Metabiota Risk Report No. 2: February 11, 2020

Monitoring and risk analytics for the 2019 novel coronavirus (COVID-19) epidemic

Executive Summary

Metabiota has been closely monitoring and analyzing the novel coronavirus event since January 2, 2020. In the past week, the WHO officially named the disease COVID-19. The COVID-19 event has now overtaken the SARS-CoV epidemic in number of cases and deaths. The current outbreak has not yet been contained as the number of new cases is continuing to increase. Metabiota is tracking and analyzing this outbreak using several technologies, including a true-to-source digital surveillance system capturing over 34 data sources with an expertly-derived fusion data stream capturing the full spatiotemporal picture of the outbreak.

Metabiota has utilized its global disease spread model to create short-term forecasts incorporating the current known characteristics of the virus. Our forecasting model predicts that, if the epidemic continues on its current trajectory, reported cumulative cases could double between February 10th and 17th. Through Metabiota's Transit Hub module, we estimate the top countries at highest risk for additional imported COVID-19 cases include: Thailand, Japan, Taiwan, South Korea, Malaysia, Singapore, and the United States (as of Feb. 11, 2020). As mentioned in our previous report, Metabiota estimates a high Pathogen Sentiment Score for SARS-CoV-2. This "fear score" indicates that the attributes of this virus are likely to generate public alarm. We are observing significant economic impacts particularly in industries related to travel and tourism and in heavily affected areas.

Introduction

Since January 2, 2020, Metabiota has been closely tracking the novel coronavirus (COVID-19) epidemic, which began in Wuhan, China. We have applied a number of our technologies to provide situational awareness and risk analytics to our partner organizations, to shed light on the epidemiology of the outbreak, as well as its potential trajectory and impact. These tools and analytics are available on Metabiota's cloud-based software (Global Epidemic Modeling and Monitoring) platform.

In addition to the tools in Metabiota's cloud-based platform, Metabiota is performing short-term forecasts through their global disease spread model which is included in this report.

Digital Surveillance

Metabiota collects and structures data from a wide variety of reporting sources to produce a dataset with the finest spatiotemporal resolution data. Currently, Metabiota is monitoring incidence across 26 countries using more than 34 public data sources for this outbreak, ranging from the Hong Kong Centre for Health Protection to the World Health Organization. An aggregated view of the data is available publicly through Metabiota's Epidemic Tracker**.**

Box 1: Situation Report as of Tuesday, February 11

- There are currently 43,119 confirmed cases with 1,018 deaths
- Cases have been confirmed in 33 territories[1] in China
- Cases have been confirmed in 25 additional countries
- There have been 13 confirmed cases in the US, 7 in California, 2 in Illinois, and 1 each in Arizona, Massachusetts, Washington state, and Wisconsin

High resolution data, available for non-commercial use, has been publicly released to Metabiota's Epidemic Data repository.

Box 2: COVID-19: Current epidemiologic assessment

What we currently know

- COVID-19 is a novel coronavirus and is related to the viruses that cause SARS (severe acute respiratory syndrome) and MERS (Middle East respiratory syndrome).
- The WHO has named the disease caused by the virus COVID-19. The Coronavirus Study Group considers COVID-19 to be closely related to SARS-CoV.
- Symptoms include fever, cough, shortness of breath, and difficulties breathing. Approximately 25% of cases will have more severe symptoms that can include pneumonia, severe acute respiratory syndrome, organ failure, and death.
- Person-to-person transmission of the virus has been confirmed in multiple countries.
- The current observed case fatality ratio is 0.02, which is lower than MERS and SARS. However, the current observed mortality data are incomplete due to the time delay between illness onset and death and potential undercounting of less severe cases.The case fatality ratio of hospitalized patients is 0.11-0.15.
- The virus seems to be transmitted mainly through respiratory droplets like other coronaviruses.

What is uncertain

- The total number of mild or asymptomatic cases that have not been counted and included official reports. At least six asymptomatic cases have been confirmed.

[1] Including provinces, special administrative regions, and municipalities

- A preliminary estimate of the basic reproductive number (R_0), the average number of cases infected by a single case in a completely susceptible population, is 1.4 - 3.3.
- The frequency of super-spreading events. Several instances of COVID-19 cases infecting a large number of people have been observed most commonly in the hospital environment.
- Efficacy of interventions to reduce outbreak burden and spread.

Interpretation

- The novel coronavirus currently appears to cause less severe clinical illness than the related viruses which cause MERS or SARS. Despite fewer severe clinical illnesses, the large number of cases has resulted in more deaths than the 2003 SARS epidemic.
- Currently, the number of new cases is continuing to increase, which indicates that the outbreak has not been contained.

Forecasting

Metabiota developed a forecasting model to predict the short-term trajectory of the novel coronavirus (COVID-19) epidemic. Our modeling framework consists of a stochastic Susceptible-Exposed-Infectious-Recovered (SEIR) metapopulation compartment model coupled with human mobility networks overlaid across a high-resolution global human population grid. We simulated 500 COVID-19 outbreaks encompassing a range of plausible parameter values (Table 1) with starting conditions similar to those reported on January 26th. We assume that there is extensive underreporting in the current outbreak.

Table 1. Coronavirus Model Parameters

Parameter	Mean value	Definition	Source(s)
Transmissibility (R_0) *	2.6	Disease transmission rate	[2] [3] [4]
Incubation Period (days)	5.2	Median time from exposure to symptom onset	[2]
Infectious Period (days)	9.2	The number of days an individual is infectious	[5]

*Superspreading is incorporated as dispersion of R_0 around the mean input value

[2] Li Q, Guan X, Wu P, et al. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. N Engl J Med. 2020; doi: 10.1056/NEJMoa2001316

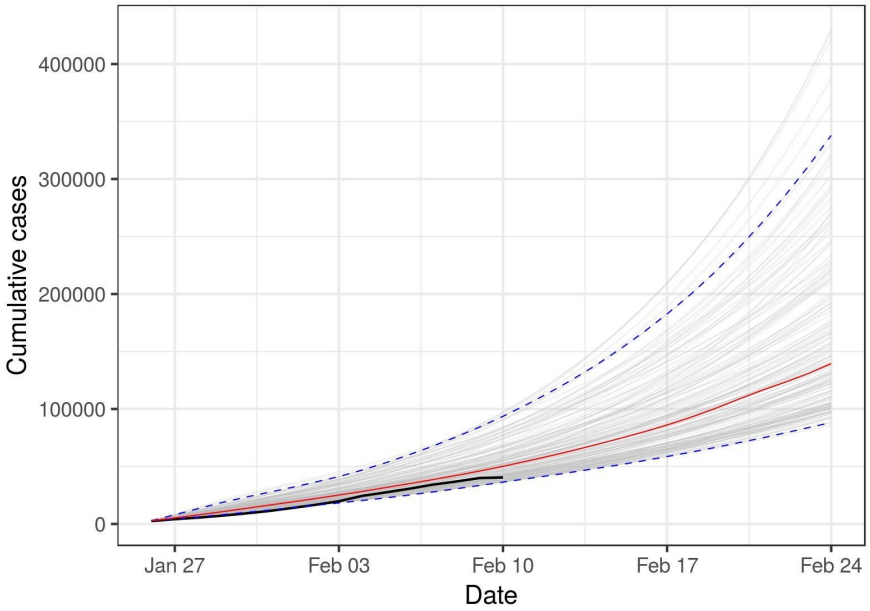
[3] Read, JM, JRE Bridgen, D Cummings, A Ho, and CP Jewell. Novel Coronavirus 2019-NCoV: Early Estimation of Epidemiological Parameters and Epidemic Predictions. *MedRxiv*, January 1, 2020, 2020.01.23.20018549.

[4] Imai N, ACori, I Dorigatti, M Baguelin, CA Donnelly, S Riley, and N Ferguson. “Report 3: Transmissibility of 2019-NCoV,” https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-2019-nCoV-transmissibility.pdf

[5] Riou J and CL Althaus, 2020. Pattern of early human-to-human transmission of Wuhan 2019-nCoV bioRxiv 2020.2001.2023.917351

We present forecasting results based on stochastically simulated events. Our forecast model predicts reported cumulative cases will approximately double between February 10th and 17th. On February 17th, our model predicts a median cumulative case count of 85,000 cases, with a lower and upper 95% confidence window of 58,000 and 180,000 cases, respectively (Figure 1). See Methodological Details, below for further information.

Figure 1: Short Term Forecasted Trajectory of the COVID-19 outbreak



The black line shows reported cumulative infections up to February 10th. Faded gray lines show individual model runs after filtering. The solid red and dashed blue lines show median cumulative case counts predicted by our forecast model and the 95% confidence window, respectively. The median and confidence windows were determined after filtering.

Since we have not seen a slowdown in the growth of the COVID-19 outbreak as of February 10th, our model assumes the outbreak will continue to grow at a similar pace for the short term forecast. However, the development of improved public health interventions within the forecast window could slow the growth rate. If we do not see containment of the outbreak within the forecasted timeline, our model predicts approximately 144,000 cumulative cases within a 95% confidence window of 88,216 and 337,876 cases by February 24th.

See Appendix 1 for further methodological details.

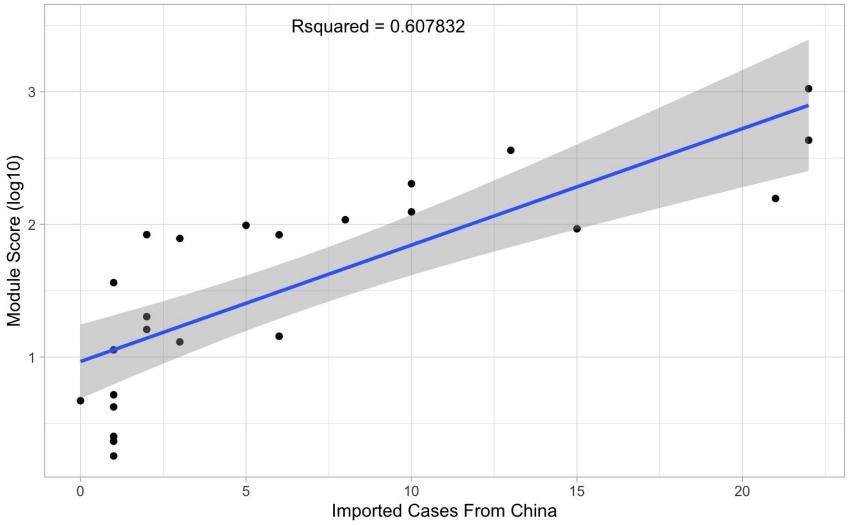
Transit Hub Risk Module

The Transit Hub Risk module (the Module) combines Metabiota's digital surveillance data with information on global air travel networks. It provides a probabilistic risk estimate of an emerging infectious disease moving through thousands of airports worldwide, and is updated daily. The Transit Hub Risk estimates provide situational awareness, and can help decision-makers identify potential regions at risk for disease importation, focus strategic attention, and allocate preparedness, surveillance and response assets to specific airports or geographies. The Transit Hub Risk module is accessible through the Metabiota software platform, and provides airport-level relative and absolute risk scores. The Module allows users to:

- Visualize and evaluate an airport's origin risk of sending and receiving cases
- Download the latest daily, and previous 14 days, conditional risk assessments by airport, pathogen, and risk type (i.e., origin or destination).

Figure 2 depicts Module aggregated country-level scores from January 27th over the cumulative number of cases with travel history to China, indicating the Module scores are positively associated with importation risk[6].

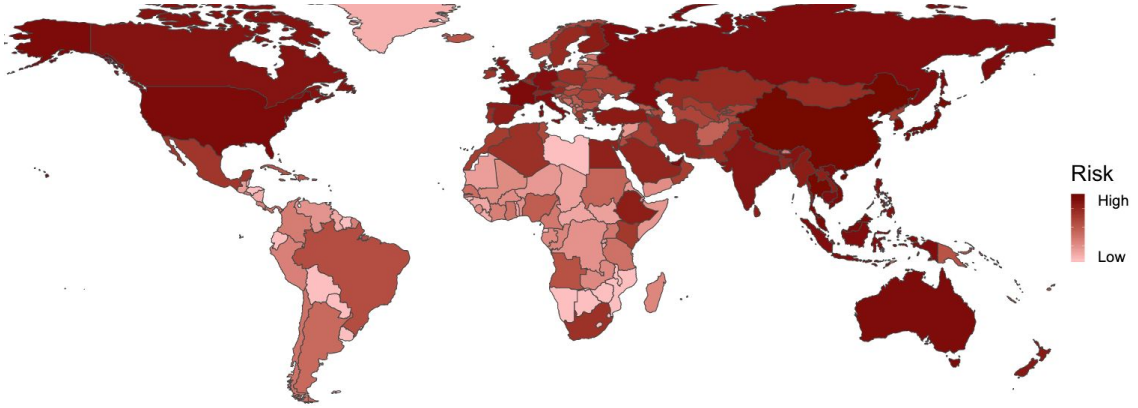
Figure 2: Transit Hub Scores Compared to Number of Imported Cases outside China



Although the COVID-19 situation is constantly evolving, our latest destination risk estimates indicate the following countries to be at the highest risk for new imported infections: Thailand, Japan, Taiwan, South Korea, Malaysia, Singapore, and the United States (Figure 3).

[6] WHO DON. Novel Coronavirus(2019-nCoV). Situation Report 21. February 10, 2020.

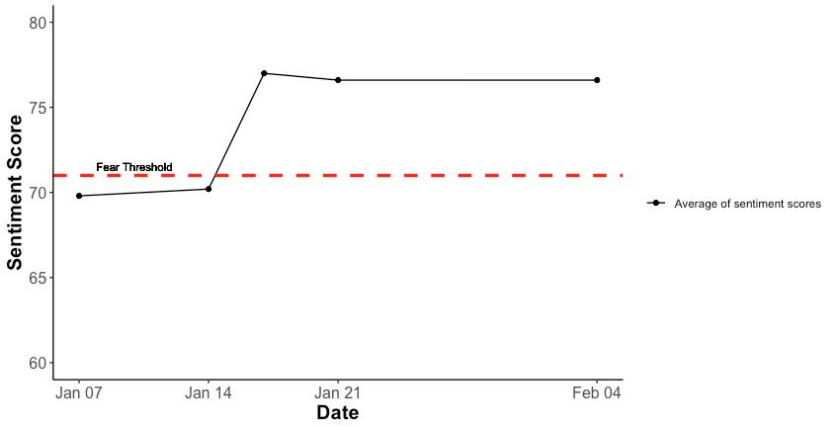
Figure 3: Rank of Aggregated Importation Risk by Country, February 11, 2020



Pathogen Sentiment Score

The Pathogen Sentiment Score provides a quantitative estimate of public fear and anxiety caused by an emerging infectious disease. The score integrates data on multiple features of each pathogen – including morbidities and symptoms, mortality risk, the availability of prophylactic and therapeutic options, disease transmission mechanisms, and novelty – in order to estimate public emotional and behavioral reaction to a potential outbreak. Not all countries react similarly to disease outbreaks, due to culture, familiarity with specific pathogens, and other spatially variable factors.[7]

Figure 4: Pathogen Sentiment Scores for SARS-CoV-2, January 7- February 4, 2020



[7] The Score is available on Metabiota's software platform, which has a specific module that tracks and displays estimates for an emerging pathogen. These estimates are updated as more is known and reported about an emerging pathogen's symptoms, case fatality ratio, transmission mechanism, and other features. Scores are updated at least biweekly and if there are significant developments in the course of an outbreak, Metabiota will revise scores as necessary.

Metabiota began scoring the COVID-19 event on January 7th. The Score has increased initially (Figure 4), due mainly to confirmation of more severe symptoms and human-to-human respiratory transmission. Since January 21, the Score has remained fairly stable, with a slight decrease due to a lower reported case fatality ratio of confirmed cases. The Score is still above 71, a key threshold for economic risk that Metabiota scientists have identified via historical backtesting. The high score suggests that this virus is likely to generate public alarm, which can lead to significant economic damage, especially in industries that rely on the public's perception of safety.

Economic Impact

Beyond the public health and epidemiological impacts of the COVID-19 event, the current outbreak continues to cause significant direct (e.g., hospitalization, sick absenteeism) and indirect (e.g., worry-well absenteeism, equity decline) economic harm. At the macro-level, the Deutsche Bank has estimated that COVID-19 event will noticeably reduce global GDP growth in 2020 with China expected to have a 1.5 percentage point lower Q1 GDP as a result of the outbreak. Other researchers have provided similar loss estimates in global GDP of approximately 0.3 percentage points in Q1.

The economic impact of the COVID-19 event for any given company largely depends on the firm's sector and geographic footprint, as well as that of its suppliers. Voluntary and involuntary restriction of movement and trade into and out of affected regions, particularly China, have noticeably affected both supply and demand. The dependencies of our global economy have been underscored through several high-profile companies announcing manufacturing, supply, and supply chain disruptions:

- Major US airlines cancelling flights to and from China and Hong Kong
- Closure of Macau's gambling centers
- Apple's iPhone and AirPod unit production disruption
- Hyundai reported stopping their production at South Korea plants; other automobile makers and manufacturers reporting supply chain disruptions
- Shipping companies that transport goods from China have reported reducing the number of seaborne vessels

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Appendix 1: Forecasting methodology

Each simulation began with outbreak conditions approximating those occurring on January 26, 2020. Initial studies estimate that only ~5% of cases were identified as of January 22[8]. Given the parameter combinations we are assuming based on current epidemiological knowledge (Table 1), we found that an estimate of 2% of cases identified was more appropriate to mimic the observed epidemic growth. Therefore, we initiated our model with the number of cumulative cases reported on January 26th in the infectious compartment of our model, and an additional 50x this amount in the exposed-and-unreported compartment. This assumption could inflate our model predictions within the forecast window if underreporting is not this extensive. Given the current overwhelmed state of public health services in the epicenters of the outbreak, we feel the assumption is within reason.

As the outbreak progresses, our model assumes new infections are also subject to underreporting, and that only 20.84% of cases are being reported in China, where most of the cases occur. Metabiota previously built a model that predicts pathogen and country specific reporting rates based on the case fatality ratio of the pathogen and the corresponding country's Metabiota's Epidemic Preparedness Index value.

To refine our forecast based on model simulations, we excluded all model runs that did not result in at least 90% of cases reported as of February 10, 2020. Once these runs were excluded, we calculated the interquartile range (IQR) of remaining case counts occurring on February 10th, and excluded runs predicting more than 3Q + 1.5xIQR (97,539) cases.

[8] Read, Jonathan M, Jessica RE Bridgen, Derek AT Cummings, Antonia Ho, and Chris P Jewell. "Novel Coronavirus 2019-NCoV: Early Estimation of Epidemiological Parameters and Epidemic Predictions." *MedRxiv*, January 1, 2020, 2020.01.23.20018549. https://doi.org/10.1101/2020.01.23.20018549.