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To Obey or Not to Obey? Can Game Theory Explain Human Behaviour in the Context of Coronavirus Disease?

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Abstract

The objective of the current study is to explain non-compliance to social distancing rules in western societies in the absence of a stringent law enforcement mechanism and vaccines. In the first part of the analysis an evolutionary game theory mechanism of two players is developed. The theoretical model assumes the existence of the Prisoner's Dilemma due to personal inconveniences associated with mask wearing, hand washing and lockdowns. The model demonstrates that in the absence of sufficient law enforcement mechanism, and regardless of the initial strategy undertaken, one of the three potential equilibria solutions is the convergence of the system to defection of both players. In the second part of the analysis, based on the freedom-house measures, we provide empirical evidence supporting the notion that law enforcement efficiency is higher in autocratic countries. We show the perseverance of higher projected infection rates per 100,000 persons in democratic countries even 8 months after the outburst of the COVID19 pandemic. Given the well-known inclination to cooperate more often than expected by game theory, this real-life outcome of non-compliance is remarkable. Moreover, the recent protests against lockdowns in China might reflect a shift from one equilibrium point (cooperation) to another (non-compliance).

Key Words: Evolutionary Game Theory; COVID19; Freedom-House Measures

JEL Codes: I12, H75, R58

1. Introduction

Since the outburst of the global COVID19 pandemic, the numbers of infections and deaths from the disease have grown steadily, with more than 43million persons who were infected (of whom almost 32 million recovered) and more than 1.15 million mortalities worldwide (on October 25, 2020 https://www.worldometers.info/coronavirus/?utm_campaign=homeAdUOA?Si). This rise continues despite the elevated worldwide awareness and the various implementation strategies of addressing the pandemic (e.g., WHO, available at: https://www.who.int/health-topics/coronavirus#tab=tab_2). Until the development and provision of an efficient vaccination, the possibility of avoiding or reducing the spread of the disease is contingent in large part on a change in behavioral patterns, namely, preserving social distancing rules. Yet, the tendency of many people, particularly those in Western democracies, is not to obey at least some of these rules, which include: 1) avoiding unnecessary travel; 2) staying away from large groups of people; 3) maintaining at least one meter distance from each other; and 4) wearing masks outside the home. The question is what the reasons for this non-compliance among large groups of people in Western democracies might be.

One possible explanation is driven from prospect theory of Tversky and Kahneman (1974) and Kahneman and Tversky (1979). According to this school of thought, the behavioral patterns of people are influenced by cognitive errors of judgement (heuristics). In our context, people are overly optimistic and, consequently, underestimate the actual prospects of being infected or dying from the disease. Another possible explanation for non-compliance among large groups of people comes from game and economic theory of negative externalities. This school of thought disputes the attribution of cognitive errors of judgement by prospect theory and emphasizes the underpriced damage the individual inflicts on others by infecting them with COVID19 virus.[1] The game theory perspective is best represented by the prisoner's dilemma (first formulated by Al Tucker, according to Aumann, 2008: 16), where cooperation produces the maximum payoff for the two players. Yet, each player has an incentive to defect.[2] Differently put, the Nash equilibrium will maximize the personal payoff of the individual, but not the collective payoff of the two players.

The current study seeks to follow the game theory school of thought. We develop an evolutionary game based on the prisoner's dilemma (hereinafter - PD) and the assumption that based on their own experience, people encountered high recovery rates and low mortality rates from coronavirus disease.[3] According to Bathun and Korinek (2020), the estimated perceived cost of an additional infection is around $80,000 and the overall social cost including externalities associated with infection is around $286,000. The game is constructed so that initially the two players cooperate and obey the rule, so as to minimize the damage to $80,000. Yet, if there is no law enforcement operatus, each player has an incentive to break the rule – and defect. Consequently, the Nash equilibrium of the game will be a $286,000 loss for each individual.

Next, following Tanimoto (2015, 2018), and the effort to explain the high cooperation levels in real-life data and laboratory experiments (e.g., 89% who choose to cooperate compared to only 11% who chose to defect in an ultimatum game – the so-called "game theory victims" – in

[1] According to O'Sullivan (2012): "An external cost occurs when a consumer pays a price that is less than the full cost of producing a product. The price of a product always includes the cost of labour, capital, and raw materials used to produce the product, but it usually does not include the environmental costs of producing the product" (page 9).

[2] According to Aumann (2008): "An equilibrium (Nash, 1951) of a strategic game is a (pure or mixed) strategy profile in which each player's strategy maximizes his payoff given that the others are using their strategies." (page 17).

[3] Referring to the Spanish influenza pandemic, Barro et al. (2020) state that: "The flu death rate of 2.1 percent out of the total population in 1918-1920 would translate into around 150 million deaths worldwide when applied to the world's population of about 7.5 billion in 2020." (page 17) Scaling the Spanish Influenza data to the relative duration of the current coronavirus pandemic (about 8 months) still yields $150 \cdot \frac{8}{24} = 50$ million deaths.

Rubinstein, 2016) an evolutionary mechanism is introduced. The Darwinian idea behind this mechanism is the survival of the strategy that yields the maximum payoff (or the minimum damage) in each round. We show that under these circumstances, three potential equilibria points emerge: 1) cooperation (the source solution). 2) defection (the sink solution). 3) polymorphic (the saddle solution). Hence, regardless of the initial cooperation proportion in [0, 1] the ultimate state is one of complete defection at $t \rightarrow \infty$ (Tanimoto, 2015: 27).

Finally, we provide empirical evidence supporting the evolution of the Nash equilibrium solution in western countries in contrast to autocratic countries. Given, for instance, that capital punishment is applied to each and every violation of the rule, obviously, the possibility of non-compliance is unrealistic in autocratic countries. Indeed, based on the conventional freedom house measures of democracies (e.g., Barro, 1999), we demonstrate a drop in projected infection rates from coronavirus with a shift from countries with higher levels of political rights and civil liberties to those with lower levels.

Moreover, a direct comparison between two of the most populated countries in the world, namely, China and India, which are similar in population size, but differ in political rights and civil liberties, demonstrates a much lower prevalence of coronavirus disease in China. These findings may be interpreted on the grounds of more efficient law enforcement system in less democratic countries.

A further support to the application of the Nash equilibrium in the context of the COVID19 pandemic comes from recent events in China. Following the protest against the Chinese government in response to the zero covid policy in the face of increasingly contagious variants, China's government announced "20 measures" aimed at softening its zero covid approach (Dyer, 2022). This might reflect a shift from one equilibrium point – cooperation – where the pandemic is avoided by lockdowns (the source solution), to another equilibrium point – non-compliance (the sink solution) – where most of the population develops herd immunity and the public internalize the voluntarily use of masks in crowded locations.

The remainder of this article is organized as follows. Section 2 provides literature review on evolutionary game theory. Section 3 develops and describes the game. Section 4 provides the empirical evidence supporting the notion that countries with lower levels of political rights and civil liberties better addressed the pandemic. Finally, Section 5 concludes and summarizes.

2. Evolutionary Game Theory: Literature Review

Having established in 1944, the biggest milestone in game theory was provided by the Nobel Prize winner John Nash (1949, 1951). The game theory perspective is best represented by the PD (first formulated by Al Tucker, according to Aumann, 2018: 16), where cooperation produces the maximum payoff for the two players. Yet, each player has an incentive to defect, so that: "An equilibrium (Nash, 1951) of a strategic game is a (pure or mixed) strategy profile in which each player's strategy maximizes his payoff given that the others are using their strategies." (Aumann, 2008 page 17). Differently put, the Nash equilibrium will maximize the personal payoff of the individual, but not the collective payoff of the two players.

The prediction of defection under the PD game raises the obvious question why do we cooperate in real life setting? Why do we observe many animals cooperating? (Tanimoto, 2015: page 3). As an example to unexplained cooperation, consider, for instance, Rubinstein (2016). The author demonstrated high levels of cooperation in an ultimatum game experiment. Of the 13,957 participants, most of them choose either to divide the $ 100 equally (49%) or to give the other side above \$50 (17%).[4] Only 11% (the so-called "game theory victims") proposed the other side the sum anticipated by game theory – between zero to \$1.

To address these questions, an important adjustment is the incorporation of evolution with game theory. Frey (2010) makes a distinction between biology and social sciences. In biology, strategies are considered to be inherited programs which control the individual's behavior. Aumann (1997) mention that like genes or alleles people develop ''rules of thumb'' that work in general, by an evolutionary process. If they work well, they are fruitful and multiply; otherwise they become rare and eventually extinct. (page 8)

As demonstrated in subsequent section, evolutionary game theory models in social sciences deal with the proportion of players who choose to cooperate ($s_1; 0 \leq s_1 \leq 1$) and the proportion of players who chose to defect ($s_2 = 1 - s_1; 0 \leq s_2 \leq 1$). The evolutionary mechanism introduced replicates strategies that yield the maximum payoff (or the minimum damage) in each round. The field was greatly promoted with increasing computational capabilities of the 90s of the twentieth century. This drives multi-agent simulations seeking answers for the question of why we can observe so much evidence of the reciprocity mechanism working among both real human social systems, and animal species, even during encounters with severe social dilemma situations, in which the theory predicts that game players should act defectively. (Tanimoto, 2015: 3). Two recent examples in the context of COVID19 vaccinations are Kabir, 2021 and Kabir et al., 2021).

[4] Imagine that you and another person (who you do not know) are to share \$100. You must make an offer as to how to split the \$100 between the two of you and he must either accept or reject your offer. In the case that he rejects the offer, neither of you will get anything. What will your offer be?

3. Social Distancing and the Prisoner's Dilemma

Consider the following two players evolutionary game (Tanimoto,2015: 22–27; 2018: 12–28):

		Player 1	
		Obey (Cooperate)	Not-Obey (Defect)
Player 2	Obey (Cooperate)	R, R	S, T
	Not obey (Defect)	T, S	P, P

Where Obey indicates compliance to social distancing rules in countries with higher levels of civil liberties. The letters stand for $R = Rewards; S = Sucker; T = Tempteation; P = Punishment$. In the case that $T > R > S > P$ the PD emerges and the Nash Equilibrium is obtained in a situation of non-compliance of both players.

As a specific numerical example based on the estimation of Bethune and Korinek (2020) consider the following example, where row (column) player corresponds to the left (right) number.

		Player 1	
		Obey (Cooperate)	Not-Obey (Defect)
Player 2	Obey (Cooperate)	–80,–80	–286, –20
	Not obey (Defect)	–20, –286	–286, –286

In this case, the game is formulated in loss terms, where $T = S > R > P$ and the objective function is to minimize the personal loss from COVID19. It may be readily verified that the dominant strategy for each player is to break the rules, so that the Nash equilibrium of the game will be a \$286,000 loss to each individual. This outcome is obtained despite the fact that cooperation reduces the loss to \$80,000 for each person.

Returning to the general model proposed by Tanimoto (2015, 2018), a more convenient way to write this game is the following:

		Player 1	
		Obey (Cooperate)	Not-Obey (Defect)
Player 2	Obey (Cooperate)	R	S
	Not obey (Defect)	T	P

And in matrix notation: $M \equiv \begin{bmatrix} R & S \\ T & P \end{bmatrix}$

We denote the proportion of players who choose to cooperate as s_1 $(0 \leq s_1 \leq 1)$ and to defect as $s_2 = 1 - s_1$. The row vector T_S is defined as $T_S = (s_1 \quad s_2)$. The row vector $T_{e_1} = (1 \quad 0)$ indicates a 100% proportion of collaborators and $T_{e_2} = (0 \quad 1)$ a 100% proportion of defectors. It may be readily verified that

$T_{e_1} M T'_{e_1} = [1 \quad 0] \begin{bmatrix} R & S \\ T & P \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = R$ and $T_{e_2} M T'_{e_2} = [0 \quad 1] \begin{bmatrix} R & S \\ T & P \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix} = P$

Where the tag represents the transpose column vector.

Next, we define the following evolutionary process for $i = 1, 2$:

$\frac{\dot{s}_i}{s_i} = T_{e_i} M T'_{e_i} - T_S M T'_S$ where $\dot{s}_i$ represents the change in s_i. The idea behind this process is the survival of the strategy that yields the maximum payoff (or the minimum damage) in each round. Substitution and simplification yields:

$$\begin{cases} \dot{s}_1 = \quad [(R-T)\cdot s_1 - (P-S)\cdot s_2]\cdot s_1 \cdot s_2 \\ \dot{s}_2 = -\,[(R-T)\cdot s_1 - (P-S)\cdot s_2]\cdot s_1 \cdot s_2 \end{cases}$$

Equilibrium is achieved where $\dot{s}_1 = \dot{s}_2 = 0$. This yields three solutions, where the two obvious ones are $T^*_{e_1} = (1 \quad 0)$ and $T^*_{e_2} = (0 \quad 1)$. Tamito (2015, 2018) demonstrates that regardless of the proportion of cooperation at the beginning of the game, the only feasible solution at the end of the game (the sink solution) is the Nash equilibrium, namely, the defection strategy of both players. As demonstrated in subsequent sections, compared to autocratic societies, western societies suffer from higher COVID19 morbidity even 8 months after the outburst of the pandemic. If infection rates are positively correlated with obedience level, this outcome provides evidence supporting the notion of lower obedience levels to lockdowns and other measures imposed by the governments among western societies. Moreover, referring to China, Dyer (2022) recently reported the protest against the Chinese government in response to the zero covid policy in the face of increasingly contagious variants. At the beginning of November 2022 China's government announced "20 measures" aimed at softening its zero covid approach. The situation in China might reflect a shift from one equilibrium point – cooperation – where the pandemic is avoided by lockdowns (the source solution), to another equilibrium point – non-compliance (the sink solution) – where most of the population develops herd immunity and the public internalize the voluntarily use of masks in crowded locations.

4. Efficiency of the Law Enforcement System

a) The Empirical Model

To test the efficiency of the law enforcement system, consider the following empirical model applied separately to three freedom house measures:

$$Case\_Per = \alpha_{1,j} + \beta_{1,j} Freedom\_House\_Measure_{1,j} + \gamma_{1,j} Freedom\_House\_Measure_{2,j} + \mu_{1,j} , \quad (j)$$

where $j = 1,2,3$, Case_Per (the dependent variable) represents the ratio between the accumulated number of coronavirus cases and the population of the country on October 25, 2020 (approximately 8 months after the outburst of the pandemic), $Freedom\_House\_Measure_{1,j}$ and

$Freedom\_House\_Measure_{2,j}$ are the independent variables, $\alpha_{1,j}$, $\beta_{1,j}$, $\gamma_{1,j}$ are parameters, and $\mu_{1,j}$ is the stochastic random disturbance term.

Given that the dependent variable is bounded between 0 and 1 ($0 \leq Case\_Per \leq 1$ – i.e., the countries do not have number of coronavirus cases, which is greater than its population size), this model is also known as the Linear Probability Model (LPM, e.g., Johnston and Dinardo, 1997: 414-418).

Referring to the independent variable(s), we use two quantitative measures and one qualitative measure of democracies ($j = 1,2,3$):

1) $Freedom\_House\_Measure_{1,1} = PR10$ and $Freedom\_House\_Measure_{2,1} = \vec{0}$, where $\vec{0}$ is a column vector of zeros. The original scale of the Political Rights (*PR*) measure is a Lickert scale from *PR*=1, the highest to *PR*=7, the lowest grade for political rights. For convenience, we rescaled the model to 1-10 scale ($PR10 = PR \cdot \frac{10}{7}$), so that after rescaling the model becomes *PR*10=1.4286 is the highest and *PR*=10 is the lowest grade.
2) $Freedom\_House\_Measure_{1,2} = CL10$ and $Freedom\_House\_Measure_{2,2} = \vec{0}$, where $\vec{0}$ is a column vector of zeros. The original scale of the Civil Liberties (*CL*) measure is a Lickert scale from *CL*=1, the highest to *CL*=7, the lowest grade for political rights. Once again, we rescaled the model to 1-10 scale, ($CL10 = CL \cdot \frac{10}{7}$), so that *CL*10=1.4286 is the highest and *CL*=10 is the lowest grade.
3) $Freedom\_House\_Measure_{1,3} = PARTLY\_FREE$ and $Freedom\_House\_Measure_{2,3} = NOT\_FREE$ are dummy variables, which receive 1 if the country was defined as "partly free" or "not free" and zero otherwise. The base category is "free", so that the constant term ($\alpha_{1,3}$) represents the projected probability of coronavirus infection in the case that the

country is free and $\beta_{1,3}$; $\gamma_{1,3}$ represent projected probability differences with respect to the base category.

Referring to the Linear Probability Model, according to Johnston and Dinardo (1997): "*A major weakness of the linear probability model is that it does not constrain the predicted value to lie between 0 and 1*" (page 417, italics in the original). Consequently, we also employ the fractional probit model (e.g., Papke and Woldridge, 1996; Woldridge, 2010):

$$pr(0 < Case\_Per < 1) = F(\alpha_{1,j+3} + \beta_{1,j+3}Freedom\_House\_Measure_{1,j} + \gamma_{1,j} + Freedom\_House\_Measure_{2,j}), \quad (j+3)$$

Where $F(Case\_Per) = \emptyset(\mathbb{Z}) = \frac{exp\left(-\mu/2\sigma^2\right)}{\sqrt{2\pi\sigma^2}}$ (the cumulative normal distribution function).

b) Descriptive Statistics

Table 1 reports the descriptive statistics of each variable (observations (*N*=168 states), mean, median, standard deviation, minimum, maximum):

The average number of cases is 247,710.1 (Cases). Multiplication by 168 states yields the total number of infected persons included in the sample (41.6152968 million). The implication is that the sample covers $\frac{41.6152968}{43.007643} = 96.76\%$ of the reported cases of coronavirus around the world. A comparison between the median (26,260 cases) and the mean (247,710.1 cases) indicates right-tailed distribution, namely, low prevalence of coronavirus cases. Even for cases population ratio (Cases_Per=Cases÷Population), the median (4.068‰=0.4068%) is still lower than the mean (7.3‰=0.73%) and the implication of right-tailed distribution is preserved. These distributions might provide evidence supporting the notion that behavioural patterns in Western democracies are not the outcomes of cognitive judgmental errors.

Table 1: Descriptive Statistics

Variable	Definition	Obs	Mean	Median	Std. Dev.	Min	Max
Cases	Accumulated number of coronavirus cases	168	247,710.1	26,260	1,006,720	3	8,725,151
Population	Population of the country	168	4.43×10^7	9,897,505	1.58×10^8	33,931	1.44×10^9
Cases_Per	cases÷population	168	0.0073	0.004068	0.0096	3.16×10^{-6}	0.0523
PR	Political rights on a Lickert scale of 1=the highest; 7=the lowest	168	3.5774	3	2.1736	1	7
CL	Civil liberties on a Lickert scale of 1=the highest; 7=the lowest	168	3.4583	3	1.8791	1	7
PR10	$PR\times\frac{10}{7}$=Political rights on a scale of 1-10	168	5.1105	4.2857	3.1051	1.4286	10
CL10	$CL\times\frac{10}{7}$=Civil liberties on a scale of 1-10	168	4.9405	4.2857	2.6845	1.4286	10
Free	1=Free countries; 0=otherwise	168	0.4301	–	0.4898	0	1
Partly_Free	1=Partly free country; 0=otherwise	168	0.2435	–	0.4410	0	1
Not_Free	1=Non-free country; 0=otherwise	168	0.3264	–	0.4769	0	1

Notes: Measures of democracies for 2020 are based on the freedom house measures available at: https://freedomhouse.org/explore-the-map?type=fiw&year=2020.

The average population size in each country is 44.3 million persons (Population). Multiplication by 168 states yields the total population in the sample (7.4424 billion). Once again, the implication is that the sample covers $\frac{7.4424}{7.5} = 99.232\%$ of the world's population. A comparison between the median ($0.9897 \cdot 10^7$) and the mean (4.43×10^7) indicates right-tailed distribution. Namely, most of the countries are not heavily populated. Two prominent outliers, which are included in the sample and analyzed separately are India and China. Both countries consist $\frac{1.439323776 + 1.380004385}{7.5} = 37.59\%$ of the world's population.

Referring to the measures of democracies, for both the political rights and civil liberties measures, on a scale of 1=the best; 7=the worst; the median (*PR*=*CL*=3) is lower than the mean

(PR=3.5774; CL=3.4583). The implication is right-tailed distribution, namely, many countries receive better grades on political rights and civil liberties, while a few countries receive worse grades on political rights and civil liberties. Yet, according to the qualitative measure of democracy, of the 168 countries in the sample, only 43.01% are defined as "free". 24.35% are defined as "partially free" and 32.64% are defined as "not free".

c) A Comparison between China and India

Table 2 compares China and India. As previously noted, both countries comprise more than 37% of the world population. In terms of size of population, the countries are similar. Yet, while India is considered "the largest democracy in the world", China is ranked in the worst place in the Lickert scale ladder:

Table 2: A Comparison between China and India

Variable	Definition	China	India
Cases	Accumulated number of coronavirus cases	85,810	7,909,959
Population	Population of the country	1,439,323,776	1,380,004,385
Cases_Per	Cases÷Population	0.0596×10^{-3}	5.73×10^{-3}
PR	Political rights on a Lickert scale of 1=the highest; 7=the lowest	7	2
CL	Civil liberties on a Lickert scale of 1=the highest; 7=the lowest	6	3
PR10	$PR\times\frac{10}{7}$=Political rights on a scale of 1-10	10	2.8571
CL10	$CL\times\frac{10}{7}$=Civil liberties on a scale of 1-10	8.5714	4.2857
Free	1=Free countries; 0=otherwise	No	Yes
Partly Free	1=Partly free country; 0=otherwise	No	No
Not Free	1=Non free country; 0=otherwise	Yes	No

Notes: In term of number of coronavirus cases, and even though the populations of both countries are similar in magnitude, while China is located in the 69% percentile, India is located on the 99% percentile. In terms of political rights China receives the worst grade (7 points).

Indeed, compared to India, the number of coronavirus cases in China is much smaller (7,909,959 vs. only 85,810) even though the population of these countries are similar. While China is in the 69% percentile, India is located in the 99% percentile. This is also demonstrated by the cases-population ratio (in India – 5.73‰=0.573%; in China – 0.0596‰=0.00596%). Yet, in political rights and civil liberties terms, China receives the worst grades (7) and is considered "not free", while India receives a much better grade (2-3) and is considered "free".

d) Regression Results

Table 3 reports the regression outcomes based on the models given by equations (1)-(6):

Table 3: Coronavirus Infection and Measures of Democracies

	(1)	(2)	(3)	(4)	(5)	(6)
Method	LPM	LPM	LPM	Fractional	Fractional	Fractional
VARIABLES	Case_Per	Case_Per	Case_Per	$\mathbb{Z}[\Phi[\text{Case\_Per}]]$	$\mathbb{Z}[\Phi[\text{Case\_Per}]]$	$\mathbb{Z}[\Phi[\text{Case\_Per}]]$
Constant	0.0107***	0.0114***	0.0101***	-2.279***	-2.249***	-2.324***
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
PR10	-6.59×10^{-4}***	–	–	-0.0341**	–	–
	(0.00964)	–	–	(0.0165)	–	–
CL10	–	-8.16×10^{-4}***	–	–	-0.0417***	–
	–	(0.00342)	–	–	(0.00539)	–
Partly_Free	–	–	-0.00427***	–	–	-0.201***
	–	–	(0.00827)	–	–	(0.00721)
Not_Free	–	–	-0.00478**	–	–	-0.233**
	–	–	(0.0178)	–	–	(0.0357)
Observations	168	168	168	168	168	168
F-Statistics	6.86***	8.82***	4.28**	5.75**	7.74***	9.24***

Notes: Columns (1), (2) and (3) [(4), (5) and (6)] report the outcomes obtained from the LPM, which is a simple OLS procedure [fractional probit regression estimation]. The dependent variable Case_Per is the ratio between number of coronavirus cases and the population of the country. In columns (5) and (6), the base category is "Free". Robust *p*-values are given in parentheses. ** $p<0.05$; ***$p<0.01$

As may be observed from the results, a one point increase in PR10 and CL10 (i.e., worsening the political rights and civil liberties) is associated with 0.659‰=0.0659% (p=0.00964) and 0.816‰=0.0816% (p=0.00342) *drop* in the projected cases-population ratio. A shift from the base category of "free country" to "partially free country" is associated with 4.27‰=0.427% (*p*=0.00827) *drop* in the projected cases-population ratio. Finally, a shift from the base category of "free country" to "not free country" is associated with 4.78‰=0.478% (*p*=0.0178) *drop* in the projected cases-population ratio.

Figures 1 and 2 are based on the outcomes reported in columns (4) and (5) of Table 3. Once again, the figures show a reduction in projected cases-population ratio from 1.035% and 1.10% for countries with the highest measure of political rights and civil liberties measures to only 0.44% and 0.38% for countries with the worst levels of political rights and civil liberties.

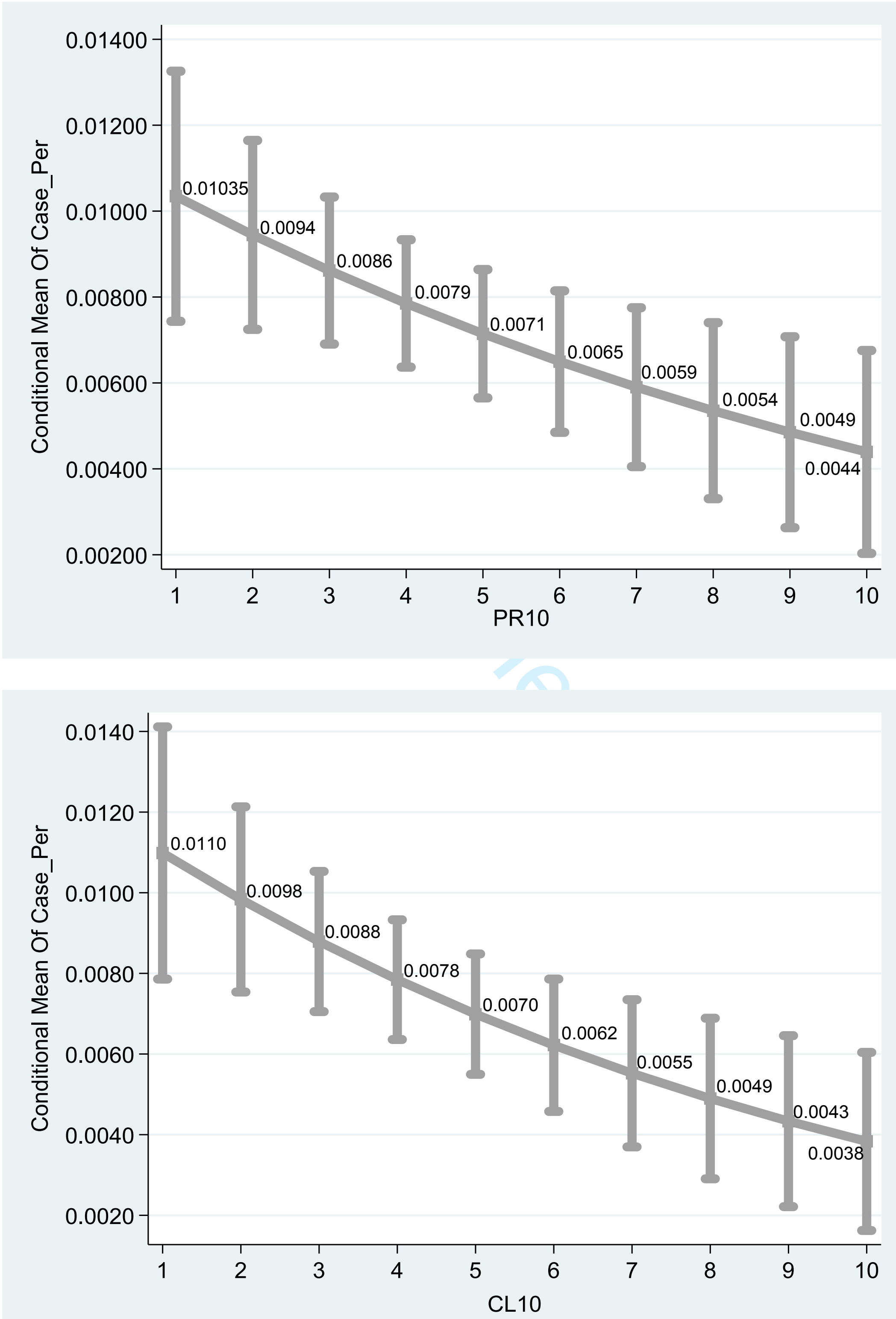
5. Summary and Conclusions

Following the evolutionary game theory school of thought, the objective of the current study is to explain non-compliance to social distancing rules in western societies. The key assumption is rational economic behaviour, where based on gathered information and other sources, people are perfectly aware of the low prospects to be infected from coronavirus, particularly compared to the previous Spanish flue pandemic (Barro et al., 2020).

In the first part of the analysis, we develop an evolutionary game based on the PD (e.g., (Tanimoto,2015: 22-27; 2018: 12-28). Bathun and Korinek (2020) estimated the perceived cost of an additional infection to be around $80,000 and the the true social cost including infection externalities to be around $286,000.

The Darwinian idea behind the evolutionary mechanism is the survival of the strategy that yields the maximum payoff (or the minimum damage) in each round. We show that under these circumstances, three potential equilibria points emerge: 1) cooperation (the source solution). 2) defection (the sink solution). 3) polymorphic (the saddle solution). Hence, regardless of the initial

Figure 1: Coronavirus Infection and Political Rights



Notes: Figure 1 and 2 are based on the regression outcomes obtained from columns (4)-(5) in Table 3.

cooperation proportion in [0, 1] the ultimate state is one of complete defection at $t\rightarrow\infty$ (Tanimoto, 2015: 27).

In the second part of the analysis, we provide empirical evidence supporting the notion that law enforcement systems in less democratic countries are more efficient. Based on the conventional freedom house measures of democracies (e.g., Barro, 1999), we demonstrate a drop in projected infection rates from coronavirus with a shift from countries with higher levels of to those with lower grades of political rights and civil liberties to. Moreover, a direct comparison between two of the most populated countries in the world, China and India, which are similar in population size, but differ in political rights and civil liberties, demonstrates a much lower prevalence of coronavirus disease in China.

A further support to the application of the Nash equilibrium in the context of the COVID19 pandemic emanates from the protest against the Chinese government in response to the zero covid policy in the face of increasingly contagious variants, China's government announced "20 measures" aimed at softening its zero covid approach (Dyer, 2022). This might reflect a shift from one equilibrium point – cooperation – where the pandemic is avoided by lockdowns (the source solution), to another equilibrium point – non-compliance (the sink solution) – where most of the population develops herd immunity and the public internalize the voluntarily use of masks in crowded locations.

A possible criticism of these outcomes may arise due to the credibility of information obtained from non-democratic countries. One could argue that less democratic governments are potentially inclined to conceal the true extent of the COVID19 pandemic. Yet, the information revolution and the availability of highly sophisticated technologies, make it difficult to conceal information. In that context, and based on satellite images obtained via search engines, Nsoesie et al. (2020) were able to indicate early disease activity in the Fall of 2019 in Wuhan China, which is considered the source of the COVID19 outburst.

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To Obey or Not to Obey? Can Game Theory Explain Human Behavior in the Context of Coronavirus Disease?

Abstract

The objective of the current study is to explain non-compliance to social distancing rules in western societies in the absence of a stringent law enforcement mechanism and vaccines. In the first part of the analysis an evolutionary game theory mechanism of two players is developed. The theoretical model assumes the existence of the Prisoner's Dilemma due to personal inconveniences associated with mask wearing, hand washing and lockdowns. The model demonstrates that in the absence of sufficient law enforcement mechanism, and regardless of the initial strategy undertaken, one of the three potential equilibria solutions is the convergence of the system to defection of both players. In the second part of the analysis, based on the freedom-house measures, we provide empirical evidence supporting the notion that law enforcement efficiency is higher in autocratic countries. We show the perseverance of higher projected infection rates per 100,000 persons in democratic countries even 8 months after the outburst of the COVID19 pandemic. Given the well-known inclination to cooperate more often than expected by game theory, this real-life outcome of non-compliance is remarkable. Moreover, the recent protests against lockdowns in China might reflect a shift from one equilibrium point (cooperation) to another (non-compliance).

Key Words: Evolutionary Game Theory; COVID19; Freedom-House Measures

JEL Codes: I12, H75, R58

1. Introduction

Since the outburst of the global COVID19 pandemic, the numbers of infections and deaths from the disease have grown steadily, with more than 43million persons who were infected (of whom almost 32 million recovered) and more than 1.15 million mortalities worldwide (on October 25, 2020 https://www.worldometers.info/coronavirus/?utm_campaign=homeAdUOA?Si). This rise continues despite the elevated worldwide awareness and the various implementation strategies of addressing the pandemic (e.g., WHO, available at: https://www.who.int/health-topics/coronavirus#tab=tab_2). Until the development and provision of an efficient vaccination, the possibility of avoiding or reducing the spread of the disease is contingent in large part on a change in behavioral patterns, namely, preserving social distancing rules. Yet, the tendency of many people, particularly those in Western democracies, is not to obey at least some of these rules, which include: 1) avoiding unnecessary travel; 2) staying away from large groups of people; 3) maintaining at least one meter distance from each other; and 4) wearing masks outside the home. The question is what the reasons for this non-compliance among large groups of people in Western democracies might be.

One possible explanation is driven from prospect theory of Tversky and Kahneman (1974) and Kahneman and Tversky (1979). According to this school of thought, the behavioral patterns of people are influenced by cognitive errors of judgement (heuristics). In our context, people are overly optimistic and, consequently, underestimate the actual prospects of being infected or dying from the disease. Another possible explanation for non-compliance among large groups of people comes from game and economic theory of negative externalities. This school of thought disputes the attribution of cognitive errors of judgement by prospect theory and emphasizes the underpriced damage the individual inflicts on others by infecting them with COVID19 virus.[1] The game theory perspective is best represented by the prisoner's dilemma (first formulated by Al Tucker, according to Aumann, 2008: 16), where cooperation produces the maximum payoff for the two players. Yet, each player has an incentive to defect.[2] Differently put, the Nash equilibrium will maximize the personal payoff of the individual, but not the collective payoff of the two players.

The current study seeks to follow the game theory school of thought. We develop an evolutionary game based on the prisoner's dilemma (hereinafter - PD) and the assumption that based on their own experience, people encountered high recovery rates and low mortality rates from coronavirus disease.[3] According to Bathun and Korinek (2020), the estimated perceived cost of an additional infection is around $80,000 and the overall social cost including externalities associated with infection is around $286,000. The game is constructed so that initially the two players cooperate and obey the rule, so as to minimize the damage to $80,000. Yet, if there is no law enforcement operatus, each player has an incentive to break the rule – and defect. Consequently, the Nash equilibrium of the game will be a $286,000 loss for each individual.

Next, following Tanimoto (2015, 2018), and the effort to explain the high cooperation levels in real-life data and laboratory experiments (e.g., 89% who choose to cooperate compared to only 11% who chose to defect in an ultimatum game – the so-called "game theory victims" – in

[1] According to O'Sullivan (2012): "An external cost occurs when a consumer pays a price that is less than the full cost of producing a product. The price of a product always includes the cost of labour, capital, and raw materials used to produce the product, but it usually does not include the environmental costs of producing the product" (page 9).

[2] According to Aumann (2008): "An equilibrium (Nash, 1951) of a strategic game is a (pure or mixed) strategy profile in which each player's strategy maximizes his payoff given that the others are using their strategies." (page 17).

[3] Referring to the Spanish influenza pandemic, Barro et al. (2020) state that: "The flu death rate of 2.1 percent out of the total population in 1918-1920 would translate into around 150 million deaths worldwide when applied to the world's population of about 7.5 billion in 2020." (page 17) Scaling the Spanish Influenza data to the relative duration of the current coronavirus pandemic (about 8 months) still yields $150 \cdot \frac{8}{24} = 50$ million deaths.

Rubinstein, 2016) an evolutionary mechanism is introduced. The Darwinian idea behind this mechanism is the survival of the strategy that yields the maximum payoff (or the minimum damage) in each round. We show that under these circumstances, three potential equilibria points emerge: 1) cooperation (the source solution). 2) defection (the sink solution). 3) polymorphic (the saddle solution). Hence, regardless of the initial cooperation proportion in [0, 1] the ultimate state is one of complete defection at $t \rightarrow \infty$ (Tanimoto, 2015: 27).

Finally, we provide empirical evidence supporting the evolution of the Nash equilibrium solution in western countries in contrast to autocratic countries. Given, for instance, that capital punishment is applied to each and every violation of the rule, obviously, the possibility of non-compliance is unrealistic in autocratic countries. Indeed, based on the conventional freedom house measures of democracies (e.g., Barro, 1999), we demonstrate a drop in projected infection rates from coronavirus with a shift from countries with higher levels of political rights and civil liberties to those with lower levels.

Moreover, a direct comparison between two of the most populated countries in the world, namely, China and India, which are similar in population size, but differ in political rights and civil liberties, demonstrates a much lower prevalence of coronavirus disease in China. These findings may be interpreted on the grounds of more efficient law enforcement system in less democratic countries.

A further support to the application of the Nash equilibrium in the context of the COVID19 pandemic comes from recent events in China. Following the protest against the Chinese government in response to the zero covid policy in the face of increasingly contagious variants, China's government announced "20 measures" aimed at softening its zero covid approach (Dyer, 2022). This might reflect a shift from one equilibrium point – cooperation – where the pandemic is avoided by lockdowns (the source solution), to another equilibrium point – non-compliance (the sink solution) – where most of the population develops herd immunity and the public internalize the voluntarily use of masks in crowded locations.

The remainder of this article is organized as follows. Section 2 provides literature review on evolutionary game theory. Section 3 develops and describes the game. Section 4 provides the empirical evidence supporting the notion that countries with lower levels of political rights and civil liberties better addressed the pandemic. Finally, Section 5 concludes and summarizes.

2. Evolutionary Game Theory: Literature Review

Having established in 1944, the biggest milestone in game theory was provided by the Nobel Prize winner John Nash (1949, 1951). The game theory perspective is best represented by the PD (first formulated by Al Tucker, according to Aumann, 2018: 16), where cooperation produces the maximum payoff for the two players. Yet, each player has an incentive to defect, so that: "An equilibrium (Nash, 1951) of a strategic game is a (pure or mixed) strategy profile in which each player's strategy maximizes his payoff given that the others are using their strategies." (Aumann, 2008 page 17). Differently put, the Nash equilibrium will maximize the personal payoff of the individual, but not the collective payoff of the two players.

The prediction of defection under the PD game raises the obvious question why do we cooperate in real life setting? Why do we observe many animals cooperating? (Tanimoto, 2015: page 3). As an example to unexplained cooperation, consider, for instance, Rubinstein (2016). The author demonstrated high levels of cooperation in an ultimatum game experiment. Of the 13,957 participants, most of them choose either to divide the $ 100 equally (49%) or to give the other side above $50 (17%).[4] Only 11% (the so-called "game theory victims") proposed the other side the sum anticipated by game theory – between zero to $1.

To address these questions, an important adjustment is the incorporation of evolution with game theory. Frey (2010) makes a distinction between biology and social sciences. In biology, strategies are considered to be inherited programs which control the individual's behavior. Aumann (1997) mention that like genes or alleles people develop ''rules of thumb'' that work in general, by an evolutionary process. If they work well, they are fruitful and multiply; otherwise they become rare and eventually extinct. (page 8)

As demonstrated in subsequent section, evolutionary game theory models in social sciences deal with the proportion of players who choose to cooperate ($s_1; 0 \leq s_1 \leq 1$) and the proportion of players who chose to defect ($s_2 = 1 - s_1; 0 \leq s_2 \leq 1$). The evolutionary mechanism introduced replicates strategies that yield the maximum payoff (or the minimum damage) in each round. The field was greatly promoted with increasing computational capabilities of the 90s of the twentieth century. This drives multi-agent simulations seeking answers for the question of why we can observe so much evidence of the reciprocity mechanism working among both real human social systems, and animal species, even during encounters with severe social dilemma situations, in which the theory predicts that game players should act defectively. (Tanimoto, 2015: 3). Two recent examples in the context of COVID19 vaccinations are Kabir, 2021 and Kabir et al., 2021).

[4] Imagine that you and another person (who you do not know) are to share $100. You must make an offer as to how to split the $100 between the two of you and he must either accept or reject your offer. In the case that he rejects the offer, neither of you will get anything. What will your offer be?

2.3. Social Distancing and the Prisoner's Dilemma

Consider the following two players evolutionary game (Tanimoto,2015: 22–27; 2018: 12–28):

		Player 1	
		Obey (Cooperate)	Not-Obey (Defect)
Player 2	Obey (Cooperate)	R, R	S, T
	Not obey (Defect)	T, S	P, P

Where Obey indicates compliance to social distancing rules in countries with higher levels of civil liberties. The letters stand for $R = Rewards; S = Sucker; T = Tempteation; P = Punishment$. In the case that $T \geq R \geq S \geq P$ the PD emerges and the Nash Equilibrium is obtained in a situation of non-compliance of both players.

As a specific numerical example based on the estimation of Bethune and Korinek (2020) consider the following example, where row (column) player corresponds to the left (right) number.

		Player 1	
		Obey (Cooperate)	Not-Obey (Defect)
Player 2	Obey (Cooperate)	−80,−80	−286, −20
	Not obey (Defect)	−20, −286	−286, −286

In this case, the game is formulated in loss terms, where $T = S \geq R \geq P$ and the objective function is to minimize the personal loss from COVID19. It may be readily verified that the dominant strategy for each player is to break the rules, so that the Nash equilibrium of the game will be a $286,000 loss to each individual. This outcome is obtained despite the fact that cooperation reduces the loss to $80,000 for each person.

Returning to the general model proposed by Tanimoto (2015, 2018), a more convenient way to write this game is the following:

		Player 1	
		Obey (Cooperate)	Not-Obey (Defect)
Player 2	Obey (Cooperate)	R	S
	Not obey (Defect)	T	P

And in matrix notation: $M \equiv \begin{bmatrix} R & S \\ T & P \end{bmatrix}$

We denote the proportion of players who choose to cooperate as s_1 $(0 \leq s_1 \leq 1)$ and to defect as $s_2 = 1 - s_1$. The row vector T_S is defined as $T_S = (s_1 \quad s_2)$. The row vector $T_{e_1} = (1 \quad 0)$ indicates a 100% proportion of collaborators and $T_{e_2} = (0 \quad 1)$ a 100% proportion of defectors. It may be readily verified that

$$T_{e_1} M T'_{e_1} = [1 \quad 0] \begin{bmatrix} R & S \\ T & P \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = R \text{ and } T_{e_2} M T'_{e_2} = [0 \quad 1] \begin{bmatrix} R & S \\ T & P \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix} = P$$

Where the tag represents the transpose column vector.

Next, we define the following evolutionary process for $i = 1, 2$:

$\frac{\dot{s}_i}{s_i} = T_{e_i} M T'_{e_i} - T_S M T'_S$ where $\dot{s}_i$ represents the change in s_i. The idea behind this process is the survival of the strategy that yields the maximum payoff (or the minimum damage) in each round. Substitution and simplification yields:

$$\begin{cases} \dot{s}_1 = [(R-T) \cdot s_1 - (P-S) \cdot s_2] \cdot s_1 \cdot s_2 \\ \dot{s}_2 = -[(R-T) \cdot s_1 - (P-S) \cdot s_2] \cdot s_1 \cdot s_2 \end{cases}$$

Equilibrium is achieved where $\dot{s}_1 = \dot{s}_2 = 0$. This yields three solutions, where the two obvious ones are $T^*_{e_1} = (1 \quad 0)$ and $T^*_{e_2} = (0 \quad 1)$. Tamito (2015, 2018) demonstrates that regardless of the proportion of cooperation at the beginning of the game, the only feasible solution at the end of the game (the sink solution) is the Nash equilibrium, namely, the defection strategy of both players. As demonstrated in subsequent sections, compared to autocratic societies, western societies suffer from higher COVID19 morbidity even 8 months after the outburst of the pandemic. If infection rates are positively correlated with obedience level, this outcome provides evidence supporting the notion of lower obedience levels to lockdowns and other measures imposed by the governments among western societies. Moreover, referring to China, Dyer (2022) recently reported the protest against the Chinese government in response to the zero covid policy in the face of increasingly contagious variants. At the beginning of November 2022 China's government announced "20 measures" aimed at softening its zero covid approach. The situation in China might reflect a shift from one equilibrium point – cooperation – where the pandemic is avoided by lockdowns (the source solution), to another equilibrium point – non-compliance (the sink solution) – where most of the population develops herd immunity and the public internalize the voluntarily use of masks in crowded locations.

~~3.~~4. Efficiency of the Law Enforcement System

a) The Empirical Model

To test the efficiency of the law enforcement system, consider the following empirical model applied separately to three freedom house measures:

$$Case\_Per = \alpha_{1,j} + \beta_{1,j} Freedom\_House\_Measure_{1,j} + \gamma_{1,j} Freedom\_House\_Measure_{2,j} + \mu_{1,j} , \qquad (j)$$

where $j = 1,2,3$, Case_Per (the dependent variable) represents the ratio between the accumulated number of coronavirus cases and the population of the country on October 25, 2020 (approximately 8 months after the outburst of the pandemic), $Freedom\_House\_Measure_{1,j}$ and

$Freedom\_House\_Measure_{2,j}$ are the independent variables, $\alpha_{1,j}$, $\beta_{1,j}$, $\gamma_{1,j}$ are parameters, and $\mu_{1,j}$ is the stochastic random disturbance term.

Given that the dependent variable is bounded between 0 and 1 ($0 \leq Case\_Per \leq 1$ – i.e., the countries do not have number of coronavirus cases, which is greater than its population size), this model is also known as the Linear Probability Model (LPM, e.g., Johnston and Dinardo, 1997: 414-418).

Referring to the independent variable(s), we use two quantitative measures and one qualitative measure of democracies ($j = 1,2,3$):

1) $Freedom\_House\_Measure_{1,1} = PR10$ and $Freedom\_House\_Measure_{2,1} = \vec{0}$, where $\vec{0}$ is a column vector of zeros. The original scale of the Political Rights (*PR*) measure is a Lickert scale from *PR*=1, the highest to *PR*=7, the lowest grade for political rights. For convenience, we rescaled the model to 1-10 scale ($PR10 = PR \cdot \frac{10}{7}$), so that after rescaling the model becomes *PR*10=1.4286 is the highest and *PR*=10 is the lowest grade.
2) $Freedom\_House\_Measure_{1,2} = CL10$ and $Freedom\_House\_Measure_{2,2} = \vec{0}$, where $\vec{0}$ is a column vector of zeros. The original scale of the Civil Liberties (*CL*) measure is a Lickert scale from *CL*=1, the highest to *CL*=7, the lowest grade for political rights. Once again, we rescaled the model to 1-10 scale, ($CL10 = CL \cdot \frac{10}{7}$), so that *CL*10=1.4286 is the highest and *CL*=10 is the lowest grade.
3) $Freedom\_House\_Measure_{1,3} = PARTLY\_FREE$ and $Freedom\_House\_Measure_{2,3} = NOT\_FREE$ are dummy variables, which receive 1 if the country was defined as "partly free" or "not free" and zero otherwise. The base category is "free", so that the constant term ($\alpha_{1,3}$) represents the projected probability of coronavirus infection in the case that the

country is free and $\beta_{1,3}$; $\gamma_{1,3}$ represent projected probability differences with respect to the base category.

Referring to the Linear Probability Model, according to Johnston and Dinardo (1997): "*A major weakness of the linear probability model is that it does not constrain the predicted value to lie between 0 and 1*" (page 417, italics in the original). Consequently, we also employ the fractional probit model (e.g., Papke and Woldridge, 1996; Woldridge, 2010):

$$pr(0 < Case\_Per < 1) = F(\alpha_{1,j+3} + \beta_{1,j+3} Freedom\_House\_Measure_{1,j} + \gamma_{1,j} + Freedom\_House\_Measure_{2,j}), \quad (j+3)$$

Where $F(Case\_Per) = \emptyset(\mathbb{Z}) = \frac{exp\left(-\mu/2\sigma^2\right)}{\sqrt{2\pi\sigma^2}}$ (the cumulative normal distribution function).

b) Descriptive Statistics

Table 1 reports the descriptive statistics of each variable (observations (*N*=168 states), mean, median, standard deviation, minimum, maximum):

The average number of cases is 247,710.1 (Cases). Multiplication by 168 states yields the total number of infected persons included in the sample (41.6152968 million). The implication is that the sample covers $\frac{41.6152968}{43.007643} = 96.76\%$ of the reported cases of coronavirus around the world. A comparison between the median (26,260 cases) and the mean (247,710.1 cases) indicates right-tailed distribution, namely, low prevalence of coronavirus cases. Even for cases population ratio (Cases_Per=Cases÷Population), the median (4.068‰=0.4068%) is still lower than the mean (7.3‰=0.73%) and the implication of right-tailed distribution is preserved. These distributions might provide evidence supporting the notion that behavioural patterns in Western democracies are not the outcomes of cognitive judgmental errors.

Table 1: Descriptive Statistics

Variable	Definition	Obs	Mean	Median	Std. Dev.	Min	Max
Cases	Accumulated number of coronavirus cases	168	247,710.1	26,260	1,006,720	3	8,725,151
Population	Population of the country	168	4.43×10^7	9,897,505	1.58×10^8	33,931	1.44×10^9
Cases_Per	cases÷population	168	0.0073	0.004068	0.0096	3.16×10^{-6}	0.0523
PR	Political rights on a Lickert scale of 1=the highest; 7=the lowest	168	3.5774	3	2.1736	1	7
CL	Civil liberties on a Lickert scale of 1=the highest; 7=the lowest	168	3.4583	3	1.8791	1	7
PR10	$PR\times\frac{10}{7}$=Political rights on a scale of 1-10	168	5.1105	4.2857	3.1051	1.4286	10
CL10	$CL\times\frac{10}{7}$=Civil liberties on a scale of 1-10	168	4.9405	4.2857	2.6845	1.4286	10
Free	1=Free countries; 0=otherwise	168	0.4301	–	0.4898	0	1
Partly_Free	1=Partly free country; 0=otherwise	168	0.2435	–	0.4410	0	1
Not_Free	1=Non-free country; 0=otherwise	168	0.3264	–	0.4769	0	1

Notes: Measures of democracies for 2020 are based on the freedom house measures available at: https://freedomhouse.org/explore-the-map?type=fiw&year=2020.

The average population size in each country is 44.3 million persons (Population). Multiplication by 168 states yields the total population in the sample (7.4424 billion). Once again, the implication is that the sample covers $\frac{7.4424}{7.5} = 99.232\%$ of the world's population. A comparison between the median $(0.9897 \cdot 10^7)$ and the mean (4.43×10^7) indicates right-tailed distribution. Namely, most of the countries are not heavily populated. Two prominent outliers, which are included in the sample and analyzed separately are India and China. Both countries consist $\frac{1.439323776 + 1.380004385}{7.5} = 37.59\%$ of the world's population.

Referring to the measures of democracies, for both the political rights and civil liberties measures, on a scale of 1=the best; 7=the worst; the median (*PR*=*CL*=3) is lower than the mean

(PR=3.5774; CL=3.4583). The implication is right-tailed distribution, namely, many countries receive better grades on political rights and civil liberties, while a few countries receive worse grades on political rights and civil liberties. Yet, according to the qualitative measure of democracy, of the 168 countries in the sample, only 43.01% are defined as "free". 24.35% are defined as "partially free" and 32.64% are defined as "not free".

c) A Comparison between China and India

Table 2 compares China and India. As previously noted, both countries comprise more than 37% of the world population. In terms of size of population, the countries are similar. Yet, while India is considered "the largest democracy in the world", China is ranked in the worst place in the Lickert scale ladder:

Table 2: A Comparison between China and India

Variable	**Definition**	**China**	**India**
Cases	Accumulated number of coronavirus cases	85,810	7,909,959
Population	Population of the country	1,439,323,776	1,380,004,385
Cases_Per	Cases÷Population	0.0596×10^{-3}	5.73×10^{-3}
PR	Political rights on a Lickert scale of 1=the highest; 7=the lowest	7	2
CL	Civil liberties on a Lickert scale of 1=the highest; 7=the lowest	6	3
PR10	$PR\times\frac{10}{7}$=Political rights on a scale of 1-10	10	2.8571
CL10	$CL\times\frac{10}{7}$=Civil liberties on a scale of 1-10	8.5714	4.2857
Free	1=Free countries; 0=otherwise	No	Yes
Partly Free	1=Partly free country; 0=otherwise	No	No
Not Free	1=Non free country; 0=otherwise	Yes	No

Notes: In term of number of coronavirus cases, and even though the populations of both countries are similar in magnitude, while China is located in the 69% percentile, India is located on the 99% percentile. In terms of political rights China receives the worst grade (7 points).

Indeed, compared to India, the number of coronavirus cases in China is much smaller (7,909,959 vs. only 85,810) even though the population of these countries are similar. While China is in the 69% percentile, India is located in the 99% percentile. This is also demonstrated by the cases-population ratio (in India – 5.73‰=0.573%; in China – 0.0596‰=0.00596%). Yet, in political rights and civil liberties terms, China receives the worst grades (7) and is considered "not free", while India receives a much better grade (2-3) and is considered "free".

d) Regression Results

Table 3 reports the regression outcomes based on the models given by equations (1)-(6):

Table 3: Coronavirus Infection and Measures of Democracies

	(1)	(2)	(3)	(4)	(5)	(6)
Method	LPM	LPM	LPM	Fractional	Fractional	Fractional
VARIABLES	Case_Per	Case_Per	Case_Per	$\mathbb{Z}[\Phi[\text{Case\_Per}]]$	$\mathbb{Z}[\Phi[\text{Case\_Per}]]$	$\mathbb{Z}[\Phi[\text{Case\_Per}]]$
Constant	0.0107***	0.0114***	0.0101***	-2.279***	-2.249***	-2.324***
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.01)
PR10	-6.59×10^{-4}***	–	–	-0.0341**	–	–
	(0.00964)	–	–	(0.0165)	–	–
CL10	–	-8.16×10^{-4}***	–	–	-0.0417***	–
	–	(0.00342)	–	–	(0.00539)	–
Partly_Free	–	–	-0.00427***	–	–	-0.201***
	–	–	(0.00827)	–	–	(0.00721)
Not_Free	–	–	-0.00478**	–	–	-0.233**
	–	–	(0.0178)	–	–	(0.0357)
Observations	168	168	168	168	168	168
F-Statistics	6.86***	8.82***	4.28**	5.75**	7.74***	9.24***

Notes: Columns (1), (2) and (3) [(4), (5) and (6)] report the outcomes obtained from the LPM, which is a simple OLS procedure [fractional probit regression estimation]. The dependent variable Case_Per is the ratio between number of coronavirus cases and the population of the country. In columns (5) and (6), the base category is "Free". Robust *p*-values are given in parentheses. ** $p<0.05$; *** $p<0.01$

As may be observed from the results, a one point increase in PR10 and CL10 (i.e., worsening the political rights and civil liberties) is associated with 0.659‰=0.0659% (p=0.00964) and 0.816‰=0.0816% (p=0.00342) *drop* in the projected cases-population ratio. A shift from the base category of "free country" to "partially free country" is associated with 4.27‰=0.427% (p=0.00827) *drop* in the projected cases-population ratio. Finally, a shift from the base category of "free country" to "not free country" is associated with 4.78‰=0.478% (p=0.0178) *drop* in the projected cases-population ratio.

Figures 1 and 2 are based on the outcomes reported in columns (4) and (5) of Table 3. Once again, the figures show a reduction in projected cases-population ratio from 1.035% and 1.10% for countries with the highest measure of political rights and civil liberties measures to only 0.44% and 0.38% for countries with the worst levels of political rights and civil liberties.

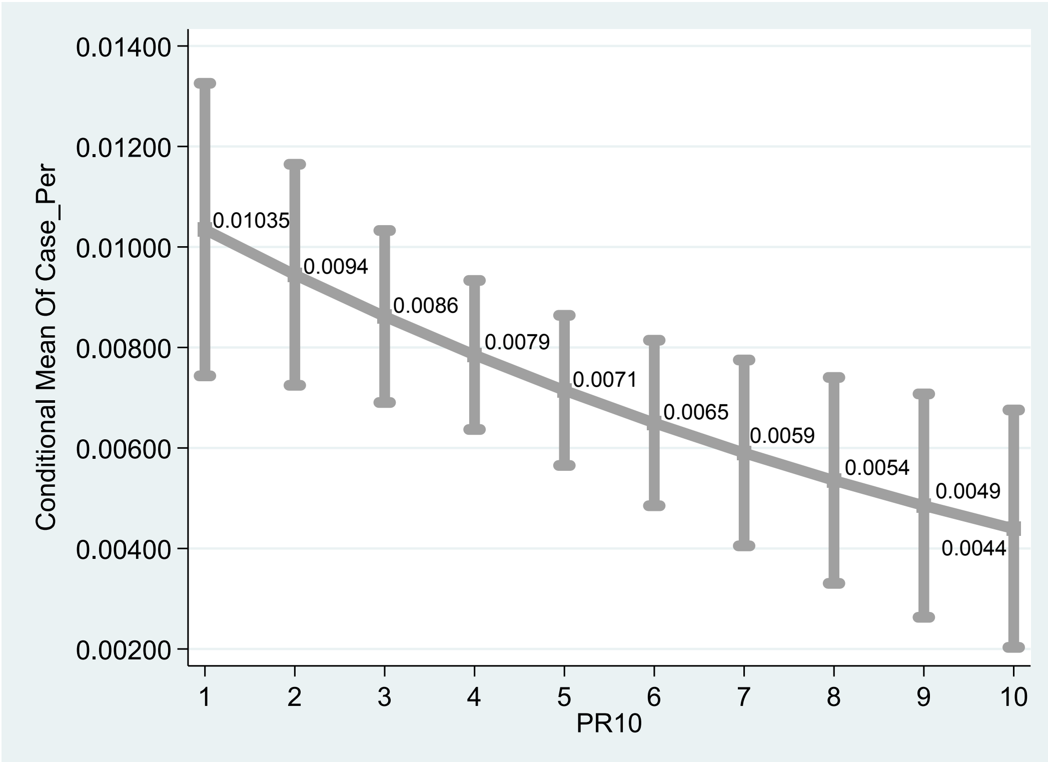
4.5. Summary and Conclusions

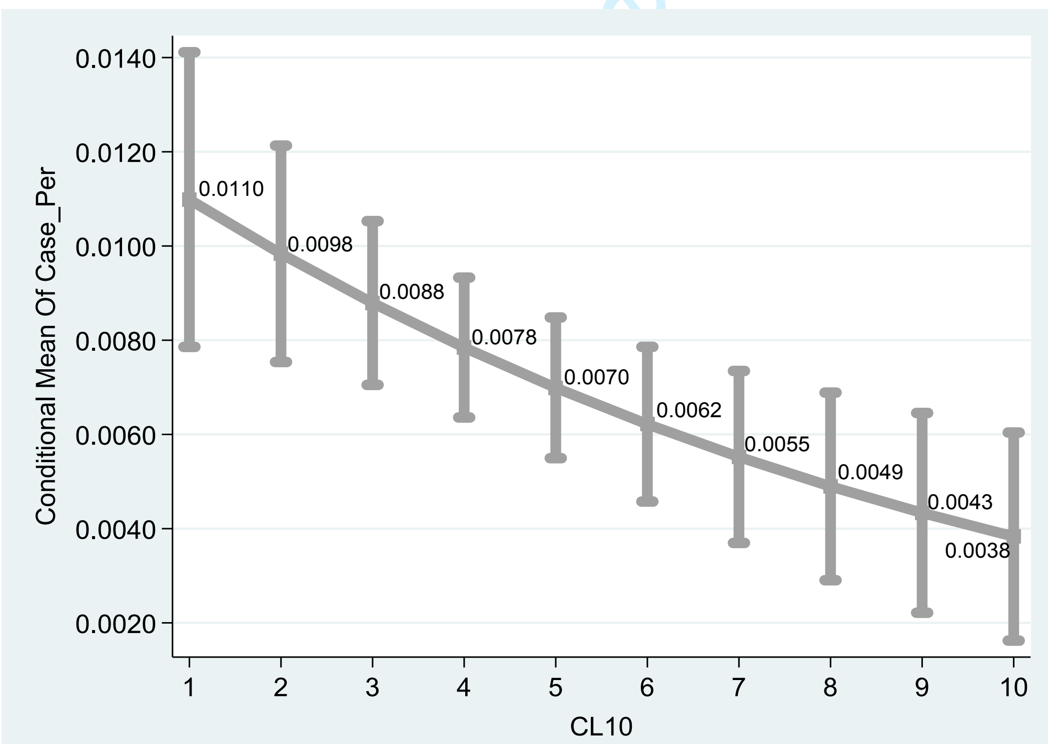
Following the evolutionary game theory school of thought, the objective of the current study is to explain non-compliance to social distancing rules in western societies. The key assumption is rational economic behaviour, where based on gathered information and other sources, people are perfectly aware of the low prospects to be infected from coronavirus, particularly compared to the previous Spanish flue pandemic (Barro et al., 2020).

In the first part of the analysis, we develop an evolutionary game based on the PD (e.g., (Tanimoto,2015: 22-27; 2018: 12-28). Bathun and Korinek (2020) estimated the perceived cost of an additional infection to be around \$80,000 and the the true social cost including infection externalities to be around \$286,000.

The Darwinian idea behind the evolutionary mechanism is the survival of the strategy that yields the maximum payoff (or the minimum damage) in each round. We show that under these circumstances, three potential equilibria points emerge: 1) cooperation (the source solution). 2) defection (the sink solution). 3) polymorphic (the saddle solution). Hence, regardless of the initial

Figure 1: Coronavirus Infection and Political Rights





Notes: Figure 1 and 2 are based on the regression outcomes obtained from columns (4)-(5) in Table 3.

cooperation proportion in [0, 1] the ultimate state is one of complete defection at $t \to \infty$ (Tanimoto, 2015: 27).

In the second part of the analysis, we provide empirical evidence supporting the notion that law enforcement systems in less democratic countries are more efficient. Based on the conventional freedom house measures of democracies (e.g., Barro, 1999), we demonstrate a drop in projected infection rates from coronavirus with a shift from countries with higher levels of to those with lower grades of political rights and civil liberties to. Moreover, a direct comparison between two of the most populated countries in the world, China and India, which are similar in population size, but differ in political rights and civil liberties, demonstrates a much lower prevalence of coronavirus disease in China.

A further support to the application of the Nash equilibrium in the context of the COVID19 pandemic emanates from the protest against the Chinese government in response to the zero covid policy in the face of increasingly contagious variants, China's government announced "20 measures" aimed at softening its zero covid approach (Dyer, 2022). This might reflect a shift from one equilibrium point – cooperation – where the pandemic is avoided by lockdowns (the source solution), to another equilibrium point – non-compliance (the sink solution) – where most of the population develops herd immunity and the public internalize the voluntarily use of masks in crowded locations.

A possible criticism of these outcomes may arise due to the credibility of information obtained from non-democratic countries. One could argue that less democratic governments are potentially inclined to conceal the true extent of the COVID19 pandemic. Yet, the information revolution and the availability of highly sophisticated technologies, make it difficult to conceal information. In that context, and based on satellite images obtained via search engines, Nsoesie et al. (2020) were able to indicate early disease activity in the Fall of 2019 in Wuhan China, which is considered the source of the COVID19 outburst.

~~5.~~6. References

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