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Success for big infectious disease reimbursement policy in China[*]

Kun-xi Nie[1,*], Chan Wang[2]

[1]Department of Tourism Management, Shihezi University, Shihezi, 832003, P.R. China

[2]School of Finance, Institute of Guangdong Economy & Social Development, Guangdong University of Finance & Economics (GDUFE), Guangzhou, 510320, P.R. China.

Abstract

Big infectious diseases do harm to the whole society and it is highly crucial to control them on time. China has successful experience of launching reimbursement policy to control big infectious diseases, Severe Acute Respiratory Syndromes (SARS), efficiently. By evolution model, this article illustrates the efficiency of big infectious disease reimbursement policy in China. On one hand, the number of infected persons decreases under big infectious disease reimbursement policy in China. On the other hand, the total expenditures to cure also under control. In summary, big infectious disease reimbursement policy in China can support as an efficient example to cope with big infectious diseases.

Corresponding author: Chan Wang, School of Finance, Institute of Guangdong Economy & Social Development, Guangdong University of Finance & Economics(GDUFE), Guangzhou, 510320, P.R. China, Email: wangchan0512@163.com

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Introduction

Infectious disease always threatens life of human being and even destroys social stability. People feel terrible when infectious diseases appear and nearly have no way to avoid the damage. Therefore, infectious disease is an important social issue and government should take step to control it. It is crucial for government to suppress infectious diseases.

In 2003, China out broke the serious infectious diseases Severe Acute Respiratory Syndromes (SARS), which was extremely horrible for its spread infection high death rate. According to statistics, 5,327 residents in mainland China were infected with SARS, and 349 of them died. Besides, 1,755 cases were reported in Hong Kong, China and 300 infectors were death. At the same time, 665 cases in Taiwan, China with 180 deaths, and the death rate was about 10.7%. It is well know that China is a country with a large population. Due to the high population density, high mobility and poor sanitation in some areas, SARS infected rapidly. Although those conditions are conducive to the spread of SARS, the Chinese government took a compulsory means to control it. As soon as an infected person is identified, mandatory isolation and free treatment are provided to stop transmission and reduce mortality, which is the key for the infectious disease defense successful

In mid-February, 2018, a serious flu in the United States was spreading, and people are reported died from the flu almost every day. According to experts, this is probably the worst flu in the United States in decades, which is comparable to the 2009 peak of swine flu. According to the statistics of U.S Centers for Disease Control and Prevention (CDC) , 4,064 people across the country died from flu and pneumonia just in the third week of 2018, which is 10% of the same period mortality rate of the U.S.A. And the situation is still deteriorating because the death is continue rising. During the swine flu in 2009 and 2010, a total of 60.8 million Americans were infected, 274,000 of them were hospitalized, while about 12,500 died. The death toll from ongoing flu may far exceed this number. In the United States, even the flu outbreak is not serious, about 12,000 people will die. If it is in a severe season, the death may reach 56,000, of which 80% are elderly. The main reason for the high infected and deaths of flu in the United States should attribute to the nonfeasance government, because it taken no effective measures to against the spread of infectious diseases.

Comparing the conditions between the United States and China, we know that on one hand, the population number and density of the United States are much less than China. On the other hand, the United States has the best medical conditions in the world. But the statistics data above show that the damage caused by infectious diseases in the U.S.A is far serious that that in China. Even though the flu in U.S.A is much milder than SARS in China, there are still tens thousands of people killed by infectious diseases in the United States, but during the SARS, the death toll in China is no more than 829. In comparison, the number of deaths from infectious diseases in the United States is at least 10 times that that due to infectious diseases in China. Then we can infer that there are something the Chinese government did much better that the American government during the big infectious disease period.

To control the infectious diseases, China chooses compulsory segregation of patients and treats them for free. As a developing country, China's medical level is not high enough, and its population is so large that it cannot withstand the serious consequences of infectious diseases. Therefore, it is essential to take coercive measures to control infectious diseases like China, it can be said that this method of controlling infectious diseases is successful. In other words, during the outbreak of infectious diseases, government intervention is extremely important for controlling infectious diseases.

The major purpose of this paper is to theoretically demonstrate that the Chinese government's intervention in large-scale infectious diseases is successful and efficient. And this paper intends to draw on the traditional infectious disease model to analyze the Chinese government's compensation system for major diseases to reduce the harm of infectious diseases.

Infectious disease model is initially proposed by [7]. Taken the situation and the types of infection disease into account, many scholars extended the classical model of Kermack & McKendrick (1927) [7]. For example, Bloom, Black, & Rappuoli (2017) [1] addressed the path of sudden infectious diseases by employed the extended model [7]. And based on Kermack & McKendrick's model [9], analyzed both the opportunities and the challenge in infectious disease control. Combined the properties of infectious disease into Kermack & McKendrick's model [4], considered malaria in Uganda and offered the corresponding treatment plan. Recently [2], analyzed the effects of insecticide on infectious diseases.

About governmental intervention in infectious diseases [6], combined governmental policies into infectious disease model and proposed governmental intervention to reduce the public harm. Furthermore [5], introduced treatment expenditures in infectious disease model with economic perspective. Recently [8], proposed treatment combined with recovery to cope with infectious diseases. Sims [10], analyzed the treatment of unpredictable epidemics with behavioral economics.

Recently, some research, such as Wang & Nie (2016), Wang & Chen (2017) and Chen et al. (2017) [3,11, 12] suggested using medical reimbursement to solve the dispute between hospitals and patients and some other issues. But little literature discussed the reimbursement to cope with big infectious diseases in economics. Based on the successful experience of coping with SARS in 2003, this article resorts infectious disease model to capture the rationality of reimbursement on preventing big infectious diseases.

Model Setup

Assume the number of population to be *N* in this group, including susceptibles, infected and healers, which are denoted as *S*, *I* and *R*, respectively. The average effective contact (transferable) with other people for a person in a unit time is β; the number of people who are cured within the unit time is γ; the treatment cost is α; and the government compensation is μ. In reality, the number of patients or the number of people participating in the treatment depends on the treatment cost. In order to promote infected patients to take treatment promptly, the government should gives moderate compensation. Furthermore, we suppose $\gamma = e^{-\alpha+\mu}$ in this study and obviously $\gamma \in (0,1)$. As the cost of treatment increases, the number of people participating in treatment decreases, but government financial compensation can effectively promote the participation of infected patients in treatment. According to the model proposed by [7] and based on China's successful experience in dealing with SARS, this paper establish the compensation model for important infectious diseases as follows:

$$dS/dt = -\beta IS/N, \quad ....(1)$$

$$dI/dt = \beta IS/N - e^{-\alpha+\mu}I, \quad ....(2)$$

$$dR/dt = e^{-\alpha+\mu}I. \quad ....(3)$$

Function (1)-(3) meet the constraint *S (t) + I (t) + R (t) = N*. Compared to traditional infectious disease models, this model analyzes treatment costs and the impact of government interventions on infectious diseases. Different from traditional infectious disease models, the above model considers the impact of government intervention on infectious diseases. According to function (3), we know that government intervention will significantly increase the population of the cured individuals, thereby reduce the spread speed among the infected population.

Model Analysis

According to $\gamma = e^{-\alpha+\mu}$, $\gamma \in (0,1)$, the number of people cured in a unit time is determined by the cost of treatment α and government compensation μ. Assume that the initial conditions of the equation are $S(t=0) = S_0$, $I(t=0) = I_0$, and $R(t=0) = R_0$, while $S_0 + I_0 = R_0 = N$. And the number of three kinds of people at each stage is: $S(T) = S_t$, $I(t) = I_t$ and $R(t) = R_t$.

Since the above model cannot obtain the analytic solutions, all the following analysis will by practice by numerical simulation with Excel and the recursive formulas used in the simulation are:

$$S_t = S_{t-1} + dS/dt = S_{t-1} - \beta IS/N \quad ....(4)$$

$$I_t = I_{t-1} + dI/dt = I_{t-1} - \beta IS/N - e^{-\alpha+\mu} ....(5)$$

$$R_t = R_{t-1} + dR/dt = R_{t-1} + e^{-\alpha+\mu}I \quad ....(6)$$

The initial setting are $S_0 = 0.4$, $I_0 = 0.4$, $R_0 = 0.2$, $N_t = 1$, $\beta = 1$. Notice that $N_t = 1$ means the total population is standard to be 1 and unchanged, while $\beta = 1$ represents that the infected people will effective contact with all other person in the area.

Without Government Intervention

Observing the functions (1)-(3), the following phenomena can be obtained: in the case of no government compensation ($\mu = 0$), if the cost of treatment is high, not many people have enough ability to pay for the treatment, and people's willingness to accept treatment is very low, so the number of people cured within a unit of time is also very small under the conditions of $\mu = 0$, $\alpha \to \infty$, $\gamma \to 0$, But when the cost of treatment is low, people have enough ability to pay, so the willingness to treat increases, and the number of people cured per unit time increases if $\mu = 0$, $\alpha \to 0$, $\gamma \to 1$.

The numerical simulation results based on equations (4)-(6) are offered by figure 1 as follows:

As figure 1 show, at high cost, even after 10,000 periods, the number of infected people is still as high as 0.5. But figure 2 illustrates that at low cost condition, the number of infected people will drops to zero after about 1774 periods. The cost of treatment has an important impact on the transmission of infectious diseases. Figure 1 shows the relationships between the number of three groups and the cost of treatment. When the cost of treatment is high, the number of infections per stage increases (*see* figure 1). Conversely, the number of infections drops sharply after a limited period, indicating that the infection is effectively and quickly controlled (*see* figure 2). This conclusion is also in constant with the reality. For example, although the common cold is contagious, it can be quickly controlled because of the low cost of treatment.

According to the assumption that the total population is constant, combined with the conclusion of figure 2, when the treatment cost is low, the number of healers quickly reaches a maximum, and the number of infected persons is almost zero. This indicates that the epidemic is effectively controlled. According to figure 1, the total number of social treatments and the total cost (the total number of infections multiplied by the individual treatment costs) were further analyzed. The cost of treatment for high-cost treatments was close to infinity; the number of low-cost treatments was 1654.48, and the cost of treatment was 8272.40. Therefore, it is explained in accordance with figure 2. When treatment costs are low, the government does not have to intervene.

With Government Intervention

Finally, in the case of free treatment, then patients' willingness to treat reaches the highest, and the number of people healed per unit time is also the highest, which is the ideal state. In other words, if $\mu - \alpha = 0$, then it has $\gamma = 0$.

Under the condition that the government gives certain compensation ($\mu \neq 0$, $\mu >> 0$), if the treatment cost is greater than the government compensation, both high treatment cost and low government compensation will lead to a decrease in people's willingness to treat. And the number of people cured within a unit of time will decrease corresponding, which means When $- \alpha + \mu \to \infty$, $\gamma \to 0$. If the government compensation and treatment costs are equal, which equal to free treatment, people's willingness to treat will also reach the maximum, and this is also an ideal condition. Or $- \alpha + \mu = 0$ lead to $\gamma = 1$.

It is unrealistic for the government to compensate more than the treatment cost ($\mu \geq \alpha$). Low willingness to spend money on the treatment of infectious diseases leads to quick spreading of infectious diseases and thus affects society sustainability. The government compensates people to control the disease, but compensates the government supply will only enough for people to treat infectious diseases. After all more compensates means higher expenditures for the government. Therefore, government compensations must be no more than the treatment expenditures, or $\mu \leq \alpha$. To consistent with the real policy of Chinese government, this paper assumes $\mu - \alpha = 0$, then $\gamma = 1$. Under this condition, the number evolution of the three group are shown in figure 3.

Figure 3 shows that the number of infected people drop rapidly and will reach to zero in the eighth period. Besides, according to figure 3, we learn that only 5.59 people need treatment under full government subsidy, much less than that under no government intervention. But the total cost of treatment is related to unit person treatment cost, which is 55.88 at high cost

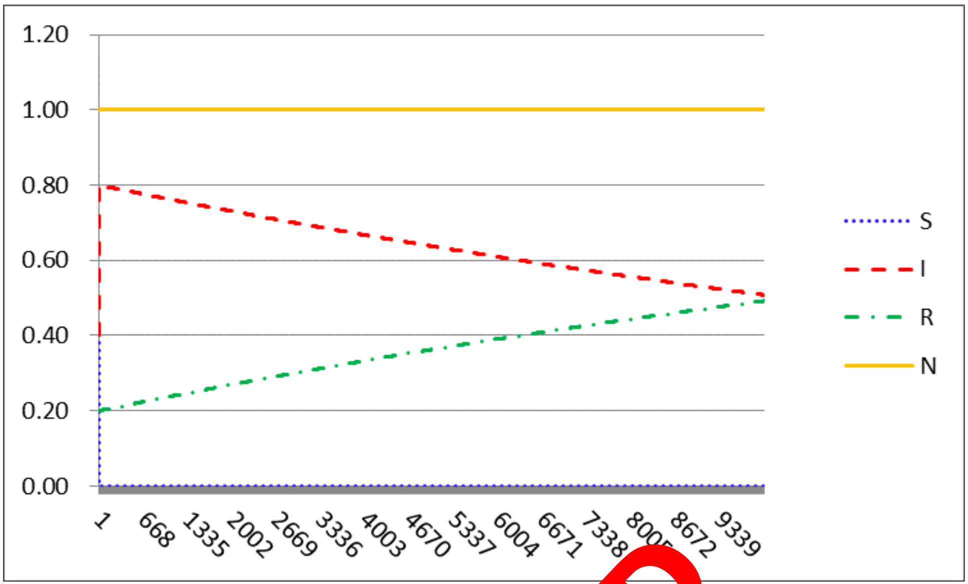

Figure 1. High expenditures α = 10, [illegible] μ = 0,

Note: The horizontal axis is the [illegible] number of time periods, and the verti- [illegible] cal axis indicates the number of people in [illegible] each period. The

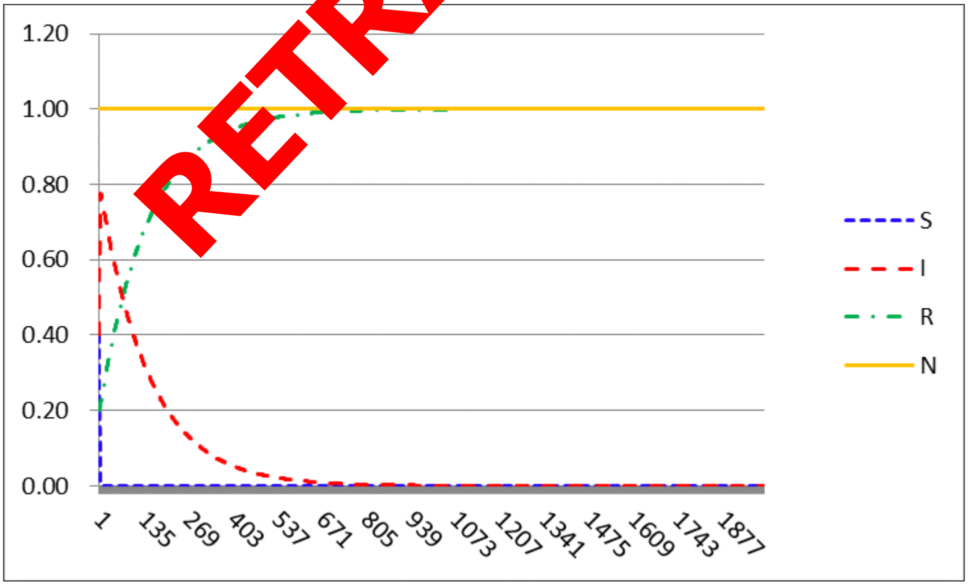

Figure 2. Low expenditures α = 5, μ = 0,

Note: The horizontal axis is the number of time periods, and the vertical axis indicates the number of people in each period. The initial setting is $S_0 = 0.4, I_0 = 0.4, R_0 = 0.2, \beta = 1$, 2000 times of simulation.

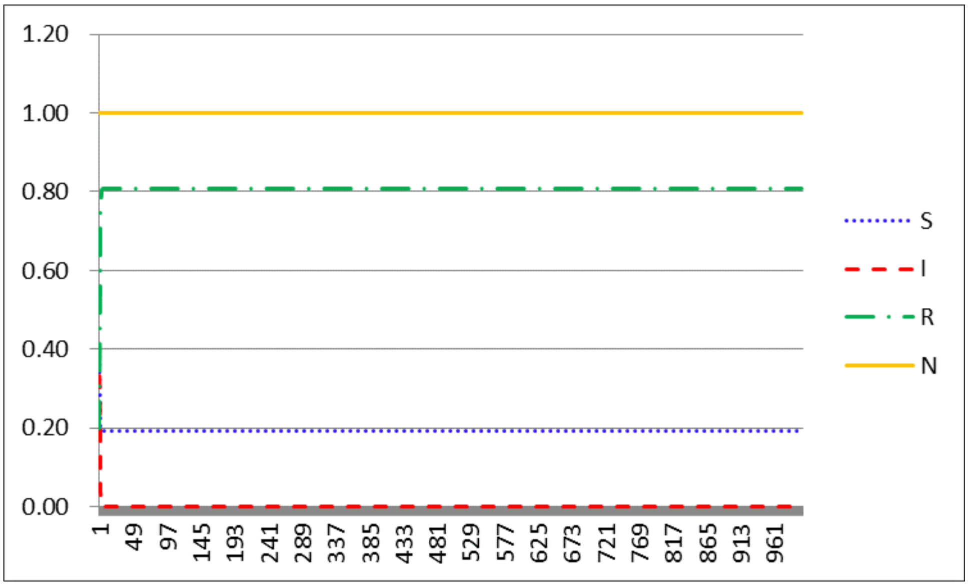

Figure 3. Full government subsidies α = 5, μ = 5,

Note: The horizontal axis is the number of time periods, and the vertical axis indicates

and 27.94 at low cost . Figure 3 shows that when the cost of treatment is high, the expenditures of implementing the full compensation mechanism are also high.

Comparison Analysis

Following we will compares the number of people infected and the total costs of treatment in both cases to illustrate the impact of government intervention. Since the calculation process above cannot obtain a specific analytical solution, the research process will obtain the results through the numerical simulation process. Assuming the total number of people , that is, regardless of the new birth and death of the population, indicates the number of susceptible people, infected people and patients cured. Furthermore, we assume the number of effective contact.

The following is the numerical simulation of the number of infected persons in different parameters, including three cases: high cost ($\alpha = 10$, $\mu = 0$), low cost ($\alpha = 5$, $\mu = 0$), and full subsidy ($\alpha = 5$, $\mu = 5$).

Through comparative analysis between high-cost and low-cost, the impact of treatment cost on the evolution of infectious diseases was obtained. The impact of government intervention on the evolution of infectious diseases was captured by comparing the results between no subsidy and full subsidy. The simulation results are shown by the figure 4, for more details of the numerical simulation, please see the appendix.

From the above figure (Figure 4), two important conclusions can be drawn: First, the treatment cost of infectious diseases has a critical influence on the evolution of the infectious disease infection. Specifically, under the condition of high cost and no government intervention ($\alpha = 10$, $\mu = 0$), even after 10,000 periods of time evolution, the proportion of infected people still exceeds 50%, and the highest number of infected people is close to 80%. At low cost, even without government intervention ($\alpha = 5$, $\mu = 0$), the number of infected people will decrease rapidly over time, but the maximum number of infected people will exceed 77%, and it will take a very long period of time (1774 periods) to control the disease. In other words, infectious will fall to 0 or everyone is cured after 1774 periods. Second,

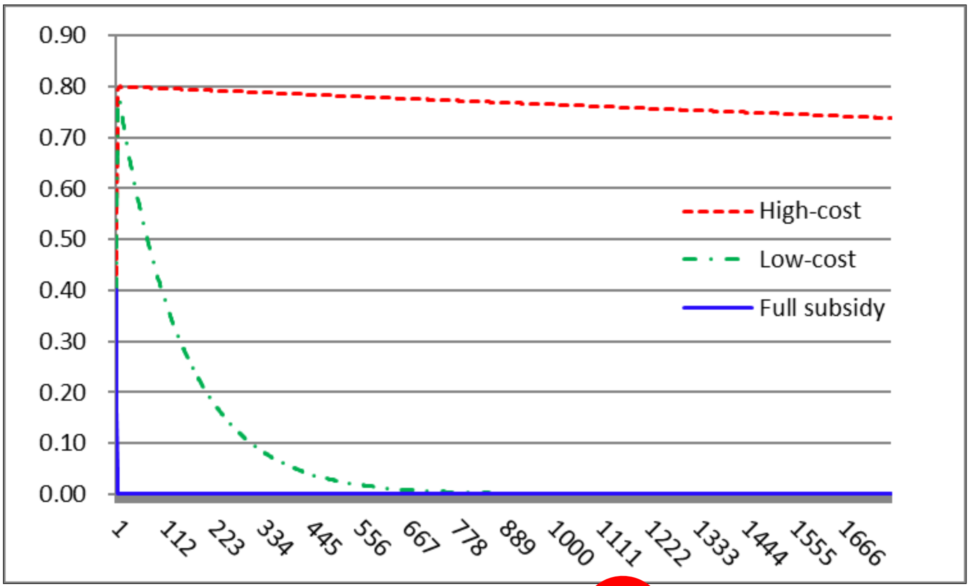

Figure 4. Numerical simulation results of the number of infected people

Notes: The horizontal axis is the time period t, the vertical axis indicates the number of infections I_t in each period. The total popu-

government intervention has an important impact on the evolution of infectious diseases. If the government implements full subsidy for infectious disease (without considering the impact of data costs under full subsidy), the number of infected people will drop rapidly and will fall to zero in the eighth period. Infectious diseases can be effectively controlled in a short period of time.

Concluding Remarks

This article extends infectious disease model to introduce the big infectious disease reimbursement policy in China and shows that why this reimbursement policy is successful. Without government reimbursement, this article finds that high expenditures accelerate the disease infection. Therefore, it is necessary to launch full reimbursement policy for infectious diseases under high expenditures incurred by treatment condition. The higher the treatment costs are, the more important the government intervention is.

The conclusions of this article offer theoretical support to control big infectious diseases. Moreover, for emerging infectious diseases, the uncertainty yields high treatment expenditures and government should establish complete reimbursement policy to control these diseases.

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Table 1. Appendix: Numerical Simulation Results

t	S_t	I_t	R_t	S_t	I_t	R_t	S_t	I_t	R_t
	$\alpha = 10, \mu = 0$			$\alpha = 5, \mu = 0$			$\alpha = 5, \mu = 5$		
0	0.40000	0.40000	0.20000	0.40000	0.40000	0.20000	0.40000	0.40000	0.20000
1	0.24000	0.55998	0.20002	0.24000	0.55730	0.20270	0.24000	0.16000	0.60000
2	0.10560	0.69435	0.20004	0.10625	0.68730	0.20645	0.20160	0.03840	0.76000
3	0.03228	0.76765	0.20008	0.03322	0.75570	0.21108	0.19386	0.00774	0.79840
4	0.00750	0.79239	0.20011	0.00812	0.77571	0.21617	0.19236	0.00150	0.80614
5	0.00156	0.79830	0.20015	0.00182	0.77678	0.22140	0.19207	0.00029	0.80764
6	0.00031	0.79950	0.20018	0.00041	0.77296	0.22663	0.19201	0.00006	0.80793
7	0.00006	0.79972	0.20022	0.00009	0.76807	0.23184	0.19200	0.00001	0.80799
8	0.00001	0.79973	0.20025	0.00002	0.76296	0.23702	0.19200	0.00000	0.80800
9	0.00000	0.79971	0.20029	0.00001	0.75784	0.24216	0.19200	0.00000	0.80800
10	0.00000	0.79967	0.20033	0.00000	0.75273	0.24726	0.19200	0.00000	0.80800
11	0.00000	0.79964	0.20036	0.00000	0.74766	0.25234	0.19200	0.00000	0.80800
12	0.00000	0.79960	0.20040	0.00000	0.74263	0.25737	0.19200	0.00000	0.80800
13	0.00000	0.79956	0.20044	0.00000	0.73762	0.26238	0.19200	0.00000	0.80800
14	0.00000	0.79953	0.20047	0.00000	0.73265	0.26735	0.19200	0.00000	0.80800
15	0.00000	0.79949	0.20051	0.00000	0.72772	0.27228	0.19200	0.00000	0.80800
16	0.00000	0.79945	0.20055	0.00000	0.72281	0.27719	0.19200	0.00000	0.80800
17	0.00000	0.79942	0.20058	0.00000	0.71794	0.28206	0.19200	0.00000	0.80800
18	0.00000	0.79938	0.20062	0.00000	0.71310	0.28690	0.19200	0.00000	0.80800
19	0.00000	0.79935	0.20065	0.00000	0.70830	0.29170	0.19200	0.00000	0.80800
20	0.00000	0.79931	0.20069	0.00000	0.70353	0.29647	0.19200	0.00000	0.80800
..	…	…	…	…	…	…	…	…	…
1774	0.00000	0.73813	0.26187	0.00000	0.00000	1.00000	0.19200	0.00000	0.80800
…	…	…	…	…	…	…	…	…	…
10000	0.00000	0.50808	0.49192	0.00000	0.00000	1.00000	0.19200	0.00000	0.80800
…	…	…	…	…	…	…	…	…	…

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Availability of Data and Material

No additional data are available.

Competing Interests

The authors declare that they have no competing interests.

Consent for Publication

Not applicable.

Ethics Approval and Consent to Participate

Not applicable.

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