Journal of Infectious Diseases & Therapy
ISSN: 2332-0877

Research Article Open Access

Summaries, Simulations and Comparing of COVID-19 Foreign input Epidemics in Shanghai and Mainland China During 2022

Lequan Min*

School of Mathematics and Physics, University of Science and Technology Beijing, Beijing, China

Abstract

Background: The outside input COVID-19 epidemic is an important issue for studying the prevention and disease control measures and the spread of the COVID-19 epidemic. Following our previous study for the mainland China epidemic during December 31st 2021 to December 6th 2022, this paper studies the foreign input epidemics in Shanghai and Mainland China during this period.

Methods: Using differential equations and real word data modelings and simulates COVID-19 epidemic in Shanghai and mainland China during December 31, 2021 to December 06, 2022, estimates the input transmission rates and the recovery rates to the symptomatic and the asymptomatic infections.

Results: The simulation results were in good agreement with the real word data on the end point days of investigated time-intervals. One month before December 6th 2022, the symptomatic foreign input transmissions both in mainland and Shanghai were under control. After day 135, the numbers of the cumulative foreign input asymptomatic individuals both in mainland and Shanghai had been increasing in wave ways. During the first 170 days, the average input transmission rates of the foreign input symptomatic and asymptomatic individuals in mainland were much lower than the average input transmission rates of the symptomatic and asymptomatic individuals in Shanghai, respectively. During the last 170 days, the average input transmission rates of the foreign input symptomatic and asymptomatic individuals in mainland were similar to and much higher the average input transmission rates of the symptomatic and asymptomatic individuals in Shanghai, respectively.

Discussion: During the first 170 days, the average recovery rates of the foreign input symptomatic and asymptomatic individuals in mainland were lower and similar to the average recovery rates of the symptomatic and asymptomatic individuals in Shanghai, respectively. During the last 170 days, the average recovery rates of the foreign input symptomatic and asymptomatic individuals in mainland were lower and much higher than the average recovery rates of the symptomatic and asymptomatic individuals in Shanghai, respectively. Foreign Input Mainland Epidemic Virtual Simulations show that that if kept the input transmission rates and the recovery rates on day 99, the numbers of the current symptomatic and asymptomatic individuals would reduce to about 1 and 41 on day 215, respectively. Foreign Input Shanghai Epidemic Virtual Simulations show that if kept the input transmission rates and the recovery rates on day 120, the numbers of the current symptomatic and asymptomatic individuals would reduce less than 1 and about 5 on day 132, respectively.

Conclusion: For the foreign input epidemic in mainland, keeping the input transmission rates of under 0.07 to the symptomatic and asymptomatic infections, and the recovery rates of over 0.125 and 0.099 to the symptomatic and asymptomatic individuals may make the numbers of the current symptomatic and asymptomatic infected individuals to decrease to very low levels in four months. For the foreign input epidemic in Shanghai, keeping the input transmission rates of under 0.04 and 0.11 to the symptomatic and asymptomatic infections, and the recovery rates of over 0.18 and 0.13 to the symptomatic and asymptomatic individuals may make the numbers of the current symptomatic and asymptomatic infected individuals to decrease to very low levels in two weeks. The low recovery rate to the foreign input asymptomatic individuals in Shanghai is the reason that the number of the cumulative asymptomatic individuals charged in medical observation increased rapidly after day 120. In a region appearing new COVID-19 variant infection, this paper recommends: (1) Administrations report timely the COVID-19 epidemic, in particularly the numbers of symptomatic and asymptomatic individuals. (2) Administrations act quickly to discover and extinguish together, cut off quickly the transmission chain until the community transmission of COVID-19 has been initially blocked. (3) Using more accuracy SARS-CoV-2 nucleic acid testing (CT value >40) discovers potential foreign input infected individuals. (4) Individual who do not have symptoms but have had close contact with someone who is, or may be, infected may take COVID-19 antigen detection at least one time every week. (5) Individuals take SARS-CoV-2 antibody detection regularly.

Keywords: COVID-19; Recovery rates; Modelings; Simulations; Foreign input infection transmission rates; Nucleic

Introduction

More than three years since the first SARS-CoV-2 infections were reported, the world is entering a new phase of the COVID-19 pandemic. Despite the current downward trend in incidence, hundreds of thousands of people continue to be infected each week. Furthermore, many uncertainties remain about the potential emergence of new SARS-CoV-2 variants of concern [1]. Mainland China prevents effectively the spread of COVID-19 epidemics before 2022. Omicron and Delta variant virus appearing makes the numbers of the symptomatic and the asymptomatic COVID-19 infected individuals to increase rapidly, in particularly the asymptomatic cases [2,3]. In several previous papers, we have studied the mainland China epidemic during January 2020 to December 2022, estimates the infection transmission rates, the recovery rates death rates and the preventive measures through modelings and numerical simulations [4-9]. This paper studies the foreign input Epidemics in Shanghai and mainland China (includes Shanghai) during December 31th 2021 to December 6th 2022.

Materials and Methods

The dataset of the China COVID-19 epidemics from December 31,

***Corresponding author:** Dr. Lequan Min, School of Mathematics and Physics, University of Science and Technology Beijing, Beijing, China, E-mail: 13501029489@163.com

Received: 12-Jun-2023, Manuscript No. JIDT-23-102084; **Editor assigned:** 16-Jun-2023, PreQC No. JIDT-23-102084 (PQ);**Reviewed:** 30-Jun-2023, QC No. JIDT-23-102084; **Revised:** 07-Jul-2023, Manuscript No. JIDT-23-102084 (R); **Published:** 14-Jul-2023, DOI: 10.4172/2332-0877.1000555

Citation: Min L (2023) Summaries, Simulations and Comparing of COVID-19 Foreign input Epidemics in Shanghai and Mainland China During 2022. J Infect Dis Ther 11: 555.

2021 to December 6, 2022 was collected and edited from the National Health Commission of the People's Republic of China official website [2] and the Health Commission of Shanghai official website. Using differential equation models stimulates the outcomes of the numbers of the current symptomatic individuals, the current asymptomatic individuals (charged in medical observations), the cumulative recovered symptomatic individuals and cumulative asymptomatic individuals (discharged from medical observations) [7-9]. Equation parameters were determined by so-called minimization error square criterion described in references [7-9]. Using virtual simulations estimates the outcomes of the COVID-19 foreign input epidemics in mainland China and in Shanghai. Simulations and figure drawings were implemented via Matlab programs.

Analysis and simulations of foreign input COVID-19 epidemics in mainland China and Shanghai

Figure 1 shows the outcomes of the numbers of the Current Symptomatic Individuals (CSI) and the Current Asymptomatic Individuals (CAI). Figure 2 shows the outcomes of the numbers of the Cumulative Recovered Symptomatic Individuals (CCSI) and the Cumulative Recovered Asymptomatic Individuals (CCAI) discharged from medical observations. The cyan circles and magenta circles represent the outcomes of the numbers of the mainland China cases. The blue circles and red circles represent the outcomes of the numbers of the Shanghai cases.

Generally speaking the foreign input epidemics in mainland China were under control before the current symptomatic and asymptomatic infection increased rapidly in the last month. On December 31, 2021 (denoted by day 0), the numbers of the CSI, the CAI, the CCSI, and the CCAI were 802, 485, 33, and 22, respectively. After about one year (day 340, December 6 2022), the numbers of the CSI, the CAI, the CCSI, and the CCAI reached 589, 1737, 17055, and 25398, respectively. The maximal number of the CSI was 2612 on day 73 (March 14). The minimal number of the CSI was 154 on day 129 (May 10). The maximal number of the CAI was 1802 on day 76 (March 17). The minimal number of the CAI was 372 on day 195 (July 14). On days zero and 340 the proportions (CAI/CSI × 100) of the CAI cases to CSI case were about 60.5% and 294.9%, respectively. There existed several other peak points and valley points of the current symptomatic infections, for examples on days 16 (January 16), 41 (February 9), 229 (August 18), and 242 (August 30), 287 (October 14), 319 (November 11), 331(November 27) (Figures 1 and 3). Later visual simulations show that if kept the input transmission rates and the recovery rates during days 91-99, the numbers of the CSI and the CAI would decrease to low levels see the cyan and magenta dash lines in Figure 1. For the foreign input epidemic in Shanghai, the number of the CSI was under control before the current symptomatic infection increased rapidly in the last month. However, the number of the CAI had been increasing in oscillation way. On December 31, 2021 the numbers of the CSI, the CAI, the CCSI, and the CCAI were 179, 0, 5 and 0, respectively. On December 6, 2022 the numbers of the CSI, the CAI, the CCSI, and the CCAI reached 67, 584, 3122, and 2500, respectively. The maximal number of the CSI was 2612 on day 73 (March 14). The minimal number of the CSI was 3 on day 143 (May 23). The maximal number of the CAI was 1802 on day 76 (March 17). The minimal number of the CAI was 372 on day 195 (July 14). On days zero and 340, the proportions (CAI/CSI × 100) of the CAI cases to CSI case were about 0% and 871.6%, respectively. There existed several other peak points and valley points of the current symptomatic infections, for examples on days 18 (January 18), 48 (February 16), 120 (April 30), 130 (May 10), 193 (June 12), and 228 (August 16), 243 (August 31), 271 (September 28), 288 (October 15), 308 (November 4), 319 (November 15) (see Figure 1 and Table 1). Later visual simulations show that if kept the input transmission rates and the recovery rates during days 110-120, the numbers of the current symptomatic and asymptomatic infected individuals would decrease shortly to low levels see the blue and red dash lines in Figure 1.

Model

In order to estimate numerically the transmission rates and the recovery rates to the symptomatic and asymptomatic infections, we need to set up a mathematic model to simulate the dynamics of the input transmissions and recoveries of the infection disease. Assume that the dynamics of an epidemic can be described by m-time intervals, which correspond different input transmission rates, and recovery rates. At l^{th} time-interval, assume that the current symptomatic infected individual I and asymptomatic infected individuals Ia input a region at input transmission rates $\beta_{11}(l)$ and $\beta_{22}(l)$ respectively (Figure 1). A symptomatic individual is cured at a rate an asymptomatic individual returns to normal at a rate $\kappa(l)$. Then the model has the form described by equation (1) [7-9]:

$$\frac{dI}{dt} = \beta_{11}(l)I - \kappa(l)I \quad \text{..... (1a)}$$

$$\frac{dI_a}{dt} = \beta_{22}(l)I_a - \kappa_a(l)I_a \quad \text{..... (1b)}$$

$$\frac{dI_r}{dt} = \kappa(l)I \quad \text{..... (1c)}$$

$$\frac{dI_{ra}}{dt} = \kappa_a(l)I_a \quad \text{.....(1d)}$$

For l=1,2,…,m, over the l^{th} time interval $[t_{l-1}, t_l]$ denote $I_c(t_l)$ to be the number of the reported current symptomatic infected (hospitalized) individuals, and $I_{ca}(t_l)$ be the number of the reported current asymptomatic individuals (charged in medical observations) (Figure 2). Denote Icr(tl) to be the numbers of the reported current cumulative recovered symptomatic infected individuals and I_{car}(tl) be the number of the reported current cumulative asymptomatic individuals discharged from medical observations, respectively. Then the equation parameters $\beta_{11}(l)$, $\beta_{22}(l)$, $\kappa(l)$ and $\kappa_a(l)$ can be determined by the minimization error square criterion (Table 1) [7-9]:

$$\delta = \min_{\beta_{11}(l),\beta_{22}(l),\kappa(l),\kappa_a(l),\alpha\in[0,1]}((I(t_l)-I_c(t_l)))^2 + (I_a(t_l)-I_c(t_l))^2 + (I_r(t_l)-I_{cr}(t_l))^2 + (I_{ra}(t_l)-I_{cra}(t_l))^2)^{1/2}$$

Simulations

In the case of the foreign input individuals in mainland China, it can be assumed that the input transmissions are divided into 37 time intervals (see solid cyan and magenta dots in Figure 1). The end of points of time interval t_{l-1}, t_l's are given by [9]:

$$t_1 = 10, t_2 = 16, t_3 = 20, t_4 = 30, t_5 = 41, t_6 = 49, t_7 = 43, t_8 = 64, t_9 = 73, t_{10} = 76,$$
$$t_{11} = 82, t_{12} = 90, t_{13} = 99, t_{14} = 106, t_{15} = 115, t_{16} = 120, t_{17} = 129, t_{18} = 137, t_{19} = 150,$$
$$t_{20} = 159, t_{21} = 177, t_{22} = 184, t_{23} = 159, t_{24} = 210, t_{25} = 233, t_{26} = 242, t_{27} = 246, t_{28} = 251, t_{29} = 267, t_{30} = 271, t_{31} = 287, t_{32} = 297, t_{33} = 306, t_{34} = 314, t_{35} = 325, t_{36} = 320,$$
$$t_{37} = 340$$

The calculated parameters are shown in Table 3. The corresponding simulation results of equation (1) are shown by the solid cyan lines and magenta lines in Figures 1-4 (also see the solid blue lines and red lines [9]. Observe that the simulation results of equation (1) were in good agreement with the data of the foreign input COVID-19 epidemics (Table 3) [9]. On the end points of the 37 investigated time-interval t_{l-1}, t_l's, the simulated numbers and the actual reported numbers were approximate the same errors were less than one individual, respectively.

In the case of the foreign input individuals in Shanghai it can be assumed that the input transmissions are divided into 31 time-intervals

see solid blue and red dots in Figure 1. The end points of time-interval t_{l-1}, t_l's are given by

$t_1 = 8, t_2 = 15, t_3 = 18, t_4 = 30, t_5 = 41, t_6 = 48, t_7 = 56, t_8 = 64, t_9 = 70, t_{10} = 77,$
$t_{11} = 85, t_{12} = 93, t_{13} = 100, t_{14} = 109, t_{15} = 120, t_{16} = 130, t_{17} = 143, t_{18} = 151, t_{19} = 162,$
$t_{20} = 170, t_{21} = 193, t_{22} = 201, t_{23} = 217, t_{24} = 228, t_{25} = 243, t_{26} = 271, t_{27} = 288, t_{28} = 311, t_{29} = 319, t_{30} = 331, t_{31} = 340$

The calculated parameters are shown in Table 2. The corresponding simulation results of equation (1) are shown by the solid blue lines and red lines in Figure 1 and Figure 2. Observe that the simulation results of equation (1) were in good agreement with the data of the foreign input COVID-19 epidemic (see Table 1). On the end points of the 31 investigated time-interval $t_{l-1}t_l$'s the simulated numbers and the actual reported numbers were approximate the same errors were less than one individual, respectively.

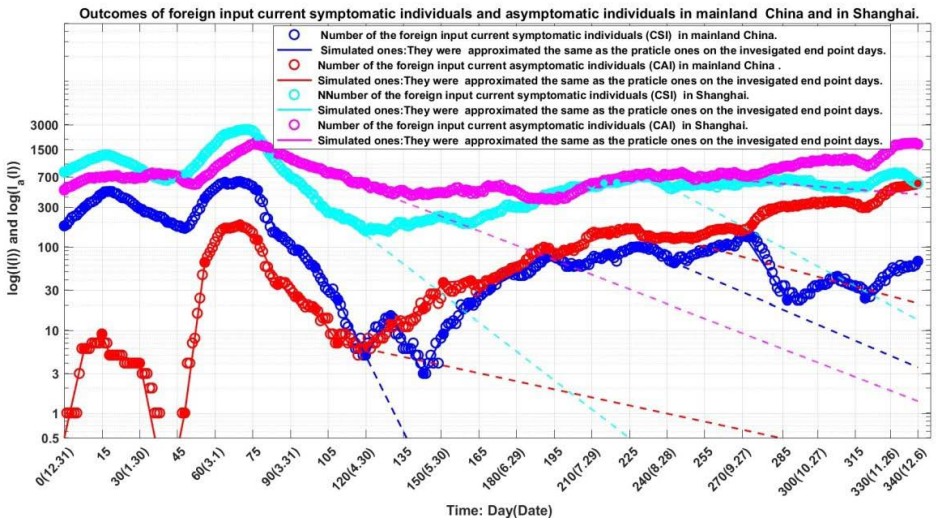

Figure 1: Outcomes of foreign input current symptomatic individuals and asymptomatic individuals in mmainland China and in Shanghai. **Note:** (○): the outcome of the number of the foreign input CSI in mainland China;(▬): Cyan solid line: the outcome of the corresponding simulations of equation (1).(○): Magenta circles: the outcome of the numbers of the foreign input CAI in mainland China;(▬): Magenta solid line: the outcome of the corresponding simulations of equation (1).(○): Blue circles: outcome of the number of the foreign input CSI in Shanghai;(▬): blue solid line: the outcome of the corresponding simulations of equation (1).(○): Red circles: the outcome of the numbers of the foreign input CAI in Shanghai,(▬):red line: outcome of the corresponding simulations of equation (1).(⠿): The dash lines colored by blue, red, and cyan, magenta correspond to the virtual simulation results of equation (1). See Section Virtual Simulations for details

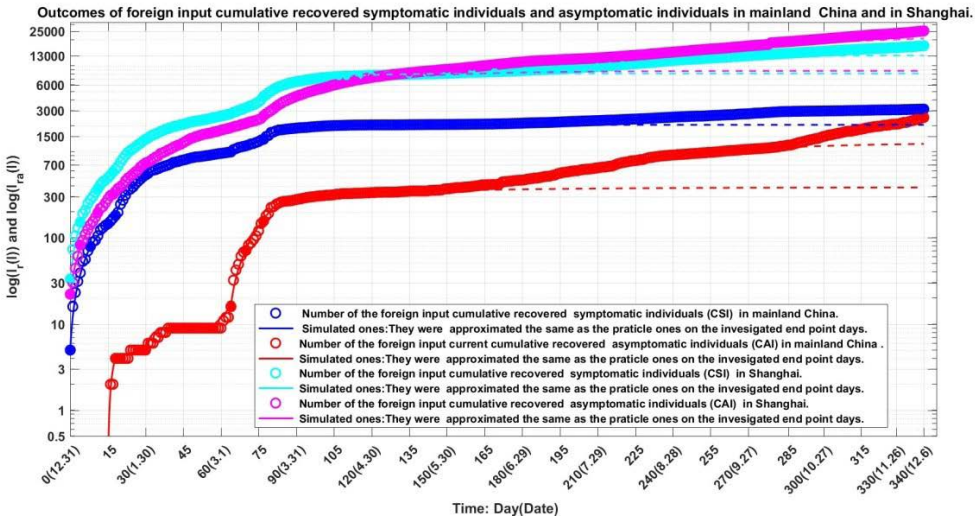

Figure 2: Outcomes of foreign input cumulative recovered symptomatic individuals and asymptomatic individuals in mainland China and in Shanghai. (○) : Cyan circles: the outcome of the number of the foreign input CCSI in mainland China;(▬): Cyan solid line: the outcome of the corresponding simulations of equation (1).(○) : Magenta circles: the outcome of the numbers of the foreign input CCAI in mainland China;(▬): Magenta solid line: the outcome of the corresponding simulations of equation (1). (○): Blue circles: outcome of the number of the foreign input CCSI in Shanghai;(▬): Blue solid line: the outcome of the corresponding simulations of equation (1). (○): Red circles: the outcome of the numbers of the the foreign input CCAI in Shanghai;(▬): red line: outcome of the corresponding simulations of equation (1).(⠿) : The dash lines colored by blue, red, cyan, and magenta correspond to the virtual simulation results of equation (1). See Section Virtual Simulations for details.

Results

The input transmission rates 's and 's of the foreign input mainland symptomatic individuals and the asymptomatic individuals waved (Tables 1 and 3).

Day	Date	I(I)	Ia (I)	Ir (I)	Ira (I)
0	12.31	179	0	5	0
8	1.08	301	6	79	0
15	1.15	436	9	145	0
18	1.18	467	5	181	4
30	1.30	290	4	534	5
41	2.10	198	0	749	9
48	2.17	167	1	845	9
56	2.25	385	65	914	9
64	3.05	603	168	992	16
70	3.11	614	184	1171	71
77	3.18	482	121	1391	155
85	3.26	141	35	1809	264
93	4.03	92	25	1908	288
100	4.10	56	18	1976	306
109	4.19	23	7	2024	325
120	4.30	5	6	2047	334
130	5.10	15	12	2049	339
143	5.23	3	18	2068	353
151	5.31	9	37	2072	371
162	6.11	21	39	2088	400
170	6.19	32	40	2106	417
193	7.12	78	96	2200	535
201	7.20	58	92	2250	600
217	8.05	82	142	2337	701
228	8.16	100	165	2417	809
243	8.31	64	125	2548	926
271	9.28	136	162	2770	1068
288	10.15	23	303	2946	1218
311	11.07	41	354	3006	1730
319	11.15	24	299	3043	1923
331	11.27	54	520	3077	2147
340	12.06	67	584	3122	2500

Table 1: The data set of the foreign input COVID-19 individuals in Shanghai on the investigated point days of the time-intervals.

I	Days	β11 (I)	β22 (I)	κ(I)	κa (I)
1	0-8	0.1044	0.31	0.0395	0
2	9-15	0.0789	0.0578	0.0259	0
3	16-18	0.04935	0.016	0.02645	0.2
4	19-30	0.0395	0.0001	0.0792	0.016
5	31-41	0.0463	0	0.081	0.35
6	42-48	0.051	0.343	0.0755	0
7	49-56	0.1376	0.52185	0.033	0
8	57-64	0.07616	0.1268	0.0201	0.0081
9	65-70	0.05204	0.06727	0.04903	0.052
10	71-77	0.02306	0.0198	0.05764	0.0797
11	78-85	0.0347	0.041	0.1883	0.196
12	86-93	0.0543	0.06	0.1078	0.102
13	94-100	0.063	0.0725	0.134	0.121
14	101-109	0.045	0.0755	0.1437	0.179
15	110-120	0.04	0.115	0.18	0.13
16	121-130	0.132	0.13	0.0205	0.06
17	131-143	0.0705	0.103	0.195	0.072
18	144-151	0.232	0.1767	0.094	0.086
19	152-162	0.18	0.074	0.103	0.069
20	163-170	0.139	0.0567	0.086	0.054
21	171-193	0.1177	0.11805	0.079	0.08
22	194-201	0.0555	0.081	0.0926	0.0865
23	202-217	0.1	0.082	0.0785	0.0548
24	218-228	0.09857	0.0777	0.0803	0.064
25	229-243	0.0785	0.0356	0.1083	0.0541
26	245-271	0.1099	0.04479	0.083	0.03557
27	272-288	0.0584	0.07605	0.1627	0.0392
28	289-311	0.109	0.07466	0.084	0.0679
29	312-319	0.0771	0.0523	0.145	0.07405
30	320-331	0.1443	0.0928	0.0767	0.0467
31	332-340	0.1069	0.084	0.083	0.07115

Table 2: The equation parameters of the foreign input COVID-19 epidemics in Shanghai during2021.12.31-2022.12.6.

I	Days	β11(I)	β22(I)	κ(I)	κa(I)
1	0-10	0.06598	0.059898	0.031686	0.025982
2	11-16	0.048874	0.036028	0.027328	0.033269
3	17-20	0.029875	0.038568	0.044693	0.028747
4	21-30	0.028319	0.0448	0.061721	0.049466
5	31-41	0.03988	0.05593	0.068146	0.04846
6	41-49	0.071617	0.03329	0.05165	0.06217
7	50-53	0.1081	0.051367	0.02996	0.058598
8	54-64	0.09732	0.092677	0.024133	0.035659
9	65-73	0.04952	0.0754	0.03447	0.03071
10	74-76	0.03432	0.06993	0.066998	0.032389
11	77-82	0.038166	0.060467	0.138124	0.091284
12	83-90	0.0536	0.069155	0.13185	0.09877
13	91-99	0.07069	0.07171	0.1243	0.0987
14	100-106	0.06096	0.0984	0.1347	0.12125
15	107-115	0.06364	0.10523	0.08938	0.136545
16	116-120	0.05144	0.12518	0.104307	0.12722
17	121-129	0.08128	0.10827	0.0826	0.13768
18	130-137	0.09695	0.12695	0.079	0.13
19	138-150	0.0941	0.119	0.073	0.0117
20	151-159	0.844	0.1352	0.107	0.1334
21	160-177	0.10473	0.149139	0.07605	0.1467
22	178-184	0.0832	0.12049	0.0928	0.147448
23	185-195	0.1093	0.0954	0.0724	0.1016
24	196-210	0.0951	0.11067	0.08266	0.0809
25	211-233	0.09644	0.108814	0.0853	0.09647
26	234-242	0.07978	0.10523	0.1168	0.1107
27	243-246	0.11682	0.12355	0.0881	0.10485
28	247-251	0.082	0.08861	0.0827	0.12873
29	252-267	0.09476	0.126917	0.09566	0.11455
30	268-271	0.114	0.11	0.0805	0.137
31	272-287	0.090601	0.1749	0.08809	0.1576
32	288-297	0.0667	0.11525	0.07108	0.10499
33	298-306	0.09948	0.1157	0.11996	0.10974
34	307-314	0.0997	0.11022	0.098	0.10486
35	315-320	0.0903	0.07925	0.0869	0.11032
36	321-331	0.11485	0.13131	0.08148	0.07855
37	332-340	0.08437	0.098321	0.1157	0.09539

Table 3: The equation parameters of the foreign input COVID-19 epidemics in mainland China during 2021.12.31-2022.12.06.

During the first 170 days

The foreign input COVID-19 infected individuals in mainland China: The maximal input transmission rates of the symptomatic infection and asymptomatic infection reached to 0.1081 and 0.149139, respectively. The minimal input transmission rates of the symptomatic infection and asymptomatic infection reached to 0.028319 and 0.03329, respectively. The average input transmission rates were about 0.065417 and 0.082219, respectively.

The foreign input COVID-19 infected individuals in Shanghai: The maximal input transmission rates of the symptomatic infection and asymptomatic infection reached to 0.232 and 0.52185, respectively. The minimal input transmission rates of the symptomatic infection and asymptomatic infection reached to 0.02306 and 0, respectively. The average input transmission rates were about 0.082441 and 0.118351, respectively.

During the last 170 days the foreign input COVID-19 infected individuals in mainland China: The maximal input transmission rates of the symptomatic infection and asymptomatic infection reached to 0.11682 and 0.1749, respectively. The minimal input transmission rates of the symptomatic infection and asymptomatic infection reached to 0.0667 and 0.07925, respectively. The average input transmission rates were about 0.095419 and 0.11552, respectively.

The foreign input COVID-19 infected individuals in Shanghai: The maximal input transmission rates of the symptomatic infection and asymptomatic infection reached to 0.1385 and 0.11805, respectively. The minimal input transmission rates of the symptomatic infection and asymptomatic infection reached to 0.02745 and 0.0356, respectively. The average input transmission rates were about 0.091569 and 0.074337, respectively.

The recovery rates $\kappa(l)$'s and $\kappa_a(l)$'s of the foreign input symptomatic infection individuals and the asymptomatic infection individuals in Mainland China and Shanghai waved (Table 2 and Table 3).

During the first 170 days the foreign input COVID-19 infected individuals in mainland China: The maximal recovery rates of the symptomatic infection and asymptomatic infection reached to 0.138124 and 0.1467, respectively. The minimal recovery rates of the symptomatic infection and asymptomatic infection reached to 0.024133 and 0.025982, respectively. The average recovery rates were about 0.075290 and 0.083056, respectively.

During the first 170 days the foreign input COVID-19 infected individuals in Shanghai: The maximal recovery rates of the symptomatic infection and asymptomatic infection reached to 0.195 and 0.35, respectively. The minimal recovery rates of the symptomatic infection and asymptomatic infection reached to 0.0201 and 0, respectively. The average recovery rates of were about 0.086981 and 0.08874, respectively.

During the last 170 days the foreign input COVID-19 infected individuals in mainland China: The maximal recovery rates of the symptomatic infection and asymptomatic infection reached to 0.11996 and 0.1576, respectively. The minimal recovery rates of the symptomatic infection and asymptomatic infection reached to 0.07108 and 0.07855, respectively. The average recovery rates were about 0.09025 and 0.113553, respectively.

During the last 170 days the foreign input COVID-19 infected individuals in Shanghai: The maximal recovery rates of the symptomatic infection and asymptomatic infection reached to 0.1522 and 0.0865, respectively. The minimal recovery rates of the symptomatic infection and asymptomatic infection reached to 0.0756 and 0.0331, respectively. The average recovery rates were about 0.09792 and 0.061575, respectively.

- During days 0-16, the input transmission rates $\beta_{11}(t)$ and $\beta_{22}(t)$ of the foreign input infected mainland individuals decreased, and the recovery rates $\kappa(t)$ and $\kappa_a(t)$ decreased and increased. Which made the numbers of the current symptomatic and asymptomatic individuals increase from 802 and 485 to local maximal values (peak points) 1286 and 727 on days 16 and 21 (Figures 3 and 4) and (Tables 3 and 4) [9].

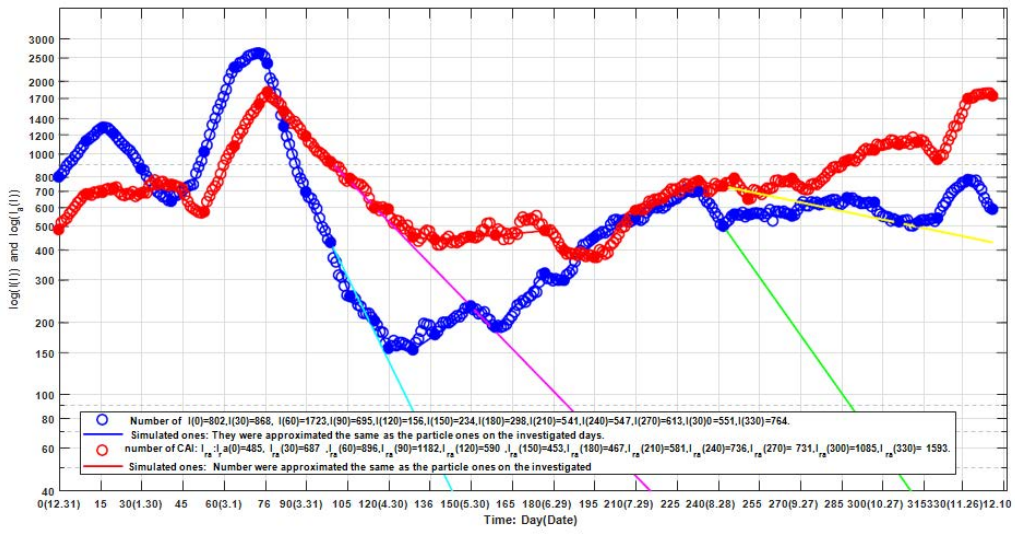

Figure 3: Outcomes of current symptomatic individuals and asymptomatic individuals (foreign input in mainland China). **Note:** (○) Blue circles: outcome of the number of the Current Symptomatic Individuals (CSI) I(0)=802, I(30)=868, I(60)=1723, I(90)=695, I(120)=156, I(150)=234, I(180)=298, I(210)=541, I(240)=547, I(270)=613, I(30)0=551, I(330)=764; (—) Blue line: outcome of the corresponding simulations of equation (2). (○) Red circles: outcome of the numbers of the Current Asymptomatic Individuals (CAI) charged in medical observations Ira: Ira(0)=485, Ira(30)=687; Ira(60)=896, Ira(90)=1182, Ira(120)=590, Ira(150)=453, Ira(180)=467, Ira(210)=581, Ira(240)=736, Ira(270)=731, Ira(300)=1085, Ira(330)=1593; (—) Red line: outcome of the corresponding simulations of equation (2). (—) : The lines colored by cyan and magenta correspond to the virtual simulation results of equation (2). See Section Foreign Input Epidemic Virtual Simulations for details.

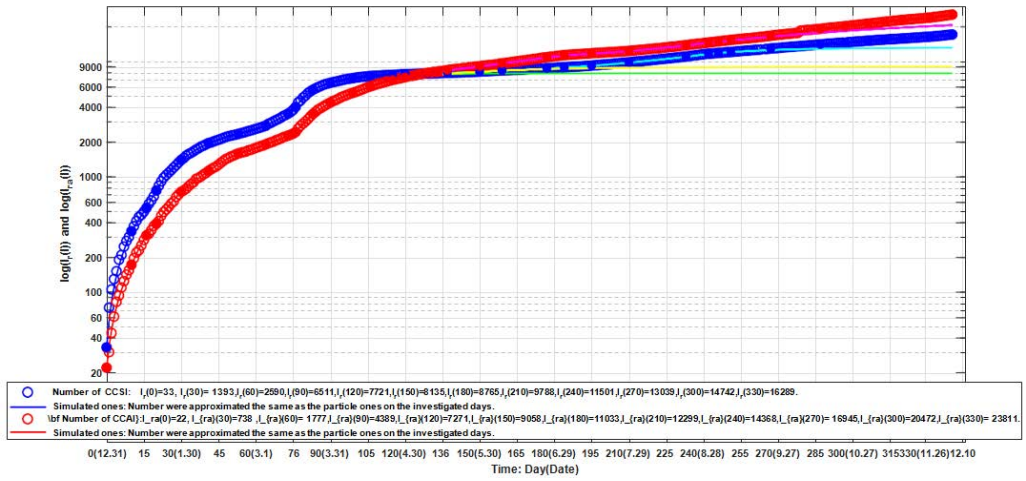

Figure 4: Outcomes of cumulative current symptomatic individuals and asymptomatic individuals (foreign input in China). (○) Blue circles: outcome of the number of the Current Cumulative Recovered Symptomatic Individuals (CCSI): Ir(0)=33, Ir(30)=1393, Ir(60)=2590, Ir(90)=6511, Ir(120)=7721, Ir(150)=8135, Ir(180)=8765, Ir(210)=9788, Ir(240)=11501, Ir(270)=13039, Ir(300)=14742, Ir(330)=16289; (—) Blue line: outcome of the corresponding simulations of equation (2); (○) Red circles: outcome of the numbers of the Current Cumulative Asymptomatic Individuals (CCAI) discharged in medical observations Ira(0)=22, Ira(30)=738, Ira(60)=1777, Ira(90)=4389, Ira(120)=7271, Ira(150)=9058, Ira(180)=11033, Ira(210)=12299, Ira(240)=14368, Ira(270)=16945, Ira(300)=20472, Ira(330)=23811; (—) Red line: outcome of the corresponding simulations of equation (2). The lines colored by cyan and magenta correspond to the virtual simulation results of equation (2). See Section Foreign Input Epidemic Virtual Simulations for details.

- During days 0-15, the input transmission rates $\beta_{11}(t)$ and $\beta_{22}(t)$ of the foreign input Shanghai infected individuals and the recovery rate $\kappa(t)$ decreased significantly and $\kappa_a(t)=0$. However which still made the numbers of the current symptomatic and asymptomatic individuals increase from 179 and 0 to local maximal values 436 and 9 on day 15, respectively (Figure 1 and Tables 1 and 2).

- During days 16-41, the input transmission rates $\beta_{11}(t)$ and $\beta_{22}(t)$ of the foreign input mainland infected individuals decreased and increased in wave ways, the recovery rates $(\kappa(t)$ and $\kappa_a(t))$ increased in wave ways. Which made the numbers of the current symptomatic individuals and the asymptomatic individuals decrease form 1286 and 720 to local minimal values (valley points) 636 and 575 on day 41 and day 53, respectively (Figures 1 and 3) (Tables 3 and 4).

Day	Date	I(I)	Ia(I)	Ir(I)	Ira(I)
0	12.31	802	485	33	22
1	1.01	822	519	73	30
10	1.1	1130	681	336	172
16	1.16	1286	692	534	309
20	1.2	1212	720	757	390
30	1.3	868	687	1393	738
41	2.1	636	746	1952	1120
53	2.22	1020	575	2342	1588
64	3.05	2281	1077	2758	1902
73	3.14	2612	1610	3516	2268
76	3.17	2368	1802	4016	2434
82	3.23	1300	1498	5492	3335
90	3.31	695	1182	6511	4389
99	4.09	429	927	7128	5321
106	4.16	256	790	7444	6048
115	4.25	203	596	7628	6894
120	4.3	156	590	7721	7271
129	5.09	154	452	7836	7914
137	5.17	178	441	7941	8378
150	5.3	234	453	8135	9058
159	6.08	191	460	8339	9606
177	6.26	320	481	8681	10848
184	7.03	299	398	8882	11300
195	7.14	449	372	9176	11730
210	7.29	541	581	9788	12299
233	8.21	699	772	10998	13790
242	8.3	501	735	11623	14541
246	9.03	562	792	11810	14861
251	9.08	560	648	12042	15323
271	9.28	632	715	13084	17050
267	9.24	552	790	12893	16636
287	10.14	657	935	13991	19106
297	10.24	629	1036	14448	20140
306	11.02	523	1093	15068	21191
314	11.1	530	1141	15481	22128
320	11.16	541	947	15760	22817
331	11.27	781	1692	16346	23926
340	12.06	589	1737	17055	25398

Table 4: The data set of the foreign input COVID-19 individuals in mainland China on the investigated point days.

- During days 15-48, the input transmission rates $\beta_{11}(t)$ and $\beta_{22}(t)$ of the foreign input Shanghai infected individuals, and

the recovery rates $((\kappa(t))$ and $\kappa_a(t))$ decreased and increased in wave ways. Which made the numbers of the current symptomatic individuals and the asymptomatic individuals decrease form 436 and 9 to local minimal values (valley points) 167 and 0 on day 48 and day 46, respectively (Figure 1 and Tables 1 and 2).

- During days 41-73, the input transmission rates $\beta_{11}(t)$ and $\beta_{22}(t)$ of the foreign input mainland infected individuals increased and decreased in wave ways, the recovery rats $((\ (t))$ and $_a(t))$ decreased in wave ways which made the numbers of the current symptomatic individuals and the asymptomatic individuals increase from 636 and 575 to local maximal values 2612 and 1802 on day 73 and day 76, respectively (Figures 1 and 3) (Tables 3 and 4).

- During days 48-70, the input transmission rates $\beta_{11}(t)$ and $\beta_{22}(t)$ of the foreign input Shanghai infected individuals increased and decreased in wave ways, the recovery rate $\kappa(t)$ decreased in wave ways, the recovery rate $\kappa_a(t)$ increased which made the numbers of the current symptomatic individuals and the asymptomatic individuals increase from 167 and 0 to local maximal values 614 and 184 on day 70, respectively (Figure 1 and Tables 1 and 2).

- During days 73-129, the input transmission rates $\beta_{11}(t)$ and $\beta_{22}(t)$ of the foreign input mainland individuals decreased and increased in wave ways, the recovery rates $\kappa(t)$ and $\kappa_a(t)$ increased in wave ways which made the numbers of the current symptomatic individuals and the asymptomatic individuals decrease form 2612 and 1802 to local minimal values 154 and 419 on day 129 and day 138, respectively (Figure 3 and Tables 3 and 4) [9].

- During days 70-120, the input transmission rates $\beta_{11}(t)$ and $\beta_{22}(t)$ of the foreign input Shanghai individuals decreased in wave ways, the recovery rates $\kappa(t)$ and $\kappa_a(t)$ increased significantly in wave ways which made the numbers of the current symptomatic individuals and the asymptomatic individuals decrease form 614 and 184 to local minimal values 5 and 5 on day 119 and day 117, respectively (Figure 1 and Tables 1 and 2).

- During days 129-233, the input transmission rates $\beta_{11}(t)$, $\beta_{22}(t)$ of the foreign input mainland individuals and the recovery rates $\kappa(t)$ and $\kappa_a(t)$ increased and decreased in wave ways which made the numbers of the current symptomatic individuals and the asymptomatic individuals increase from 154 and 419 to local maximal values 712 and 772 on days 234 and 233, respectively (Figures 1 and 3 and Tables 3 and 4).

- During days 120-228, the transmission input rates $\beta_{11}(t)$, $\beta_{22}(t)$ of the foreign input Shanghai individuals and the recovery rate $\kappa(t)$ and $\kappa_a(t)$ increased and decreased in wave ways which made the numbers of the current symptomatic individuals and the asymptomatic individuals increase from 5 and 5 to local maximal values 100 and 165 on day 228, respectively (see Figure 1 and Tables 1 and 2).

- During days 233-242, the input transmission rates $\beta_{11}(t)$, $\beta_{22}(t)$ of the foreign input mainland individuals, and the recovery rates $\kappa(t)$ and $\kappa_a(t)$ decreased and increased significantly which made the numbers of the current symptomatic individuals and the asymptomatic individuals decrease from 712 and 772 to local minimal values 501 and 735 on day 242, respectively (Figures 1 and 3, Tables 3 and 4).

- During days 228-243, the input transmission rates $\beta_{11}(t)$, $\beta_{22}(t)$ of the foreign input Shanghai individuals and the recovery rate $\kappa(t)$ decreased and increased significantly. Which made the numbers of the current symptomatic individuals and the asymptomatic individuals decrease from 100 and 165 to local minimal values 64 and 125 on day 243, respectively (Figure 1, Tables 1 and 2).

- During days 242-259, the input transmission rates $\beta_{11}(t)$, $\beta_{22}(t)$ of the foreign input mainland individuals and the recovery rates $\kappa(t)$ and $\kappa_a(t)$ changed in wave ways. Which made the numbers of the current symptomatic individuals and the asymptomatic individuals increase from 501 and 735 to local maximal values 586 and 777 on days 259 and 262, respectively (Figures 1 and 3, Tables 3 and 4).

- During days 243-271, the input transmission rates $\beta_{11}(t)$, $\beta_{22}(t)$ of the foreign input Shanghai individuals and the recovery rates $\kappa(t)$ and $\kappa_a(t)$ decreased and increased significantly which made the numbers of the current symptomatic individuals and the asymptomatic individuals reach a local maximal value 136 and an "increased" value 162 on days 271, respectively (Figure 1, and Tables 1 and 2).

- During days 259-271, the transmission input rates $\beta_{11}(t)$, $\beta_{22}(t)$ of the foreign input mainland individuals increased and decreased, and the recovery rates $\kappa(t)$ and $\kappa_a(t)$ decreased and increased which made the numbers of the current symptomatic individuals and the asymptomatic individuals change from 101 and 162 to a local maximal value 632 and local minimum value 710 on days 271 and 272, respectively (Figures 1 and 3, Tables 3 and 4).

- During days 271-311, the input transmission rates $\beta_{11}(t)$, $\beta_{22}(t)$ of the foreign input mainland individuals increased and decreased, and the recovery rates $\kappa(t)$ and $\kappa_a(t)$ decreased and increased which made the numbers of the current symptomatic individuals and the asymptomatic individuals change from 632 and 710 to a local minimal value 502 and a local maximum value 1170 on days 311, respectively (Figures 1 and 3, Tables 3 and 4).

- During days 271-288, the input transmission rate $\beta_{11}(t)$ and the recovery rate $\kappa(t)$ of the foreign input Shanghai individuals decreased and increased significantly, the input transmission rate $\beta_{22}(t)$ and the recovery rate $\kappa_a(t)$ of the foreign input Shanghai individuals increased and decreased significantly which made the numbers of the current symptomatic individuals and the asymptomatic individuals decrease from 136 and 162 to local minimum values 23 and 303 on day 288, respectively (Figure 1 and Tables 1 and 2).

- During days 311-320, the transmission rates $\beta_{11}(t)$, $\beta_{22}(t)$ of the foreign input mainland individuals increased and decreased, and the recovery rates $\kappa(t)$ and $\kappa_a(t)$ decreased and increased. Which made the numbers of the current symptomatic individuals and the asymptomatic individuals change from 502 and 1170 to an "increased" value 541 and a local minimum value 1170 on day 320, respectively (Figures 1 and 3, Tables 3 and 4).

- During days 288-311, the input transmission rate $\beta_{11}(t)$ and the recovery rate $\kappa(t)$ of the foreign input Shanghai individuals increased and decreased significantly, the input transmission rate $\beta_{22}(t)$ and the recovery rate $\kappa_a(t)$ of the foreign input Shanghai individuals decreased slightly and increased significantly which made the numbers of the current symptomatic individuals and the asymptomatic individuals increase from 23 and 303 to local maximum values 41 and 354 on day 311, respectively (Figure 1 and Tables 1 and 2).

- During days 311-319, the transmission rates $\beta_{11}(t)$, $\beta_{22}(t)$ of the foreign input Shanghai individuals increased and the recovery rates $\kappa(t)$ and $\kappa_a(t)$ decreased and increased significantly which made the numbers of the current symptomatic individuals and the asymptomatic individuals change from 41 and 354 to local minimum values 24 and 297 on days 319 and 318, respectively (Figure 1 and Tables 1 and 2).

- During days 320-331, the transmission rates $\beta_{11}(t)$, $\beta_{22}(t)$ of the foreign input mainland individuals, and the recovery rate $\kappa(t)$ and $\kappa_a(t)$ increased and decreased, respectively which made the numbers of the current symptomatic individuals change form 541 and 1170 to a local maximal value 781 and an "increased" value 1692 on day 331, respectively (Figures 1 and 3 and Tables 3 and 4).

- During days 331-340, the transmission rates $\beta_{11}(t)$, $\beta_{22}(t)$ of the foreign input mainland individuals, and the recovery rates $\kappa(t)$ and $\kappa_a(t)$ significantly increase and decrease, respectively which made the numbers of the current symptomatic and asymptomatic individuals decrease from 781 and 1783 (on day 338) to 589 and 1737 on day 340, respectively (Figures 1 and 3 and Tables 3 and 4).

During days 319-340, the transmission rates $\beta_{11}(t)$, $\beta_{22}(t)$ of the foreign input Shanghai individuals decreased, the recovery rates $\kappa(t)$ and $\kappa_a(t)$ increased, respectively which still made the numbers of the current symptomatic and asymptomatic individuals increase from 24 and 299 to 67 and 584, respectively (Figure 1 and Tables 1 and 2).

Note: Equations (1a) and (1b) imply that in time-interval t_{l-1}, t_l, guarantee that the numbers of the current symptomatic and asymptomatic individuals decrease.

$$\begin{cases} \beta_{11}(l)I(t) - \kappa(l)I(t) < 0 \\ \beta_{22}(l)I_a(t) - \kappa_a(l)I_a(t) < 0 \end{cases}$$

Comparing

- During the first 170 days, the average input transmission rates of the foreign input in mainland symptomatic and asymptomatic individuals were about 0.065417 and 0.082219, which were much lower than the average transmission rates 0.082411 and 0.118351 of the symptomatic and asymptomatic individuals in Shanghai, respectively (see $\beta_{11}(l)$'s, $\beta_{22}(l)$'s in Table 3 and $\beta_{11}(l)$'s, $\beta_{22}(l)$'s in Table 2.

- During the last 170 days, the average input transmission rates of the foreign input in mainland symptomatic and asymptomatic individuals were about were about 0.095419 and 0.11552, which were similar and much higher to the average transmission rates 0.091569 and 0.074337 of the symptomatic and asymptomatic individuals in Shanghai, respectively (see $\beta_{11}(l)$'s, $\beta_{22}(l)$'s in Table 3 and $\beta_{11}(l)$'s, $\beta_{22}(l)$ in Table 2.

- During the first 170 days, the average recovery rates of the foreign input in mainland symptomatic and asymptomatic individuals were about 0.075290 and 0.083056, respectively, which were lower and similar to the average recovery rates 0.086981 and 0.08874 of the symptomatic and asymptomatic individuals in Shanghai, respectively (see $(\kappa(l)$'s, $\kappa_a(l))$'s in Table 3 and $(\kappa(l)$'s, $\kappa_a(l))$'s in Table 2).

- During last 170 days, the average recovery rates of the foreign input in mainland symptomatic and asymptomatic individuals were about 0.09025 and 0.113553, respectively, which were lower and much higher than the average recovery rates 0.09792 and 0.06175 of the symptomatic and asymptomatic individuals in Shanghai, respectively (see $(\kappa(l)$'s, $\kappa_a(l))$'s in Table 3 and $(\kappa(l)$'s, $\kappa_a(l))$ in Table 2).

- During December 31st 2021 to December 6th 2022, the numbers of the foreign input symptomatic and asymptomatic individuals in mainland (including Shanghai) changed from 802 and 485 to 589 and 1737, respectively. The numbers of the foreign input symptomatic and asymptomatic individuals in Shanghai changed form 179 and 0 to 67 and 584, respectively. On December 31st 2021 and December 6th 2022, the proportion of the numbers the input symptomatic individuals in Shanghai and in mainland (including Shanghai) were about 22.3% and 11.4%, respectively; the proportion of the numbers the input asymptomatic individuals in Shanghai and in mainland (including Shanghai) were about 0% and 33.6%, respectively.

Virtual simulations

Foreign input mainland epidemic virtual simulations: (1) Assume that after day 99 (April 9, 2022), it still keeps the transmission rates $\beta_{11}(13)$, $\beta_{22}(13)$, the recovery rates $\kappa(13)$, and $\kappa_a(13)$ until day 340 (December 6, 2022). The simulation results of equation (1) are shown in Figures 1 and 2 by cyan dash lines and magenta dash lines, respectively. Calculated results show that on day 215 (August 3), the numbers of the current symptomatic and the current asymptomatic infected individuals would reduce to about 1 and 41, respectively; On day 340 the numbers of the asymptomatic infected individuals cumulative recovered symptomatic individuals and the cumulative asymptomatic individuals discharged from medical observations would reach about 0, 1, 8123, and 8706, respectively.

(2) Assume that after day 242 (August 30, 2022), it still keeps the transmission rates $\beta_{11}(26)$, $\beta_{22}(26)$ the recovery rates $\kappa(26)$, and $\kappa_a(26)$ until

day 340. The simulation results of equation (1) are shown in Figures 1 and 2 by cyan dash lines and magenta dash lines, respectively. Calculated results show that on day 340, the numbers of the current symptomatic and the current asymptomatic infected individuals would reduce to about 13 and 430, respectively; the numbers of the cumulative recovered symptomatic individuals and the cumulative recovered asymptomatic individuals would reach about 13162 and 20712, respectively.

Foreign input Shanghai epidemic virtual simulations: (1) Assume that after day 120 (May 30, 2022), it still keeps the transmission rates $\beta_{11}(15)$, and $\beta_{22}(15)$, the recovery rates $\kappa(15)$, and $\kappa_a(15)$ until day 340 (December 6, 2022). The simulation results of equation (1) are shown in Figure 1 and Figure 2 by blue dash lines and red dash lines, respectively. Calculated results show that on day 132 (May 13), the numbers of the current symptomatic and the current asymptomatic infected individuals would reduce to less 1 and about 5, respectively; On day 340, the the numbers of the current symptomatic and the current asymptomatic infected individuals, the numbers of the cumulative recovered symptomatic individuals and the cumulative recovered asymptomatic individuals would reach about 0, 0, 2054, and 384, respectively.

(2) Assume that after day 243 (August 31, 2022), it still keeps the transmission rates $\beta_{11}(25)$, and $\beta_{22}(25)$, the recovery rates $\kappa(25)$, and $\kappa_a(25)$ until day 340. The simulation results of equation (1) are shown in Figure 1 and Figure 2 by blue dash lines and red dash lines, respectively. Calculated results show that on day 340, the numbers of the current symptomatic and the current asymptomatic infected individuals would reduce to about 4 and 21, respectively; the numbers of the cumulative recovered symptomatic individuals and the cumulative recovered asymptomatic individuals would reach about 2768 and 1231, respectively.

Discussion

It is the first time to summary and simulate the foreign input the COVID-19 epidemic in Shanghai from December 31th 2021 to December 6 th 2022. It shows a clear picture to understand the input transmission rates and the recovery rates of the symptomatic and asymptomatic individuals in this epidemic. It uses a model to simulate the foreign input the COVID-19 epidemic in Shanghai. The simulation results were in good agreement with the real word data [3] on the end points of the investigated time-intervals, the errors were less than one. The simulation results can provide possible interpretations and estimations to the foreign input transmission rates and the recovery rates of the symptomatic and asymptomatic individuals in this epidemic. One month before December 6th 2022, the symptomatic foreign input transmissions both in mainland and Shanghai were under control. After day 135, the numbers of the cumulative foreign input asymptomatic individuals both in mainland and Shanghai had been increasing in wave ways. During the first 170 days, the average input transmission rates of the foreign input symptomatic and asymptomatic individuals in mainland were much lower than the average input transmission rates of the symptomatic and asymptomatic individuals in Shanghai, respectively. During the last 170 days, the average input transmission rates of the foreign input symptomatic and asymptomatic individuals in mainland were similar to and much higher the average input transmission rates of the symptomatic and asymptomatic individuals in Shanghai, respectively. During the first 170 days, the average recovery rates of the foreign input symptomatic and asymptomatic individuals in mainland were lower and similar to the average recovery rates of the symptomatic and asymptomatic individuals in Shanghai, respectively. During the last 170 days, the average recovery rates of the foreign input symptomatic and asymptomatic individuals in mainland were lower and much higher than the average recovery rates of the symptomatic and asymptomatic individuals in Shanghai, respectively. As results, on days zero and 340, the proportions of the numbers of the current symptomatic and asymptomatic individuals in Shanghai were 0% and about 871.6%, respectively; the the proportions of the numbers of the current symptomatic and asymptomatic individuals in mainland China were about 60.5% and 294.9%, respectively.

Foreign Input Mainland Epidemic Virtual Simulations show, if kept the input transmission rates and the recovery rates on day 99, the numbers of the current symptomatic and asymptomatic individuals would reduce to about 1 and 41 on day 215, respectively.

Foreign Input Shanghai Epidemic Virtual Simulations show, if kept the input transmission rates and the recovery rates on day 120, the numbers of the current symptomatic and asymptomatic individuals would reduce less than 1 and about 5 on day 132, respectively.

Conclusion

This research suggests that asymptomatic COVID-19 transmissions may be the main threaten in the prevention and control the spread of COVID-19 epidemic. In a region appearing outside input new COVID-19 variant virus infections, this paper recommends corresponding administrations timely report the COVID-19 epidemic, in particularly the numbers of the current symptomatic, asymptomatic and died individuals. All administrations act quickly to discover and extinguish together, cut off quickly the transmission chain until the community transmission of COVID-19 has been initially blocked. For this purpose, the administrations should at least maintain the prevention and control measures implemented 7 days after reaching the turning point. Using more accuracy SARS-CoV-2 nucleic acid testing (CT value>40) discovers potential foreign input infected individuals. Individual who do not have symptoms but have had close contact with someone who is, or may be, infected may take COVID-19 antigen detection at least one time every week. Individuals are suggested to take SARS-CoV-2 antibody detection regularly in order to discover early symptomatic or asymptomatic infections. It is expected that this research provides further understandings to the potential emergence of outside input new SARS-CoV-2 variants, and prevention requirements.

Conflict of Interest

The author declares no potential conflict of interest.

Data Availability Statement

Data are available on reasonable request. Please email the author.

Ethical Statement

Not applicable/No human participants included.

Acknowledgement

The author gratefully acknowledges Prof. Jixun Chu, Mr. Yiwen Zhang and Miss Han Wang at the University of Science and Technology Beijing for editing and checking some dataset in Shanghai.

References

1. WHO (2023) WHO policy brief: COVID-19 surveillance, 11 April 2023.
2. National Health Commission of the People's Republic of China (2021) Epidemic Bulletin (in Chinese) 2021.12.31-2022.12.31.
3. Health Commission of Shanghai (2020) Epidemic bulletin (in Chinese) 2021.12.31-2022.12.06.

4. Min L (2023) Modelling, simulations and analysis of the first and second COVID-19 epidemic in Beijing. MedRxiv.
5. Min L (2022) Summaries, analysis and simulations of recent COVID-19 epidemic in Shanghai May 16, 2022. MedRxiv.
6. Min L (2022) Summaries, analysis and simulations of recent COVID-19 epidemic in Shanghai. J Infect Dis Ther 10:005.
7. Min L (2022) Summaries, analysis and simulations of recent COVID-19 epidemic in Mainland China July 12, 2022. MedRxiv.
8. Min L (2022) Summaries, analysis and simulations of recent covid-19 epidemics in Mainland China. J Infect Dis Ther 10: 505.
9. Min L (2022) Summaries, analysis and simulations of recent COVID-19 epidemic in Mainland China during May 1st - December 6th 2022. J Infect Dis Ther 11: 534.