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# The role of vaccines in COVID-19 control strategies in Singapore and China

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## ARTICLE INFO

### Keywords:

Living with COVID  
 COVID-zero strategy  
 Vaccine rollouts  
 Population density  
 Domestic vaccine production capacity

## ABSTRACT

**Objectives:** In this article, we critically review the development and implementation of COVID-19 vaccination in Singapore and China during the pandemic.

**Methods:** We collect and analyze data from a range of sources, including scholarly articles, statistics and documents from national governments in the two countries, and reports from international organizations.

**Results:** There are important differences in the two countries' approaches to the evolving pandemic, and thus the roles that COVID-19 vaccination plays in the overall response strategies in these two countries.

**Conclusions:** Whereas Singapore adopted a "living with the virus" strategy, China continued to pursue a COVID-zero strategy. The overall COVID-19 response strategy of Singapore was largely shared by many countries in the world, while that of China was more unique and hardly imitated elsewhere. Nevertheless, vaccination played a significant role in both countries' responses to the pandemic. A comparison and contrast between the vaccination processes in these two countries thus shed important light on the drivers and outcomes of COVID-19 vaccination in different settings.

## Introduction

Two Asian countries—Singapore and China— have acted swiftly to roll out COVID-19 vaccines among their populations despite distinctions in their overall COVID-19 response strategies.<sup>1</sup> Singapore was one of the first countries in Asia to begin its vaccine rollout campaign in December 2020. According to the Singaporean Ministry of Health (MOH), 82% of the country's population had been fully vaccinated by the time of this writing (1 October 2021), one of the highest vaccination rates in the world [1]. China's vaccine rollout commenced even earlier, in the middle of 2020 [2], largely thanks to its ability to develop and produce COVID-19 vaccines domestically. By the end of September 2021, the cumulative number of COVID-19 vaccines administered reached more than 2.2 billion doses in China, with more than 70% of the population fully vaccinated [2]. Vaccines produced in China not only met the domestic demand but also were distributed internationally,

including to Singapore [3]. Meanwhile, both countries continued to impose other preventive measures, such as lockdowns, social distancing, and border controls, although the level of stringency in COVID-related policies differs between these two countries.<sup>2</sup>

However, there were important differences in the two countries' approaches to the evolving pandemic, especially during their respective recent outbreaks. These differences were in part due to the differences in their demographic, economic, and political environments. With a small population (5.7 million), good access to vaccines, and a largely export-oriented economy, Singapore adopted a "co-existence" or "living with COVID" strategy with the aim of reopening the economy on the wings of its high vaccination rate. Therefore, Singapore placed paramount importance on vaccination over all other control measures. However, China continued to implement a COVID-Zero strategy. In China, the vaccine rollout, although still viewed as a high priority, was complemented with other strong controls during recent outbreaks in several

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<sup>1</sup> The article is based on data up to the end of September 2021 and thus does not cover the development afterwards such as that caused by the Omicron variant.

<sup>2</sup> For example, the level of stringency in COVID-related policies can be measured by the Oxford stringency index which is a composite measure based on nine response indicators, such as school closures, workplace closures, and travel bans. According to this index, China and Singapore reached average stringency levels of 71.54 and 50.71 respectively over the period between 21 Jan. 2020 and 1 Oct. 2021. For comparison, the average stringency indices of France, Germany, Japan, Russia, the UK and the US were estimated to be 59.08, 62.17, 50.53, 41.02, 55.46, 61.32, and 50.53 over the same period. (<https://www.bsg.ox.ac.uk/research/research-projects/covid-19-government-response-tracker>). We thank one of the reviewers for suggesting the Oxford stringency index as a measure of the level of stringency in COVID-related policies in different countries.

cities and regions.

In this article, we critically review the development and implementation of COVID-19 vaccination in Singapore and China during the pandemic. We focus on Singapore and China in this article because these two countries have very different demographic, political, and economic contexts, which have led to distinctive COVID-19 mitigation strategies. Yet, both countries considered vaccination a critical means to combat the pandemic and have strived to promote COVID-19 vaccination among their populations. A comparison and contrast between the vaccination processes in these two countries thus shed important light on the drivers and outcomes of COVID-19 vaccination in different settings. In this article, we collect and analyze data from a range of sources, including scholarly articles, statistics and documents from national governments in the two countries, and reports from international organizations. Since this is a rapidly evolving phenomenon, we also engage the gray literature in our review and analysis, including company reports, news reports and online information. We use multiple sources of data to verify information in a triangulation process.<sup>3</sup>

In the following sections, we first provide an overview of the contexts of Singapore and China, outlining their differences in several important demographic, political and economic dimensions. We then review the pre-vaccine and ongoing COVID-19 mitigation strategies in these two countries, with a focus on the rollout process and the effects of COVID-19 vaccination in both countries. Since China is one of the few countries in the world that produces and exports COVID-19 vaccines, we also discuss the country's vaccine development and export. We then explore the interplay between vaccination and other pandemic response measures. We end this article with a discussion comparing and contrasting between the COVID-19 vaccination in the two countries based on information up to 30 September 2021.

### The contexts of Singapore and China

Singapore is one of the most densely populated nations, with 7,953 people per square kilometer of land area [4]. Its economy is also one of the most open in the world, with ratios of exports and imports of goods and services to the gross domestic product reaching 174% and 146% in 2019 [5]. Due to the border control and lockdown measures introduced amid the COVID-19 pandemic, Singapore's gross domestic product fell by 5.4% in fiscal year 2020, the worst-ever economic recession in the country [6]. The tourism industry, a pillar industry in Singapore, shrank about 6 times more in 2020 than in 2019 [7]. Revenue from shopping, accommodations, food and beverage, sightseeing, entertainment and gaming, and other related industries also declined by about 80% in 2020 [7]. The health system in Singapore is relatively robust, though. The number of ICU beds per 100,000 people in Singapore (5.89) is relatively low, compared with those in other developed countries, such as Germany (33.9) and the US (25.8) [8]. However, the COVID-19 death rate in Singapore was among the world's lowest, at 0.1% as of 1 October 2021 [1].

China had a population of more than 1.4 billion in 2019, with an average population density of 149 people per square kilometer of land area [4]. However, there is considerable disparity across regions, with a vast majority of people living in East and Central China, resulting in a

high level of population density in these areas [9]. China relies less on the international trade for its national economy than an export-oriented economy like Singapore, with the ratios of exports and imports to the gross domestic product being 18.50% and 17.34% in 2019 respectively [10]. In recent years, domestic consumer spending has played an increasingly important role in its national economy, contributing 57.8% of the GDP growth in 2019, compared to 35.3% in 2008 [11]. Politically, the single-party system in China has enabled the government to centralize decision making and mobilize resources. Finally, the capacity of the health system in China is less abundant than those in developed countries. For example, there were just 3.6 ICU beds in every 100,000 people in China in 2020 [12].

### The COVID-19 pandemic in Singapore and China and Pre-vaccine responses

Table 1 summarizes the COVID-19 epidemiological situation in Singapore and China by the end of September 2021.

Singapore confirmed its first case of COVID-19 in January 2020 [1]. In March 2020, local clusters of COVID-19 started to emerge when Singaporeans residing overseas were encouraged to return home. In early April 2020, the return of these Singaporeans led to a significant spike in the number of cases of imported COVID-19 (Fig. 1 in the section "COVID-19 Vaccine Rollouts in Singapore and China" below) [1]. After the first lockdown in late April, the bulk of the cases shifted from imported cases to local clusters among migrant workers. In May 2020, daily cases of COVID-19 reached a peak, with about 500 daily new cases reported. About one fifth of Singapore's population are migrant workers. Many of them lived in dormitories, living conditions ideal for the spread of a virus [1]. The preventive measures and vaccination that Singapore Government conducted, including COVID-19 tests for all migrant workers in dormitories, had worked well in controlling the spread of the virus until September 2021, when the Delta variant emerged. The Delta variant drastically increased the case number to an average of 900 daily cases in September 2021 (Fig. 1) [1]. As of 1 October 2021, there were 99,430 confirmed cases of COVID-19 in Singapore accounting for 1.7% of the total population. Among those, 34 required ICU care, and the country recorded 103 deaths related to COVID-19 as of 1 Oct. 2021. Of the COVID-19 cases, 5.4% were imported, 34% were locally transmitted, and 60.5% were clusters among permanent residents or visitors residing in dormitories [1].

Drawing on experience with the severe acute respiratory syndrome (SARS) epidemic in 2003 and the influenza virus (H1N1) pandemic in 2009, the Singaporean government promptly instituted public health and containment measures to respond to the COVID-19 pandemic [1]. In the initial stage, Singapore predominantly relied on its primary health care network, where general practitioner (GP) clinics were the first point of contact for most patients [1]. Then the MOH promptly set up a testing operations center to mobilize laboratories with COVID-19 testing capacity [13]. As the number of COVID-19 cases increased, Singapore issued the COVID-19 (Temporary Measures) Act 2020 in April 2020. This act, together with the existing Infectious Diseases Act and Immigration Act, provided the government with considerable executive power to introduce and enforce a range of administrative measures to deal with the COVID-19 outbreak [1]. Lockdowns and border controls were implemented to reduce the transmission of COVID-19 to and within Singapore. For example, after clusters were identified among migrant workers, the Singaporean government quarantined 20,000 migrant workers in several dormitories to control the virus among this population [1]. After the prompt implementation of a series of government controls, the number of cases gradually fell to the single digits in September 2020 [1].

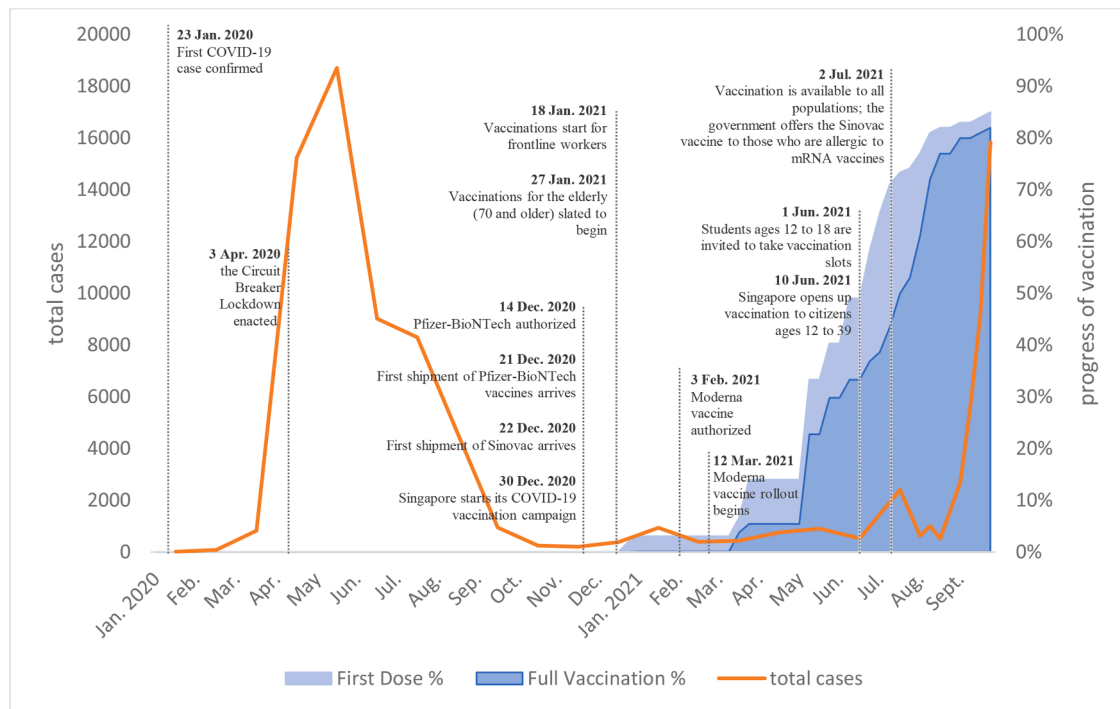
The first country to report the COVID-19 outbreak, China reported a total of 96,162 cases of COVID-19 up to September 30 2021, with the largest spike in February 2020 [2]. China decided to close its international border on 28 March 2020 [2]. Since March 2020 up to the time of

<sup>3</sup> There has been criticism over the transparency of COVID-19 data from China in Western media (e.g. <https://www.forbes.com/sites/georgecalhoun/2022/01/17/chinas-manipulation-of-covid-data-the-two-smoking-guns/?sh=b43570b32f3e>). Access to trial data and documents in public domain in relation to Chinese COVID-19 vaccines, including those that have been most widely used such as Sinovac and Sinopharm, also seems to be limited (e.g. Tanveer, S., Rowhani-Farid, A., Hong, K., Jefferson, T., & Doshi, P. (2021). *Transparency of COVID-19 vaccine trials: decisions without data. BMJ evidence-based medicine*). In this article, we have utilized both English- and Chinese language sources to search, collect and verify the information.

**Table 1**  
The COVID-19 Pandemic in Singapore and China up to 30 September 2021.

Country	Total cases	Total deaths	Total recovered	Active Cases	ICU cases	Total Covid-19 Cases/ Million population	Covid-19 related deaths / Million population	Total tests (million)	Tests ('000)/ million population	Population (million)
China	96,162	4636	90,634	892	4	66.8	3.22	160	111	1439
Singapore	96,521	95	78,174	18,252	34	16,975.2	16.71	NA*	NA*	5.686

Sources of data: nhc.gov.cn and moh.gov.sg. \*The number of tests in Singapore up to 30 September 2021 was not disclosed by the government.



**Fig. 1.** Milestones of the COVID-19 pandemic and vaccination in Singapore.

this writing, the epidemic was controlled in China despite small-scale outbreaks in specific cities or regions [2]. Since its major outbreak, China has implemented a range of measures to control the raging virus. For example, the Chinese city of Wuhan entered a stringent 76-day lockdown beginning 23 January 2020 [14]. Two dedicated hospitals were rapidly built in Wuhan to receive and treat COVID-19 patients [14]. China increased its public health threat status to the highest level during the initial stage of the outbreak [2].

China had no large-scale outbreaks of COVID-19 since March 2020 and has since implemented a COVID-Zero strategy [2]. A number of stringent measures were taken to support this strategy, including extensive COVID-19 testing and contact tracing, mask wearing, social distancing, frequent hand washing, and ventilation [2]. If anything, China’s nucleic acid testing such as polymerase chain reaction (PCR) has even been tightened recently. These measures were observed in recent COVID-19 outbreaks in regions and cities such as Guangzhou [15] and Nanjing [16]. In both cases, the government took a stringent approach to containment. For example, COVID-19 tests were required of all citizens in the cities, and rigid travel and social restrictions were imposed. In Nanjing, for example, five rounds of nucleic acid testing were carried out from 21 July 2021 to 6 August 2021, with a total of more than 36 million tests taken by 9 million citizens in the city [17].

**Supplies of vaccines in Singapore and China**

Singapore was the first nation in Asia to receive the Pfizer-BioNTech COVID-19 vaccine and started its vaccination campaign in December

2020 [18]. Despite an initial shortage in early 2021, a supply of vaccines progressively became available, especially when the Moderna vaccine was rolled out in March 2021 [1]. In December 2020, the Singaporean government allocated more than \$1 billion Singaporean dollars (US \$750 million) for vaccines [19]. As of this writing, two mRNA vaccines, Pfizer-BioNTech and Moderna, have been approved for use in Singapore and included in its national vaccination program. Individuals can choose which of the two vaccines they prefer [1]. Meanwhile, the Sinovac vaccine, an inactivated vaccine technology produced by China, was permitted at more than 20 private health care clinics under the Special Access Route following the World Health Organization’s emergency use listing [1]. The Singapore MOH reported a lower efficacy rate for the Sinovac vaccine (about 51%) compared to Pfizer-BioNTech’s and Moderna’s approved mRNA vaccines (about 90%) [1]. Partly for this reason, Sinovac has only been provided to specific groups in the population, such as those who are unable to receive mRNA vaccines for medical reasons. As of 1 October 2021, a total of 200,358 Sinovac vaccines had been administered in Singapore to 102,915 individuals [1].

China is in a different position from Singapore in terms of vaccine supply. China is one of the few countries in the world that has developed and produced COVID-19 vaccines. Shortly after the start of the COVID-19 pandemic in Wuhan, the Ministry of Science and Technology of China initiated emergency response research and sponsored 12 COVID-19 vaccine candidates based on five different technologies: inactivated vaccines, adenovirus vector vaccines, recombinant protein vaccines, nucleic acid vaccines, and attenuated influenza vaccines [20]. On 12 April 2020, the world’s first inactivated COVID-19 vaccine, developed

by the Wuhan Institute of Biological Products (WIBP), entered phase I and II clinical trials [21]. Soon afterward, a vaccine developed by the Beijing Institute of Biological Products (BBIBP) began phase I and II clinical trials on 27 April 2020 [21]. In July 2020, Sinopharm started its phase III trial in the United Arab Emirates [21]. One week later, WIBP's vaccine received emergent approval to conduct a phase III trial from the United Arab Emirates [21].

Because China has not experienced any major COVID-19 outbreaks since mid-2020, phase III clinical trials of many Chinese vaccines were carried out abroad [22]. For example, phase III clinical trials of China National Biotec Group's BBIBP-CorV and WIBP-CorV vaccines were undertaken in the United Arab Emirates, Jordan, Peru, Argentina, and Egypt in 2020 [21]. Across 125 nations, more than 60,000 participants enrolled in trials of BBIBP-CorV, and more than 45,000 participants enrolled in trials of WIBP-CorV [21]. From 21 July to 16 December 2020, Sinovac carried out phase III clinical trials for CoronaVac in Brazil, Turkey, Indonesia, Chile, and Hong Kong, involving approximately 30,000 participants. In September 2020, Ad5-nCov by CanSino Biologics and the Chinese Academy of Military Sciences began trials in eight countries, including Argentina, Chile, Ecuador, and Pakistan. More than 40,000 participants were involved in these trials [21].

As a result of research and development, seven vaccines were in use in China at the time of this writing, among which those of Sinovac and Sinopharm were most widely used (Table 2) [23]. According to the Ministry of Industry and Information Technology of China, China's annual production capacity of COVID-19 vaccines reached 5 billion doses as of July 2021 [24]. Notably, major COVID-19 vaccines developed in foreign countries, including the Pfizer and Moderna vaccines were not approved at the time of this writing.

China's high production capacity for COVID-19 vaccines not only met domestic demand but also enabled the export of these vaccines [3]. On 22 June 2021, authorities in China approved the export of four Chinese vaccines. By 1 October 2021, China had exported 1.3 billion doses of COVID-19 vaccine and donated 71.9 million doses to 112 countries, of which 946 million doses had been delivered [3]. Sinopharm and Sinovac are the two largest exporters of COVID-19 vaccines from China, accounting for 36.65% and 60.15% of Chinese vaccine exports [3].

The financial performance of Chinese pharmaceutical companies has benefited considerably from vaccine sales. For example, Sinopharm's semi-annual performance report in 2021 showed that its operating income increased by 22% on a year-over-year basis, and its net profit recorded a 25.51% year-over-year increase [25]. Similarly, the sales and gross profit of Sinovac reached RMB 69.6 billion (US \$11 billion) and RMB 368.04 million (US \$58.2 million) in the first half of 2021, increased from RMB 428.6 billion (US \$67.7 million) and RMB 65.1 billion (US \$10.3 billion) in the same period in the prior year respectively [26].

### COVID-19 vaccine rollouts in Singapore and China

Figs. 1 and 2 indicate the progress of vaccine rollouts and highlight major milestones in COVID-19 vaccination in Singapore and China, respectively. As of 1 October 2021, a total of 9,235,990 doses had been administered in Singapore: 4,594,688 Singaporeans (85% of the population) had received at least the first dose, and 4,490,834 (82% of the population) had completed their full vaccination regimen [1]. Meanwhile, more than 2 billion doses of COVID-19 vaccine have been administered in China. In all, 1.05 billion people, or 72.6% of the Chinese population, have been fully vaccinated [27].

In early 2021, the Singaporean government used a diversified vaccine portfolio to cater to different populations due to the vaccine shortage. Accordingly, a vaccine rollout plan based on priority was executed. Health care, frontline, and other essential personnel were identified as a priority group, followed by the elderly (age 70 and older) [1]. From March 2021, as the supply of vaccines increased, other age

groups were progressively invited to be vaccinated. Singapore doubled its daily doses from 40,000 in June 2021 to 80,000 daily doses in July 2021 [1]. It has since opened up vaccination to all citizens 12 and older and non-citizen residents 40 and older [1]. The level of vaccine hesitancy in Singapore seemed to be relatively low compared with some other countries. For example, according to Griva et al. based on a survey in June–July 2021, the vaccine hesitancy rate was 9.9% among adults in Singapore, compared to 43.9% in Japan, 49.2% in Poland and 30% in the New Zealand [28]. Griva et al. attribute the lower vaccine hesitancy to the collectivism orientation in the Singaporean society [28].

The COVID-19 vaccination underwent a slow start in China in part owing to a relatively high level of vaccine hesitancy among the population. For example, according to a survey among medical and epidemic prevention workers in the Zhejiang province in September and October 2020, fewer than half of the respondents indicated willingness to undertake COVID-19 vaccines approved for emergency use, and only a quarter was willing to be vaccinated when vaccines were fully approved [29]. This level of vaccine hesitancy was caused by factors such as the perceived risks of vaccines, inconvenience of vaccination, reported side effects of vaccines, and insufficient confidence in the healthcare system [30, 31]. Consequently, experts suggested that skepticisms towards vaccines could be a major hurdle to COVID-19 vaccination in China [29].

However, despite a slow start, China witnessed a surge in the number of doses of vaccines delivered daily since May 2021. Several factors contributed to the uptake of vaccines, including low risk of side effects, the fear of another round of large-scale outbreaks, and rapid expansion of vaccine production capacity. China's vaccine rollout took a three-step approach [2]. The first step was to vaccinate prioritized groups, such as health care workers, transport workers, public service personnel, and other high-risk workers ages 19 to 59. In the second step, China announced in early 2021 that vaccines would be provided free for all adult residents, including foreigners living in China. The third step of the rollout was to vaccinate children younger than 18 [2]. After preliminary safety results were gathered from trials of vaccines among other age groups, two vaccines, Sinovac and BBIBP-CorV, were approved for use in children between 3 and 17 years old in June and July 2021, respectively [2]. As of 1 October 2021, 95.3 million children ages 12–17 had received 170 million doses of COVID-19 vaccines, and 200 million elders (age 60 and above) had received 390 million doses of COVID-19 vaccines [2].

In both countries, strong policy measures were introduced to promote vaccination. In Singapore, the government allocated \$11 billion Singaporean dollars (US \$8.3 billion) in February 2021 to support industries affected by the pandemic as well as COVID-19 vaccination [32]. The government also acted transparently to boost the public's trust in COVID-19 vaccines. For example, the Singaporean MOH reports the efficacy of vaccines for preventing severe disease via its official website. According to a report released by the MOH on 1 October 2021 [1], of the 45 COVID-19 deaths that had occurred over the past 28 days in Singapore, 27% were among the fully vaccinated and 73% were among the unvaccinated or partially vaccinated [1]. The MOH also reports adverse events caused by or severe allergic reactions to COVID-19 vaccines in Singapore. According to the MOH on 30 June 2021, among the total 5,470,435 mRNA doses administered by the time, there were only 6,606 reported suspected adverse events (0.12% of total doses),<sup>4</sup> including 252 serious events (0.005% of total doses). No deaths were associated with any types of COVID-19 vaccines in Singapore at the time [1].

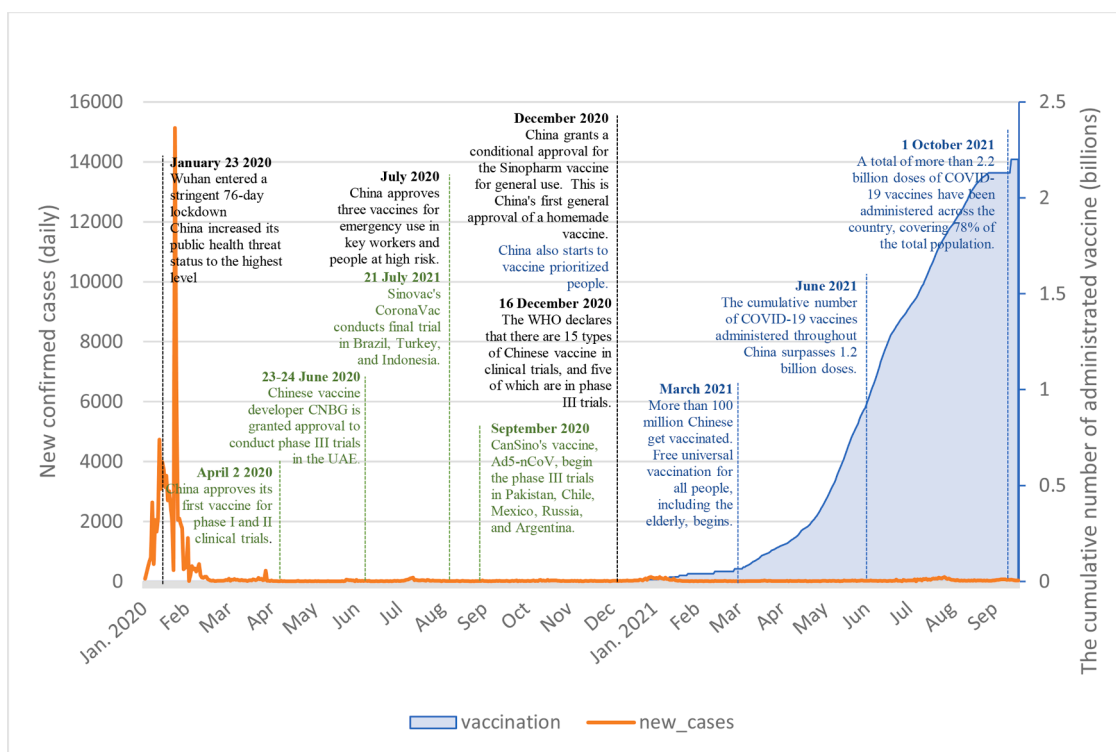
More importantly, the Singaporean government increasingly differentiated between the vaccinated and unvaccinated in its COVID-19

<sup>4</sup> According to the Singapore Health Sciences Authority, *adverse events* refers to any untoward medical occurrences in a patient administered a pharmaceutical product (including a vaccine) that does not necessarily have a causal relationship with this treatment.

**Table 2**  
Vaccines in China.

Vaccine Name	Chinese Name	Date Approved	Type of Approval	Type of Vaccine (Technology)	Number of Doses Required	Developer(s)
BBIBP-CorV	众爱可维	30/12/2020	Conditional approval for listing	Inactivated SARA-CoV-2 vaccine (Vero cell)	2	Sinopharm, China National Biotec Group Co., Beijing Institute of Biological Products
WIBP-CorV	众康可维	25/2/2021	Conditional approval for listing	Inactivated SARA-CoV-2 vaccine (Vero cell)	2	Sinopharm, China National Biotec Group Co., & Wuhan Institute of Biological Products
CoronaVac	克尔来福	5/2/2021	Conditional approval for listing	Inactivated SARA-CoV-2 vaccine (Vero cell)	2	Sinovac Research and Development Co., Ltd.
KCONVAC	可维克	14/5/2021	Approved for emergency use	Inactivated SARA-CoV-2 vaccine (Vero cell)	2	Shenzhen Kangtai Biological Products Co., Ltd.
Keweifu	科维福	9/6/2021	Approved for emergency use	Inactivated SARA-CoV-2 vaccine (Vero cell)	2	Institute of Medical Biology & Chinese Academy of Medical Sciences
Ad5-nCov	克威莎	25/2/2021	Conditional approval for listing	Recombinant novel coronavirus vaccine (adenovirus type 5 vector)	1	CanSino Biologics Inc., Institute of Bioengineering, Academy of Military Medical Sciences
ZF2001	智克威得	19/3/2021	Approved for emergency use	Recombinant SARS-CoV-2 vaccine (CHO cell)	3	Anhui Zhifei Longcom Biopharmaceutical & Institute of Microbiology, Chinese Academy of Sciences

Source: World Health Organization, COVID-19 vaccine tracker and landscape, <https://www.who.int/publications/m/item/draft-landscape-of-covid-19-candidate-vaccines>.



**Fig. 2.** Milestones of the COVID-19 pandemic and vaccination in China

Source: Authors based on data from various sources. Information relating to vaccine policies is shown in black, that regarding vaccination progress is in blue, and vaccine research and development in green.

restrictions. For example, fully vaccinated migrant workers are permitted to a lower frequency test since March 2021 [1]. Since April 2021, fully vaccinated individuals have been permitted to attend events without undergoing pre-event testing. In August 2021, Singapore doubled the permissible group size for activities such as movie going, congregational worship, sports, and weddings to 1,000 fully vaccinated persons (otherwise only 50 unvaccinated attendees are allowed) [1]. Similarly, fully vaccinated travelers from Australia, Austria, Canada, Germany, Italy, Norway, Korea, and Switzerland have been able to undergo stay-at-home quarantine since August 2021, whereas a stricter quarantine required for unvaccinated visitors [1].

In China, specific measures to facilitate the vaccination process included provision of door-to-door and evening vaccination services,

utilization of public facilities as vaccination hubs, and incentives for vaccination by offering rewards of daily supplies such as eggs and milk [33]. Some local governments have taken even stricter measures to increase the vaccination rate and some have introduced controversial policies, such as prohibiting unvaccinated individuals from entering public facilities or markets [34].

China’s COVID-19 vaccination was also supported by its domestically produced vaccines. The Chinese government views the manufacturing of vaccines as strategically important [35], and thus vaccine self-sufficiency has been at the center of its COVID mitigation strategy since the outbreak of the pandemic. This strategy has in turn been supported by the country’s research and development and manufacturing capacity. In addition, the rapid vaccine rollout in China

has been facilitated by the social memory of Chinese people. China was the first place the virus was detected in early 2020, and it undergone a very strict nationwide lockdown; thus, the Chinese were sensitive to and watchful of the potential damage COVID-19 to populous cities and regions. A survey undertaken by the Chinese Academy of Social Sciences in November 2020 indicated 60% to 70% of respondents had zero tolerance for the risk of COVID-19 infection and the rest were only willing to accept a 1% risk of infection at most [36].

### Impacts of COVID-19 vaccination in Singapore and China

A key difference between the COVID-19 responses in Singapore and China was the extent to which vaccination had been used to ease other COVID-19 control measures. In Singapore, COVID-19 control measures were increasingly tied to vaccination. Specifically, there were suggestions that Singapore's COVID-19 control measures and border controls would be relaxed contingent on various percentages of the population being vaccinated [1]. For example, the Singapore trade minister indicated in July 2021 that the government would consider easing border restrictions and allowing business and leisure travelers to enter the country once a 75% vaccination rate is achieved [1]. The Singaporean government also indicated that the country would take steps toward reopening the economy, resuming social activities, and resuming travel toward a "new normal" when at least 80% of the Singaporean population would have been fully vaccinated [1].

As of 28 August 2021, 80% of the Singapore population had completed their full regimen [1]. Although the Singaporean government gradually lifted its COVID-19 control measures in August 2021, the number of daily cases rose exponentially due to the outbreak of the Delta variant. In late September 2021, new COVID-19 cases exceeded 1,000 per day, a majority of which were caused by the Delta variant [1]. Although the Singaporean government continued to follow its reopening plan as of this writing, the increase in daily reported cases alerted the government of the need to accelerate vaccination coverage in Singapore [1]. Meanwhile, the number of severe COVID-19 cases remained within expectations of the government, as only less than 2% of the 31,057 reported cases over the last 28 days prior to 1 October 2021 were symptomatic [1]. 1.5% of the cases (or 466 patients) needed oxygen supplementation, 2% (62 patients) required ICU care, and 0.1% (31 patients) had died. Meanwhile, the Singaporean government started to invite eligible seniors to receive boosters from mid-September 2021 [1]. As of this writing, 236,849 individuals have received booster shots in addition to their second dose [1].

The progress of COVID-19 vaccination had also made an impact in the way that the government managed the pandemic in China. Since 15 March 2021, China has prioritized the visa applications of foreigners who are fully vaccinated and hold vaccination certificates [37]. Some regions with high vaccination rates, such as Beijing, began to use electronic vaccination certificates, which allows the vaccinated to enter buildings without scanning codes [38]. However, to date, vaccination is used as a complement rather than a substitute measure in the overall COVID-19 response in China. For example, an elimination strategy was adopted in response to recent COVID-19 outbreaks in several Chinese cities. For example, in August 2021, 14 months after the start of the pandemic in Wuhan, 12 new cases were detected in the same city [39]. Within 5 days, more than 18,000 medical staff and civil servants completed large-scale COVID-19 testing of 10 million citizens [39]. China has not shown any signs of relaxing its border controls by the time of this writing either. The *Wall Street Journal* projected that the border restrictions in China would likely remain for at least another year because of concerns over new variants of COVID-19 and several upcoming significant events in the country, such as the Winter Olympics in February 2022 and the Congress of the ruling Chinese Communist Party toward the end of the year [40].

### Discussion and concluding remarks

Like other countries, both Singapore and China have placed vaccination at the center of their fight against the COVID-19 pandemic. However, differences can be observed in the COVID-19 vaccination in these two countries in the contexts of their overall pandemic responses, especially in terms of the relationship between vaccination and other measures of control and prevention. This review has shed light on ongoing efforts in COVID-19 vaccination in these two countries.

The distinctive political system of China has enabled the government to mobilize resources more easily in its responses to the pandemic. For example, numerous doctors, nurses and other health workers from other regions and from the military were quickly mobilized to support the city of Wuhan at the early stage of the epidemic. Military reserve, militia forces and many state-owned enterprises also joined the campaign to support logistics and transport. For example, the two hospitals dedicated to COVID-19 patients in Wuhan (Huo Shen Shan Hospital and Lei Shen Shan Hospital) were built within 10 days and 12 days respectively. The government has also been able to conduct large-scale COVID-19 testing in short timeframes and enforce strict lockdowns even during small breakouts of COVID-19 afterwards. Economy-wide, the so-called dual circulation model that first emerged in 2020 as a key economic strategy in China emphasizes the importance of the internal market, or internal circulation, which reduces the level of urgency for an early opening of its international border. Finally, China has developed capacity to produce COVID-19 vaccines. However, despite the high vaccination rate, there exists uneven coverages among people of different age groups and regions of different economic conditions. Specifically, the vaccination rate is lower among elderly people, and that in rural and poorer regions is lower than that cities or richer provinces. For example, according to Zheng et al., around 80% of population in Guangdong – one of the richest provinces in China – was fully vaccinated by 31 August 2021, while only 30% of population was fully vaccinated in the poorer province of Gansu [41]. All these factors help explain the highly risk-averse approach China has taken in its handling of the pandemic. However, enabled by its governance model, China's approach to COVID-19 could hardly be imitated in many other countries. The slow policy transition from a COVID-zero strategy might also increase the economic risks for China due to the adverse effects on its international trade and communications.

Singapore has chosen to follow a different vaccination strategy. Unlike China, Singapore is keen to lift its border controls as soon as possible. Its export-oriented economy was adversely affected during the previous SARS and H1N1 outbreaks, in particular because of related border control measures. During the COVID-19 pandemic, the Singaporean government acted promptly to secure vaccines for the entire population, which is relatively small compared to that of some other nations. Although vaccination was voluntary, the Singaporean government promoted vaccination effectively by enhancing public trust in vaccines, for example, through the use of well-built government websites and social media. The high level of prudence and self-discipline among Singaporeans seemed to be another important factor in helping Singapore achieve a high vaccination rate.

In conclusion, whereas Singapore adopted a "living with the virus" strategy, China continued to pursue a COVID-zero strategy. The overall COVID-19 response strategy of Singapore was largely shared by many countries in the world, while that of China was more unique and hardly imitated elsewhere. Nevertheless, vaccination played a significant role in both countries' responses to the pandemic. Yet, it was clear from the experiences across different countries to date that vaccination was not the ultimate cure for COVID-19 at this stage as new variants of the virus emerged unpredictably. In both countries, policymakers have used preventive measures coupled with vaccination to mitigate the pandemic. Moving forward, a systematic approach is needed to respond to the pandemic taking into account factors in the specific country contexts, such as the level of economic development, capacity and

effectiveness of the health systems, the public sentiments, and the country's international economic relationships. It is then important to assess the drivers and outcomes of vaccination in the COVID-19 pandemic in these distinctive settings.

## Funding

None

## Ethical approval

Not required

## Patient consent

Not required

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgments

We would like to thank the editors of this special issue and the two anonymous reviewers for their guidance and many constructive comments throughout the review process.

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