer to this question, I believe, is already suggested in this paper, especially in the form of hypotheses.[24] In fact, Hypothesis 2 suggests that the state apparatus matters, and Hypothesis 6 suggests that citizens' perception also counts. But here I would like to reframe the key question raised earlier in the following manner, "What are the long-term capabilities, and are there any short-term capabilities that the state can and/or should seek out to cope with this pandemic crisis?" The reason why I rephrase the original question into the new one is because the latter one seems to be more policy relevant. For example, the new question allows us to raise a subsequent question as follows: What if all the capabilities were long-term ones and if there were no short-term capabilities? If that were the case that there were no short-term capabilities effective at dealing with a pandemic, it would mean that any short-term effort made by the government to fight off the pandemic would not work. Fortunately, however, this analysis suggests that there could be also short-term capabilities, albeit far from complete. Then what constitutes long-term capabilities and what constitutes short-term ones? Let me briefly discuss each capability in turn. As suggested above, long-term capabilities might have something to do with the state apparatus; that is, the availability of fiscal resources, and more importantly, a state's infrastructural power to penetrate the society. The reason why I call these capabilities long-term solutions is that they are hard to achieve in a short period. However, this kind of long-term capability is not a sufficient condition, but rather a necessary condition for an effective state, as the analysis of *Cooperation Equilibrium* illustrates. That is, without these capabilities the state could hardly be effective at fighting against a pandemic, but they are not enough. The United States under President Donald Trump is a case in point, let alone many countries in Europe. This is where a state's short-term

24 I have to admit that since these hypotheses have not been subject to an empirical test, their empirical validity is somewhat (or quite) dubious for now. But I proceed with these hypotheses, assuming tentative validity.

capability must come in. Presumably, how to incentivize citizens to respond favorably to a state's request for cooperation might have as much to do with a state's short-term capability as with long-term capability. As shown above, how strong a belief each citizen holds regarding the effectiveness of their protective measures, the belief that their cooperative behaviors make a difference, really matters because those citizens' firm beliefs prevent the community from plunging into disorder and chaos. Besides, it is also important that citizens have accurate information about a pandemic they face; if the government plays down its severity, it could precipitate moral hazard, wreaking havoc on the community. Therefore, a state's ability to have their citizens hold a positive belief about their cooperative behaviors and to provide them with a set of accurate information must not be ignored.

<Appendix>

I solve this game by using backwards induction as follows:

1. At the final node, the citizen decides whether to cooperate or not.
(a) If $c_G < (p_H - p_L)\ c_I$, the citizen decides to cooperate.
(b) If $c_G > (p_H - p_L)\ c_I$, the citizen decides not to cooperate.

2. At the first node, the government decides whether to request cooperation from the citizen or not.
(a) If the citizen cooperates, the government asks for cooperation if $c_R < (1 - r)\ q$; otherwise, not.
(b) If the citizen does not cooperate, the government does not ask for cooperation because $-q > -c_R - q$.

3. Therefore, two equilibria result depending on parameter conditions.
(a) *Cooperation Equilibrium* results if $c_G < (p_H - p_L)\ c_I$ and $c_R < (1 - r)\ q$.
(b) *No Request Equilibrium* results either if $c_G > (p_H - p_L)\ c_I$ or if $_G < (p_H - p_L)\ c_I$ and $c_R > (1 - r)\ q$.