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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）

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Abstract：
Based on the SIR model and different data sources, 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 over 10000 on Jan. 23.
Government started to take strong measures in response to the epidemic of new coronavirus, we assume two scenarios.
In the first scenario, when all found infected people are quarantined, the total infected and total death by the end of April 2020 could be more than 41300 and 1100 respectively; In the second scenario, if 20% run at large, the numbers could reach 67000 and 1800 respectively.
The epidemic might last until May.
Accurately estimating infected population is a key for making epidemic preventing policies.

摘要:
基于 SIR 模型和不同的数据来源，我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。我发现官方数据中有些数据不一致，而 Imai 等人报告的数据一致性较高 以 Imai 等人的数据，为基础，我估计出 1 月 23 日中国受感染的人口超过 10000。

从 1 月 22 日开始，政府采取了非常严格防疫措施。我们假设有两种情况，对政策效果进行了估测。在第一种情况下，如果完全隔离所有发现的感染者，到四月底，感染总数和死亡总数可能分别超过 41300 和 1100。在第二种情况下，如果 20％ 感染者没有被隔离，则这两个数字可能分别达到 67000 和 1800。该病毒可能要持续到五月。
估计感染和死亡人数对接下来的防疫工作的准备和物资调度至关重要。

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 (2)

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

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

We can set parameters for the SIR model to fit the about data based on the most-recent infected data. Particularly, 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

	Confirmed Cases	data with suspicions cases	Imai et al. data
Estimated parameters			
b	0.04208	0.04475	0.05708
k	5	5	5
r	0.071429	0.071429	0.071429
Death rate	0.17	0.13	0.03
Estimated Infectious population in Jan. 23			10546*

Note:* 10546 is estimated by SIR.

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

Note that is we use the confirmed cases 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.

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 two scenarios:

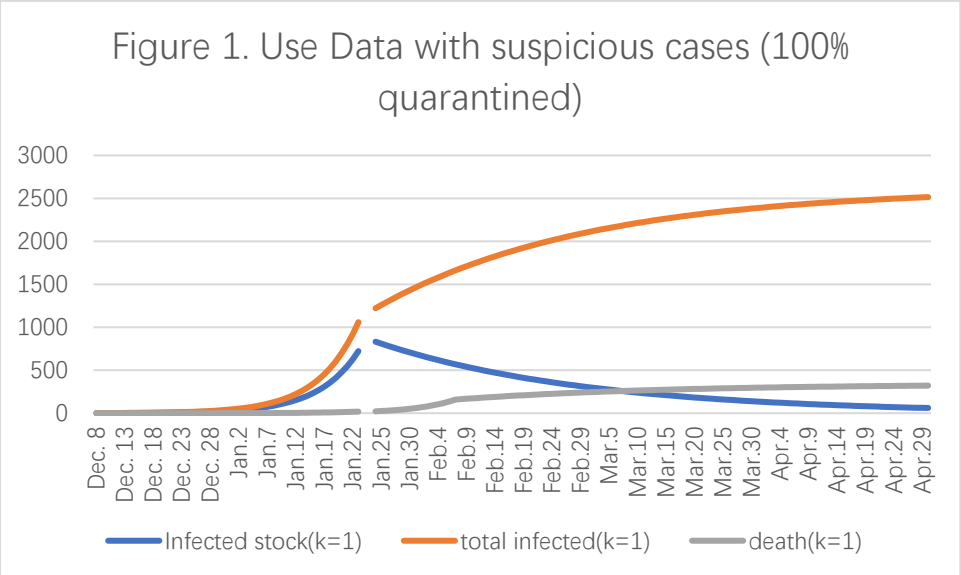
Scenario 1: The government takes strict cases that all people who are founded infected are strictly quarantined （k=1），

Scenario 2: The government takes strict cases that all infected people are less strictly quarantined, and 20% might run at large (k=1.2）.

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

The results are reported as follows.

Case I: use the official data with suspicious cases



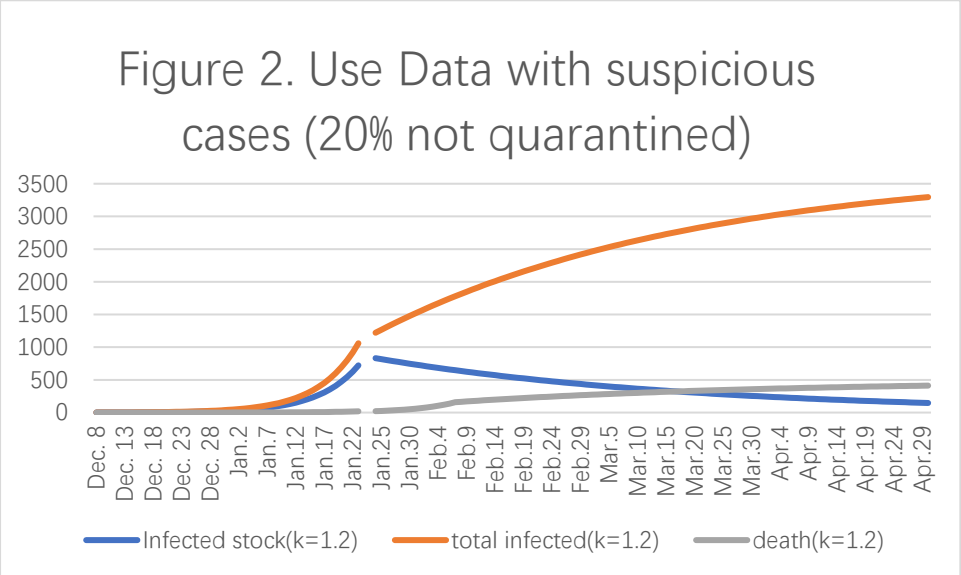
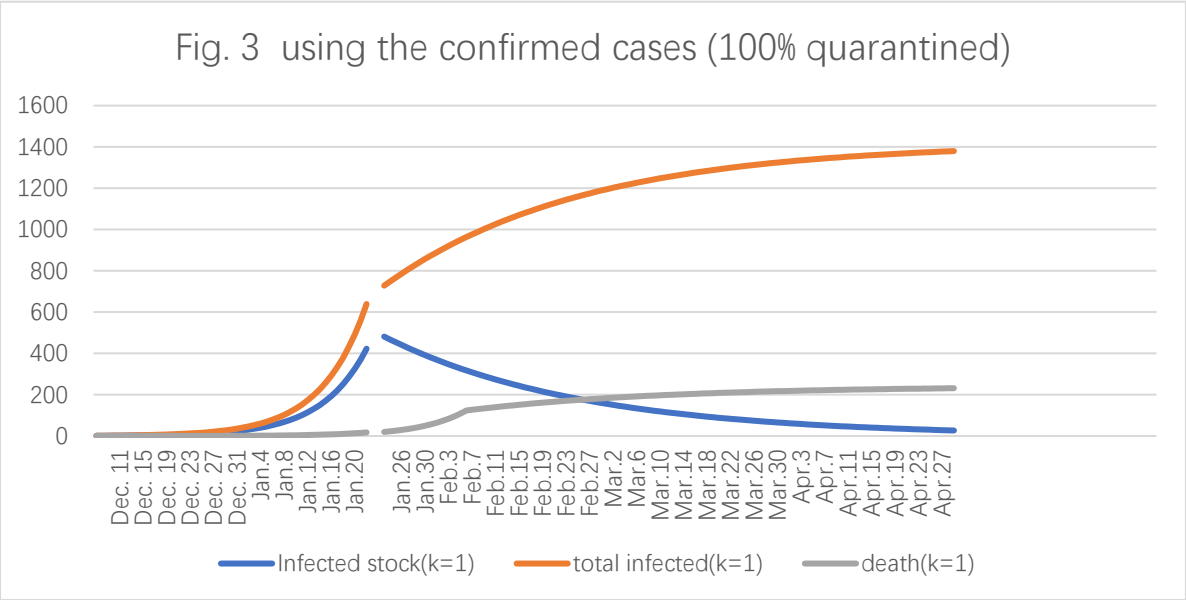


Table 3 Projection results with use of Data with suspicious cases

	100% Quarantined				20% not quarantined		
time	Infected stock(k=1)	total infected(k=1)	total death(k=1)		Infected stock(k=1.2)	total infected(k=1.2)	total death(k=1.2)
	感染存量	总感染数	总死亡数		感染存量	总感染数	总死亡数
Jan. 23		1060	18			1060	18
Jan. 30	688	1462	59		734	1518	59
Feb. 29	314	2089	240		437	2417	265
Mar. 31	136	2388	297		251	2980	359
Apr. 30	60	2515	321		147	3295	412

Case 2: use the official data of confirmed cases



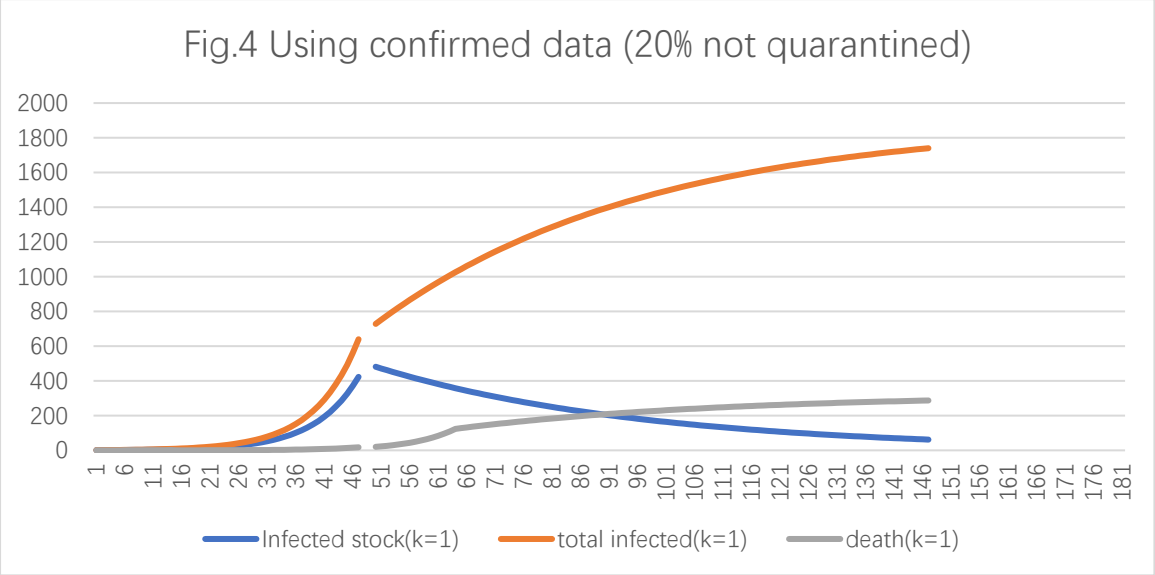
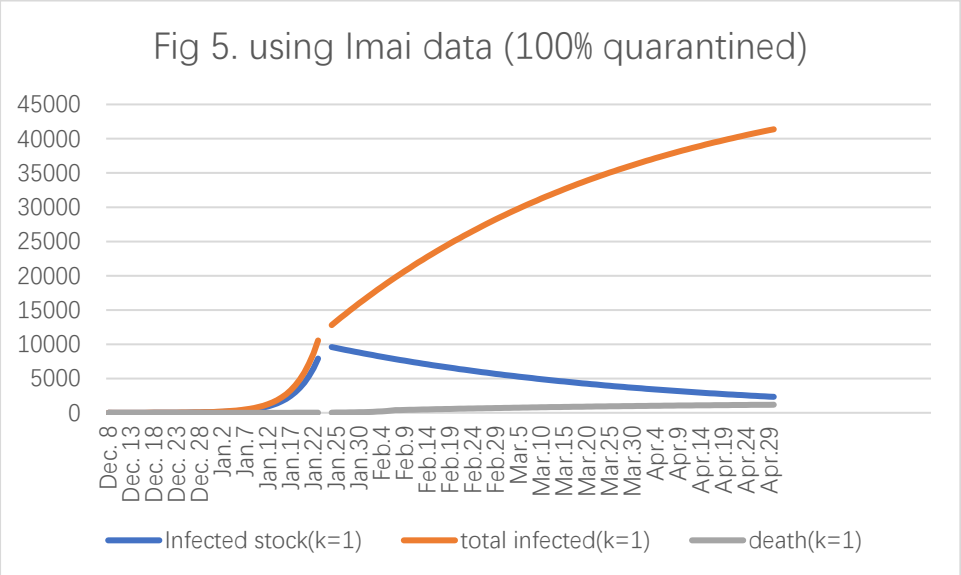


Table 4 Projection results with use of Data of confirmed cases

	100% Quarantined				20% not quarantined		
time	Infected stock(k=1)	total infected(k=1)	total death(k=1)		Infected stock(k=1.2)	total infected(k=1.2)	total death(k=1.2)
	感染存量	总感染数	总死亡数		感染存量	总感染数	总死亡数
Jan. 23		639	18			639	18
Jan. 30	391	858	50		415	888	50
Feb. 29	165	1182	180		225	1347	197
Mar. 31	65	1324	217		117	1608	257
Apr. 30	27	1380	231		62	1740	287

Case III: estimated data by Imai et al.(2020)



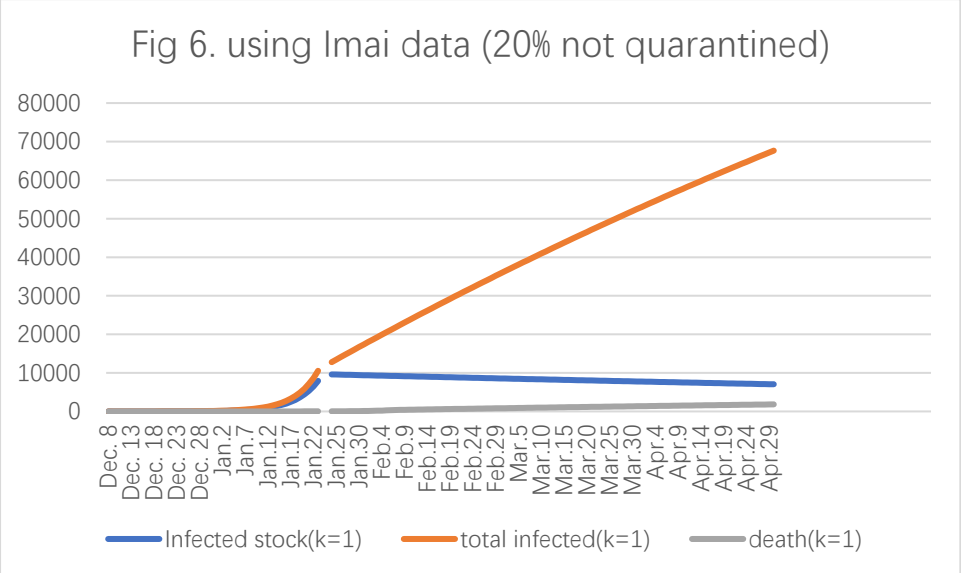


Table 5 Projection results with use of Data from Imai et al. (2020)

	100% Quarantined				20% not quarantined		
time	Infected stock(k=1)	total infected(k=1)	total death(k=1)		Infected stock(k=1.2)	total infected(k=1.2)	total death(k=1.2)
	感染存量	总感染数	总死亡数		感染存量	总感染数	总死亡数
Jan. 18	3001	4002	8		3001	4002	8
Jan. 23	7906	10546	21		7906	10546	21
Jan. 30	8668	16468	99		9394	17354	99

Feb. 29	5680	28233	695		8587	35190	803
Mar. 31	3610	36351	994		7773	52508	1347
Apr. 30	2326	41372	1179		7037	67658	1823

Reference:
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