Jan. 25, 2020

Updated Estimating Infected Population of Wuhan Coronavirus in different policy scenarios by SIR Model

（不同防疫对策下的武汉新型肺炎感染人口的估计:一个更新）

Prof. Xiaohua Yu
Professor, University of Göttingen, Germany
Email: xyu@uni-goettingen.de

Abstract：

Accurately estimating infected population is a key for making epidemic preventing policies.

Based on the SIR model and new information, I estimated the infectious population of Wuhan Coronavirus in China and project the possible policy consequence.

I find some data inconsistencies in the official data, while the reported data by Imai et al. (2020) is more reliable. Follow the data by Imai et al. the infected population is about 10000 on Jan. 23. Government started to take strong measures in response to the epidemic of new coronavirus, we assume different scenarios。

My main findings include:

1**, If the quarantine rate of infectious population is below 90%, the epidemic of Coronavirus can not be controlled. A stricter quarantine policy should be taken as soon as possible.**

2, The basic reproduction number R0=3.5, a very high number indicating powerful infectivity.

3, (a) In the case of 100% quarantine, at the end of January, the infected population and death will be projected to reach 13250 and 102 respectively; while the end of February, the numbers will be 20421 and 525 as well. Final infected population could be 26,000. and the final death would be more than 700.

(b) In the case of 90% quarantine, at the end of January, the infected population and death will be projected to reach 14475 and 102 respectively; while the end of February, the numbers will be 29561 and 671 as well. Final infected population could be 59,000, and the final death would be more than 1,500.

(d) In the case of 80% quarantine, at the end of January, the infected population and death will be projected to reach 15842 and 102 respectively; while the end of February, the numbers will be 45572 and 872 as well. Final infected population could be 19,0000, and final death will be more than 4000.

(d) In the case of 50% quarantine, at the end of January, the infected population and death will be projected to reach 20951 and 102 respectively; while the end of February, the numbers will be 215048

and 2192 as well. Final infected population could be 4,694,000, and the final death would be more than 100,000.
As the whole society has been mobilized and realized the importance and difficulty of the epidemic prevention, the epidemic will be controlled in 2-3 months.

摘要:

对武汉新型病毒感染人数的估计对，制定相关政策、有效调度资源抵抗瘟疫非常重要。

基于 SIR 模型和最新信息，我重新估算了中国武汉冠状病毒的感染人数并预测了可能的政策后果。

以最新发表的几篇论文（Imai et al., 以及 Huang et al.等），我估计出 1 月 23 日的感染人口约为 10000；
政府开始针对新的冠状病毒的流行采取强有力的措施，我们对不同的政策情境进行估计后，发现

1，如果感染人群的隔离率低于 90%，则无法控制冠状病毒的流行。政府应尽快采取更严格的检疫政策。

2, R0=3.5, 这说明病毒传染性很强。

3，（a）在 100%隔离的情境下，到 1 月底，预计感染人口和死亡人数将分别达到 13,250 和 102；而到 2 月底，这两个数字将分别为 20421 和 525。最终感染人口和死亡可能分别超过 26,000 和 700。

（b）在 90%隔离的情境下，到 1 月底，预计感染人口和死亡人数将分别达到 14,475 和 102；而到 2 月底，这两个数字将分别为 29561 和 671。最终感染人口和死亡可能分别超过 59,000 和 1,500。

（c）在 80%隔离的情境下，到 1 月底，预计感染人口和死亡人数将分别达到 15,842 和 102；而到 2 月底，这两个数字将分别为 45572 和 872。最终感染人口和死亡可能分别超过 190,000 和 4,000。

随着全社会动员起来，全社会认识到防疫的重要性和难点，疫情将在 2-3 个月内得到控制。
在疫情得到彻底控制之前，注意减少社会流动性。

Introduction

Accurately estimating infected population is a key for making .epidemic preventing policies.
SIR model has been widely used for modeling infectious diseases.
If we divide the total population into susceptible population (S), Infected population (I), and recovered population (R, Including death).

We have the following relationship

$$\frac{dS}{dt} = -b * k * S * I \quad (1)$$

$$\frac{dI}{dt} = b * k * S * I - I*r \quad (2)$$

$$\frac{dR}{dt} = I * r \quad (3)$$

Where b is the risk of transmission per contact, k is the average contact by a person; r is the recovering rated. As the recovering period for the new Coronavirus is about 14 days,
r=1/14=0.071429

We can identify the parameters of the above model based on the current data.

Data

According to the new publication **"Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China." (Huang et al. 2020)** in Lancet, the first case was confirmed **on Dec. 1, 2019**, which is one week earlier than the early report by the media. Such a time change will change the model results slightly, according to the new time, I re-estimated the model and project the new results.

The reliability of the data is crucial for estimating the parameters, which are linked accuracy of the projection.
There are two sets of reported data of infected population. One is estimated by Imai et al. (2020) and one is reported by Chinese government.
The main data is reported as follows.
Table 1:

Estimated by Imai et. (2020)		Official data		
Time	Data	Time	Confirmed	Including suspicious cases
Jan. 12	1723	Jan. 19	198	
Jan.18	4000	Jan. 20	218	
		Jan. 21	320	
		Jan. 22	478	
		Jan. 23	639	1061
		Jan. 25	1377	3360

We can set parameters for the SIR model to fit the about data based on the most-recent infected data by Imai et al. (2020). They estimated the infected population in China is about 4000. This is a better data, It is widely believed the official data in China is underreported. We use 4000 cases on Jan. 18 as the baseline to estimated the parameters[1].

The starting date of the model is Dec. 1, as Huang et al. (2020) reported the first case on that day in their paper.

In addition, we assume average contacts per person is 5 per day. Such an assumption is reasonable. Such as assumption will not affect our results. If we do not make an assumption for k, b is not identified. Here, b is the key variable.

The estimated parameters of SIR are reported as follows:
Table 2

	Imai et al. data
b	0.050065
k	5
r	0.071429
Death rate	0.03
Estimated Infectious population in Jan. 23	9105

Note:* 10546 is estimated by SIR.

Hence, the basic reproduction number R0= 0.050065*5*14=3.5. This is a very high number.

The estimating procedure and results could be seen in the appendix excel file.

Policy Projections

As governments will take strict quarantine measures to prevent the pandemic of the new virus, we will model the policy results.
We have different scenarios:

Base **Scenario: The government takes strict cases that all people who are found infected are strictly quarantined** （k=1），

Other Scenarios: The government takes strict cases that infected people are less strictly

[1] If we use the confirmed cases reported by Chinese government to estimate the death rates. The death rate is 17%, **as the death has lags behind the infection.** If we use the data including the suspicious cases, the death rate will be 13%. The death rates are higher than those the media reported. The bias might be due to under reporting of the infected cases in the official data. However, if use the infected data of Imai et al. and consider the official death report is correct, then the death rate is 3%. It is close the real observations. It also shows that the estimation of Imai et al. is trustable.

quarantined,

As K0 ranges between 1 and 5. 1 indicates most strictly quarantined, and 5 means no quarantine.

Table 3. Parameter setting

K0	% Quarantined
1	100
1.4	90
1.8	80
2.2	70
2.6	60
3	50
3.4	40
3.8	30
4.2	20
4.6	10
5	0

We expect that the epidemic of Corona virus in China will exist until May 2020. We projected the results into the end of April.

Given different quarantine rates, I report the main results as follows.

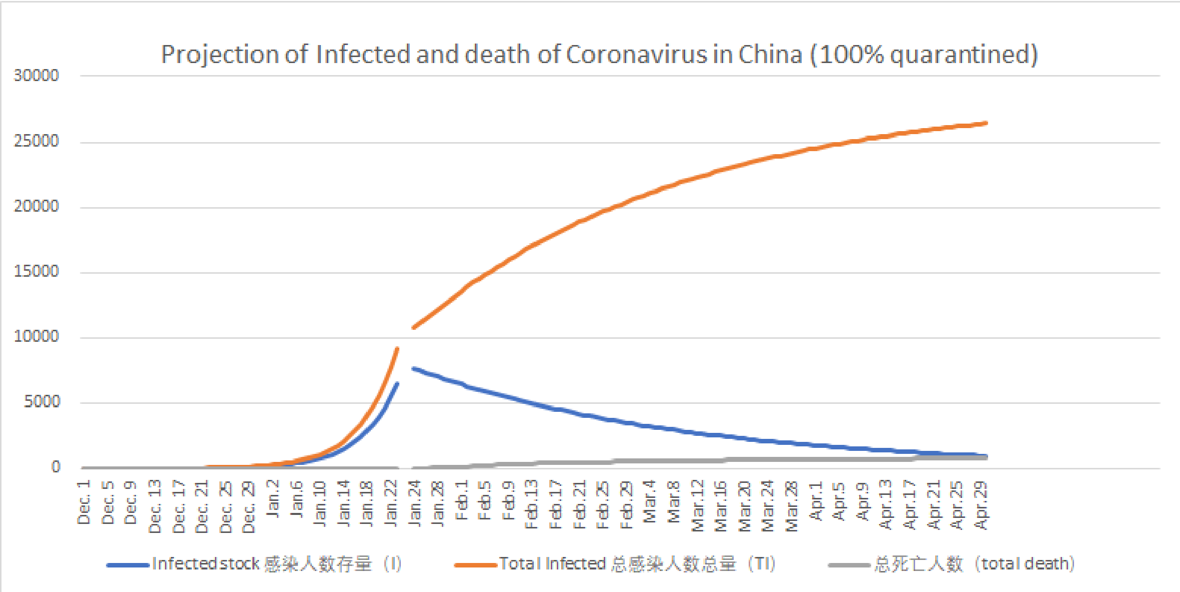

Fig. 1 K=1 (100% quarantined)

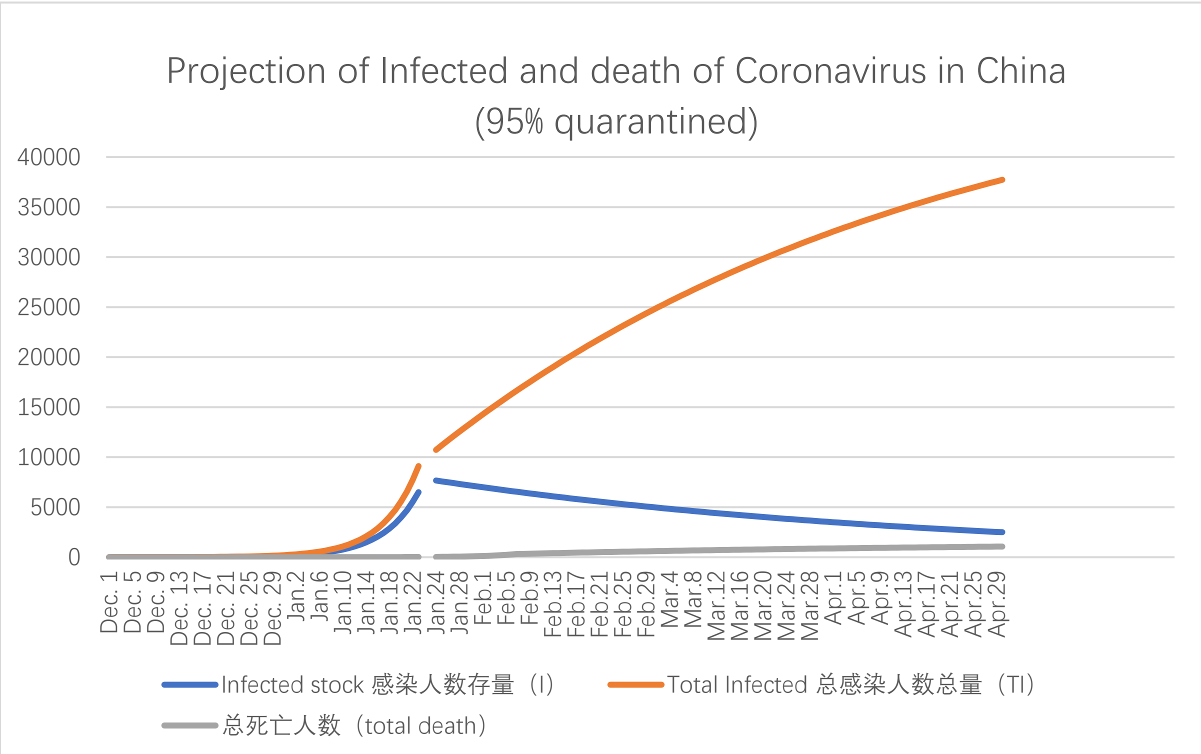

Fig. 2 K=1.2 (95% quarantined)

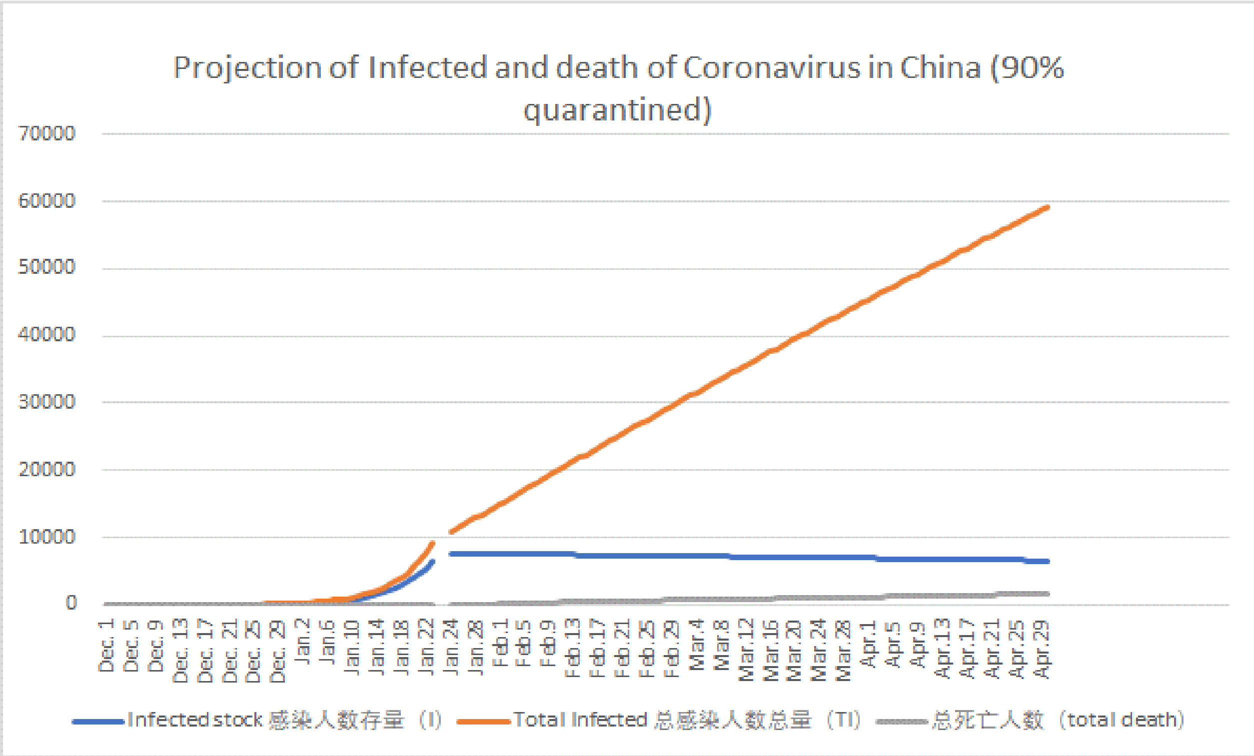

Fig. 3, K=1.4 (90% quarantined)

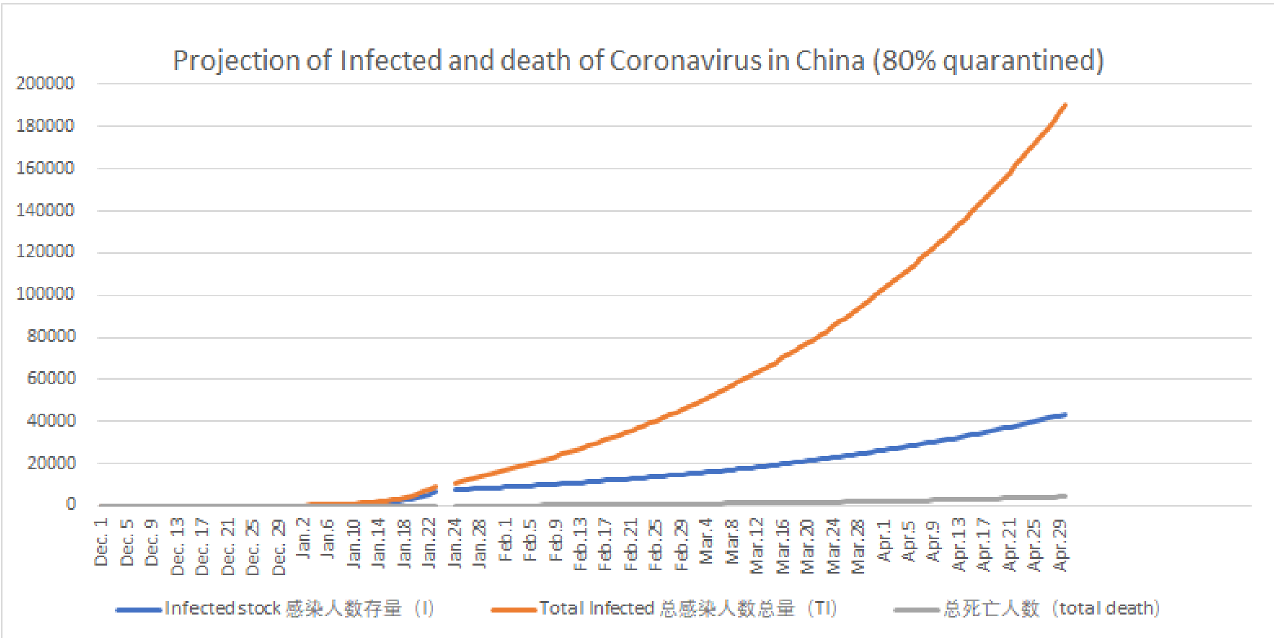

Fig. 4 K=1.8 (80% quarantined)

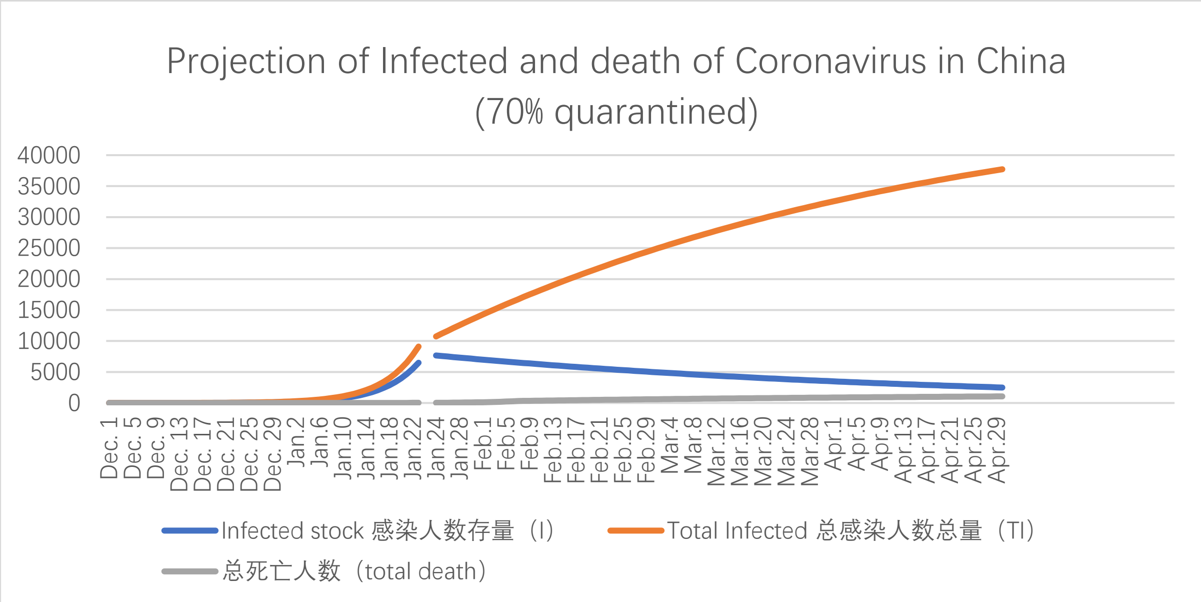

Fig. 5 K=2.2 (80% quarantined)

The above pictures clearly show that if k>1.4, or the quarantined rate is lower than 90%, the epidemic can not be controlled, and the inferred population still grows.

Table 4 Projection results

k=1	100% quarantined		100%隔离
Time	Infected stock	total infected	total death
	感染存量	总感染数	总死亡数
Jan. 23		4000	18
Jan. 30	6590	13250	102
Feb. 29	3515	20421	525
Mar. 31	1794	24427	688
Apr. 30	935	26424	770

k=1.4	90% quarantined		90%隔离
time	Infected stock	total infected	total death
	感染存量	总感染数	总死亡数
Jan. 23		1060	18
Jan. 30	7593	14475	102
Feb. 29	7275	29567	671
Mar. 31	6928	44958	1143
Apr. 30	6589	59114	1578

K=1.8	80% quarantined		80%隔离
time	Infected stock	total infected	total death
	感染存量	总感染数	总死亡数
Jan. 23		1060	18
Jan. 30	8724	15842	102
Feb. 29	14824	45572	878
Mar. 31	25863	100186	2153
Apr. 30	43557	190122	4272

K=2.2	70% quarantined		70%隔离
time	Infected stock	total infected	total death

	感染存量	总感染数	总死亡数
Jan. 23		1060	18
Jan. 30	9996	17367	102
Feb. 29	29741	73971	1173
Mar. 31	92361	257286	4481
Apr. 30	251069	754828	13930

K=2.6	60% quarantined		60%隔离
time	Infected stock	total infected	total death
	感染存量	总感染数	总死亡数
Jan. 23		1060	18
Jan. 30	11423	19065	102
Feb. 29	58707	124671	1595
Mar. 31	305813	700179	9890
Apr. 30	931152	2599482	45514

K=3	50% quarantined		50%隔离
time	Infected stock	total infected	total death
	感染存量	总感染数	总死亡数
Jan. 23		1060	18
Jan. 30	13021	20951	102
Feb. 29	113834	215048	2194
Mar. 31	859167	1799759	22127
Apr. 30	1123873	4694080	109073

k=3.4	40 % quarantined		40%隔离
time	Infected stock	total infected	total death
	感染存量	总感染数	总死亡数
Jan. 23		1060	18
Jan. 30	14807	23045	102
Feb. 29	216155	374550	3046
Mar. 31	1652705	3635312	47452
Apr. 30	584276	5278155	150710

k=3.8	30% quarantined		30%隔离
time	Infected stock	total infected	total death
	感染存量	总感染数	总死亡数
Jan. 23		1060	18
Jan. 30	16799	25365	102
Feb. 29	399643	650161	4252
Mar. 31	1737616	4957216	89565
Apr. 30	288864	5412803	160786

K=4.2	20% quarantined		20%隔离
time	Infected stock	total infected	total death
	感染存量	总感染数	总死亡数
Jan. 23		1060	18
Jan. 30	19016	27931	102
Feb. 29	712118	1108586	5948
Mar. 31	1263954	5350577	133426
Apr. 30	161856	5459859	163363

K=4.6	10% quarantined		10%隔离
time	Infected stock	total infected	total death
	感染存量	总感染数	总死亡数
Jan. 23		1060	18
Jan. 30	21478	30766	102
Feb. 29	1201368	1821836	8320
Mar. 31	877305	5449025	155697
Apr. 30	102506	5480486	164273

K=5	No quarantined		无隔离
time	Infected stock	total infected	total death
	感染存量	总感染数	总死亡数
Jan. 23		1060	18
Jan. 30	24209	33893	102
Feb. 29	1862665	2808395	11610
Mar. 31	636583	5479739	162258
Apr. 30	71542	5490374	164659

References:

M. Chinazzi, et al., Series Reports Entitled "Preliminary assessment of the International Spreading Risk Associated with the 2019 novel Coronavirus (2019-nCoV) outbreak in Wuhan City".

Imai N. (2020) Report 2: Estimating the potential total number of novel Coronavirus cases in Wuhan City, China. Available at : https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/2019-nCoV-outbreak-report-22-01-2020.pdf

Huang C. et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Jan. 24. Lancet. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)30183-5/fulltext