# Report 6: Relative sensitivity of international surveillance

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## Summary

Since the start of the COVID-19 epidemic in late 2019, there are now 29 affected countries with over 1000 confirmed cases outside of mainland China. In previous reports, we estimated the likely epidemic size in Wuhan City based on air traffic volumes and the number of detected cases internationally. Here we analysed COVID-19 cases exported from mainland China to different regions and countries, comparing the country-specific rates of detected and confirmed cases per flight volume to estimate the relative sensitivity of surveillance in different countries. Although travel restrictions from Wuhan City and other cities across China may have reduced the absolute number of travellers to and from China, we estimated that about two thirds of COVID-19 cases exported from mainland China have remained undetected worldwide, potentially resulting in multiple chains of as yet undetected human-to-human transmission outside mainland China.

## 1. Introduction

As of 20 February 2020, over 74,000 cases of COVID-19 (formerly 2019-nCoV) have been reported in China (with 2121 deaths), and cases have been detected in 29 regions and countries outside mainland China (including Hong Kong SAR and Macau SAR). Several analyses have been undertaken to predict or estimate the risk of exported cases by country on the basis of flight connections between Wuhan City, China or mainland China as a whole and other regions and countries [1-5]. In this analysis we built on published work [3] to analyse COVID-19 cases reported and confirmed in different countries that were exported from mainland China, comparing the country-specific rates of detected cases per flight volume to estimate the relative sensitivity of surveillance in different countries. We then estimated the number of COVID-19 cases exported from mainland China that have remained undetected.

## 2. Results

The number of exported cases by country was plotted as a function of the average monthly passenger volume originating from Wuhan Tianhe International Airport on international flights (Figure 1). This showed Singapore to be an outlier in terms of having relatively many exported cases compared to the measure of air traffic volume.

The relative sensitivity of surveillance in individual countries was estimated compared to Singapore. Finland, Nepal, Belgium, Sweden, India, Sri Lanka, and Canada were all found to have relative sensitivity estimates greater than 1 (i.e. more cases were detected per passenger flight than in Singapore). Thus, a second set of relative sensitivity estimates was obtained for all other individual countries compared simultaneously to Singapore, Finland, Nepal, Belgium, Sweden, India, Sri Lanka, and Canada.
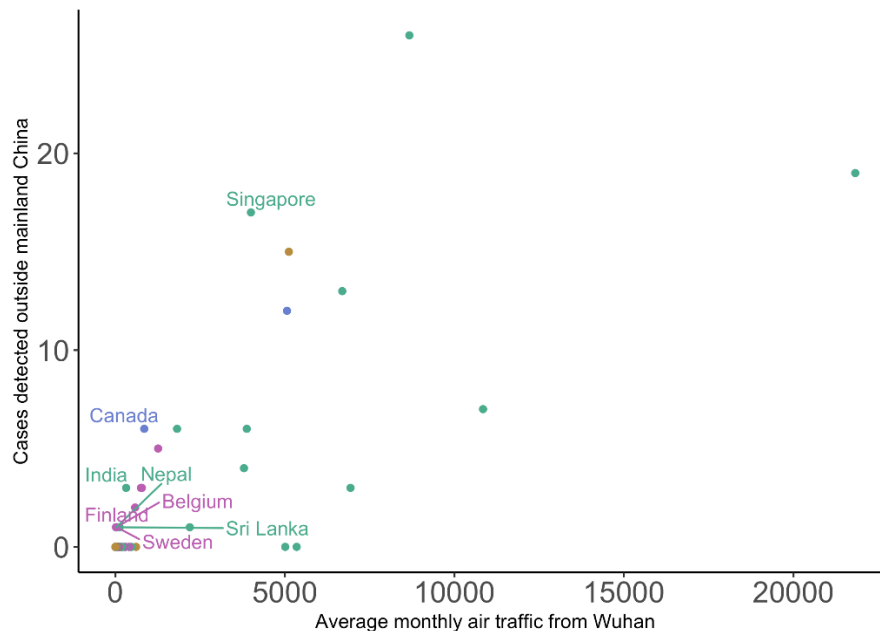


**Figure 1. The number of exported COVID-19 cases detected by region and country plotted against the average monthly international air traffic volume from Wuhan Tianhe International Airport aggregated by destination country.**

The region- and country-specific expected numbers of exported COVID-19 cases were in several cases substantially higher than the numbers detected (Figure 2). The sum of the expected numbers of exported COVID-19 cases for all regions and countries other than mainland China was 426.3, based on the analysis relative to Singapore only, and 576.5, based on the analysis relative to Singapore, Finland, Nepal, Belgium, Sweden, India, Sri Lanka, and Canada. Given that 156 such cases were detected, these central estimates suggest that between 63% (relative to Singapore only) and 73% (relative to Singapore, Finland, Nepal, Belgium, Sweden, India, Sri Lanka, and Canada) remained undetected.
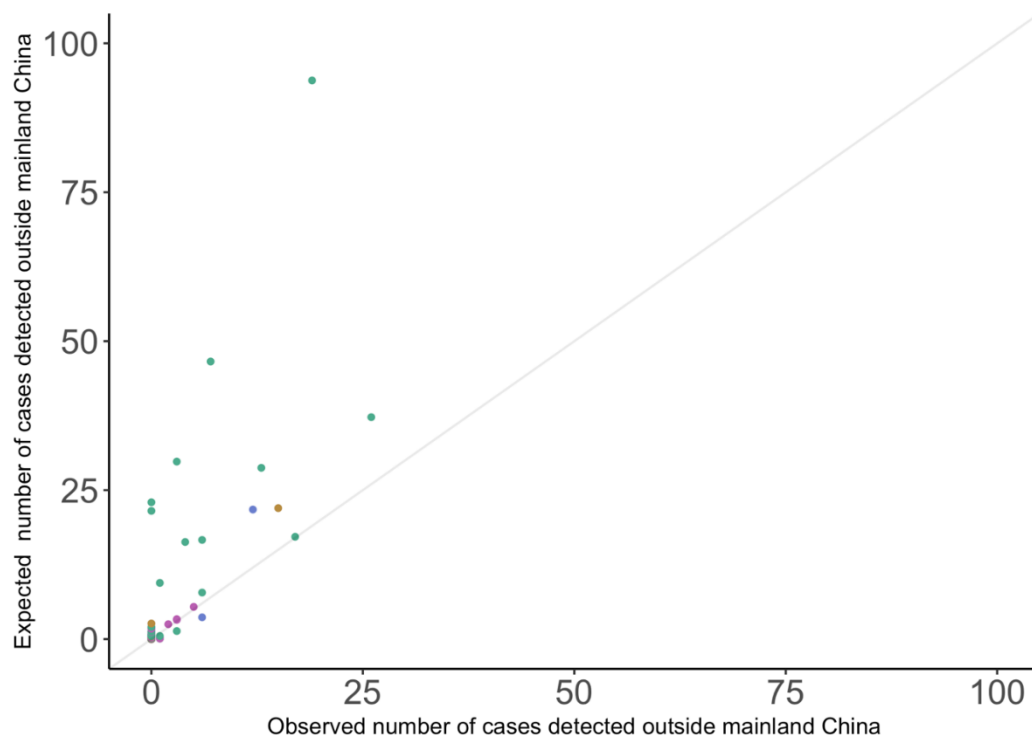
**Figure 2. The expected and observed numbers of exported COVID-19 cases by region and country, with expected values calculated relative to Singapore only. Values above the diagonal line indicate more cases were expected than were observed.**

## 3. Conclusions

Consistent with similar analyses [3], we estimated that more than half of COVID-19 cases exported from mainland China have remained undetected worldwide, potentially leaving sources of human-to-human transmission unchecked (63% and 73% undetected based on comparisons with Singapore only and with Singapore, Finland, Nepal, Belgium, Sweden, India, Sri Lanka, and Canada, respectively). Undoubtedly, the exported cases vary in the severity of their clinical symptoms, making some cases more difficult to detect than others. However, some countries have detected significantly fewer than would have been expected based on the volume of flight passengers arriving from Wuhan City, China.

## 4. Methods

Air travel data for the months of January, February, and March 2016 were obtained from the International Air Travel Association (IATA), with the sum divided by three to get destination-region- and destination-country-specific monthly averages. These numbers were not scaled up to reflect recent growth in air travel because any constant scaling of the monthly averages would simply be absorbed into the $\lambda$ estimate and not affect other results. Flows of passengers within mainland China were excluded from this analysis.

A model was developed assuming that for each country *i*, there are two numbers: $X_i$ and $F_i$ where $X_i$ is the number of exported cases (a count) and $F_i$ is the air traffic volume. Assuming Poisson distributions, the relative sensitivity of country *i*, compared to country *j*, denoted $s_{ei}$, can be used to write a joint log likelihood for the data from countries *i* and *j*:

$$l = X_i \ln(s_{ei}\lambda F_i) - s_{ei}\lambda F_i + X_j \ln(\lambda F_j) - \lambda F_j$$

ignoring additive constants. Thus, the maximum likelihood estimates are:

$$\hat{\lambda} = \frac{X_j}{F_j} \text{ and } \hat{s}_{ei} = \frac{X_i F_j}{X_j F_i}.$$

The likelihood-based confidence intervals are obtained by calculating the maximum log likelihood (over values of $\lambda$) for each value of $s_{ei}$. Then the 95% CI includes all those values of $s_{ei}$ such that $2(l_{\widehat{s_{ei}}} - l_{s_{ei}}) \leq 3.84$ (the 95th centile of the chi-squared distribution with 1 degree of freedom).

The relative sensitivities can also be estimated relative to *J* countries simultaneously using a method similar to above but with the log likelihood:

$$l = X_i \ln(s_{ei}\lambda F_i) - s_{ei}\lambda F_i + \sum_{j=1}^{J} X_j \ln(\lambda F_j) - \lambda F_j$$

Expected values could then be calculated for every country *i* as simply $\hat{\lambda} F_i$.

## 5. Data used for this analysis

We collated data on 439 cases in international travelers from media reports and provincial and national department of health press releases up until 17 February 2020. We defined a local transmission as any transmission that occurred outside of mainland China (Hong Kong and Macau are considered outside of mainland China here). We only consider cases that were not transmitted locally. That is, we only considered cases detected outside mainland China that had a travel history to China and arrived outside mainland China by air (Table 1). Based upon these inclusion criteria, a total of 156 cases were included in our analysis. The earliest date of travel for the cases included in the analysis is 1 January 2020, and the latest date of travel is 13 February 2020.

**Table 1. Number of cases detected outside mainland China with travel history to China stratified by travel history to Hubei Province, or any other province in China.**

| Country | Travel History to Hubei | No Travel History to Hubei | Unknown | Total (cases with a travel history to China) | Travelled by air |
|---|---|---|---|---|---|
| Australia | 15 | 0 | 0 | 15 | 15 |
| Belgium | 1 | 0 | 0 | 1 | 1 |
| Cambodia | 1 | 0 | 0 | 1 | 1 |
| Canada | 6 | 0 | 0 | 6 | 6 |
| Finland | 1 | 0 | 0 | 1 | 1 |
| France | 5 | 0 | 2 | 7 | 5 |
| Germany | 2 | 0 | 0 | 2 | 2 |
| Hong Kong SAR | 11 | 2 | 0 | 13 | 3 |
| India | 2 | 0 | 1 | 3 | 3 |
| Italy | 3 | 0 | 0 | 3 | 3 |
| Japan | 23 | 4 | 0 | 27 | 26 |
| Macau SAR | 5 | 3 | 0 | 8 | 0 |
| Malaysia | 9 | 4 | 0 | 13 | 6 |
| Nepal | 1 | 0 | 0 | 1 | 1 |
| Philippines | 3 | 0 | 0 | 3 | 0 |
| Singapore | 19 | 3 | 0 | 22 | 17 |
| South Korea | 11 | 2 | 0 | 13 | 13 |
| Sri Lanka | 1 | 0 | 0 | 1 | 1 |
| Sweden | 1 | 0 | 0 | 1 | 1 |
| Taiwan | 8 | 0 | 0 | 8 | 7 |
| Thailand | 14 | 3 | 5 | 22 | 19 |
| United Arab Emirates | 0 | 0 | 6 | 6 | 6 |
| United Kingdom | 0 | 1 | 2 | 3 | 3 |
| United States of America | 10 | 1 | 1 | 12 | 12 |
| Vietnam | 4 | 0 | 0 | 4 | 4 |

## 6. References

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