China’s Government Information Capacity, Medical Resource Allocation and COVID−19 Prevention and Control

Cheng Liu, Chunping Zhong, Chen Cheng, Cong Ding[*]

The fight against the COVID−19 epidemic is a war against an “invisible enemy”. Access to accurate information and appropriate allocation of medical resources are key to containing the spread of the virus as soon as possible. The Chinese government has great power to collect information from individuals and basic-level organizations. It also has strong ability to pool and allocate medical resources. The fight against COVID−19 can be deemed as a quasi-natural experiment and based on this, we examine how government information capacity and medical resource allocation influence epidemic prevention and control in 286 Chinese cities (prefecture level and above). The findings are as follows: (1) Government information capacities improve the effectiveness of prevention and control policies. At city level, for every 0.1 point of increase in government information capacity score, the number of confirmed cases will reduce by 66.5, and the number of deaths per 10000 people will be down by 0.008. (2) The quantity of medical resources available has no direct influence on the effectiveness of epidemic prevention and control, but higher allocation efficiency does bring higher effectiveness. (3) The government can, on the one hand, allocate public resources based on information, and on the other hand guide the flow of social resources by releasing relevant information. Both can improve the allocation efficiency of medical resources. These findings have some policy implications for improving global emergency management.

Keywords: COVID−19, government information capacity, medical resource allocation

1. Introduction

As a public health emergency, the novel coronavirus disease (COVID−19) has a major and far-reaching impact on China and the world, and it is a test of the public policies and governance capacities of all countries involved. On December 1, 2019, the first COVID−19 patient was reported in Wuhan. On January 23, 2020, all means of public transport were suspended in the city. As of March 8, there were more than

[*] Cheng Liu (corresponding author, email: liucheng1353@163.com), National Academy of Economic Strategy, CASS; Chunping Zhong, National Academy of Economic Strategy, CASS; Chen Cheng, the Carey Business School, Johns Hopkins University; Cong Ding, Chinese Academy of Social Sciences.

80000 confirmed cases and over 3000 deaths in China, while the number of new confirmed cases was below 100 every day, showing that the spread of the virus had been effectively contained.[1] According to Shi and Qiu (2020), one confirmed case could infect three people on average in late January, while the number reduced to 1.2 by the end of February. Pan *et al.* (2020) reached a similar conclusion in their study: The effective reproduction number of COVID−19 in China dropped from the 3.0 of January 26 to the 0.3 of March 1. Indeed, one year later, there were no nationwide outbreak in China, only local outbreaks in Beijing, Xinjiang, Liaoning and some other places.[2]

In contrast, the epidemic is spreading all over the world, becoming a major health risk to human beings. In January 2020, the World Health Organization (WHO) declared the outbreak a "public health emergency of international concern (PHEIC)", called on all countries to pay close attention to it, and required "coordinated international response". As of March 16, there were 121000000 confirmed cases and 2670000 deaths in more than 200 countries and regions. As the epidemic broke out early in China but the situation was soon contained, a detailed analysis of what China has done to fight it can provide insights that may help with global prevention and control efforts.

Epidemic prevention and control requires rapid and precise allocation of medical resources. The quantity of available medical professionals and supplies such as doctors, hospital beds, ventilators and masks, and how efficient these resources are used are top priorities. In addition, when dealing with an epidemic, any country may face a temporary shortage of medical resources. Although China has a more complete industrial chain producing all kinds of medical supplies such as masks and ventilators, the per capita numbers of doctors, hospital beds and other medical facilities are definitely not large, and medical technology in China is also less developed than in the United States and Europe. Therefore, China does not have clear advantages in terms of the quantity of medical resources it had access to.

In fact, allocation efficiency of medical resources becomes more important in case of emergency, and China shows advantages in this regard. China launched the reform and opening up policy in 1978 and since then has gradually increased the role of the market in resource allocation. Unlike in the West, market-oriented reforms in China emphasize "better playing the role of the government". In the same vein, the Chinese government has played a very important role in epidemic the prevention and control. This is a special feature of China's fight against the epidemic, which demonstrated the "China speed" and "China efficiency".

The market relies on prices to deliver information that affects supply and demand,

[1] The analysis in this paper focuses mainly on the situations in the Chinese mainland and Hong Kong, while Macao and Taiwan are not included.

[2] Koch and Okamura (2020) studied real-time data of the COVID−19 outbreaks in China, Italy and the United States, and concluded that there was no data manipulation in China.

but medical resources are public goods and information that spreads in society may not be true and can even trigger panic. Therefore, it is difficult to timely and accurately allocate medical resources based on prices alone, and the government needs to base its allocation decisions on big data. In history, when facing natural disasters and pandemics such as that of influenza, some countries also opted to strengthen information control. For example, the secret police of German Democratic Republic, the Stasi, stepped up its efforts to collect information after the heavy snow in 1979 (Hilbig *et al*., 2020).

Tighter controls, however, require stronger information capacities. In terms of information technology, China is by no means stronger than European countries or the United States, clearly less developed in chip making, cloud computing and many other aspects. However, as the Chinese government, with its almost ubiquitous presence thanks to the large number of Chinese Communist Party members and volunteers, and with sufficient access to huge numbers of cameras, facial recognition devices, can obtain data almost down to the individual level, during the epidemic. The government staff keeps track of people's health conditions, residential addresses and their whereabouts very closely. Tian *et al*. (2020) finds China's confirmed cases to be 96% fewer than the expected number in the absence of interventions. Fang *et al*. (2020) concludes that the total number of COVID−19 cases would be 64.81% higher in 347 Chinese cities outside Hubei province if Wuhan had not been locked down.

The next question is how the information capacity of the Chinese government improved the allocation efficiency of medical resources. Based on China's prevention and control practices, we believe it worked in two ways. One is that the government, with the help of information, can accurately allocate public resources. At the beginning of the outbreak, medical resources were scarce and it was impossible for all patients to get tested for the virus in a timely manner because such a test took a long time, cost a lot[1] and the overall testing capacity did not allow massive testing. In such a context, and given that the novel coronavirus is highly contagious, timely isolation of all infected persons became the most urgent task (Ferguson *et al*., 2006; Cohen and Kupferschmidt, 2020). There is little doubt that social distancing—keeping people from getting physically close—can greatly reduce virus transmission but it required strong determination to find every single patient, follow up on every potential exposure and break every possible chain of transmission (Cohen and Kupferschmidt, 2020). The Chinese government can rely on neighborhood committees in urban areas and villagers' committees in rural areas to keep track of people's health and whereabouts in real time, and once anyone is found to have an abnormal body temperature, there

[1] The per capita medical cost of confirmed cases in China is RMB 23000 yuan. According to the estimates of Bethune and Korinek (2020), the cost in the United States is 80000 dollars per case, and if accurate identification is not achieved, the cost will rise to 586000 dollars per case.

are workers to immediately start checking this person's travel records, and there are measures to effectively ensure that they stay home for a quarantine of 14 days. For all these, direct access to simple and straightforward data is the foundation. It is worth mentioning that most medical institutions in China are public institutions, making it possible for the government to allocate most medical resources. Yan *et al*. (2020) reveal through a comparison between the four countries of China, France, Sweden and Japan that responses to the epidemic take four different approaches due to the different institutional arrangements and cultural backgrounds of these countries, namely Mandate, Decree, Nudge, and Boost. China features the strongest administrative power for information control and resources allocation.

The other way in which government information capacities worked for effective epidemic control is that the government can publish personalized and detailed information to guide the rational allocation of social resources. The allocation of medical resources is about direct government control over resources on the one hand, and indirect channeling of resources by the government on the other. Both are of crucial importance. Kalyanaram and Muralidharan (2011) believe that some small "nudges" from the government, social organizations and friends can improve people's disease management and prevention behaviors. American and European countries take only mild measures in this regard, which can be regarded as conservative and passive. They give the advice but implementation depends mostly on the willingness of individuals. In comparison, Chinese people accept information released by the government more readily and are more likely to follow government advice. Once they are so told, they refrain from going out unless it is absolutely necessary, wear masks and take all preventive measures suggested. Also, the information that the Chinese government obtains and releases directly benefits the prevention and control. For example, where are the ID and place of residence of the patients as well as where they work and where they have been to. Such information helps the public see potential risks around them early and allows them to take measures accordingly.

In short, China's approach to epidemic prevention and control is to obtain massive personal information and precisely allocate medical resources. While many other countries also practice e-government, China has greater control over and makes more effective use of community and personal information, and its government has greater ability to allocate medical resources accordingly, which can be quite difficult in the United States or European countries. The marginal contribution of this paper lies in the following four aspects: First, this paper examines the impact of government information capacity on epidemic prevention and control focusing on information transmission. The COVID−19 outbreak has provided us with quasi-natural experiments for this purpose. Second, it tests the effect of medical resources on epidemic prevention and control and finds that sheer quantity has no significant influence and that only improved allocation efficiency helps with the fight. Third, it observes two specific ways in which government information capacity affects the allocation of medical resources: accurate allocation of public resources based on information and guidance for rational allocation of social resources by releasing information to the public. These two aspects involve not only internal decision-making processes of the government and information release to society, but also public and social resources. Fourth, it provides references for policy making in regards to global epidemic prevention and control. According to Ferguson *et al*. (2006), prevention and control strategies used when fighting influenza are the top priority of global public health. China acted early against the COVID−19 outbreak and China's practices serve as good reference for the world.

2. Research Hypothesis

2.1. Epidemic Prevention and Control Depends on Government Information Capacity

The spread of COVID−19 in China showed several characteristics which revealed to us the necessity of government information capacity. First, it spread rapidly from Wuhan and Hubei to the whole country. Wuhan, the epicenter of the COVID−19 outbreak, is where the first case was found on December 1, 2019. From there, the infection soon spread to other parts of Hubei province. As the Spring Festival approached, a large number of migrant workers returned to their hometowns, many from or via Wuhan, an important transportation hub in China. Big data was used to trace up to five million people who left Wuhan during the Spring Festival travel rush, so as to keep them under close watch and take necessary measures such as health checks, quarantine and treatment if necessary.

Second, the epidemic hit mainly densely populated large cities where people seldom communicated with one another directly. This means data is needed to keep track of people. As of March 8, COVID−19 had gone through a full cycle of slow rise, rapid spread, gradual decline and being basically under control. Here are the results: The 12 cities in Hubei province were the Top 12 of the country by the number of confirmed cases, followed by Chongqing, Wenzhou, Beijing, Shenzhen, Guangzhou, Shanghai, Jining, Changsha, Nanchang and Harbin. It can be seen that Wuhan, Hubei, mega-cities and cities with high population mobility were the most heavily hit.

Third, panic caused a shortage of medical resources at early after the outbreak rendering health workers and hospital beds far from enough across China, especially in Hubei. The stocks of masks, ventilators and other important supplies directly related to the fight against COVID−19 was insufficient, and their prices skyrocketed. A large number of manufacturing enterprises went out of production, so not enough masks and other supplies could be produced for some time. Even if enterprises were willing to expand production because of the high prices, they could not do so due to insufficient supply of labor and raw materials. At that time, government power was important in securing supplies of urgently needed resources, in setting up a hierarchical diagnosis and treatment system based on relevant information, and precisely allocate resources to priority groups such as medical personnel and patients, as well as to hard-hit areas such as Hubei.

As the Chinese government gradually accumulated experience in the fight and improved its practices, prevention and control measures became more and more digitalized, precise and convenient for the people. In June 2020, a local outbreak occurred in Beijing. In just one day, hundreds of thousands of contacts of the patients were located through WeChat, Alipay, and travel records. It not only effectively contained the spread of the virus and kept the outbreak local, but also reduced its impact on production and business activities.

Based on the above analysis, we put forward

Hypothesis 1: Government information capacity can enhance the effectiveness of epidemic prevention and control.

2.2. Government Information Capacity Improves the Efficiency of Medical Resource Allocation

Only when a country can collect, store, retrieve and process accurately information on its population, activities and resources, can it effectively govern the society (Brambor *et al.*, 2020). Open government data and data processing capacity are a comprehensive manifestation of the administrative capacity of a government (Young, 2020).

Generally speaking, the allocation of medical resources in various countries and regions is inefficient (Roemer, 1961; Freedman, 2016; Arrow *et al.*, 2020). Therefore, improving allocation efficiency is very important during the outbreak. the COVID−19 Regional Safety Assessment released by Deep Knowledge Group, a consulting firm based in Hong Kong, China, in June 2020, evaluates and ranks the economic, social and health safety conditions of 200 countries and regions and China ranks seventh. Some European and American countries have sound medical resources and could have done better, but their actual performance was not as good as many expected. For example, the United States ranks 58th, France ranks 60th, and the United Kingdom ranks 68th. This shows that epidemic prevention and control is not only about resource endowment, but more importantly about whether the government has strong emergency management capacity and can respond promptly with effective measures.

Government information capacity improves the efficiency of public medical resource allocation. China has set up health checkpoints at entrances to communities, villages, factories, office buildings, shopping malls, bus stations and other public facilities for epidemic control. These checkpoints keep records of people’s identity, body temperature and information of their arrival and departure. With strong government information capacity, China moved beyond manual record-taking and relied instead on modern digital technology for information collection, processing, verification and application. The health code is a typical example. From January 23 to May 6, 2020, WeChat QR codes were scanned for 140 billion times. In addition, China has a real-name system for cell phone subscription, as well as for purchases of most public transportation tickets, making it easier for the government to keep track of people's whereabouts.

Based on such information, the government launched a strict triage system and allocated public resources accurately and efficiently to find out people with abnormal temperatures, track down close contacts of suspected and confirmed cases, deliver different levels of medical services to them, identify high-risk areas and people coming out of them, and keep high-risk places such as stations under close watch. Buckee *et al.* (2020) believe that effective communication of information such as population mobility and social distancing requirements can help the government understand which information or policies are the most effective. Bethune and Korinek (2020) believe that the most effective policy is to accurately identify and control infected persons. Peto (2020) finds targeted isolation based on large-scale detection can contain virus transmission sooner and more efficiently than random quarantine.

Meanwhile, the government releases information about the epidemic situation and knowledge of prevention and control to urge people to take preventiive measures on their own initiative, and guide the rational flow of prevention and control supplies in society. Government control over information has a clear impact during abnormal time periods and among special groups of people, but the government can never replace the market and social forces, and will never be able to provide medical supplies such as masks to everyone. Therefore, for epidemic prevention for the general public, it is necessary to let the market and social forces play their roles in resource allocation. In addition, after the emergency response level was lowered, the government gradually reduced its control over information and its intervention in resource allocation, allowing the market and society to play a greater role. Therefore, long-term disease prevention and control depends on the joint efforts of the government, the market and society.

Even if the market and society fully play their roles in medical resource allocation, government information capacity will still be necessary. First of all, the government plays a leading role in information release, and this is the basis for the market and enterprises to allocate medical resources. Timely provision of epidemic-related data by the government enhances early warning capacities. Second, governments disseminate knowledge about healthcare and disease prevention and control to help people develop good health habits. Kalyanaram and Muralidharan (2011) believe that some small "nudge" from the government, social organizations and friends can improve people's disease management and prevention behaviors. Aguero and Beleche (2017) find through a study of the H1N1 influenza outbreak in Mexico that public health emergencies can prompt people to acquire health knowledge and improve their health habits. Third, there may be a lot of false information and irrational actions out of panic in society, which need to be regulated by the government to prevent systemic deviations in people's behaviors.

Therefore, we propose

Hypothesis 2: Government information capacity can improve the allocation efficiency of medical resources, which is manifested in two aspects: accurate allocation of public resources based on information and guidance of rational allocation of social resources by releasing information.

3. Empirical Research Design

3.1. Identification Strategy

This paper uses 286 Chinese cities (prefecture level and above)[1] as sample cities to observe whether government information capacity enhances the effectiveness of epidemic prevention and control by improving the allocation of medical resources. The basic econometric equations are:

$$coronavirus_i = \alpha_0 + \alpha_1 egovernment_i + \lambda X + \varepsilon_i \tag{1}$$

$$coronavirus_i = \alpha_0 + \alpha_1 health + \alpha_2 health_i \times egovernment_i + \lambda X + \varepsilon_i \tag{2}$$

where *coronavirus* denotes the numbers of confirmed cases and deaths in each city, the independent variable *egovernment* denotes government information capacity. *health* is the natural logarithm of the number of doctors (*doctors*) and the natural logarithm of the number of hospital beds (*beds*), which measures the quantity of medical resources. *X* represents a series of control variables. *connection* is the connection of different cities with Wuhan. We captured hotel room reservations in Wuhan in December 2019 from trip.com using a crawler and used the data to measure the level of connection between each city and Wuhan. We also controlled the social and economic development level of each city with the following indicators: the natural logarithm of urban resident population in millions (*pop*), the natural logarithm of gross domestic production in hundred millions (*gdp*), the ratio of value-added of tertiary industry to gross domestic production (*tgdp*), the natural logarithm of fiscal income in ten thousands (*fisinc*), the natural logarithm of the number of employees engaged in health

[1] Excluding county-level cities, autonomous prefectures, Hong Kong, Macao and Taiwan.

and social work (*employees_health*), the natural logarithm of the number of college students (*college*), the ratio of export of goods to gross domestic production (*export*), the ratio of trade in goods to gross domestic production (*trade*), the natural logarithm of the number of Internet users in ten thousand households (*internet*), and the natural logarithm of revenue of telecommunication services (*tele_revenue*). The data source is *China City Statistical Yearbook 2020*.

Equation (1) tests the impact of government information capacity on epidemic prevention and control and the role of the quantity of medical resources. Since it is difficult to measure medical resource allocation efficiency directly, we do it indirectly through α_2, the coefficient of the interaction term *egovernment* × *health* in equation (2). If the coefficient is positive, the same quantity of medical resources play a greater role in epidemic prevention and control where government information capacity is higher, meaning that the efficiency of medical resource allocation increases as government information capacity grows.

3.2. Variable Definitions

3.2.1. Epidemic Prevention and Control

This paper uses the cumulative number of confirmed cases (excluding imported cases) and death tolls of all cities on the Chinese mainland from December 2019 to March 8, 2020, to represent epidemic prevention and control performance. There are four more specific indicators: the ratio of cumulative confirmed cases to local population (*patient1*), the absolute number of cumulative confirmed cases (*patient2*), the natural logarithm of cumulative confirmed cases (*patient3*) and the death toll per 10000 people (*toll*).

3.2.2. Government Information Capacity

Government information capacity in China is mainly about information disclosure, information collection and information-based online services. Therefore, the aforementioned factors are all to be considered when measuring the government information capacity of each city. We use the number of information disclosure entries on government websites, government microblog competitiveness, financial transparency and some other indicators to score the government information capacity of each city (*egovernment*).

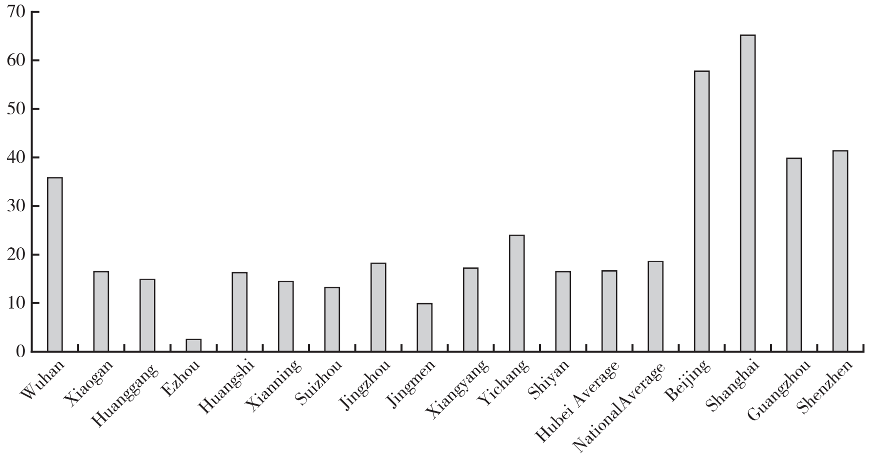

Figure 1. Government Information Capacity of the 12 Cities in Hubei and First-Tier Cities of China

3.3. Descriptive Statistics

The descriptive statistics of the main variables used in this paper are reported in Table 1. As of March 8, the average number of confirmed cases was 274, or 0.41 per 10000 people, death toll per 10000 people was 0.014, the average government information capacity score is 0.186, relatively low since the highest possible score is 1. See the table below.

Table 1. Descriptive Statistics of the Main Variables

Variable	Obs	Mean	Std. Dev	Min	Max
patient1	286	0.4101	2.8518	0	45.0429
patient2	286	274.0839	2964.1350	0	49912
patient3	286	3.2177	1.5687	0	10.8180
toll	286	0.0142	0.1321	0	2.1388
egovernment	286	0.1855	0.1068	0	1
doctors	286	8.9654	0.7437	6.7616	11.4010
beds	286	9.7778	0.7141	7.3550	12.0862
connection	285	0.3360	1.0456	0.0010	11.1080
pop	286	5.9093	0.6858	3.2268	8.0397
gdp	286	7.4155	0.9219	5.0331	10.2463
tgdp	285	42.7997	8.4816	26.1200	80.2300
fisinc	286	14.0540	1.0525	11.8526	17.9754
employees_health	285	10.0038	0.7381	7.6212	12.5888
college	279	10.6025	1.3004	7.3846	13.8712

Variable	Obs	Mean	Std. Dev	Min	Max
export	284	0.1297	0.3556	0.0000	4.4188
trade	283	0.2260	0.5891	0.0000	6.7594
internet	282	4.2762	0.8487	2.0794	6.7441
tele_revenue	282	12.5221	0.9490	9.6768	16.4520
post_offices	284	0.4303	0.2391	0.0811	1.9758
age	285	56.0316	2.6582	48	65
tenture	285	2.7930	1.5391	0	8
employees_public	285	10.7072	0.5985	8.7284	13.0781
rank	286	0.1189	0.3242	0	1

In order to give an intuitive depiction of the connection between government information capacity and epidemic prevention and control, we constructed the new indicator of *patient2/connection*, which roughly represented the actual effectiveness of epidemic prevention and control of each city excluding the objective influence of economic and social ties. the results of the Top 10 (excluding cities with zero infection) and the Bottom 10 cities (excluding cities in Hubei) are presented below. In Figure 2, the left part (from Leshan to Suzhou) is the Bottom 10 cities while the right part (from Hechi to Qitaihe) is the Top 10 cities. It is obvious that cities on the left have a significantly higher government information capacity, while those on the right have relatively low capacities. This indicates that cities with better performance in epidemic prevention and control have higher information capacity while those delivering poor prevention and control performance have lower capacity. This is only a relatively rough presentation, and more detailed measurement test will be carried out below.

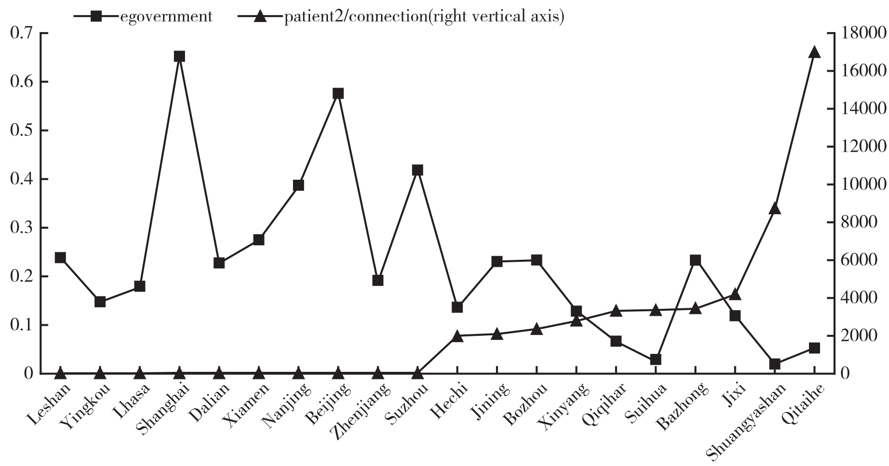

Figure 2. Connection between Epidemic Prevention and Control and Information Capacity

4. Analysis of Empirical Results

4.1. Basic Results

Epidemic prevention and control performance is regressed on government information capacity, and the results are reported in Table 2. The coefficient is significantly negative no matter which indicator is used. In addition, there is a great economic significance. For example, as shown in column (2), for every 0.1 point of increase in government information capacity, the number of confirmed cases reduce by 63.1 and in column (4), for every 0.1 point of increase in government information capacity, the death toll per 10000 people reduce by 0.008, more than half of the mean (0.014). This is consistent with the conclusions of Acemouglu and Johnson (2007). Using cross-border data, they found that intervention of epidemic prevention and control policies could significantly reduce the mortality rate.

The number of doctors and the number of hospital beds, two variables indicating the quantity of medical resources available, were tested, but the coefficients were not significant, indicating no causal relationship between the quantity of medical resources and the numbers of confirmed cases and deaths. The results may seem counterintuitive, but a closer look at what happened in the real world will prove this true. In Beijing, Shanghai and other areas with more medical resources, the numbers of confirmed cases and deaths are no lower than those in other areas. Therefore, the quantity of medical resources does not significantly enhance prevention and control effectiveness. This is probably because the time required for vaccine development and the rapid spread of the virus reduced the effect of traditional medical resources.

Table 2. Impact of Government Information Capacity on Epidemic Prevention and Control

	(1)	(2)	(3)	(4)
	patient1	*patient2*	*patient3*	*toll*
egovernment	−2.2315*	−665.3497**	3.4311***	−0.0794*
	(1.1669)	(299.9615)	(0.9362)	(0.0451)
doctors	−0.1619	35.33	0.0354	−0.0059
	(0.3177)	(57.4632)	(0.3870)	(0.0123)
beds	0.0335	0.4277	0.2408	0.0021
	(0.1799)	(72.5365)	(0.3517)	(0.0064)
connection	0.3606**	144.6948***	0.4365***	0.0125**
	(0.1522)	(53.9113)	(0.1597)	(0.0055)
pop	−0.3941*	−45.5424	0.2876	0.0133
	(0.2327)	(49.1234)	(0.2924)	(0.0088)
gdp	−0.0709	−126.9438	−0.5741*	0.0006
	(0.2679)	(86.5388)	(0.2977)	(0.0099)
tgdp	−0.0326***	−11.0261***	−0.0475***	−0.0011***
	(0.0111)	(3.8477)	(0.0123)	(0.0004)
fisinc	0.2006	100.3972*	0.8131***	0.0055
	(0.1628)	(57.0484)	(0.2283)	(0.0058)

	(1)	(2)	(3)	(4)
	patient1	*patient2*	*patient3*	*toll*
employees_health	0.4024** (0.1859)	147.6891** (70.0510)	0.6051** (0.2767)	0.0118* (0.0067)
college	0.0811 (0.0909)	10.0546 (19.5594)	0.1514 (0.1065)	0.0028 (0.0034)
export	1.1866** (0.5191)	430.0595*** (156.8548)	1.5392 (0.9640)	0.0376** (0.0184)
trade	−0.8093** (0.3423)	−290.3697*** (101.7832)	0.9745* (0.5888)	−0.0260** (0.0123)
internet	0.0027 (0.0890)	7.2004 (31.0699)	0.0735 (0.1935)	−0.0005 (0.0031)
tele_revenue	−0.1431** (0.0698)	−54.9669** (25.8375)	−0.2312* (0.1318)	−0.0045* (0.0025)
cons	0.0252 (1.7808)	782.4491 (528.8551)	−10.8873*** (2.3497)	0.0149 (0.0647)
N	268	268	268	268
R^2	0.1175	0.1715	0.4777	0.1025

Notes: Robust standard error reported in the parentheses. *p<0.1, **p<0.05, ***p<0.01.

4.2. Endogeneity Discussion

Since COVID−19 is an emergency that had never occurred before and a quasi-natural experiment, it is highly exogenous. The spread of the virus is basically not affected by national, provincial, ethnic, cultural or economic conditions. This does not rule out endogeneity completely, though.

4.2.1. Instrumental Variables

We use the number of post offices per 10000 people (*post_offices*) as the instrumental variable of government information capacity. In China, post offices are often set up at economic and social centers in cities according to population distribution and people’s needs. Also, the post services have a strong public welfare nature and post office distribution overlaps with the distribution of sub-district offices, community management committees and other basic-level government bodies. Generally, where there is a high number of post offices, the government is likely to have stronger control capacity. In addition, the post services in China were originally part of the telecommunications industry. Places with more post offices also have more telecommunications outlets, and infrastructure is likely to be sufficient for government informatization. Ploeckl (2015) used postal data (mail, telegraph, parcels and bills) for a region’s information intensity, which represented the local density of information exchanges. Therefore, the number of post offices is related to government information capacity, but not directly related to epidemic prevention and control. Moreover, Internet access and telecommunications revenues are also controlled in our empirical analysis, so the number of post offices is not likely to influence epidemic prevention and control through other variables, thus ensuring its exogeneity.

Results are shown in Table 3. With the use of instrumental variables, the coefficients of the number of confirmed cases and the number of deaths were basically significantly negative, and rising, indicating that government information capacity can indeed contribute to epidemic prevention and control. Moreover, the F value of regression results in the first stage is large, which ensures correlation between the instrumental variables and government information capacity.

Table 3. 2SLS Regression of Instrumental Variables

	(1) *patient1*	(2) *patient2*	(3) *patient3*	(4) *toll*
egovernment	−22.3645* (11.8532)	−6071.3870* (3140.8870)	−21.5743** (10.5549)	−0.7780* (0.4304)
Control Variable	yes	yes	yes	yes
N	266	266	266	266
F Value (First Stage)	21.35	21.35	21.35	21.35
Kleibergen-Paap rk Wald F tonttongtongjiltongjistatistic	28.76	28.76	28.76	28.76
Hansen J	0.2018	0.1090	0.1151	0.2434

Notes: Robust standard error reported in the parentheses. "yes" means related variables controlled. **p*<0.1, ***p*<0.05, ****p*<0.01.

4.2.2. Elimination of the Interference of Government Official Characteristics, Public Staff Size and City Rank

Government information capacity is an important aspect of government control capacity, but the latter also includes other aspects such as government official characteristics, public staff size and city rank. Therefore, we need to rule out other possible explanations for the results above.

For epidemic prevention and control, China did not only rely on digital technology, but also mobilize massive manpower, mainly local officials and government employees. In China, Party secretary is the top leader of a city and we found most of them to be male with only 9 female, and 84% to have college degrees, showing no significant difference between cities. However, the age and tenure of Party secretaries show greater differences, so we controlled them in the regressions. At the same time, we used the natural logarithm of the number of government and social organization employees (*employees_public*) to represent public staff size.

Moreover, cities in China have different administrative ranks: municipalities, sub-provincial, provincial, and prefecture-level cities. Cities of different ranks can mobilize different quantities of administrative resources, so those of higher ranks may show higher governance capacity, which may have nothing to do with government informatization. This may interfere with the research conclusions. For this, we controlled city rank (*rank*), giving the value zero to prefecture-level cities and 1 to all other cities.

Results are shown in Table 4. The *age* and *tenure* of Party secretaries have no significant impact on epidemic prevention and control, while public staff size can indeed reduce the numbers of confirmed cases and deaths. The impact of city rank is not significant. The coefficient of government informatization is still significantly negative, indicating that after excluding the interference of government official characteristics, public staff size and city rank, the basic conclusions of this paper remain.

Table 4. Elimination of the Impact of Government Official Characteristics, Public Staff Size and City Rank on Epidemic Prevention and Control

	(1)	(2)	(3)	(4)
	patient1	*patient2*	*patient3*	*toll*
egovernment	−1.6957*	475.6625**	−2.9122***	−0.0603
	(0.9810)	(224.1273)	(0.8748)	(0.0382)
age	−0.0143	−2.6347	−0.0194	0.0005
	(0.0146)	(4.2134)	(0.0243)	(0.0005)
tenture	0.0052	10.8180	−0.0094	0.0007
	(0.0348)	(19.5966)	(0.0504)	(0.0014)
employees_public	−0.8047*	139.5178**	−0.9470***	−0.0290*
	(0.4233)	(69.5658)	(0.3375)	(0.0160)
rank	−0.1470	−65.0674	−0.3165	−0.0043
	(0.1413)	(51.8952)	(0.2583)	(0.0049)
Control Variable	yes	yes	yes	yes
N	268	268	268	268
R^2	0.1427	0.2067	0.5049	0.1247

Notes: Robust standard error reported in the parentheses. "Yes" means related variables controlled. *p<0.1, **p<0.05, ***p<0.01.

5. Government Information Capacity and Medical Resource Allocation Efficiency

5.1. Information-Based Decision-Making Improves the Efficiency of the Public Resources Allocation

We can take a rough look at resource allocation efficiency based on the results of epidemic prevention and control. Table 5 show results of tests of the allocation efficiency of doctors and hospital beds respectively.

The direct influence of the numbers of doctors and beds is not significant, which is consistent with the above results. However, the interaction terms between them and government information capacity see coefficients significantly negative, indicating that the number of confirmed cases and the number of deaths reduce significantly when medical resources are precisely allocated based on information. Moreover, the stronger the government information capacity, the greater the coefficients of the interaction terms. This proves that the government's move to allocate medical resources based on information can indeed improve prevention and control effectiveness.

Table 5. Government Information Capacity and the Allocation Efficiency of Public Medical Resources

	(1)	(2)	(3)	(4)
	patient1	*patient2*	*patient3*	*toll*
Panal A: allocation efficiency of doctors				
doctors	0.0246 (0.2395)	61.9799 (54.1501)	0.3137 (0.4088)	0.0005 (0.0092)
doctors×egovernment	−0.1752* (0.0915)	53.2368** (24.9989)	−0.3119*** (0.1008)	−0.0061* (0.0035)
Panal B: allocation efficiency of hospital beds				
beds	0.1324 (0.1343)	53.1932 (50.6214)	0.3146 (0.3559)	0.0057 (0.0047)
beds×egovernment	−0.1640* (0.0873)	48.9941** (23.0195)	−0.2902*** (0.0936)	−0.0057* (0.0034)
Control Variable	yes	yes	yes	yes
N	267	267	267	267

Notes: Robust standard error reported in the parentheses. "yes" means related variables controlled. *p<0.1, **p<0.05, ***p<0.01.

5.2. Government Information Release Guides the Public to Protect Themselves

In the information age, control over people can only be based on abstract information, but the accuracy of information and the implementation of relevant policies depend on how cooperative people are out of their own initiative. Gelfand *et al*. (2011) believe that China, Japan, South Korea, Singapore and other East Asian countries have tight societies, where the collective has a strong binding force on individuals; Europe and America have loose societies, where governments have weak control over individuals.

Therefore, government information capacity is not only about how much information is obtained, but also about whether information is effectively conveyed to and accepted by the public, as well as how much they act in accordance. An excellent reflection of this is the number of masks people buy. People's spontaneous prevention and control behaviors are somewhat predictable. When they received information from the government about the epidemic, they started buying masks and other protective supplies in large quantities. With crawlers, we obtained data on daily mask sales by province in January 2020. There are three indicators for mask sales, respectively for disposable medical masks (*pcmask*), other masks (*wisemask*) and all masks (*allmask*), all used as explained variables to make time break point regression.

When testing the impact of government information release on the allocation of social medical resources, we use daily mask sales before and after January 21 to do a regression. This date is when the central government of China launched the large national publicity campaign against the epidemic. The regression results show a surge in the number of masks purchased on January 21. As supply of disposable medical masks was depleted on January 22, sales of dust masks, cotton masks and other masks imported from abroad, such as N90 and N95, surged and then stabilized. This proves that government information release actually guided the behavior of individuals and thus the allocation of medical resources in society.

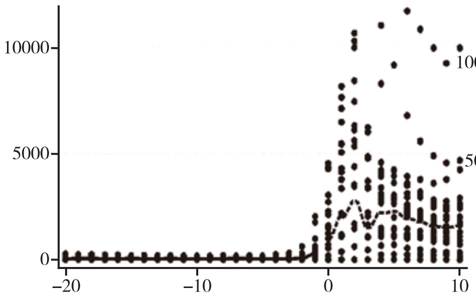

Figure 3. Changes in Sales of *allmask* in Different Regions Before and After January 21

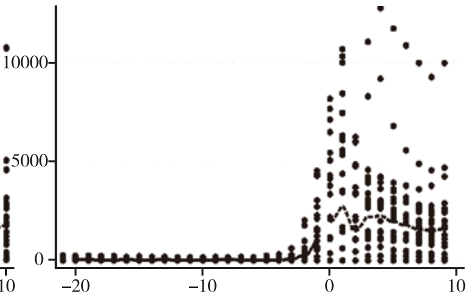

Figure 4. Changes in Sales of *allmask* in Different Regions Before and After January 21

Table 6. Breakpoint Regression Estimate Results

	(1) *pcmask*	(2) *wisemask*	(3) *allmask*
Panal A: January 21 is the break point, 3 days window period			
date	184.1516*** (42.3338)	1148.551*** (231.2789)	1329.945*** (274.9277)
Panal B: January 21 is the break point, 5 days window period			
date	184.1516*** (42.3338)	1148.551*** (231.2789)	1329.945*** (274.9277)
Panal C: January 22 is the break point, 3 days window period			
date	38.4044 (71.7957)	1322.219*** (340.8681)	1371.329*** (401.7598)
Panal D: January 22 is the break point, 5 days window period			
date	38.4044 (71.7957)	1322.219*** (340.8681)	1371.329*** (401.7598)

Notes: Robust standard error reported in the parentheses. "yes" means related variables controlled. **p*<0.1, ***p*<0.05, ****p*<0.01.

6. Conclusions

Based on this quasi-natural experiment of the COVID−19 epidemic, we examined the impact of government information capacity and medical resource allocation on epidemic prevention and control in 286 Chinese cities (prefecture-level and above). The findings are as follows: (1) Government information capacity can improve the effectiveness of prevention and control. For every 0.1 point of increase in government information capacity, the number of confirmed cases reduce by 63.1, and deaths per 10,000 people reduce by 0.008. (2) The sheer quantity of medical resources has no significant impact on epidemic prevention and control, but the allocation efficiency can improve the effectiveness of prevention and control. (3) The government can make decisions concerning the allocation of public resources based on information and release information to the public to guide the flow of social resources, both of which can improve the allocation efficiency of medical resources.

The COVID–19 epidemic is global, long, recurrent and irreversible. In the process of epidemic prevention and control, the top priority is to identify and isolate patients in a timely manner, disseminate information, and formulate targeted prevention and control policies based on information, which requires high government information capacity. COVID–19 broke out in China early and the situation was taken under control soon. Some of China's practices, therefore, can provide useful reference for global prevention and control efforts.

References

Acemoglu, D., & Johnson, S. (2007). Disease and Development: The Effect of Life Expectancy on Economic Growth. *Journal of Political Economy*, 115(6), 925–985.

Aguero, J. M., & Beleche, T. (2017). Health Shocks and Their Long-Lasting Impact on Health Behaviors: Evidence from the 2009 H1N1 Pandemic in Mexico. *Journal of Health Economics*, 54(6),40–55.

Arrow, K. J., Bilir, L. K., & Sorensen, A. (2020). The Impact of Information Technology on the Diffusion of New Pharmaceuticals. *American Economic Journal: Applied Economics*, 12(3), 1–39.

Bethune, Z. A., & Korinek, A. (2020). Covid–19 Infection Externalities: Trading Off Lives vs. Livelihoods. NBER Working Paper No. 27009.

Brambor, T., Goenaga, A., Lindvall, J., & Teorell, J. (2020). The Lay of the Land: Information Capacity and the Modern State. *Comparative Political Studies*, 53(2), 175–213.

Buckee, C. O., Balsari, S., Chan, J., et al. (2020). Aggregated Mobility Data Could Help Fight COVID–19. *Science*, 368(6487), 145–146.

Cohen, J., & Kupferschmidt, K. (2020). Countries Test Tactics in "War" Against COVID–19. *Science*, 367(6484),1287–1288.

Dixit, A., & Londregan, J. (1995). Redistributive Politics and Economic Efficiency. *American Political Science Review*, 89(4), 856–866.

Ebenstein, A. (2010). The "Missing Girls" of China and the Unintended Consequences of the One Child Policy. *Journal of Human Resources*, 45 (1), 87–115.

Fang, H., Wang, L., & Yang, Y. (2020). Human Mobility Restrictions and the Spread of the Novel Coronavirus (2019-nCoV) in China. NBER Working Paper No. 26906.

Ferguson, N., Cummings, D., Fraser, C., Cajka, J., Cooley, P., & Burke, D. (2006). Strategies for Mitigating an Influenza Pandemic. *Nature*, 442(7101), 448–52.

Freedman, S. (2016). Capacity and Utilization in Health Care: The Effect of Empty Beds on Neonatal Intensive Care Admission. *American Economic Journal: Economic Policy*, 8(2), 154–185.

Gelfand, M. J., Raver, J. L., Nishii, L., et al. (2011). Differences between Tight and Loose Cultures: A 33-nation Study. *Science*, 332(6033), 1100–1104.

Hilbig, H., Hans, L., & Sascha, R. (2020). Information Gathering in Authoritarian Regimes: Evidence from a Natural Disaster in the GDR. Working Paper.

Jia, J., Lu, X., Yuan, Y., Xu, G., Jia, J., & Christakis, N. (2020). Population Flow Drives Spatio-Temporal Distribution of COVID–19 in China. *Nature*, 582(7812), 389–394.

Kalyanaram, G., & Muralidharan, S. (2011). Nudge: Improving Decisions about Health, Wealth, and Happiness. *International Journal of Pharmaceutical and Healthcare Marketing*, 5(4), 349–352.

Li, R., Pei, S., Chen, B., Song, Y., Zhang, T., Yang, W., & Shaman, J. (2020). Substantial Undocumented Infection Facilitates the Rapid Dissemination of Novel Coronavirus (SARS-CoV2). *Science*, 368(6490), 489–493.

Pan, A., Liu, L., Wang, C., et al. (2020). Association of Public Health Interventions with the Epidemiology of the COVID–19 Outbreak in Wuhan, China. *Journal of the American Medical Association*, 323(19), 1915–1923.

Peto, J. (2020). How to Ramp up COVID–19 Mass Testing Immediately in the UK. *Financial Times*, 31 March.

Ploeckl, F. (2015). It's All in the Mail: The Economic Geography of the German Empire. University of Adelaide School of Economics Working Paper No. 2015–12.

Qiu, Y., Chen, X., & Shi, W. (2020). Impacts of Social and Economic Factors on the Transmission of Coronavirus Disease 2019 (COVID–19) in China. *Journal of Population Economics*, 33, 1127–1172.

Roemer, M. I. (1961). Bed Supply and Utilization: A Natural Experiment. *Hospitals*, 35 (22), 36–42.

Tian, H., Liu, Y., Li, Y., et al. (2020). An Investigation of Transmission Control Measures During the First 50 Days of the COVID–19 Epidemic in China. *Science*, 368(6491), 638–642.

Yan, B., Zhang, X., Wu, L., Zhu, H., & Chen, B. (2020). Why Do Countries Respond Differently to COVID–19? A Comparative Study of Sweden, China, France, and Japan. *American Review of Public Administration*, 50(6–7), 762–769.

Young, M. M. (2020). Implementation of Digital-Era Governance: The Case of Open Data in U.S. Cities. *Public Administration Review*, 80(2), 305–315.