Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimating Global direct importation risk for COVID-19

February 24, 2020

UNIVERSITY of VIRGINIA

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Importation Risk – International Spread

- Using International Airline data build international travel network (February 2019)

- For COVID-19, treat China as the source of importation.
  - Data until Feb 12th justify this assumption.

- Calculate effective distance between countries
  - based on volumes of air traffic and underlying dynamics

- Fit a linear model for COVID-19 official first reports
  - Arrival time of disease shown to match effective distance with a linear fit for H1N1 and SARS [Brockman et al. 2013]
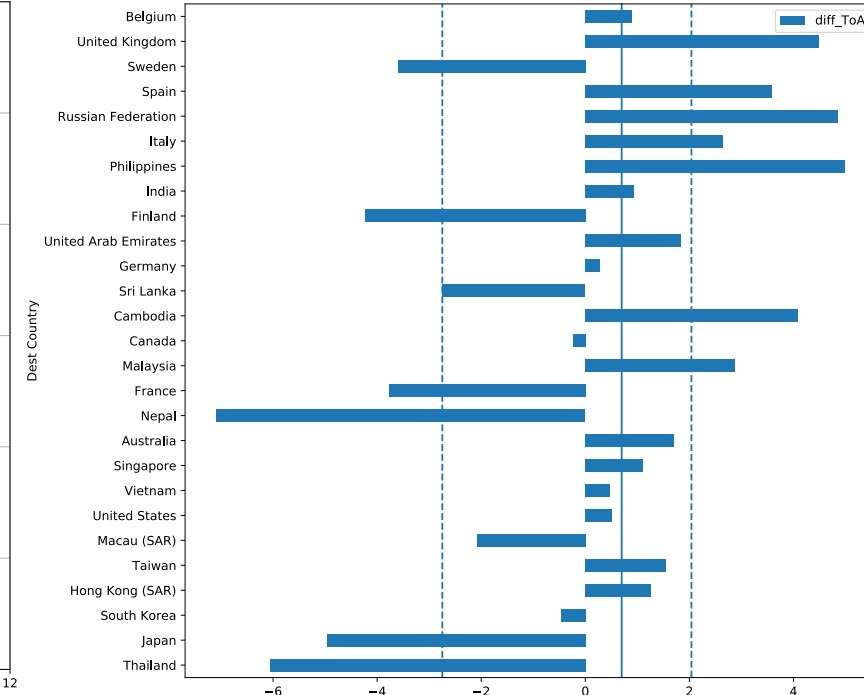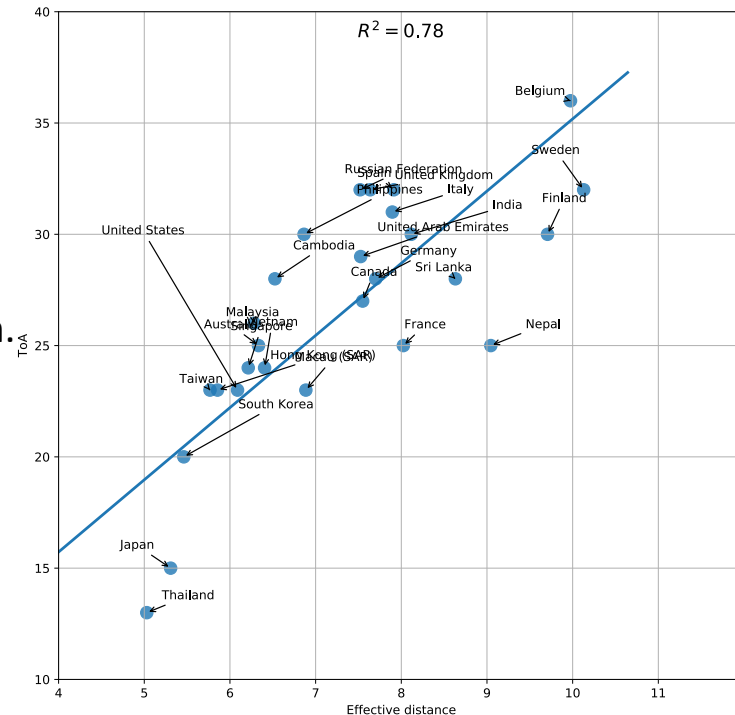

Estimated ToA earlier than actual ToA for most countries.
Some exceptions: Japan, Thailand, Nepal (spatial neighbors)
Finland, Sweden (possibly due to better surveillance)

Brockmann, Dirk, and Dirk Helbing. "The hidden geometry of complex, network-driven contagion phenomena." *science* 342.6164 (2013): 1337-1342
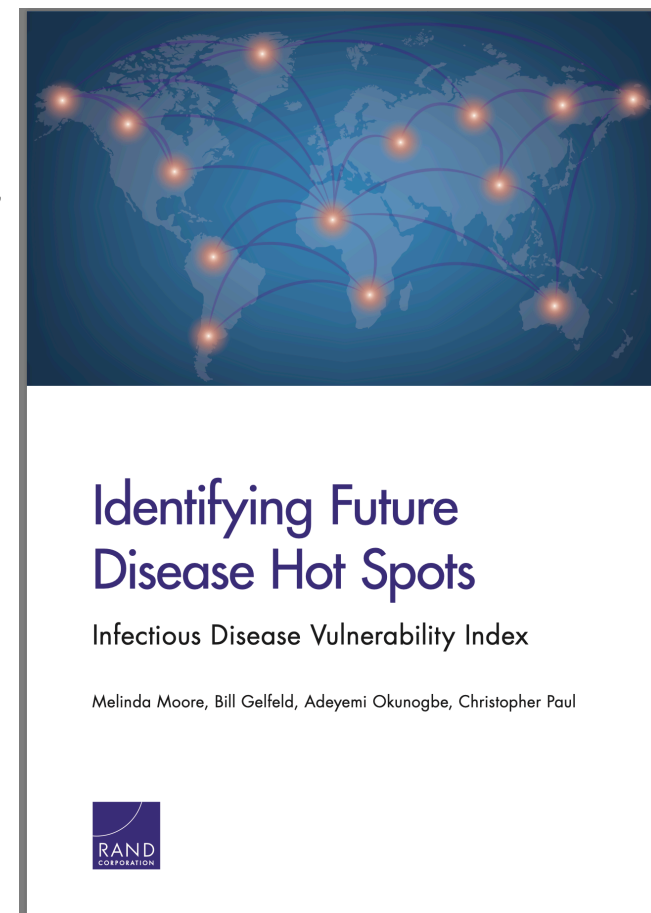
Dimensions of Risk

- Early arrival an important risk factor, however, the ability of the country to detect and mount and organized response is more important to the overall success combating the disease

- IDVI represents a country's Vulnerability to Infectious Disease outbreaks
    - Based on profiles of countries: demographic, health care, public health, disease dynamics, political-domestic, political-international, and economic
    - Data sources: World Bank, the World Health Organization, and other international organization
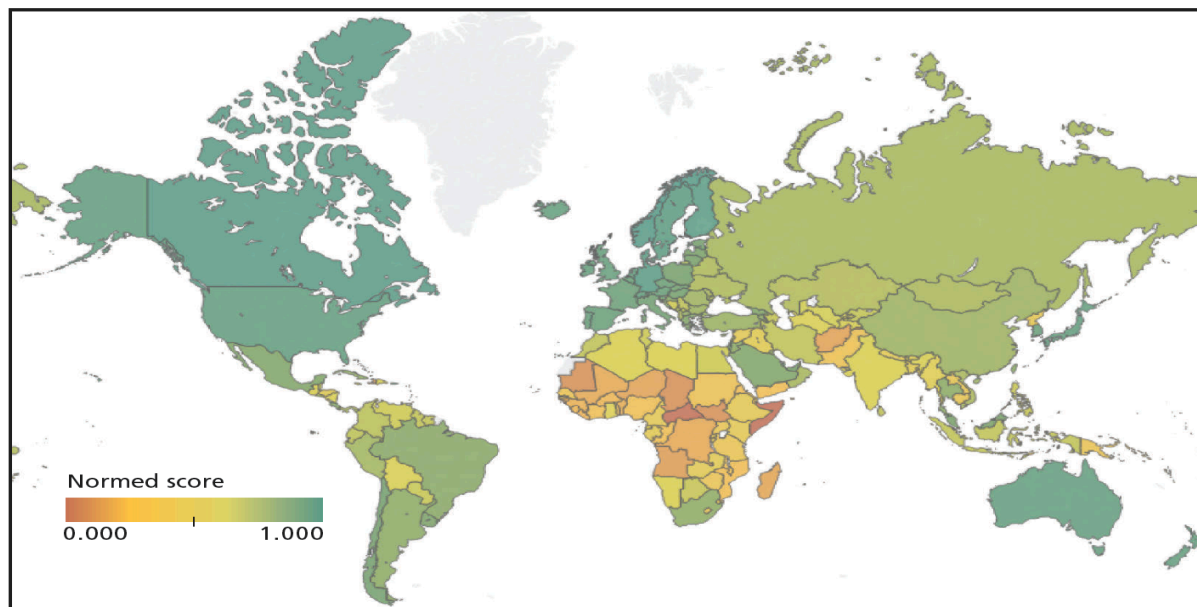
NOTE: The color shading runs from deep red (most vulnerable) to deep green (least vulnerable).
RAND RR1605-S.1

Identifying Future Disease Hot Spots

Infectious Disease Vulnerability Index

Melinda Moore, Bill Gelfeld, Adeyemi Okunogbe, Christopher Paul

RAND
CORPORATION

https://www.rand.org/content/dam/rand/pubs/research_reports/RR1600/RR1605/RAND_RR1605.pdf

Importation Risk

Estimated Time of Arrival

https://nssac.github.io/covid-19/import_risk.html
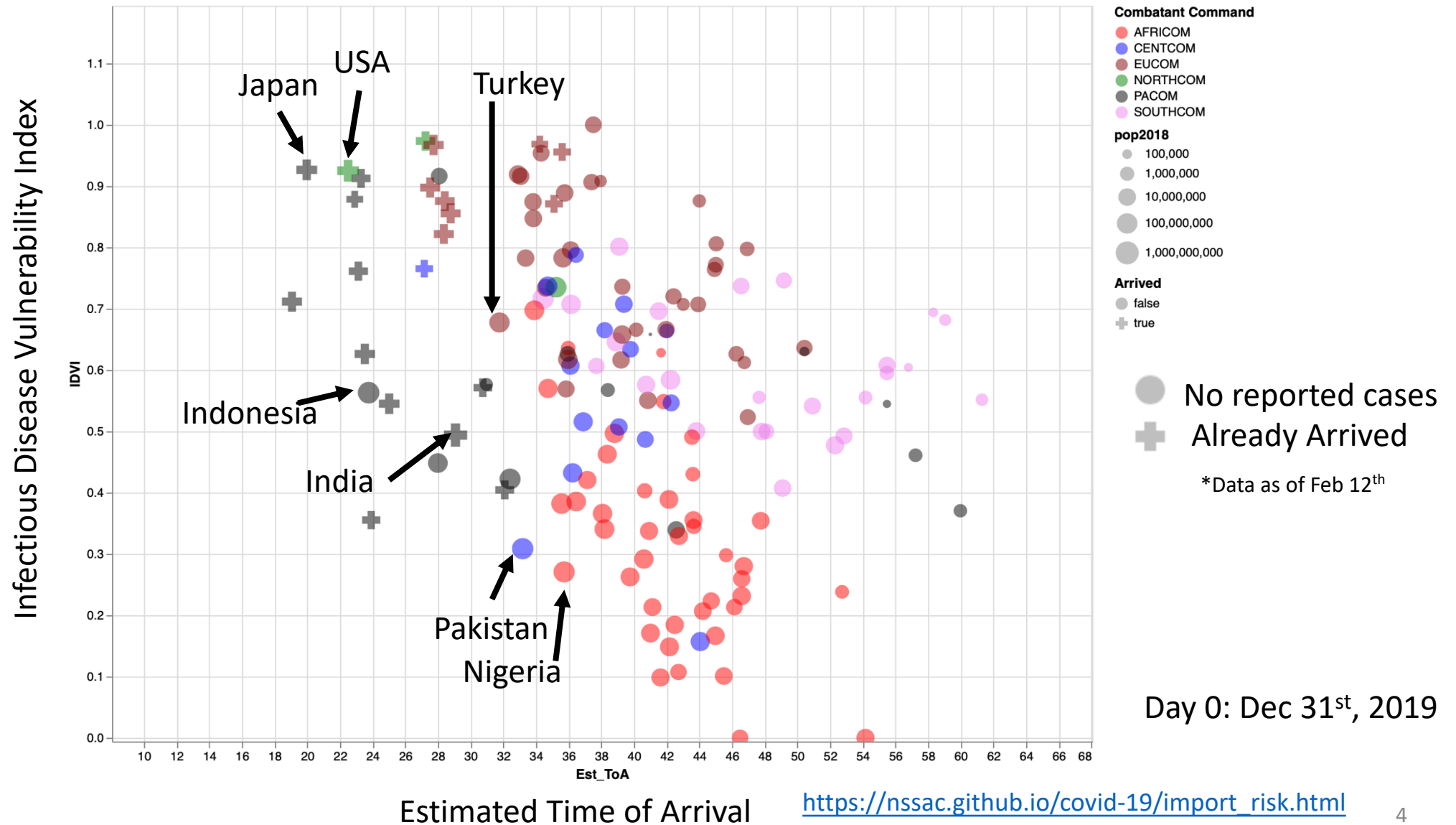
Travel Restrictions and Flight Cancellations

- Bloomberg has compiled list of all airline cancellations:
  - https://www.bloomberg.com/graphics/2020-china-coronavirus-airlines-business-effects/

- Using this list, have adjusted the flight network, based on historical IATA data, to estimate the current flight network

- Important note: Chinese airlines are not on on this list but seem to have been canceled as well, current analysis includes Chinese airline flights
  - These do appear to be cancelled, which will further reduce these estimates

The Airlines Halting China Flights as Virus Outbreak Spreads

By Demetrios Pogkas, Cedric Sam and Chloe Whiteaker
Updated: February 11, 2020, 1:15 AM EST

The coronavirus outbreak has disrupted flights to and from China, one of the world's busiest travel markets, as airlines around the globe halt service.

Commercial flights to and from Wuhan, where the virus is centered, have mostly stopped. Cancellations have spread to major hubs in Beijing and Shanghai. Carriers from British Airways to Singapore Airlines to United Airlines have suspended flights to China's biggest cities.

Governments are also cracking down on the entry of non-citizens who have recently traveled to China. The U.S. is temporarily barring foreign nationals who have visited China unless they are immediate relatives of American citizens or permanent residents. Only seven U.S. airports were receiving flights from China as of Feb. 3, 2020.

**Airlines Halting Flights Due to Coronavirus Outbreak**
From first cancellation on Jan. 23 through April 30. Data as February 11, 2020, 1:15 AM EST

North America

Airline								Air Canada
Based in								Canada
Suspended								Flights to Beijing and Shanghai
Dates of suspension								
Jan. 30			Feb. 29					

Airline								American Airlines
Based in								U.S.
Suspended								All flights to China; and Hong Kong service from Dallas (from Feb. 1 to Feb. 21) and Los Angeles (Feb. 1 to March 27)
Dates of suspension								
Jan. 31			Mar. 27					

Airline								Delta
Based in								U.S.
Suspended								All flights to China
Dates of suspension								
Feb. 2			Apr. 30					

airline	based_in	suspensions	start_date	end_date	codes
Air Canada	Canada	Flights to Beijing and Shanghai	Jan. 30	Feb. 29	AC
American Airlines	U.S.	All flights to China; and Hong Kong service from Dallas (from Feb. 1 to Feb. 21) and Los Angeles (F	Jan. 31	Mar. 27	AA
Delta	U.S.	All flights to China	Feb. 2	Apr. 30	DL
United Airlines	U.S.	Service to Beijing, Shanghai and Chengdu; and Hong Kong service from Feb. 8 until Feb. 20	Feb. 5	Mar. 28	UA
Air India	India	Flights between Delhi and Shanghai, and between Delhi and Hong Kong (from Feb. 8)	Jan. 31	Feb. 14	AI
Air Seoul	South Korea	Flights between Incheon and Zhangjiajie and Linyi in China	Jan. 28		RS
AirAsia	Malaysia	All flights to Wuhan and selected flights to mainland China; all flights between the Philippines and r	Jan. 24	Feb. 29	AK
All Nippon Airways	Japan	Flights to nine cities in China, including Beijing, Shanghai and Guangzhou, from Tokyo and Osaka;	Jan. 23	Mar. 29	EL
Asiana Airlines	South Korea	Flights to eleven cities including Beijing, Guangzhou and Shanghai; reduced frequency of flights to	Feb. 4	Mar. 28	OZ
Cathay Dragon	Hong Kong	Flights to and from Hangzhou, Ningbo, Wenzhou, Sanya and Haikou (from Feb. 2 to March 28); Gu	Jan. 24	Mar. 31	KA
Cathay Pacific	Hong Kong	Cut capacity of flights to and from mainland China by 90%; cut global capacity by about 30%	Jan. 30	Mar. 31	CX
Cebu Pacific	Philippines	Flights to mainland China and Taiwan, cut capacity to Hong Kong and Macau	Feb. 2	Mar. 29	5J
China Airlines	Taiwan	Flights to and from Wuhan	Jan. 23	Feb. 29	CI
Eastar Jet	South Korea	Flights to Shanghai, Zhengzhou and another four cities in China; flights to Macau and Hong Kong (	Jan. 30	Mar. 1	ZE
HK Express	Hong Kong	Cut capacity of flights between Hong Kong and Seoul (Feb. 12‰ÛÒMarch 26), Osaka (Feb. 16‰Û	Feb. 12	Mar. 26	UO
IndiGo	India	Flights between Bengaluru and Hong Kong, between Delhi and Chengdu (both from Feb. 1 to Feb.	Feb. 1	Feb. 26	6E

Flight network Reductions

- Effective distance from China increases for all countries (Overall increase of nearly 10%)

- Differences are not uniform
  - Many African countries (served via Qatar) increase in distance
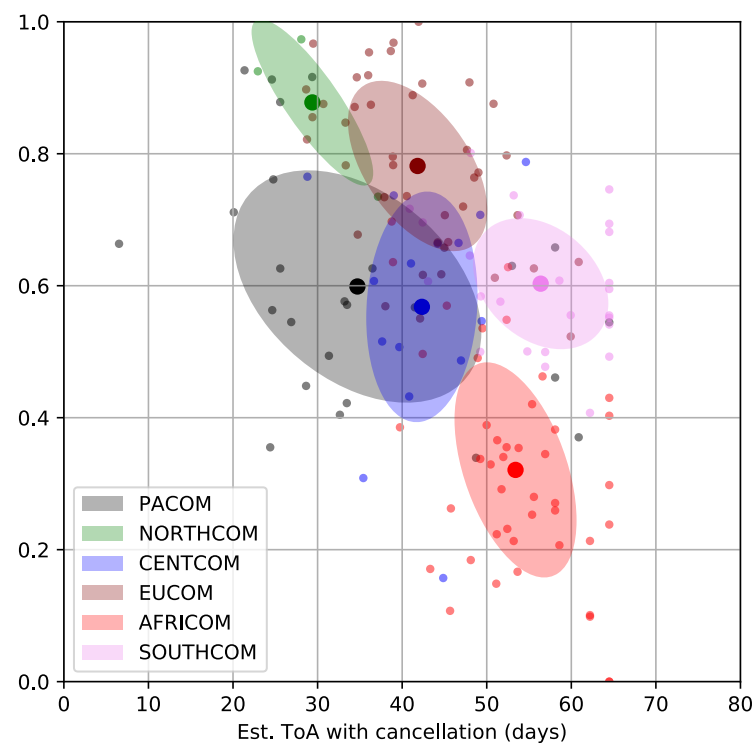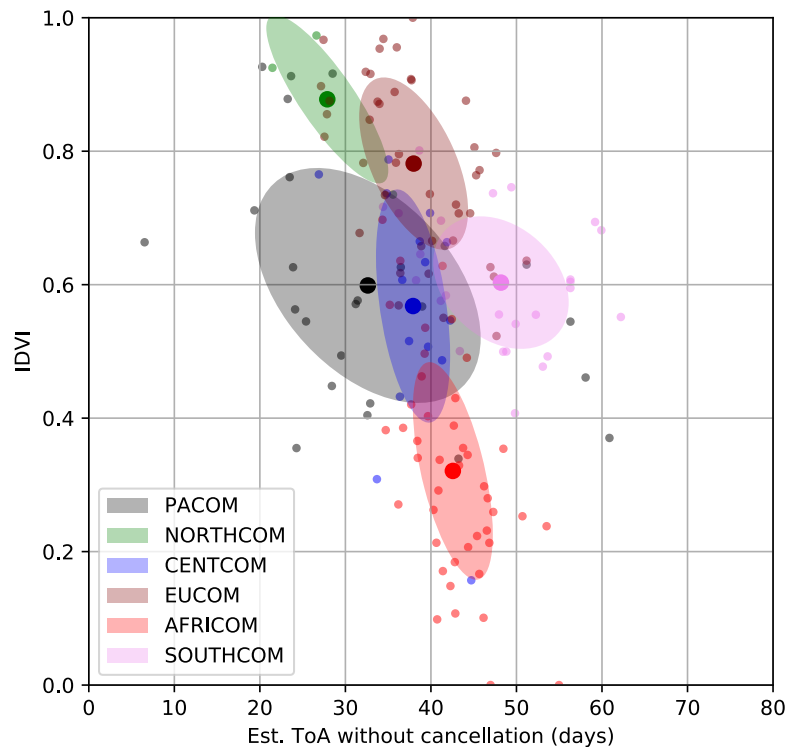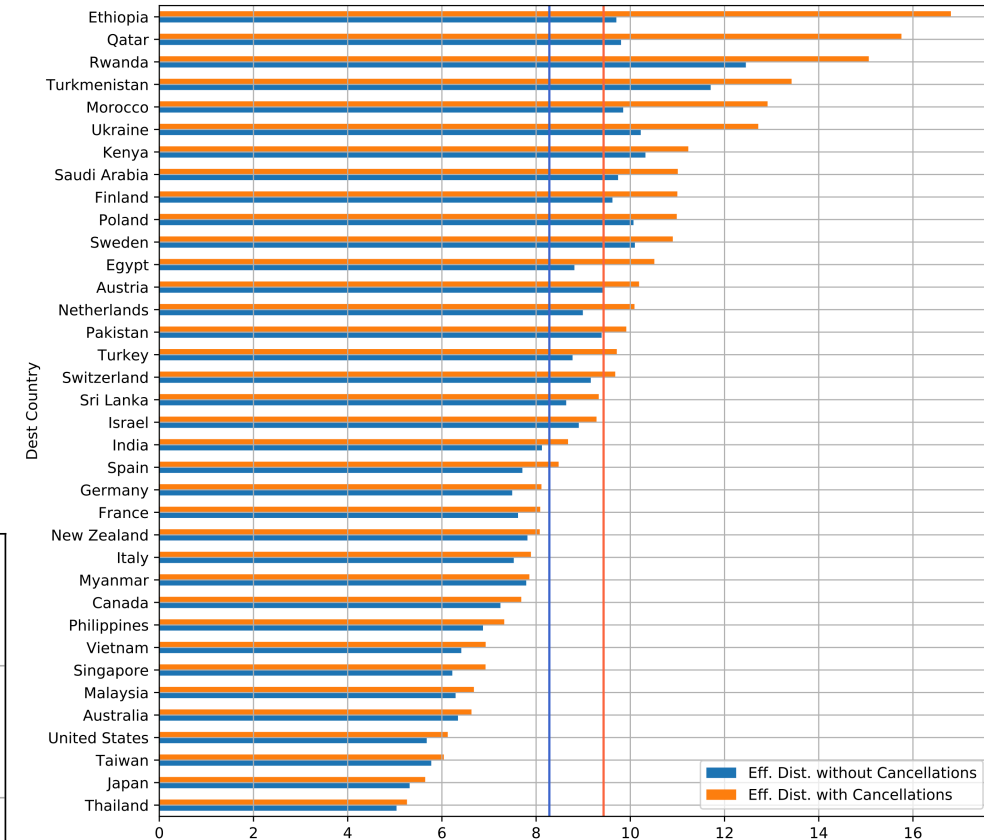
Most average increase by *COM
- AFRICOM ~ 10 days
- SOUTHCOM ~ 8 days
- CENTCOM, EUCOM ~ 3 days

Ongoing work & Limitations

- Incorporating additional airline cancellations (including Chinese airlines which are not officially reported in Bloomberg)

- Quantifying uncertainty and moving towards a more dynamic measure incorporating more exportation origins

- Accounting for current number of cases, and providing counts of imported cases

- The effective distance calculation is based purely on airline traffic (February 2019) and does not include other modes (land/sea)

- While IDVI captures vulnerability, other metrics might be better for incorporating detection/reporting delays at country level

- We are rapidly moving from 'time of arrival' questions to the 'potential undetected cases' regime.

Questions?

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MedrXiv: Evaluating the impact of international airline suspensions on COVID-19 direct importation risk
https://www.medrxiv.org/content/10.1101/2020.02.20.20025882v1

Additional resources:

COVID-19 Surveillance Dashboard
http://nssac.bii.virginia.edu/covid-19/dashboard/

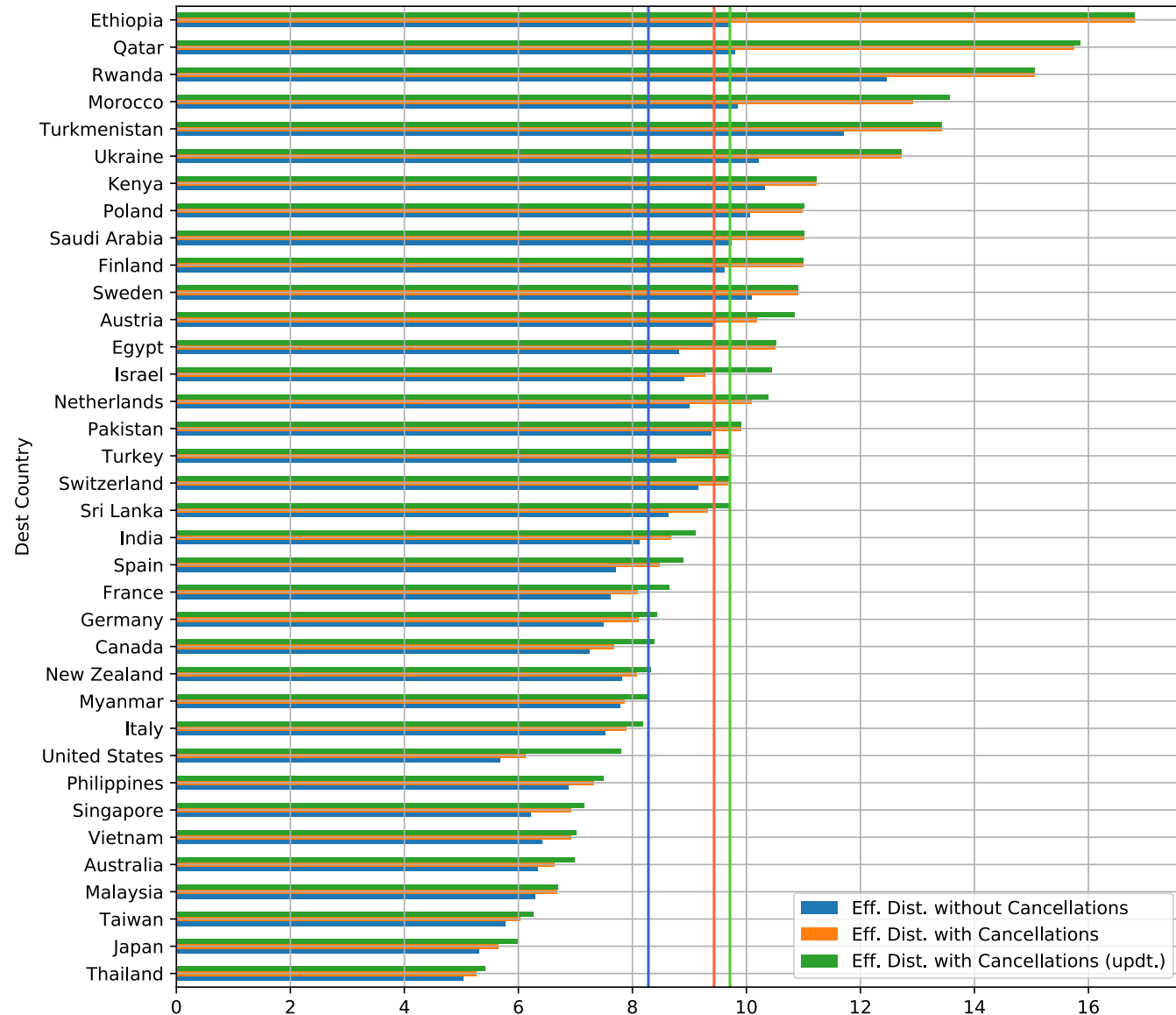COVID-19 Cases and Clusters Outside China
http://nssac.bii.virginia.edu/covid-19/cluster-dashboard/

Backup slides

Including Chinese airlines

Adding (unofficial)
suspensions
in Chinese airlines
marginally increases
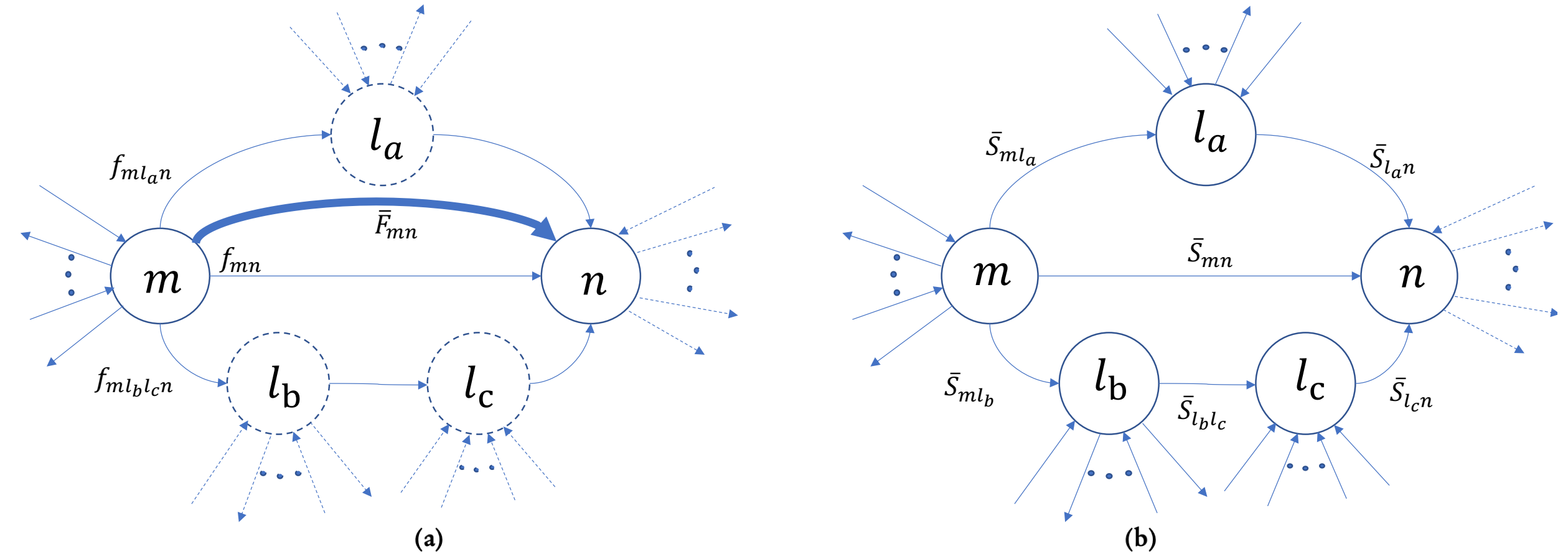the effective distance.

OAG vs IATA data

Figure 5. A toy example that compares networks derived from IATA and OAG data. Nodes n and m are considered as source and destination, respectively. (a) Network constructed using IATA data. $\bar{F}_{mn} = f_{mn}/\sum_k F_{mk}$, $\bar{F}_{ml_an} = f_{ml_an}/\sum_k F_{mk}$, and $\bar{F}_{m\ell_b\ell_cn} = f_{m\ell_b\ell_cn}/\sum_k F_{mk}$, the bold arrow is used to represents $\bar{F}_{mn} = \bar{f}_{m\ell_an} + \bar{f}_{mn} + \bar{f}_{m\ell_b\ell_cn}$, the total fraction of flow from origin m to destination n. (b) Network constructed using the OAG data. The dashed lines are used to represent nodes and outflows that do not contribute to the computation of the edge weights in the graph.

Effective distance using IATA data

- Obtain source-origin flow using IATA data.

- We denote the flow between origin m and n as F_{mn}.

- Computation of F_{mn}:
  - Query all source-destination passenger volumes.
  - Volumes can correspond to direct or stop-over flights. For source WUH and destination SFO,

    possible routes WUH->SFO, WUH->FRA->SFO, WUH->HKG-> CDG->SFO.
  - Sum flows from all the individual routes to get F_{mn}.

- Computation of outflow probability $\bar{F}_{mn} = F_{mn} / \sum_k F_{mk}$.

- Effective distance $d_{mn}^{IATA} = 1 - \log \bar{F}_{mn}$.