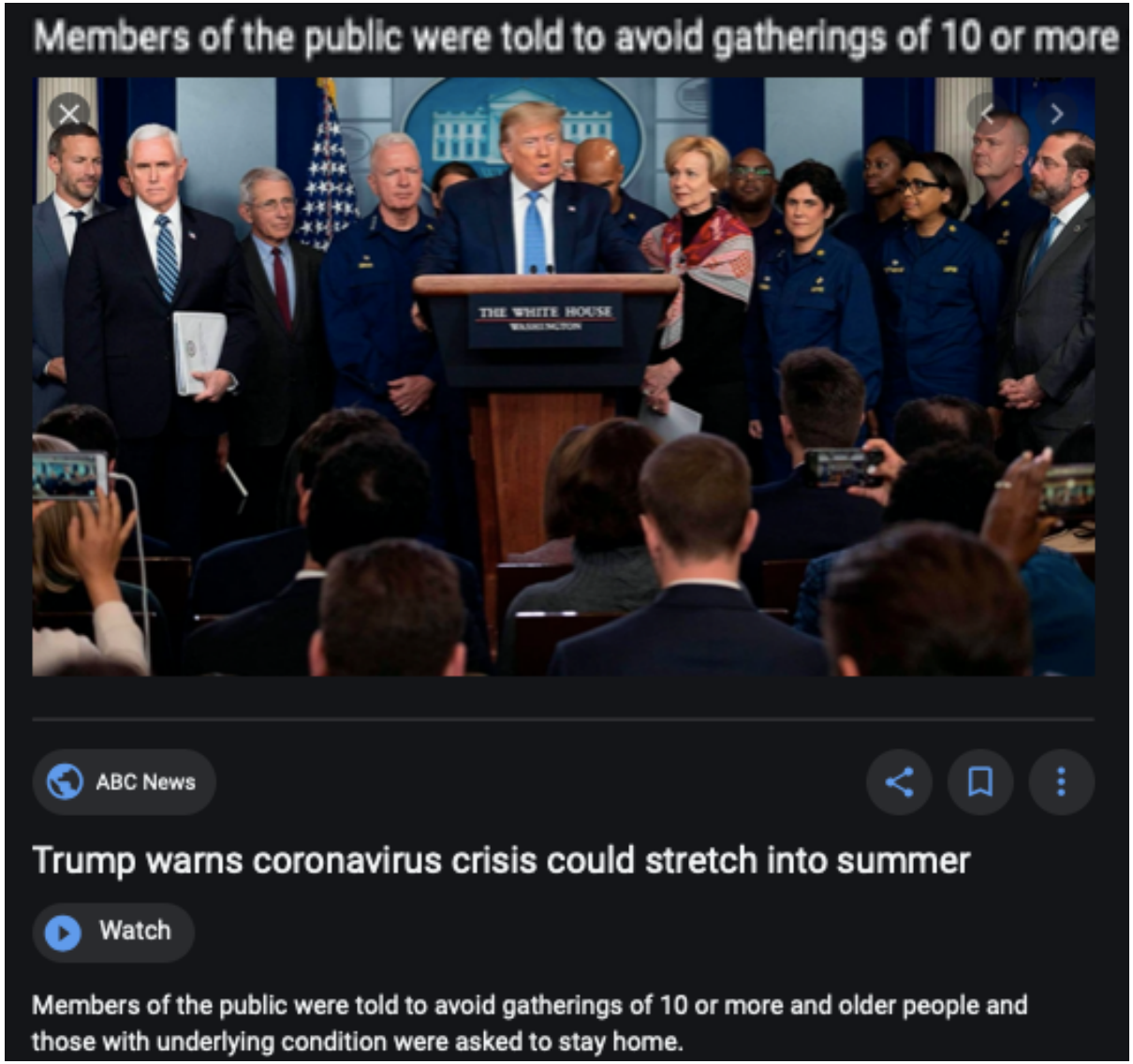
Coronavirus!

Stupidest People Alive:

- This is crazy AF:
  - You gather together in a group of 50 to announce that everyone should avoid groups of ten or more?
  - The press doesn't ask: what are we doing here?
  - The general advisors do not ask: what are we doing here?
  - The *public health* advisors do not ask: what are we doing here?
- This sums up at least the American federal government's reaction to the coronavirus crisis.



audio time

Where We Think We Are with Coronavirus

Brad DeLong

2020-05-06

< https://www.icloud.com/keynote/0YKEi7HeOrVGvKYtt9FEqH7nA>

<https://github.com/braddelong/public-files/blob/master/coronavirus.pptx>

Simple Extrapolations and Inferences

Where we think we are, as of We May 6, 2020:

- We still do not know: no random panel
- I have my extrapolations: perhaps 9M cases?
- Time to distinguish between Greater New York and the rest of the country?

Coronavirus Extrapolations

Date	Deaths	Inferred Cases = Deaths x 100 Lagged 2 Weeks	Cases = 1.5 x Cases(-3)	Cases = 3 x Cases(-3)	Cases = 6 x Cases(-3)	Cases = 12 x Cases (-3)		Confirmed Cases	Inferred Cases/ Confirmed Cases
2020-05-06	74371	8,910,958	9,578,400					1,237,633	7.2
2020-04-30	63856	8,322,175	7,535,400					1,095,023	7.6
2020-04-23	50236	7,437,100	5,192,550	10,385,100				886,442	8.4
2020-04-16	34617	6,385,600	2,506,800	5,013,600	10,027,200			639,664	10.0
2020-04-09	16712	5,023,600	913,200	1,826,400	3,652,800	7,305,600		432,132	11.6
2020-04-02	6088	3,461,700	194,400	388,800	777,600	1,555,200		216,721	16.0
2020-03-26	1296	1,671,200	30,900	61,800	123,600	247,200		69,194	24.2
2020-03-19	206	608,800	6,150	12,300	24,600	49,200		9,415	64.7
2020-03-12	41	129,600	1,800	3,600	7,200	14,400		1,312	98.8
2020-03-05	12	20,600	150	300	600	1,200		159	129.6
2020-02-27	1	4,100						59	69.5
2020-02-20		1,200						15	80.0
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								1	0.0
	https://www.icloud.com/numbers/0EzBEAgAQojAip4VJWYWIWICQ								

audio time

Coronavirus Cases:

3,780,522

view by country

Deaths:

261,703

Recovered:

1,275,536

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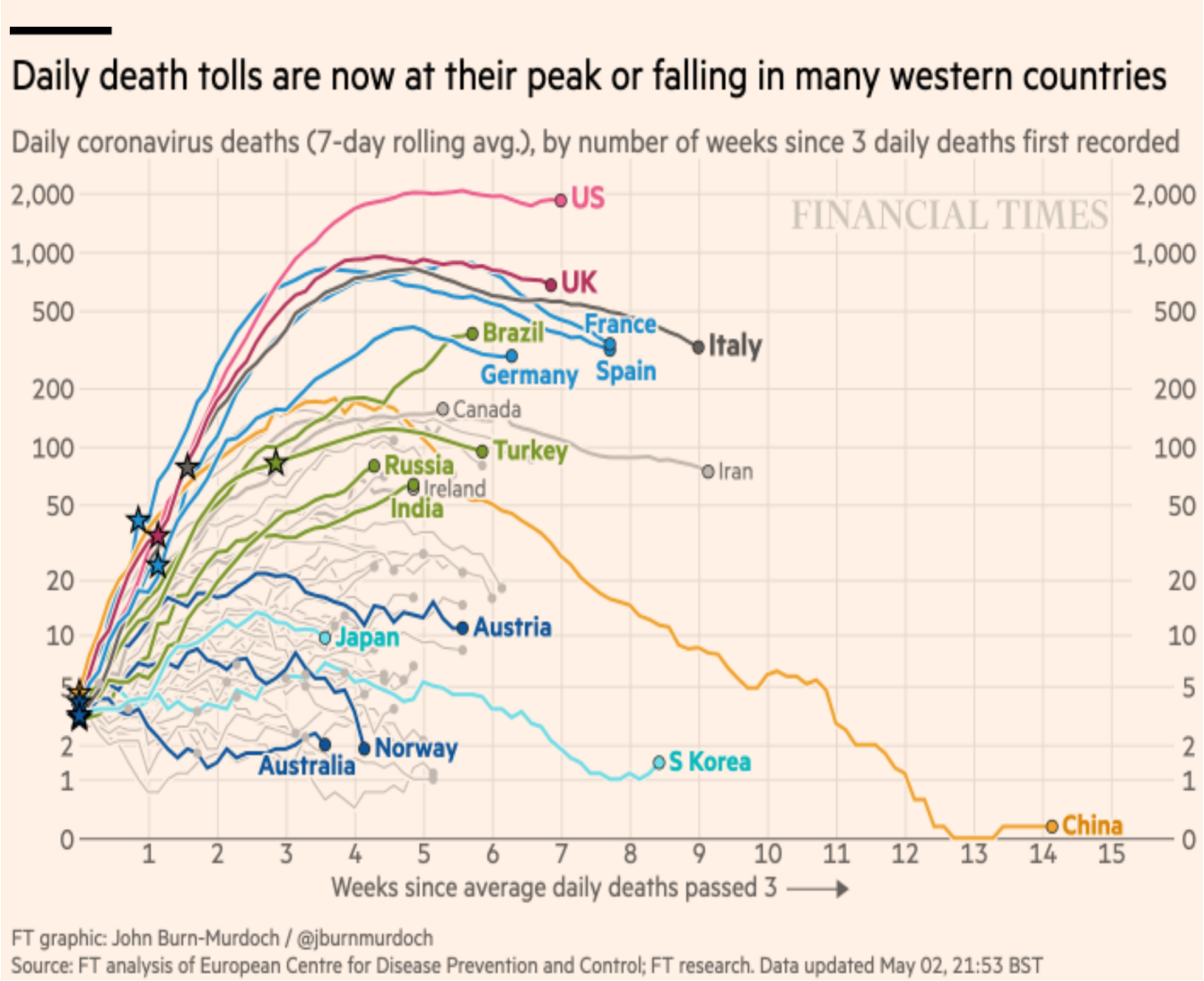
The United States Is Alone in Doing No More than Flattening the Death Line

And that is including New York:

- And odds are that the U.S. daily death curve is about to start heading northeast again
- How far and how fast will it move?
- Cases x 150 during March
- Cases x 3 during April
- Am I wrong to expect a doubling outside New York in May?



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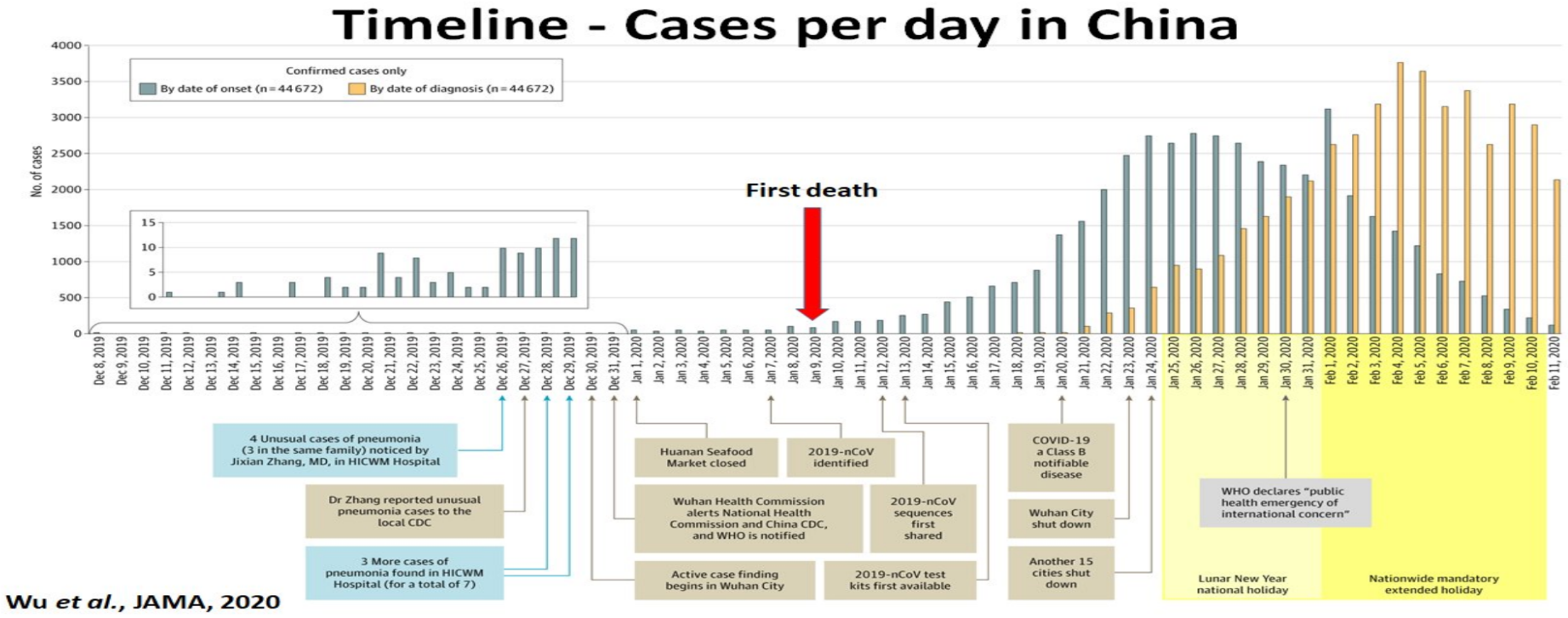
What We Think Happened in Wuhan

Wuhan beat it quickly—we think

- Shut down Wuhan when there were 200 cases per day
- Seems to have been a good choice



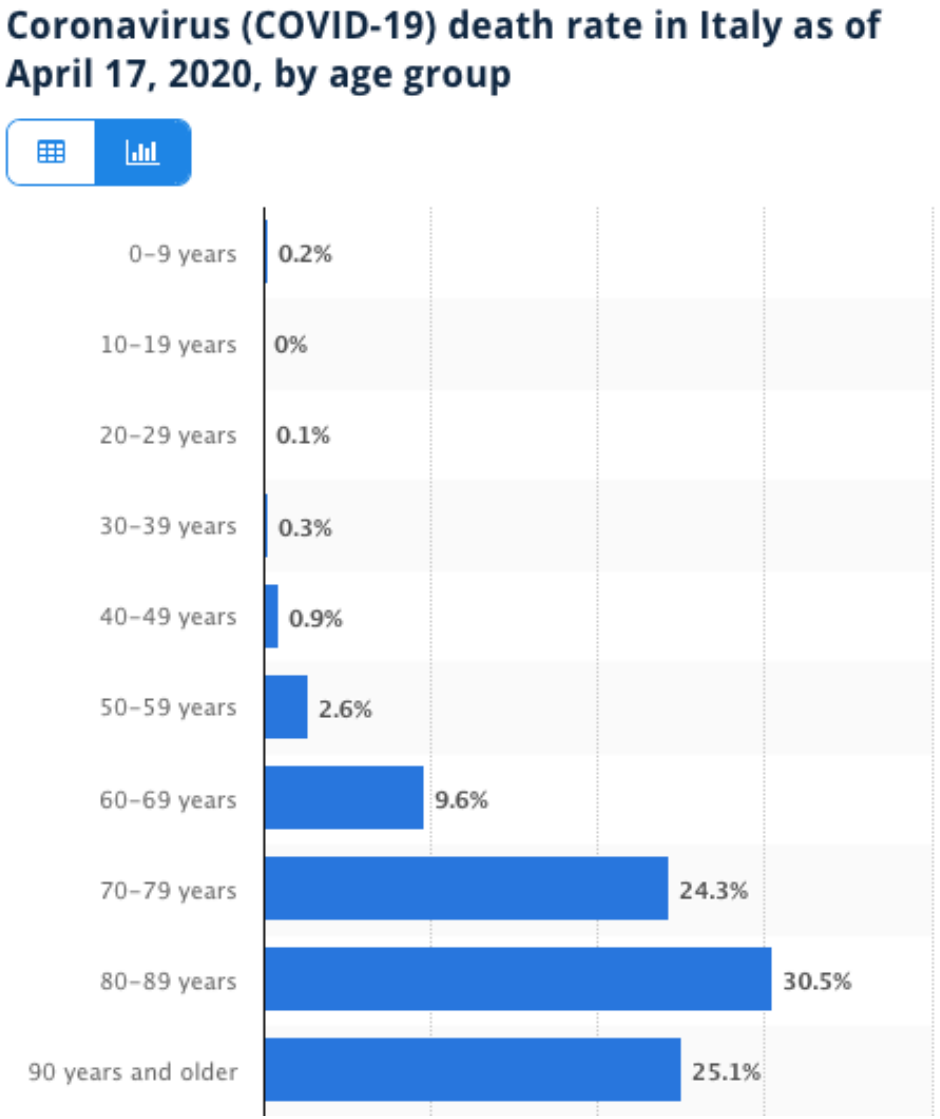
audio time

Death for Geezers!

Mortality for the Youngs low…

- It can be a (very bad) flu for them—for you students…
- Morbidity…
- For olders: 3% in your 50s, 9% in your 60s
  - And a doubling—or is it 5%?—mortality for the asthmatic
  - And a doubling—or is it 5%?—mortality for the overweight
  - And an extra ???? if you have high blood pressure
  - And an extra ???? if you have high blood sugar

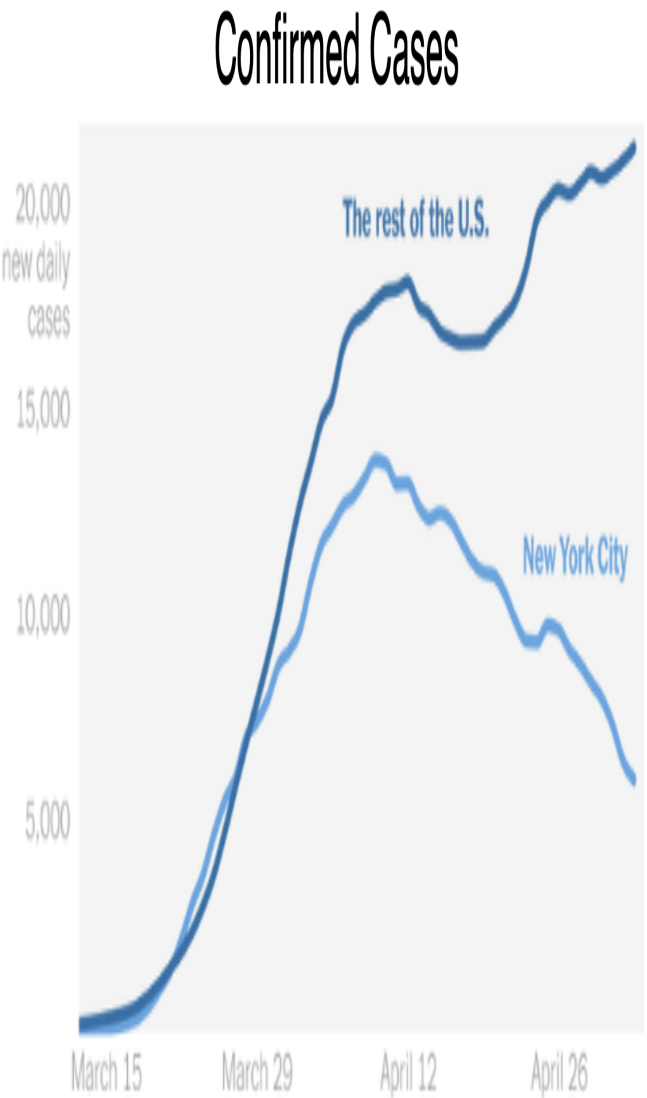
audio time

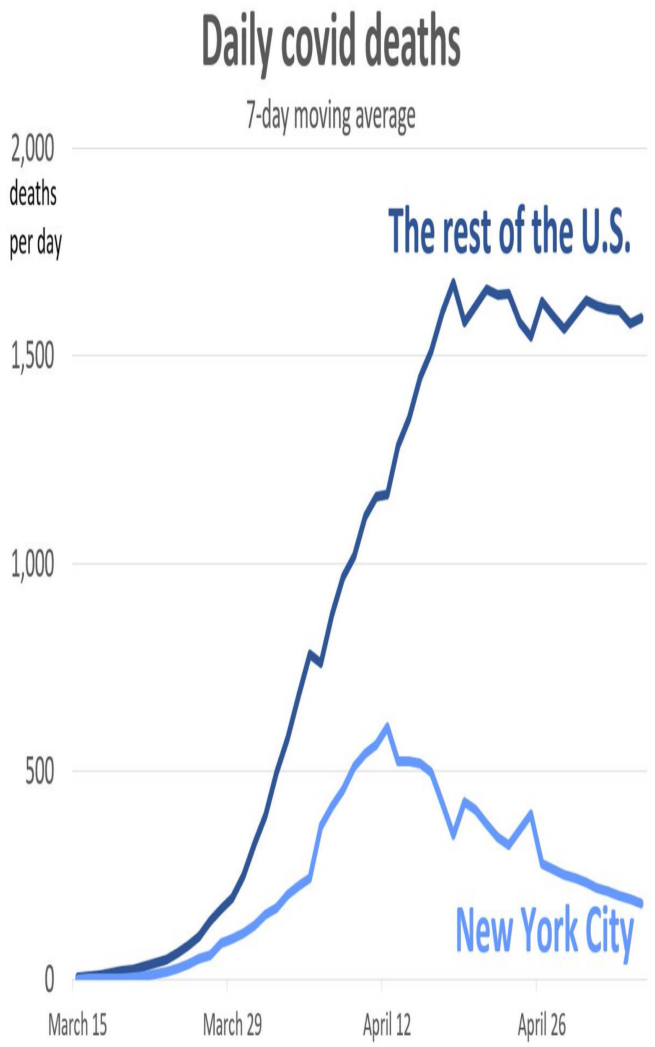


Separating New York City

New York City is well past its first epidemic peak:

- The rest of the country is not
- Perhaps 20% of the population of New York City has been brushed by the virus
- Perhaps 2.5% of the country has been brushed by the virus
- "Reopening" elsewhere will produce a lot of bad stuff





audio time

Integrating Public Health with Economics

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- Jim Stock: *Coronavirus Data Gaps and the Policy Response* <https://drive.google.com/file/d/12MV466ZZy5xHir4xdPhoTrL1oO8CbZU-/view>:
  - The basic SIR epidemiological model of contagion
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  - Estimates in the epidemiological literature range from 0.18 to 0.86.
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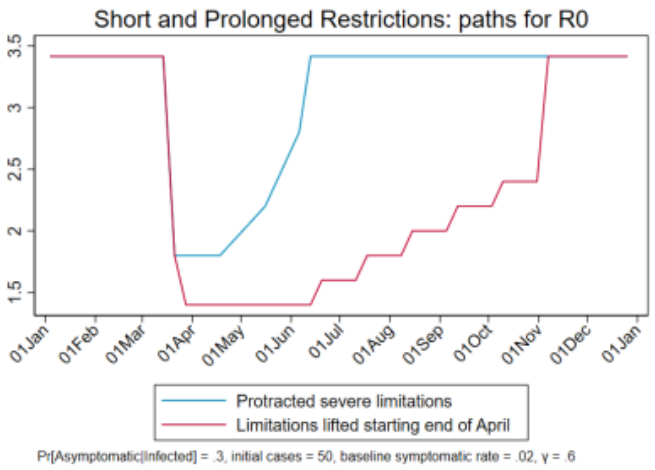
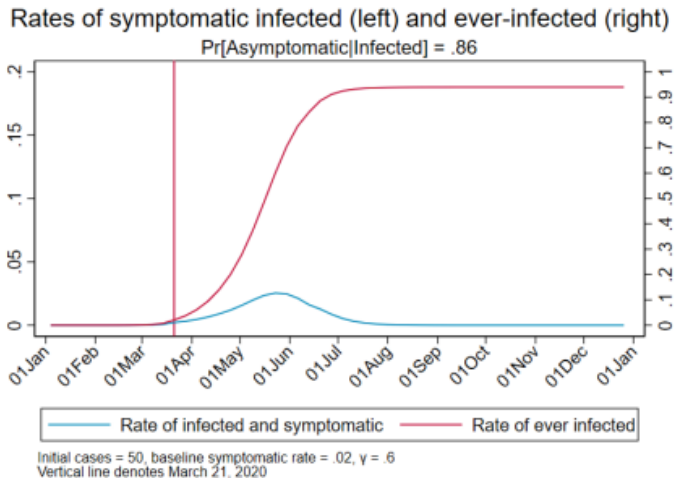


Figure 2. High asymptomatic rate, short-duration policy



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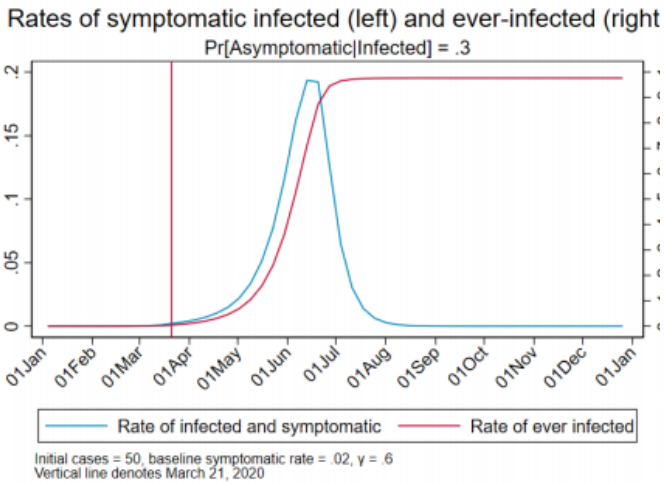
$$\Delta R_t = \gamma I_{t-1},$$

$$\Delta I_t = \beta I_{t-1} \frac{S_{t-1}}{N} - \gamma I_{t-1}$$

audio time

Figure 3. Low asymptomatic rate, short-duration policy



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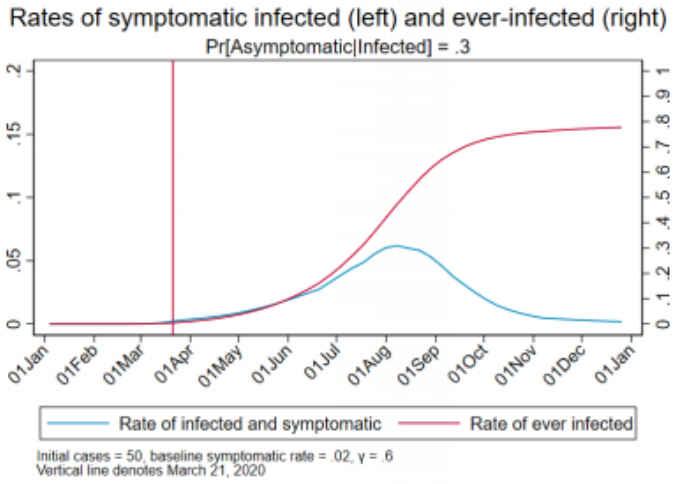
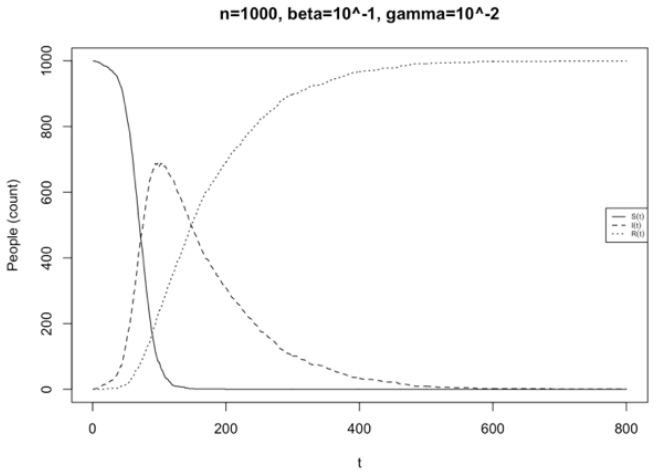


Second Best: Epidemic Models

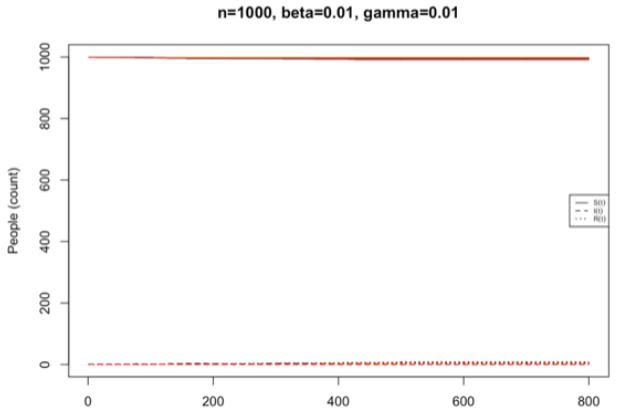
A requested special topic:

- Written and presented by Cosma Shalizi
- Of Carnegie-Mellon University
- <http://www.stat.cmu.edu/~cshalizi/dm/20/lectures/special/epidemics.html#(1)>
- 36-462/662, Spring 2020
- 16 April 2020 (Lecture 25)

What One Simulation Looks Like



What If We Make Contagion Harder?



audio time :: From Cosma Shalizi of Carnegie-Mellon: <http://www.stat.cmu.edu/~cshalizi/dm/20/lectures/special/epidemics.html#(1)>

Bringing the Economy Back Up from Anæsthesia

Major issues:

- Certificates of immunity:
  - Which requires test, test, test:
    - And not just disease virus tests
    - Presence-of-antibodies tests
- How quickly can we match the immune with public-contact jobs?
- What jobs can be done with minimal infection risk?
- What minimal-infection substitutes can we find for previous jobs?
- How quickly can restrictions be relaxed without the virus coming roaring back?
- How do we avoid having the market give a "shutdown" signal to enterprises we in fact want restarted?
  - Which is pretty much all of them
- How much of the potential caseload do we want to push out beyond the vaccine-arrival date?

ALL THESE QUESTIONS ARE ANSWERABLE IF WE LEARN THE ASYMPTOMATIC HENCE NON-TESTED RATE!!

audio time

Keeping the Economy from Crashing During the Lockdown

Nick Rowe: We have a 50% output cut in 100% of the sectors:

- A temporary 100% output cut in 50% of the sectors (what the Coronavirus does) is very different from a 50% output cut in 100% of the sectors
- Nick's thought experiment:
  - In three months we are going to invent unobtanium:
    - Substantial intertemporal substitutibility
    - Plus lower cross-good contemporaneous substitutitbility
    - Hence high desired savings rate now
  - Flex-price market thus produces a nominal rate at the zero lower bound and a high inflation rate over the next three to six months
  - Plus liquidity-constrained workers in affected sectors see their demand go to zero immediately
  - Can we get there? Should we get there? What should we do instead?
  - We need a good RBC economist: are there any?…

<https://worthwhile.typepad.com/worthwhile_canadian_initi/2020/03/relative-supply-shocks-unobtainium-walras-law-and-the-coronavirus.html>

audio time

Keeping the Economy from Crashing During the Lockdown II

Nick Rowe:

- <https://worthwhile.typepad.com/worthwhile_canadian_initi/2020/03/relative-supply-shocks-unobtainium-walras-law-and-the-coronavirus.html>
- Plus: to extend the thought experiment:
  - We just lost the ability to make "unobtainium"
  - So we *should* be substituting leisure for work, and moving workers into relatively unproductive labor, making the commodities we can still produce right now
  - How should relative prices move as a result? How should we make them move?

Plus: distributional issues

Plus: bankruptcy and credit chain issues

audio time

References

Directly cited here:

- **Financial Times** (2020): Coronavirus Tracked: The Latest Figures as the Pandemic Spreads <https://www.ft.com/coronavirus-latest>
- **Nick Rowe** (2020): *Relative Supply Shocks, Unobtainium, Walras' Law, and the Coronavirus* <https://worthwhile.typepad.com/worthwhile_canadian_initi/2020/03/relative-supply-shocks-unobtainium-walras-law-and-the-coronavirus.html>
- **Jim Stock** (2020): *Coronavirus Data Gaps and the Policy Response* <https://drive.google.com/file/d/12MV466ZZy5xHir4xdPhoTrL1oO8CbZU-/view>

What I am watching:

- **Jim Stock** (2020): *Coronavirus Data Gaps and the Policy Response* <https://drive.google.com/file/d/12MV466ZZy5xHir4xdPhoTrL1oO8CbZU-/view>
- **Max Roser & Hannah Ritchie**: *Coronavirus Disease (COVID-19)* <https://ourworldindata.org/coronavirus>…
- **Worldometer**: *Coronavirus Update (Live)* <https://www.worldometers.info/coronavirus/>…
- *FT Coronavirus Tracker* <https://www.ft.com/content/a26fbf7e-48f8-11ea-aeb3-955839e06441>
- *Josh Marshall's COVID Twitter List* <https://twitter.com/i/lists/1233998285779632128>
- **NEJM Group**: *Updates on the Covid-19 Pandemic* <http://m.n.nejm.org/nl/jsp/m.jsp?c=%40kxNtXckRDOq8oG0jJvAXsIzN4mPECIPhltxoTSdTU9k%3D&cid=DM89089_NEJM_COVID-19_Newsletter&bid=173498255>: 'From the New England Journal of Medicine, NEJM Journal Watch, NEJM Catalyst, and other trusted sources...

audio time

Catch Our Breath…

Continue the Discussion:

- Ask a couple of questions?
- Make a couple of comments?
- Any more readings to recommend?

Files:

- <https://www.icloud.com/keynote/0YKEi7HeOrVGvKYtt9FEqH7nA>
- <https://www.bradford-delong.com/2020/04/coronavirus.html>
- github:<https://github.com/braddelong/public-files/blob/master/coronavirus.pptx>
- https://github.com/braddelong/public-files/blob/master/coronavirus.pdf>
- html file: <https://www.bradford-delong.com/2020/04/coronavirus.html>
  - html edit: <https://www.typepad.com/site/blogs/6a00e551f08003883400e551f080068834/post/6a00e551f080038834025d9b3bd66a200c/edit>
- <https://delong.typepad.com/files/2020-04-01-coronavirus.pdf>

audio time

Notes

Where We Think We Are with Coronavirus ARCHIVE

Brad DeLong

2020-04-18

< https://www.icloud.com/keynote/0YKEi7HeOrVGvKYtt9FEqH7nA>

<https://github.com/braddelong/public-files/blob/master/coronavirus.pptx>

Where We Think We Are with Coronavirus 2020-04-20

Where we think we are, as of Mo Apr 20 2020:

- We really do not know: no random samples…
  - If 1% *recorded* mortality from virus brushing close enough to confer temporary immunity…
  - And if two weeks from diagnosis to death…
  - Then U.S. in late March was catching one in fifteen cases
- And if that still holds, than 12 million people in the U.S. have or have had the disease
- And 500,000 are catching it and gaining at least temporary immunity every day out the past week straight-line log:
- The U.S. flattened but not bent down the curve:
  - R[0] = 1
  - 2500 *recorded* deaths/day
  - True mortality probably twice as high
- 2.3 million total *confirmed* cases worldwide; 160 thousand *confirmed* dead…

audio time

Coronavirus Extrapolations

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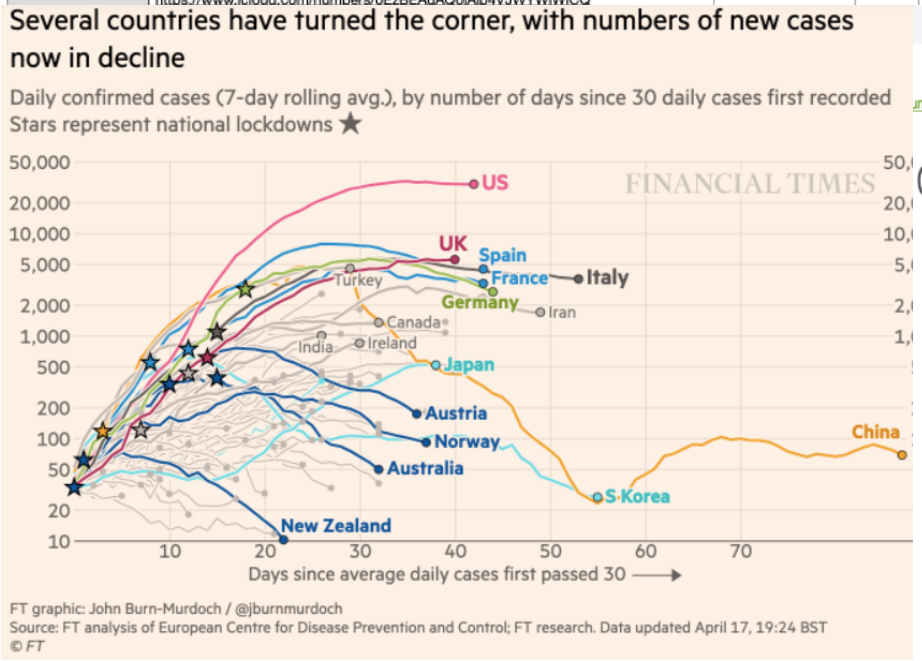
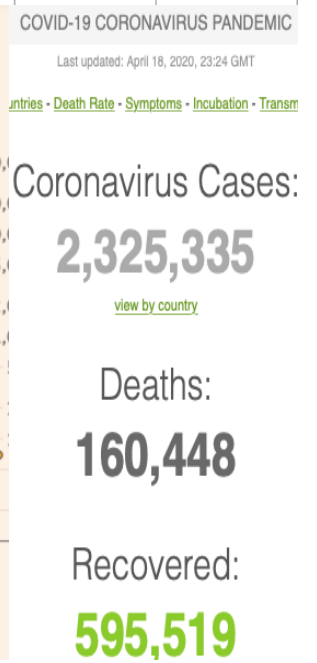
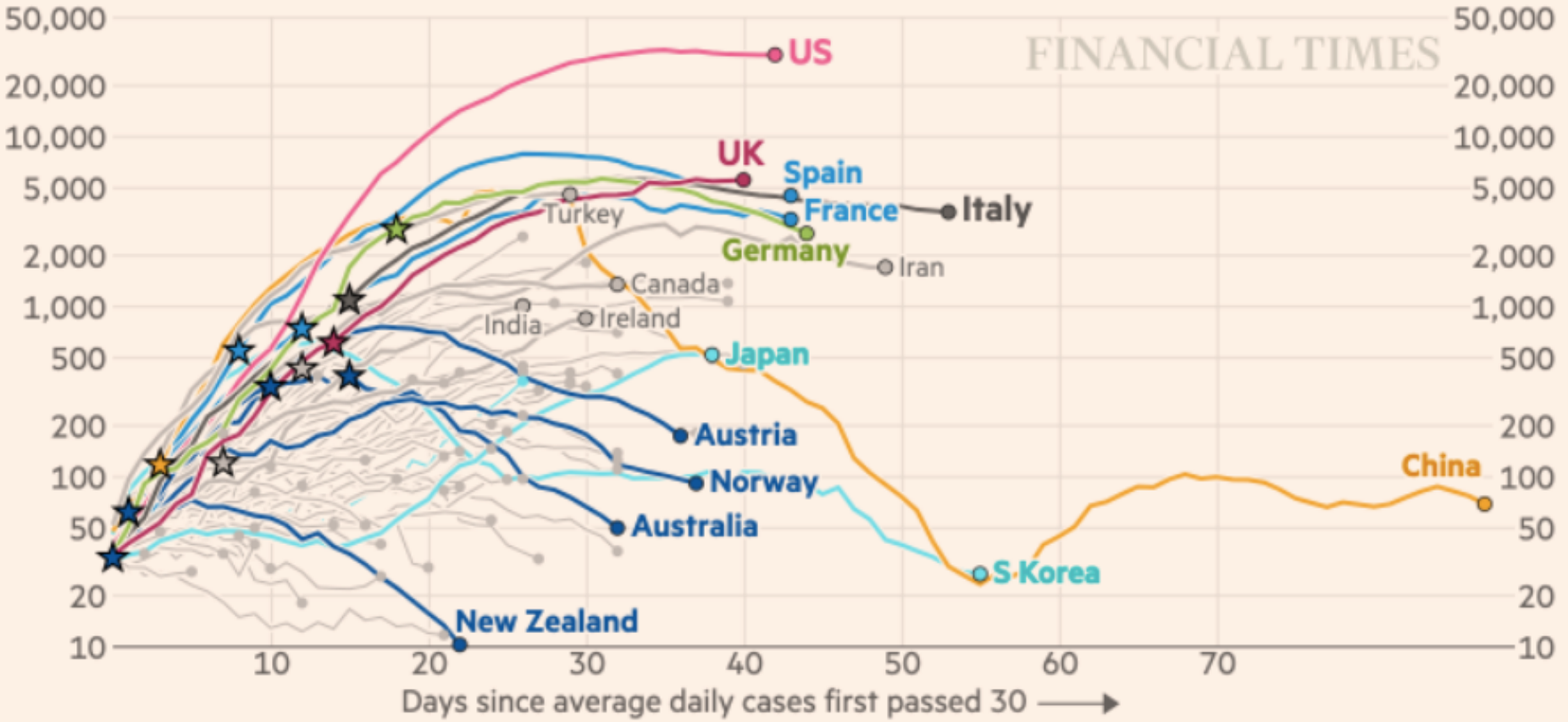




Several countries have turned the corner, with numbers of new cases now in decline

Daily confirmed cases (7-day rolling avg.), by number of days since 30 daily cases first recorded
Stars represent national lockdowns ★



FT graphic: John Burn-Murdoch / @jburnmurdoch
Source: FT analysis of European Centre for Disease Prevention and Control; FT research. Data updated April 17, 19:24 BST

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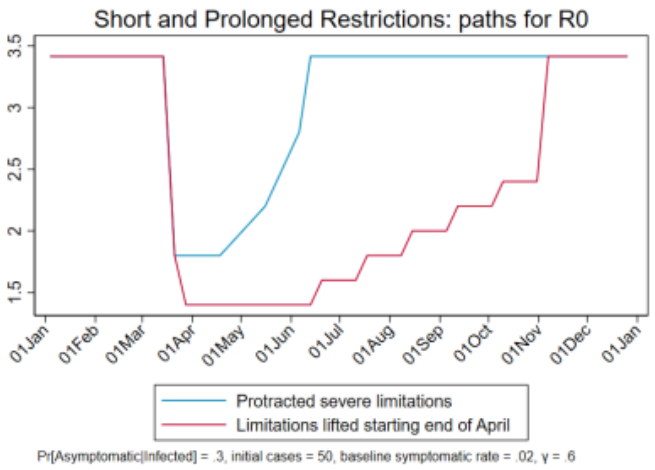
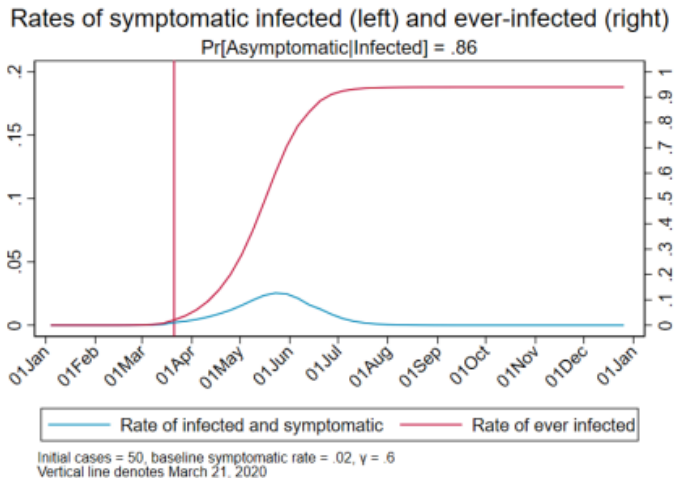


Figure 2. High asymptomatic rate, short-duration policy



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$$\Delta R_t = \gamma I_{t-1},$$

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audio time

Figure 3. Low asymptomatic rate, short-duration policy

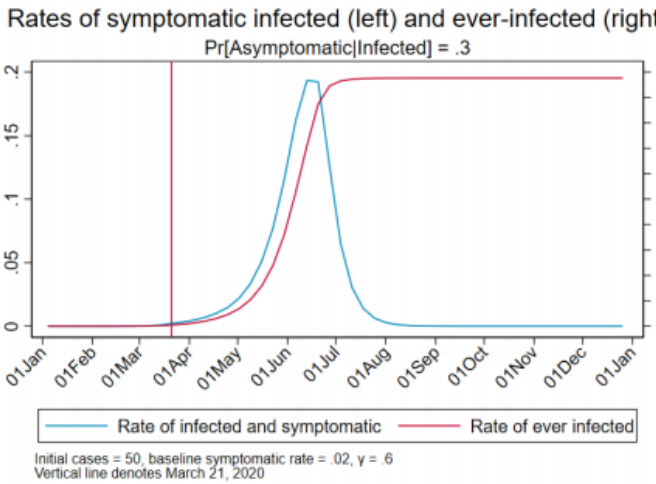
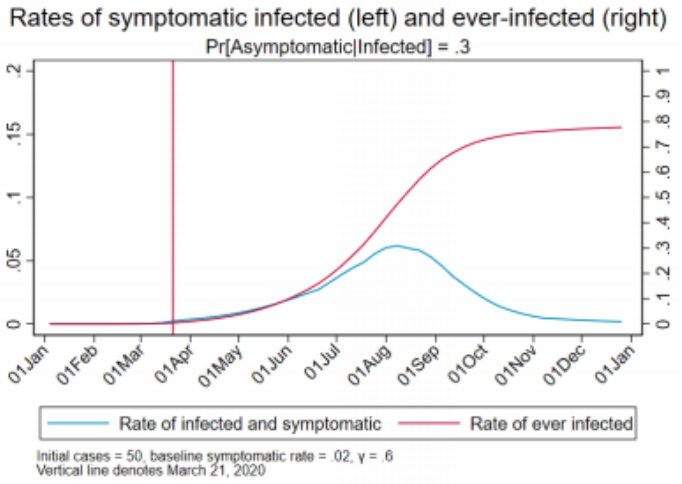


Figure 4. Low asymptomatic rate, severe long-duration policy



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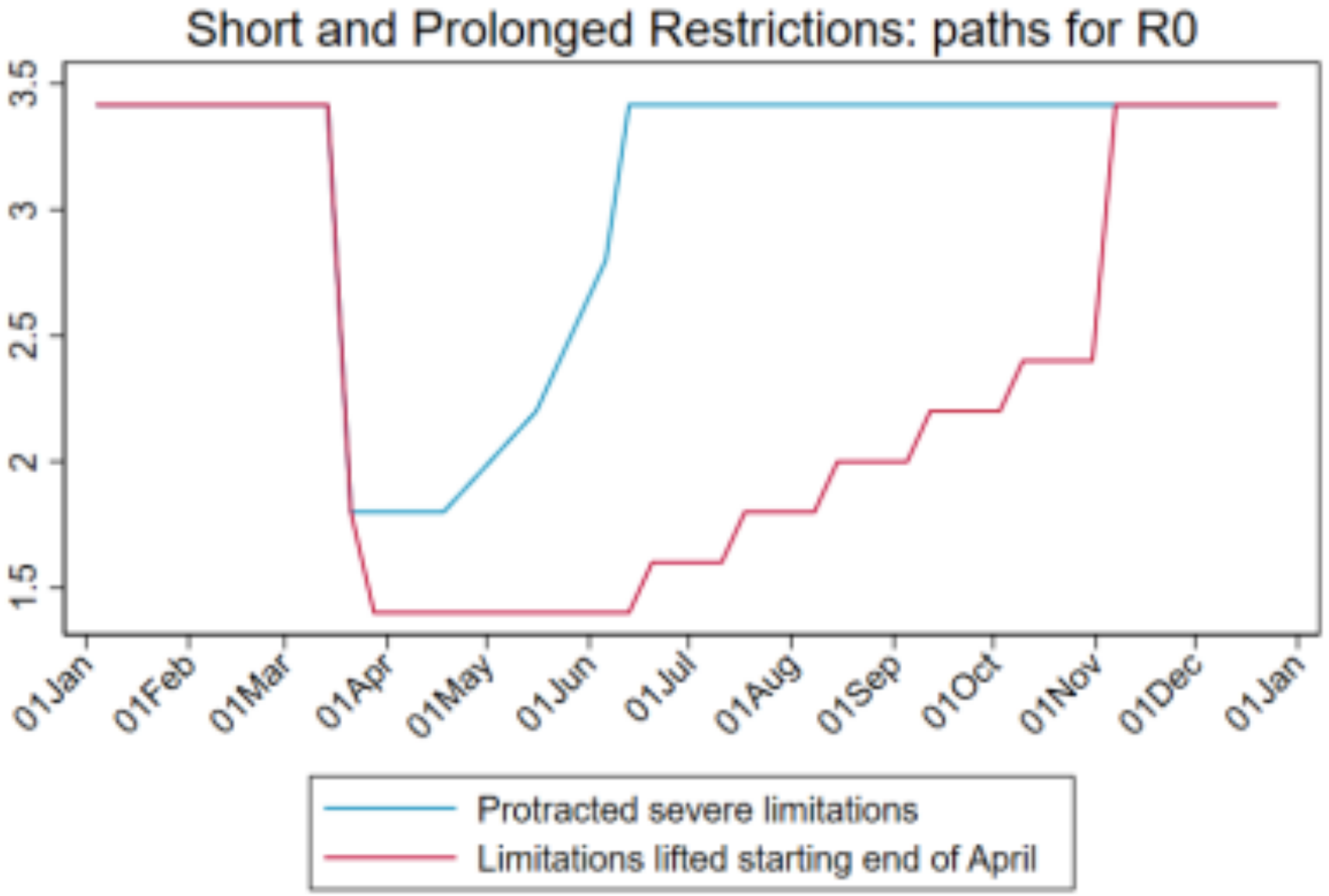


Pr[Asymptomatic|Infected] = .3, initial cases = 50, baseline symptomatic rate = .02, γ = .6

Figure 2. High asymptomatic rate, short-duration policy

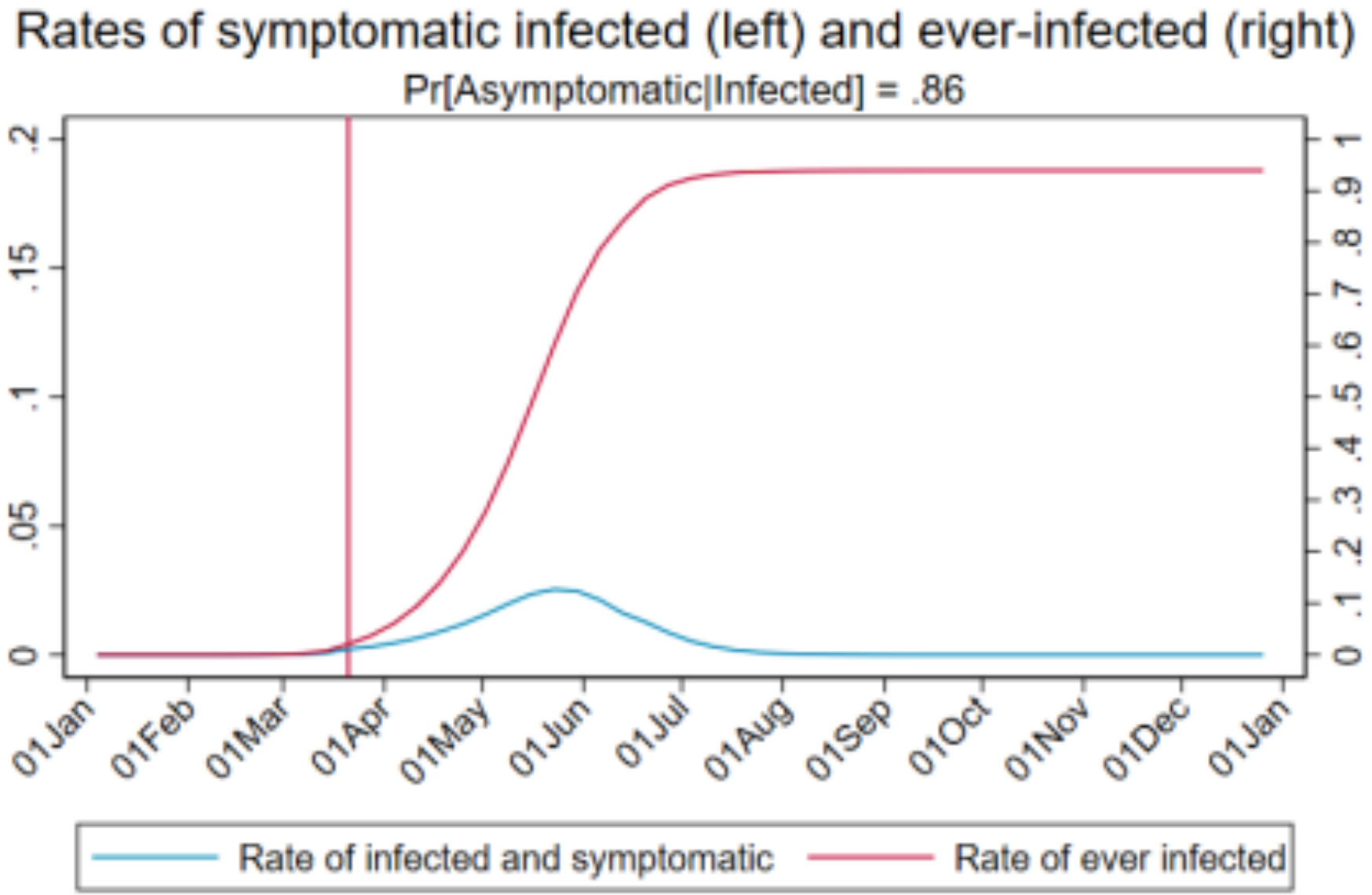


Figure 3. Low asymptomatic rate, short-duration policy

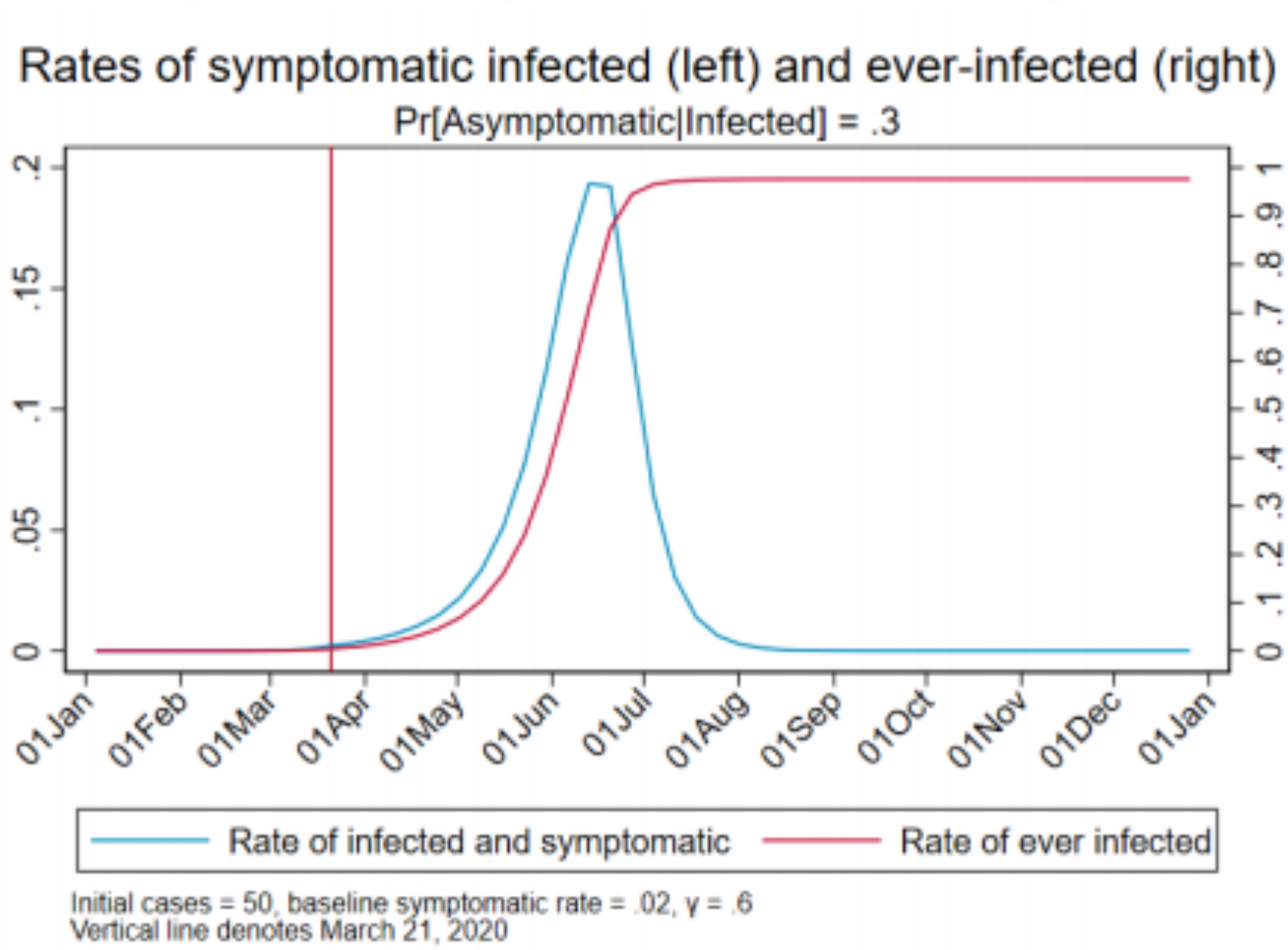
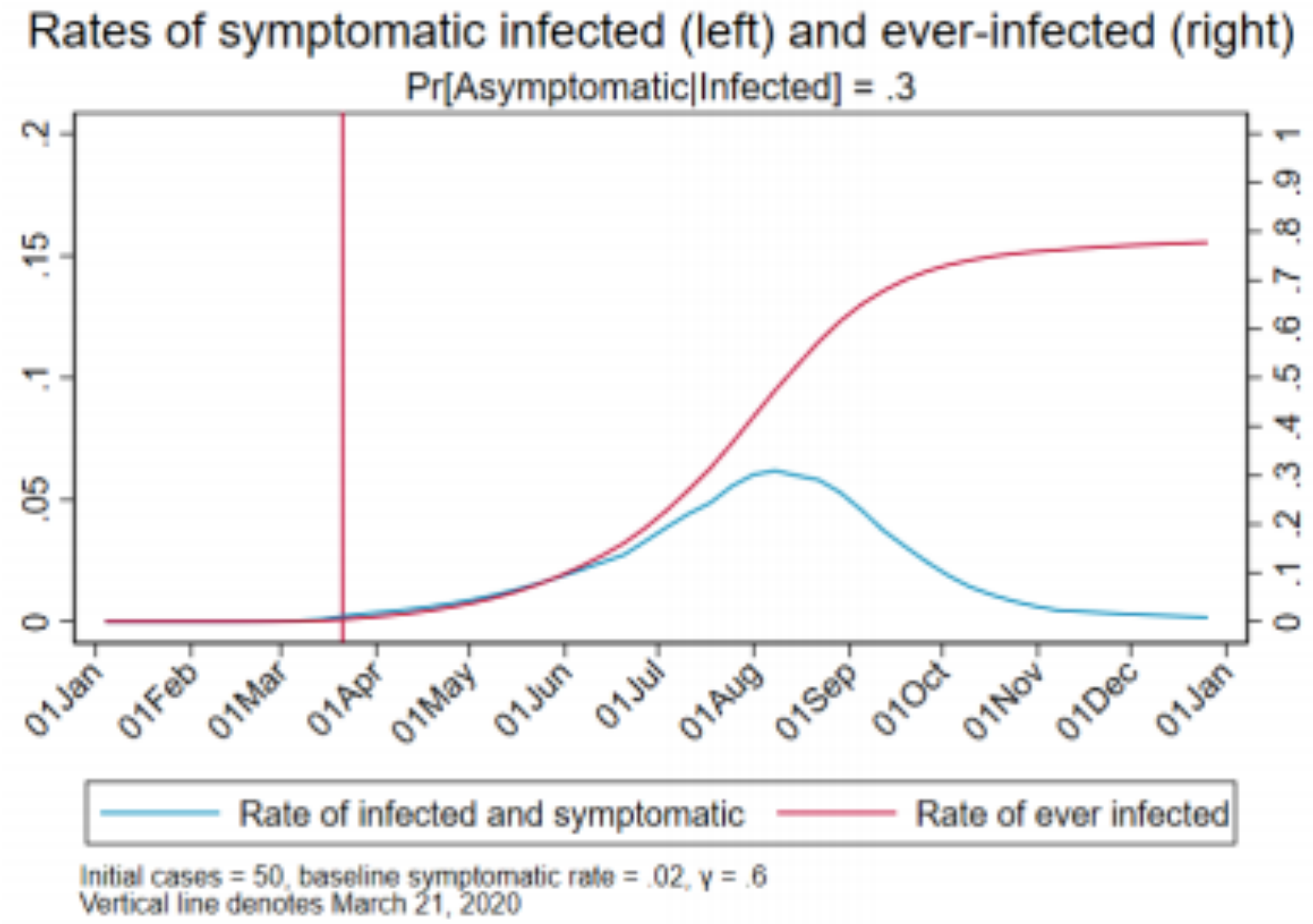


Figure 4. Low asymptomatic rate, severe long-duration policy



Most Afflicted States

40% of all cases in NY-NJ-CT:

- Other hot spots:
  - MA-RI (Biogen)
  - LA (Mardi Gras)
  - DC
  - MI
- But it looks like others will be coming up fast…
- As of 2020-

audio time

USA State	Total Cases	New Cases	Total Deaths	New Deaths	Active Cases	Tot Cases/ 1M pop	Deaths/ 1M pop	Total Tests	Tests/ 1M pop
New York	241,041	+7,090	17,671	+540	199,483	12,286	901	596,532	30,407
New Jersey	81,420	+2,953	4,070	+230	76,079	9,167	458	164,278	18,496
Massachusetts	36,372	+1,970	1,560	+156	26,694	5,325	228	156,806	22,958
Louisiana	23,580	+462	1,267	+54	22,263	5,056	272	137,999	29,591
Connecticut	17,550	+741	1,086	+50	16,399	4,900	303	58,213	16,254
Rhode Island	4,491	+314	137	+19	4,344	4,250	130	32,826	31,067
District Of Columbia	2,666	+190	91	+5	1,967	3,895	133	13,268	19,384
Michigan	30,791	+768	2,308	+81	25,246	3,092	232	102,366	10,280
Delaware	2,538	+215	67	+6	2,005	2,673	71	14,794	15,581
Pennsylvania	31,731	+1,810	1,102	+145	29,979	2,481	86	153,965	12,037
Illinois	29,160	+1,585	1,259	+125	27,851	2,274	98	137,404	10,717
USA Total	738,792	+29,057	39,014	+1,867	631,509	2,232	118	3,722,145	11,245
Maryland	12,308	+736	463	+38	11,074	2,050	77	65,370	10,889
South Dakota	1,542	+131	7		983	1,784	8	11,660	13,491
Georgia	17,841	+409	677	+9	17,133	1,733	66	74,208	7,206
Colorado	9,433	+386	411	+20	8,524	1,705	74	44,606	8,065
Washington	11,802	+643	624	+25	9,463	1,618	86	135,706	18,604
Indiana	10,641	+487	545	+26	10,082	1,603	82	56,873	8,569
Mississippi	3,974	+181	152	+12	3,822	1,330	51	38,765	12,970
Vermont	803	+24	38	+3	765	1,285	61	12,566	20,106
Nevada	3,626	+102	151	+9	2,306	1,241	52	35,955	12,301
Florida	25,492	+739	748	+22	24,058	1,238	36	253,183	12,292
Tennessee	6,762	+173	145	+3	3,383	1,017	22	90,586	13,620
New Hampshire	1,342	+55	38	+1	791	999	28	13,424	9,991
Idaho	1,668	+13	44	+1	1,171	988	26	16,183	9,588
Alabama	4,723	+151	147	+3	4,556	971	30	42,538	8,744
Utah	2,931	+126	25	+2	2,463	962	8	59,944	19,684
Virginia	8,053	+562	258	+27	6,685	957	31	51,931	6,172
Missouri	5,517	+234	184	+2	5,149	906	30	53,525	8,789
Ohio	10,222	+1,115	451	+33	9,651	878	39	83,131	7,141
New Mexico	1,798	+87	53	+2	1,280	859	25	36,632	17,507
South Carolina	4,246	+160	119	+3	1,389	857	24	38,833	7,836
Iowa	2,513	+181	74	+10	1,432	802	24	22,947	7,325

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Indiana	**10,641**	**+487**	**545**	**+26**	**10,082**	**1,603**	**82**	**56,873**	**8,569**
Mississippi	**3,974**	**+181**	**152**	**+12**	**3,822**	**1,330**	**51**	**38,765**	**12,970**
Vermont	**803**	**+24**	**38**	**+3**	**765**	**1,285**	**61**	**12,566**	**20,106**
Nevada	**3,626**	**+102**	**151**	**+9**	**2,306**	**1,241**	**52**	**35,955**	**12,301**
Florida	**25,492**	**+739**	**748**	**+22**	**24,058**	**1,238**	**36**	**253,183**	**12,292**
Tennessee	**6,762**	**+173**	**145**	**+3**	**3,383**	**1,017**	**22**	**90,586**	**13,620**

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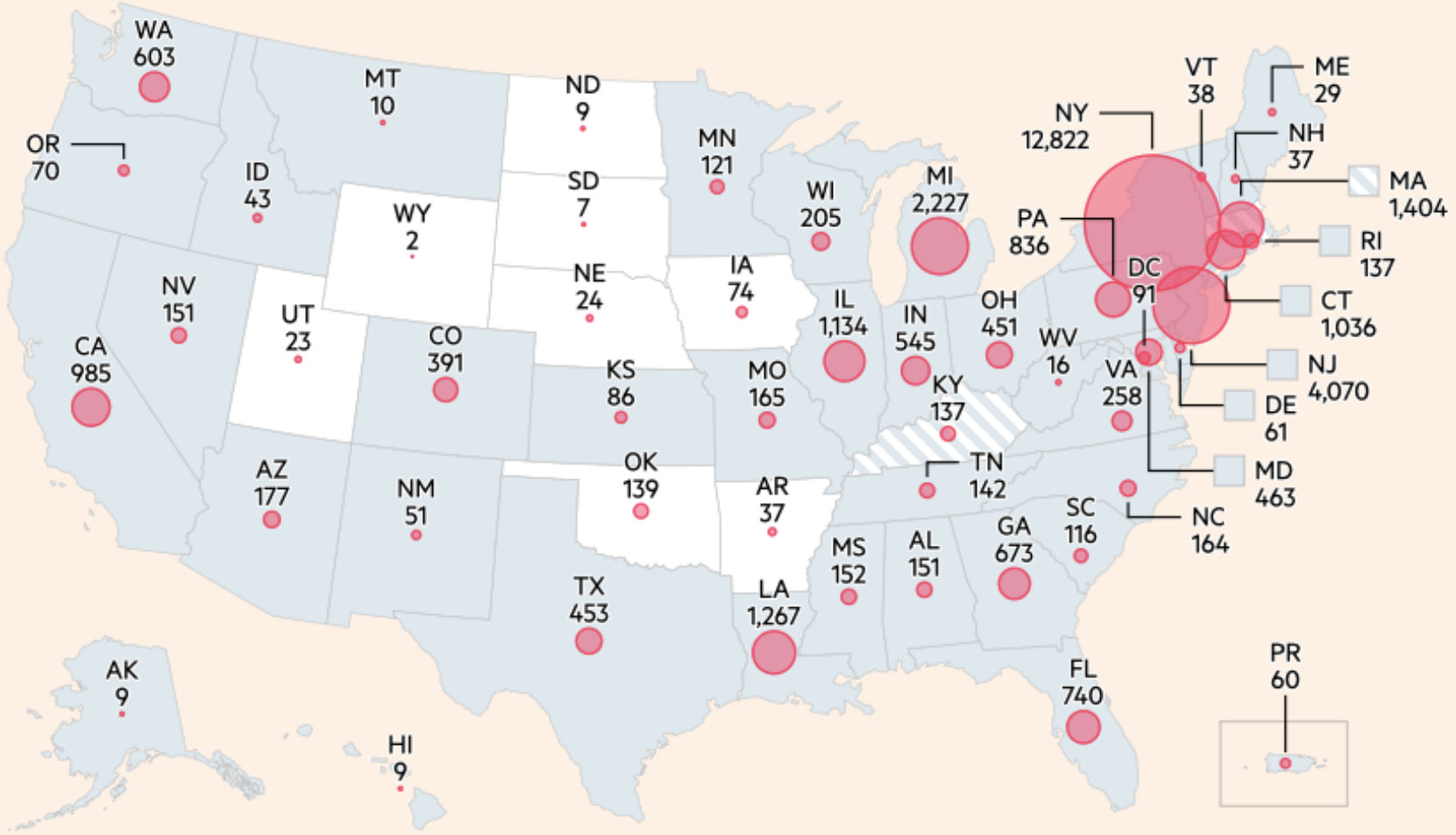
Coronavirus situation in the US

Total deaths as of 7:36pm Apr 18 BST



Graphic: Steven Bernard and Cale Tilford

Sources: Johns Hopkins University, CSSE; Worldometers; FT research

*Includes 'shelter in place' orders

**Includes Kentucky's 'healthy at home' order

Bringing the Economy Back Up from Anæsthesia

Major issues:

- Certificates of immunity:
  - Which requires test, test, test:
    - And not just disease virus tests
    - Presence-of-antibodies tests
- How quickly can we match the immune with public-contact jobs?
- What jobs can be done with minimal infection risk?
- What minimal-infection substitutes can we find for previous jobs?
- How quickly can restrictions be relaxed without the virus coming roaring back?
- How do we avoid having the market give a "shutdown" signal to enterprises we in fact want restarted?
  - Which is pretty much all of them
- How much of the potential caseload do we want to push out beyond the vaccine-arrival date?

ALL THESE QUESTIONS ARE ANSWERABLE IF WE LEARN THE ASYMPTOMATIC HENCE NON-TESTED RATE!!

audio time

Keeping the Economy from Crashing During the Lockdown

Nick Rowe: We have a 50% output cut in 100% of the sectors:

- A temporary 100% output cut in 50% of the sectors (what the Coronavirus does) is very different from a 50% output cut in 100% of the sectors
- Nick's thought experiment:
  - In three months we are going to invent unobtanium:
    - Substantial intertemporal substitutibility
    - Plus lower cross-good contemporaneous substitutitbility
    - Hence high desired savings rate now
  - Flex-price market thus produces a nominal rate at the zero lower bound and a high inflation rate over the next three to six months
  - Plus liquidity-constrained workers in affected sectors see their demand go to zero immediately
  - Can we get there? Should we get there? What should we do instead?
  - We need a good RBC economist: are there any?…

<https://worthwhile.typepad.com/worthwhile_canadian_initi/2020/03/relative-supply-shocks-unobtainium-walras-law-and-the-coronavirus.html>

audio time

Keeping the Economy from Crashing During the Lockdown II

Nick Rowe:

- <https://worthwhile.typepad.com/worthwhile_canadian_initi/2020/03/relative-supply-shocks-unobtainium-walras-law-and-the-coronavirus.html>
- Plus: to extend the thought experiment:
  - We just lost the ability to make "unobtainium"
  - So we *should* be substituting leisure for work, and moving workers into relatively unproductive labor, making the commodities we can still produce right now
  - How should relative prices move as a result? How should we make them move?

Plus: distributional issues

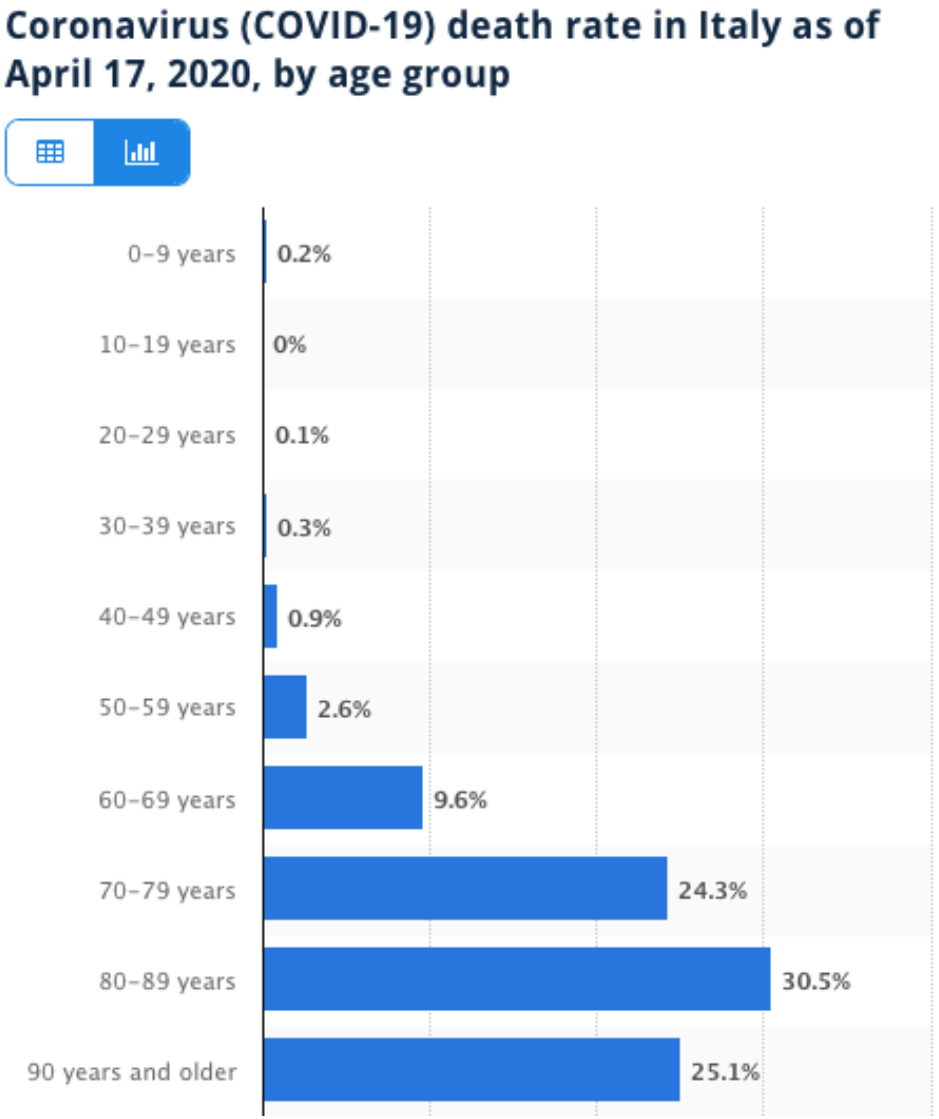
Plus: bankruptcy and credit chain issues

audio time

MOAR Coronavirus!

Death for Geezers!

- Mortality for the Youngs very low…
- It's the flu for them—for you…
- For the olders:
  - And an extra doubling—or is it 5%? —mortality for the asthmatic
  - And an extra doubling—or is it 5%? —mortality for the overweight
  - And an extra ???? if you have high blood pressure
  - And an extra ???? if you have high blood sugar

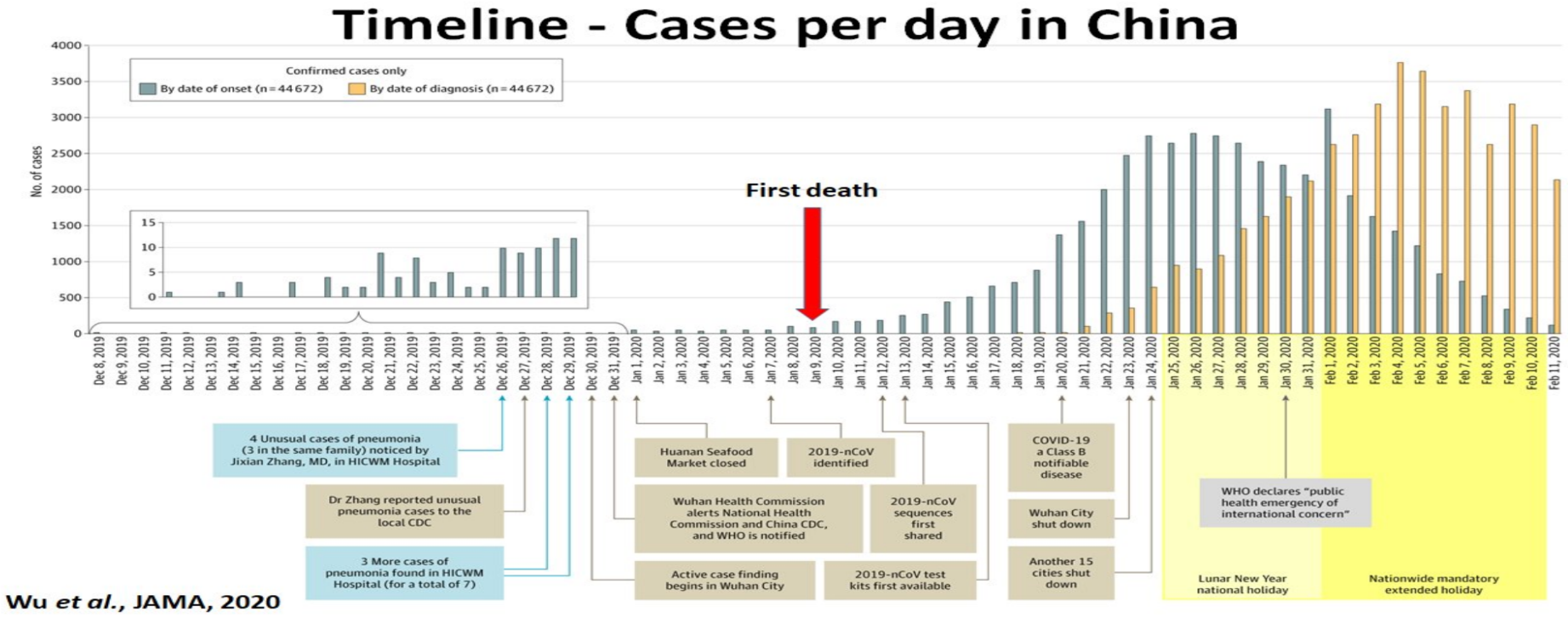


audio time

What We Think Happened in Wuhan

Wuhan beat it quickly—we think

- Shut down Wuhan when there were 200 cases per day
- Seems to have been a good choice



audio time

References

Directly cited here:

- **Financial Times** (2020): Coronavirus Tracked: The Latest Figures as the Pandemic Spreads <https://www.ft.com/coronavirus-latest>
- **Nick Rowe** (2020): *Relative Supply Shocks, Unobtainium, Walras' Law, and the Coronavirus* <https://worthwhile.typepad.com/worthwhile_canadian_initi/2020/03/relative-supply-shocks-unobtainium-walras-law-and-the-coronavirus.html>
- **Jim Stock** (2020): *Coronavirus Data Gaps and the Policy Response* <https://drive.google.com/file/d/12MV466ZZy5xHir4xdPhoTrL1oO8CbZU-/view>

What I am watching:

- **Jim Stock** (2020): *Coronavirus Data Gaps and the Policy Response* <https://drive.google.com/file/d/12MV466ZZy5xHir4xdPhoTrL1oO8CbZU-/view>
- **Max Roser & Hannah Ritchie**: *Coronavirus Disease (COVID-19)* <https://ourworldindata.org/coronavirus>…
- **Worldometer**: *Coronavirus Update (Live)* <https://www.worldometers.info/coronavirus/>…
- *FT Coronavirus Tracker* <https://www.ft.com/content/a26fbf7e-48f8-11ea-aeb3-955839e06441>
- *Josh Marshall's COVID Twitter List* <https://twitter.com/i/lists/1233998285779632128>
- **NEJM Group**: *Updates on the Covid-19 Pandemic* <http://m.n.nejm.org/nl/jsp/m.jsp?c=%40kxNtXckRDOq8oG0jJvAXsIzN4mPECIPhltxoTSdTU9k%3D&cid=DM89089_NEJM_COVID-19_Newsletter&bid=173498255>: 'From the New England Journal of Medicine, NEJM Journal Watch, NEJM Catalyst, and other trusted sources...

audio time

Catch Our Breath…

Continue the Discussion:

- Ask a couple of questions?
- Make a couple of comments?
- Any more readings to recommend?

Files:

- <https://www.icloud.com/keynote/0YKEi7HeOrVGvKYtt9FEqH7nA>
- <https://www.bradford-delong.com/2020/04/coronavirus.html>
- github:<https://github.com/braddelong/public-files/blob/master/coronavirus.pptx>
- https://github.com/braddelong/public-files/blob/master/coronavirus.pdf>
- html file: <https://www.bradford-delong.com/2020/04/coronavirus.html>
  - html edit: <https://www.typepad.com/site/blogs/6a00e551f08003883400e551f080068834/post/6a00e551f080038834025d9b3bd66a200c/edit>
- <https://delong.typepad.com/files/2020-04-01-coronavirus.pdf>

audio time

Notes

2020-04-06 Coronavirus

Where we think we are, as of Mo Apr 6:

- We really do not know
- No random samples…
- If we extrapolate out the past week straight-line log:
  - We will have 440,000 deaths in three weeks
  - But it is unlikely to be that bad
- Best thing I have read comes from Jim Stock <https://drive.google.com/file/d/12MV466ZZy5xHir4xdPhoTrL1oO8CbZU-/view>:
  - The basic SIR epidemiological model of contagion
  - The effect of social distancing and business shutdowns on epidemic dynamics enters the model through a single parameter: the case transmission rate β
  - Re-express the model in terms of β and the asymptomatic (or not very symptomatic) hence non-tested rate—the fraction of the infected who are not tested
  - The COVID-19 non-testing rate is unidentified in our model
  - Estimates in the epidemiological literature range from 0.18 to 0.86.
    - The asymptomatic rate could be estimated accurately and quickly by testing a random sample
- The optimal policy response and its economic consequences hinge critically on the asymptomatic rate

Coronavirus Extrapolations

Date	Deaths	Cases = Deaths x 100	Constant Weekly New Cases	Cases = 5 x Cases(-3)	Cases = 20 x Cases (-3)	Cases = Cases (-3) x exp(3 x week ch)
2020-04-05	9618		3,102,000	4,809,000	19,236,000	55,832,145
2020-03-29	2484		869,400	1,242,000	4,968,000	53,654,400
2020-03-22	414		144,900	207,000	828,000	8,942,400
2020-03-15	69	961,800	19,800	34,500	138,000	128,966
2020-03-08	26	248,400	10,100	13,000	52,000	45,697,600
2020-03-01	1	41,400	370	500	2,000	100,000
2020-02-23		6,900	37	50	200	10,000
2020-02-16		2,600	4	5	20	
2020-02-09		100				
2020-02-02		10				
2020-01-26		1				
		0				
	https://www.icloud.com/numbers/0Ez8EAgAQoiAip4VJWYWIWiCQ					

Coronavirus Cases:

1,342,235

view by country

Deaths:

74,554

Recovered:

278,182

United States

Coronavirus Cases:

364,059

Deaths:

10,792

Recovered:

19,536

USA State	Tot Cases/ 1M pop	Deaths/ 1M pop
USA Total	1,100	33
New York	6,662	243
New Jersey	4,626	113
Michigan	1,729	73
California	404	10
Louisiana	3,188	110
Massachusetts	2,026	38
Florida	662	12
Pennsylvania	1,016	13
Illinois	956	24
Washington	1,095	46
Texas	263	5
Georgia	710	22

Coronavirus II

We do not really know where we are, as of Mo Apr 6:

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view by country

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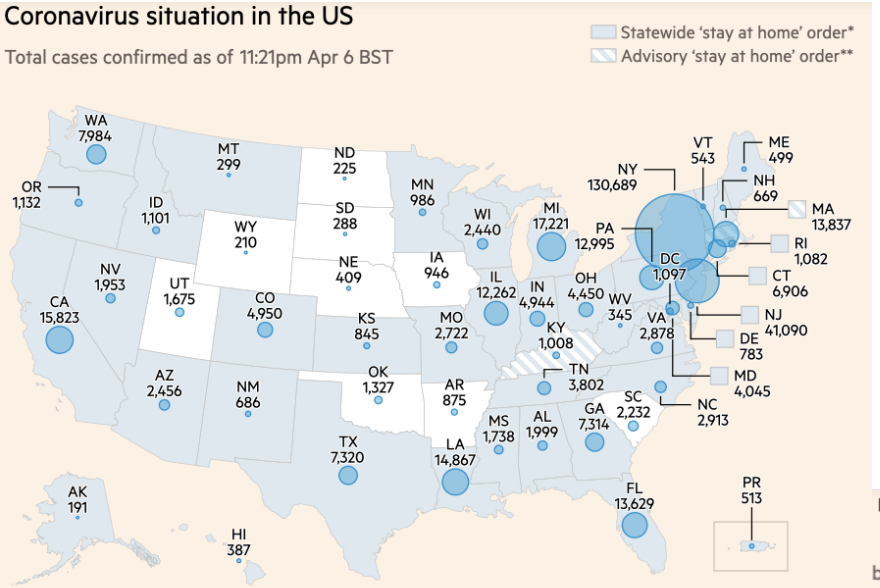
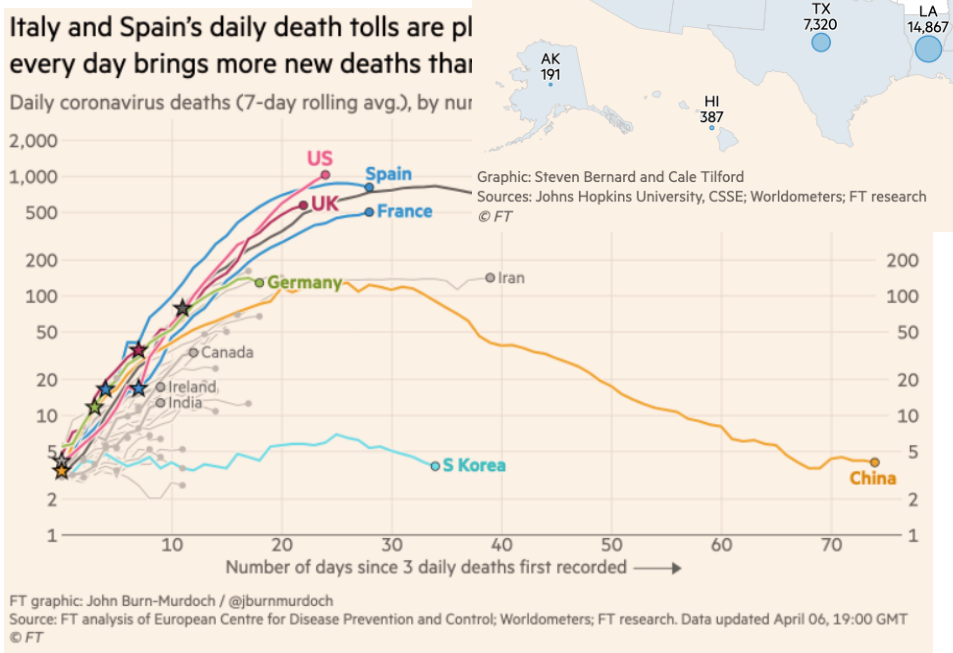
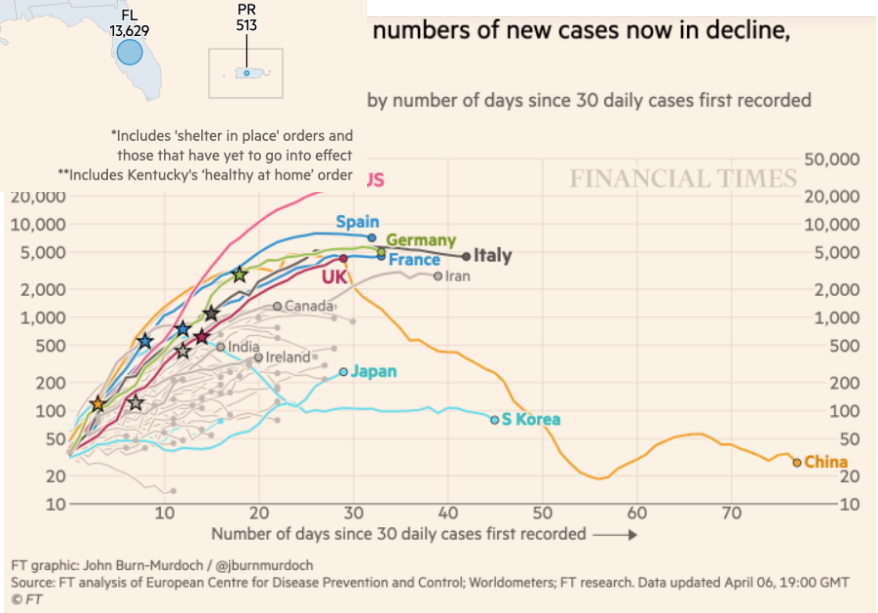
Financial Times Graphs Blown Up...

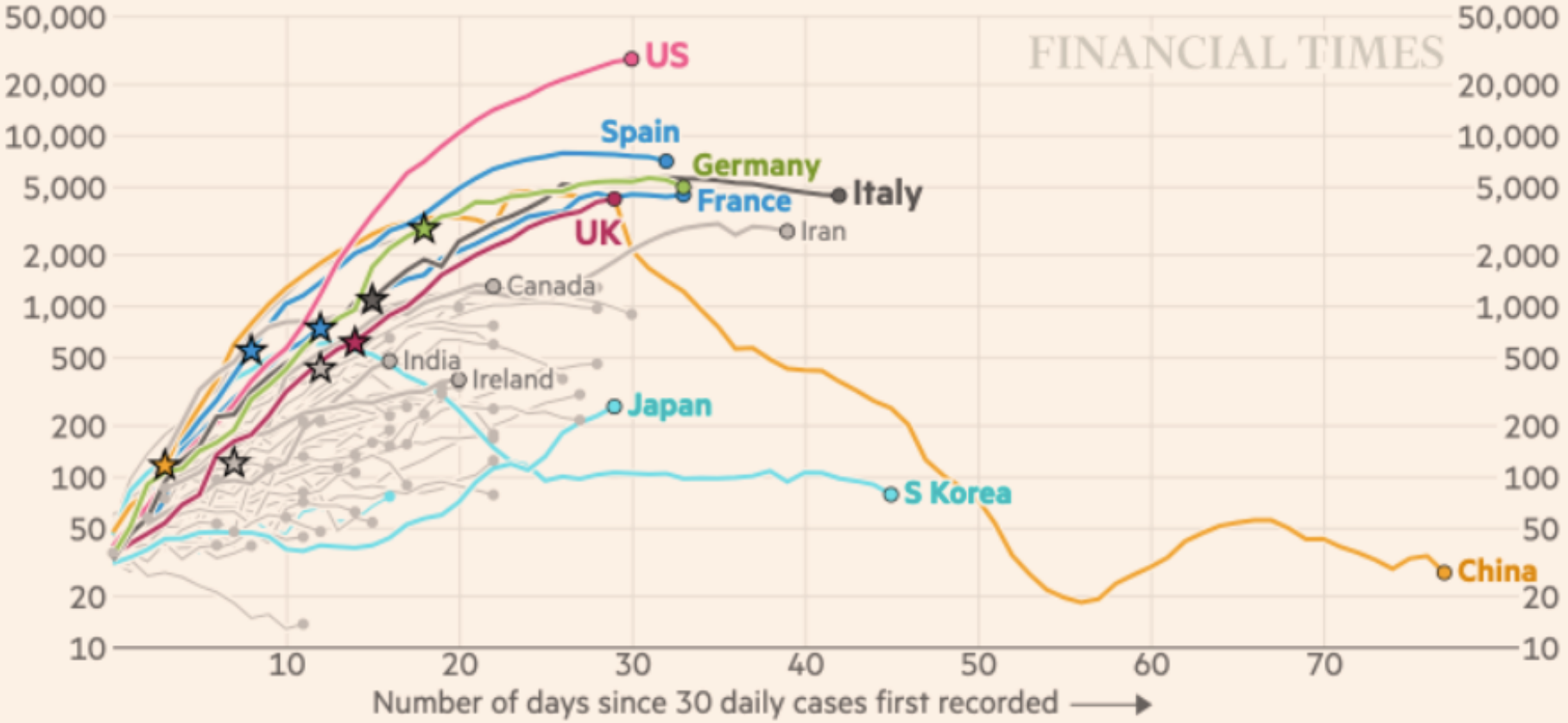






Italy has turned the corner, with numbers of new cases now in decline, following in China's footsteps

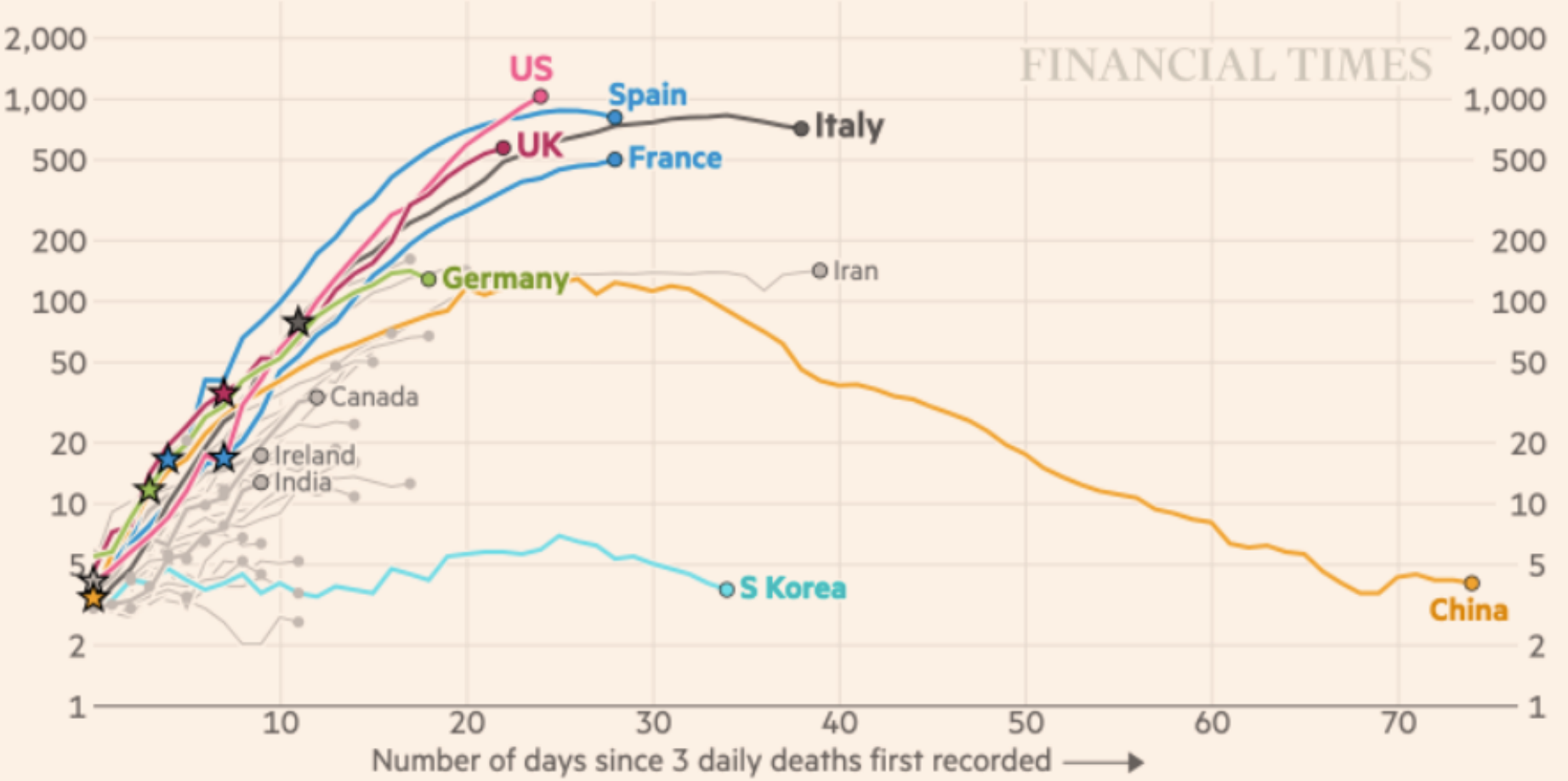
Daily confirmed cases (7-day rolling avg.), by number of days since 30 daily cases first recorded
Stars represent national lockdowns ★



FT graphic: John Burn-Murdoch / @jburnmurdoch
Source: FT analysis of European Centre for Disease Prevention and Control; Worldometers; FT research. Data updated April 06, 19:00 GMT

Italy and Spain's daily death tolls are plateauing, but in the UK and US every day brings more new deaths than the last

Daily coronavirus deaths (7-day rolling avg.), by number of days since 3 daily deaths first recorded

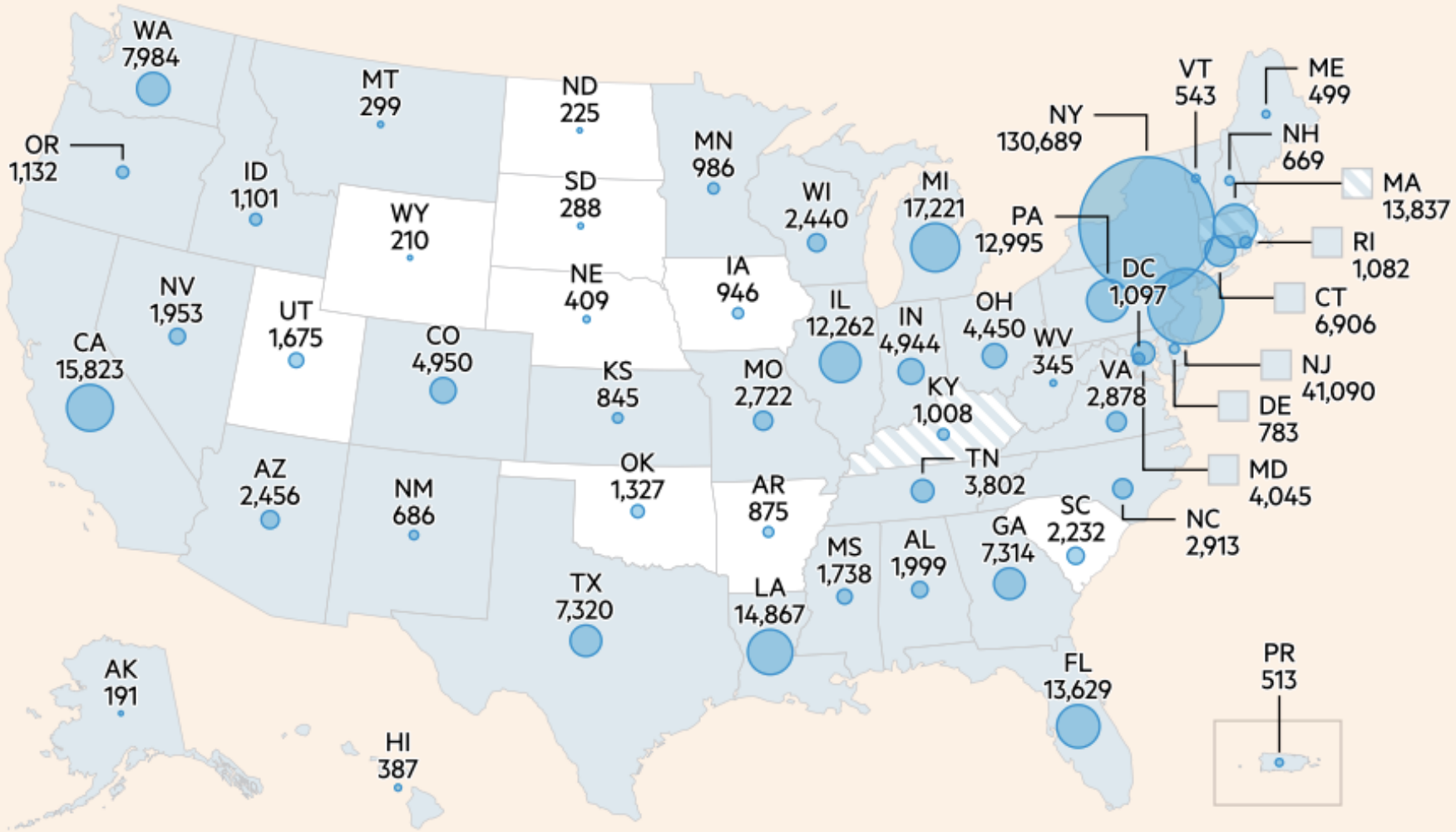


FT graphic: John Burn-Murdoch / @jburnmurdoch

Source: FT analysis of European Centre for Disease Prevention and Control; Worldometers; FT research. Data updated April 06, 19:00 GMT

Coronavirus situation in the US

Total cases confirmed as of 11:21pm Apr 6 BST



Graphic: Steven Bernard and Cale Tilford

Sources: Johns Hopkins University, CSSE; Worldometers; FT research

*Includes 'shelter in place' orders and those that have yet to go into effect

**Includes Kentucky's 'healthy at home' order

James Stock (2020)

Standard SIR model:<https://drive.google.com/file/d/12MV466ZZy5xHir4xdPhoTrL1oO8CbZU-/view>:

- **S**usceptible, **I**nfected, **R**ecovered (& immune), transmission rate β, recovery rate γ, reproduction number R_0, asymptomatic hence non-tested rate π_0
- Calibration: half-life of infection one week: $\gamma = 0.5$, $s_0 = 0.02$, 50 cases on Jan 24
- For March 21, 2020, the positive test

$$\Delta S_t = -\beta I_{t-1} \frac{S_{t-1}}{N}$$

$$\Delta R_t = \gamma I_{t-1},$$

$$\Delta I_t = \beta I_{t-1} \frac{S_{t-1}}{N} - \gamma I_{t-1}$$

Figure 2. High asymptomatic rate, short-duration policy

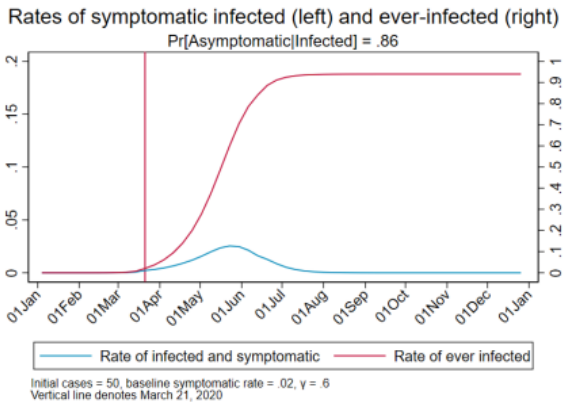


Figure 3. Low asymptomatic rate, short-duration policy

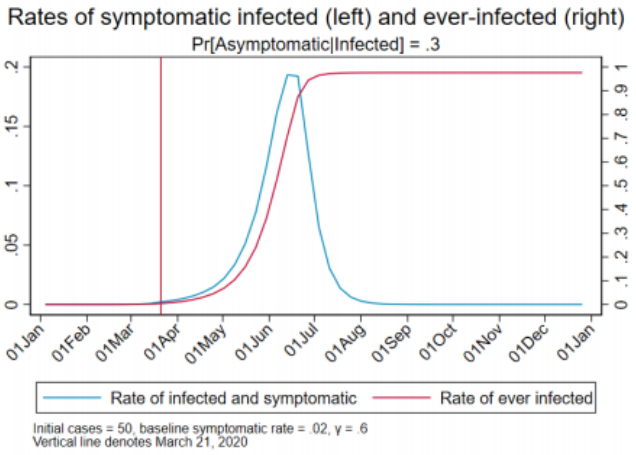
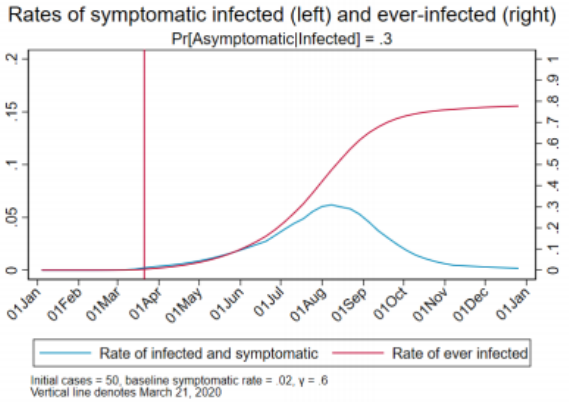


Figure 4. Low asymptomatic rate, severe long-duration policy



<https://drive.google.com/file/d/12MV466ZZy5xHir4xdPhoTrL1oO8CbZU-/view>

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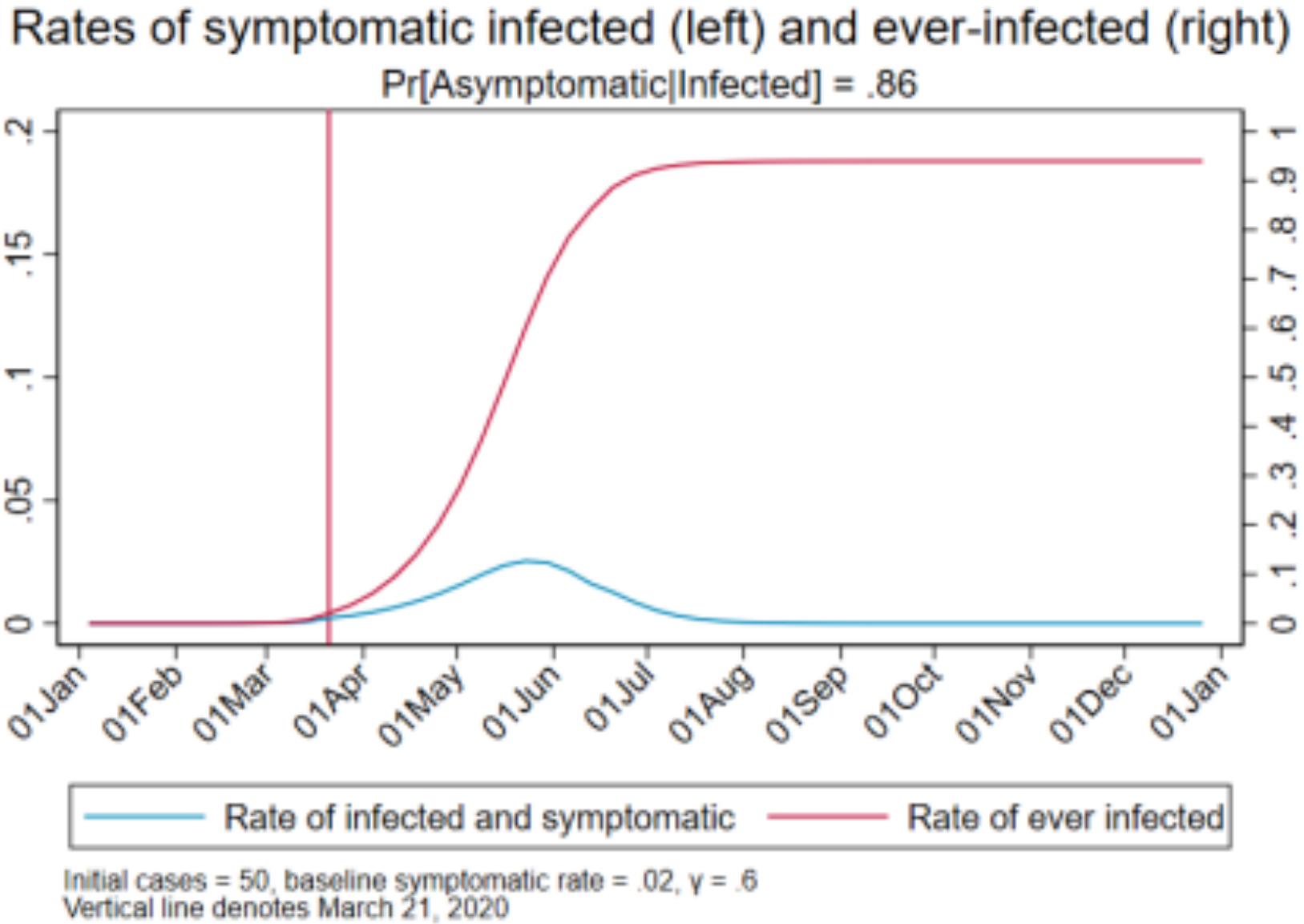

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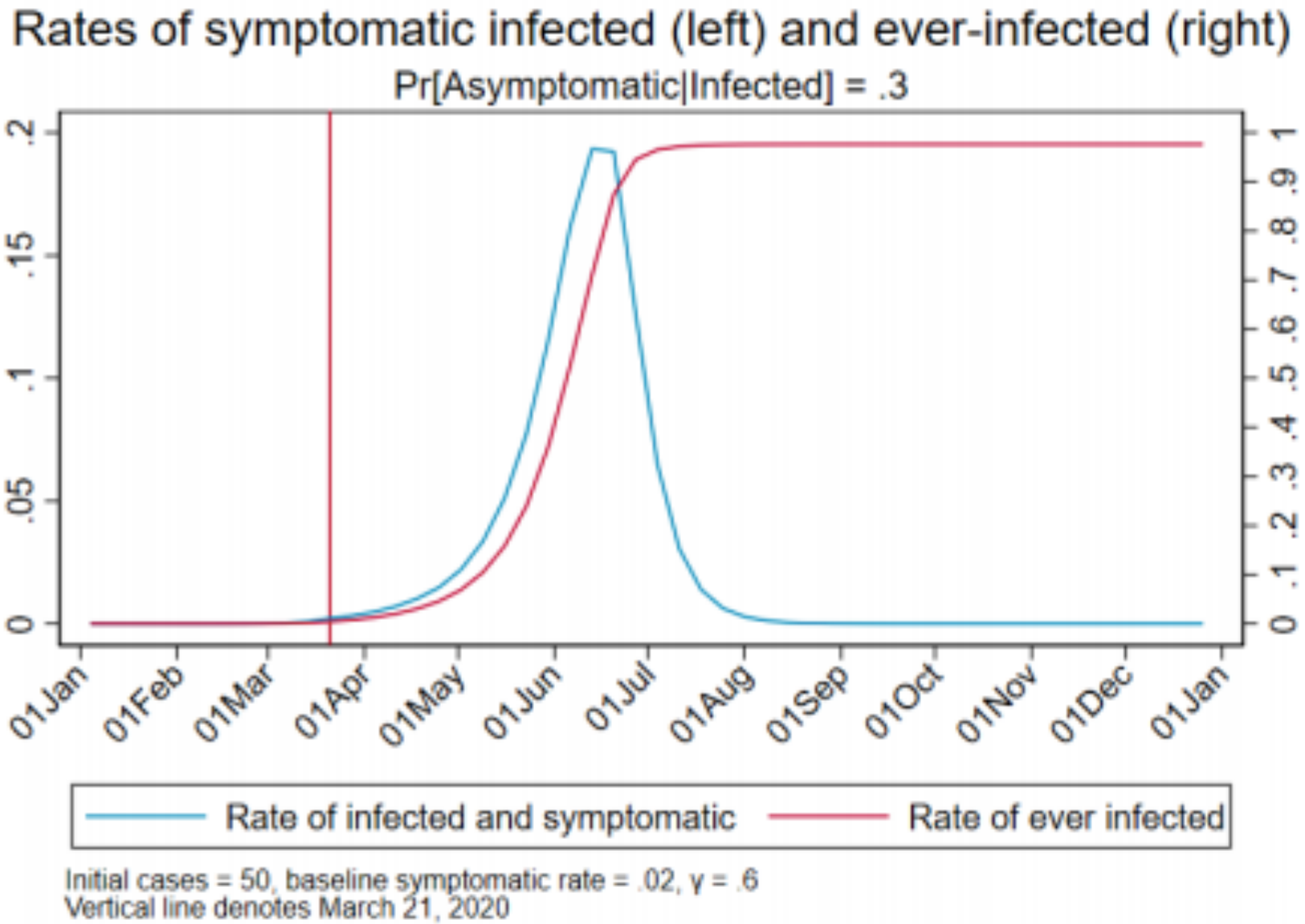

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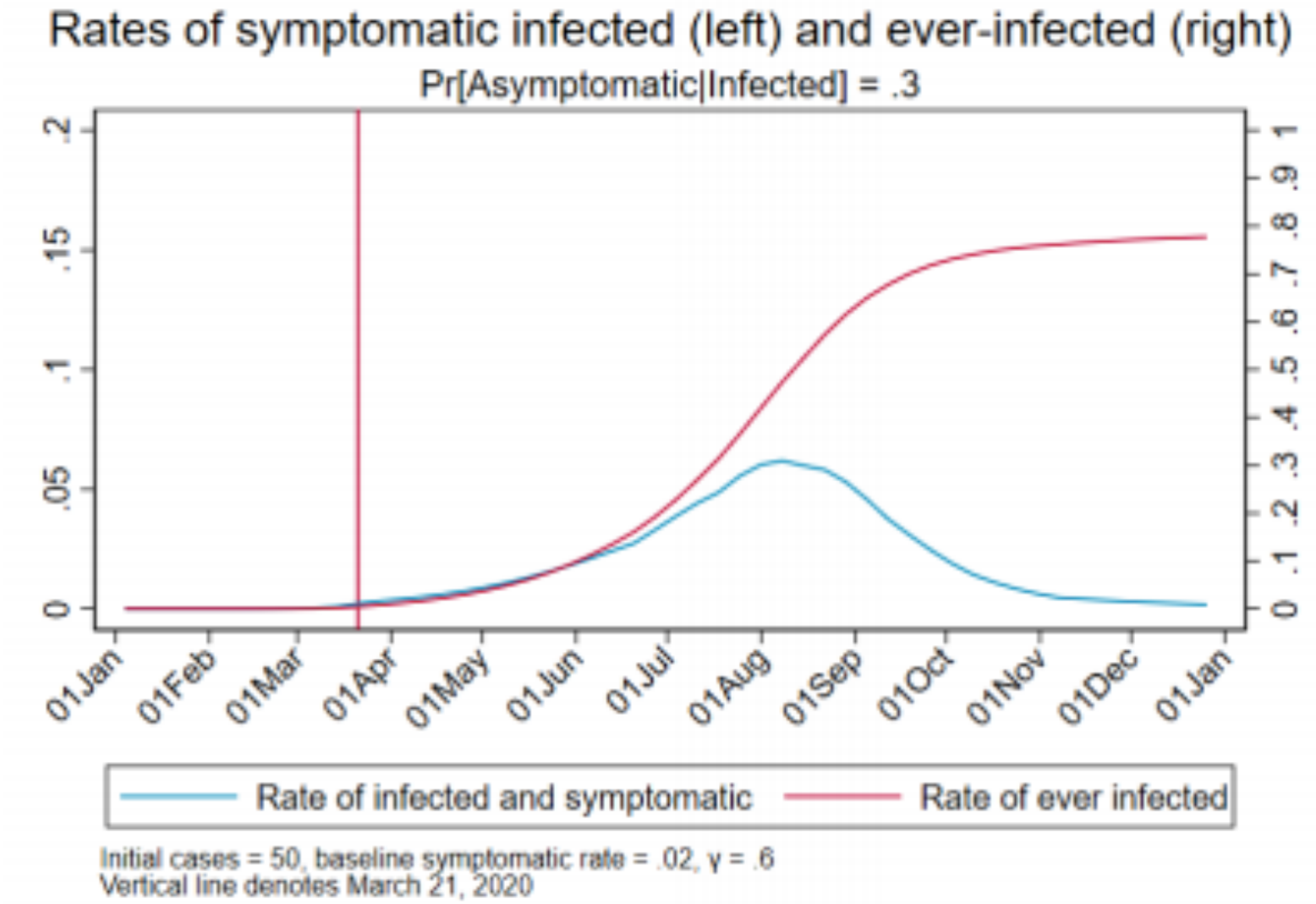


$$\Delta S_t = -\beta I_{t-1} \frac{S_{t-1}}{N}$$

$$\Delta R_t = \gamma I_{t-1},$$

$$\Delta I_t = \beta I_{t-1} \frac{S_{t-1}}{N} - \gamma I_{t-1}$$

Bringing the Economy Back Up from Anæsthesia

Major issues:

- Certificates of immunity:
    - Which requires test, test, test:
        - And not just disease virus tests
        - Presence-of-antibodies tests
- How quickly can we match the immune with public-contact jobs?
- What jobs can be done with minimal infection risk?
- What minimal-infection substitutes can we find for previous jobs?
- How quickly can restrictions be relaxed without the virus coming roaring back?
- How do we avoid having the market give a “shutdown” signal to enterprises we in fact want restarted?
    - Which is pretty much all of them
- How much of the potential caseload do we want to push out beyond the vaccine-arrival date?

ALL THESE QUESTIONS ARE ANSWERABLE IF WE LEARN THE ASYMPTOMATIC HENCE NON-TESTED RATE!!

Keeping the Economy from Crashing During the Lockdown

Nick Rowe: We have a 50% output cut in 100% of the sectors:

- A temporary 100% output cut in 50% of the sectors (what the Coronavirus does) is very different from a 50% output cut in 100% of the sectors
- Nick's thought experiment:
  - In three months we are going to invent unobtanium:
    - Substantial intertemporal substitutibility
    - Plus lower cross-good contemporaneous substitutitbility
    - Hence high desired savings rate now
  - Flex-price market thus produces a nominal rate at the zero lower bound and a high inflation rate over the next three to six months
  - Plus liquidity-constrained workers in affected sectors see their demand go to zero immediately
  - Can we get there? Should we get there? What should we do instead?
  - We need a good RBC economist: are there any?…

<https://worthwhile.typepad.com/worthwhile_canadian_initi/2020/03/relative-supply-shocks-unobtainium-walras-law-and-the-coronavirus.html>

Keeping the Economy from Crashing During the Lockdown II

Nick Rowe:

- <https://worthwhile.typepad.com/worthwhile_canadian_initi/2020/03/relative-supply-shocks-unobtainium-walras-law-and-the-coronavirus.html>
- Plus: to extend the thought experiment:
  - We just lost the ability to make "unobtainium"
  - So we *should* be substituting leisure for work, and moving workers into relatively unproductive labor, making the commodities we can still produce right now
  - How should relative prices move as a result? How should we make them move?

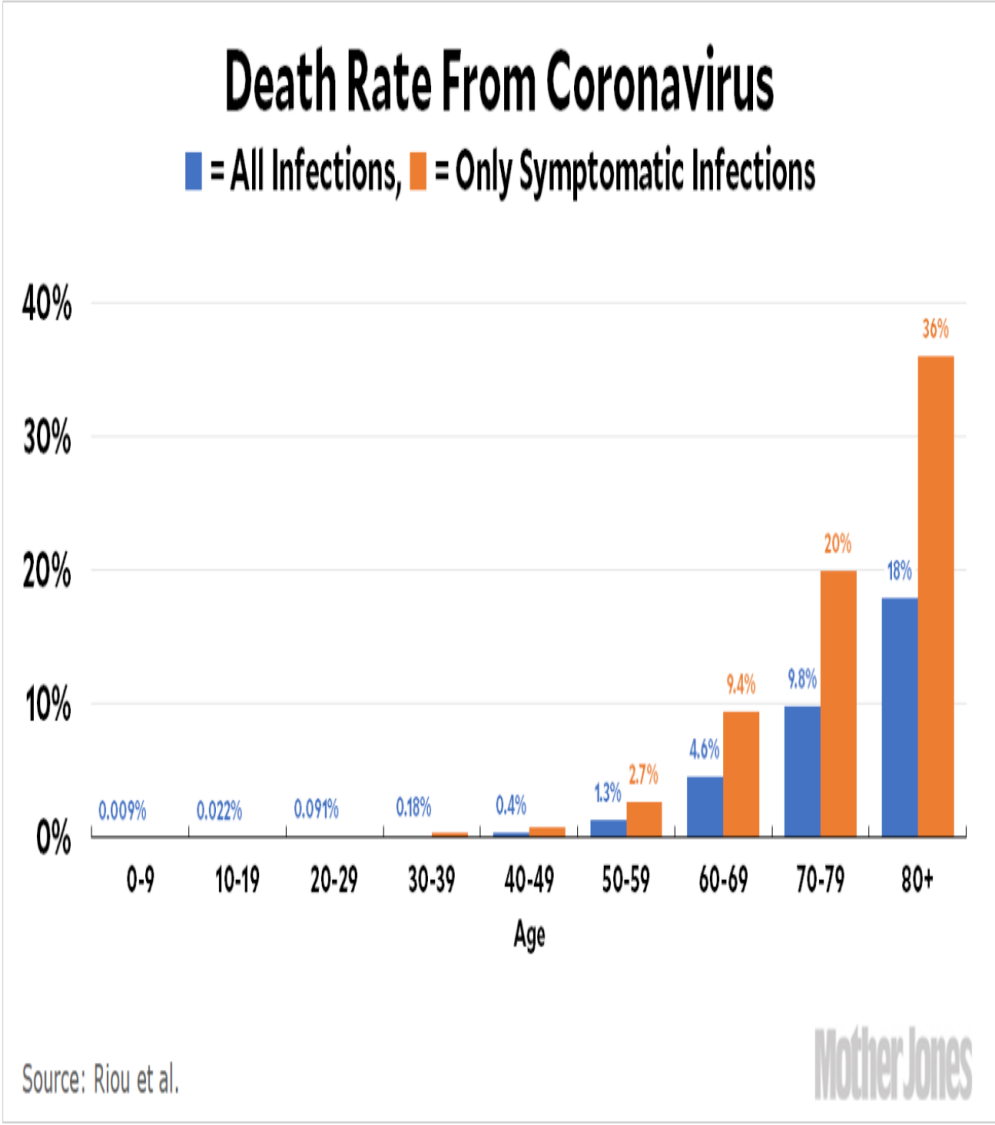
Plus: distributional issues

Plus: bankruptcy and credit chain issues

MOAR Coronavirus!

Death for Geezers!

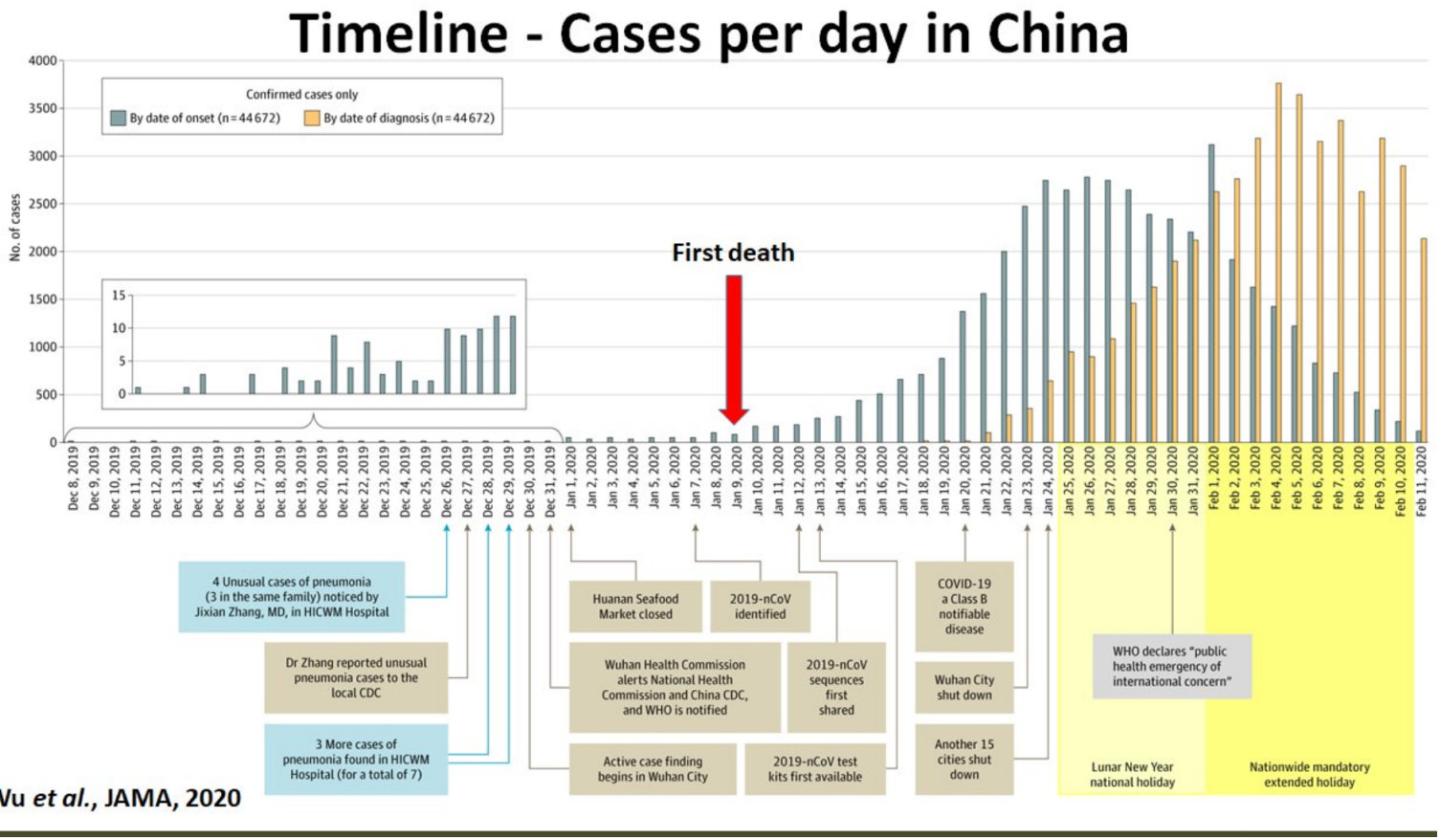
- Mortality for the Youngs very low…
- It's the flu for them—for you…
- And an extra doubling—or is it 5%?—mortality for the asthmatic
- And an extra doubling—or is it 5%?—mortality for the overweight



What We Think Happened in Wuhan

China beat it quickly & relatively easily!

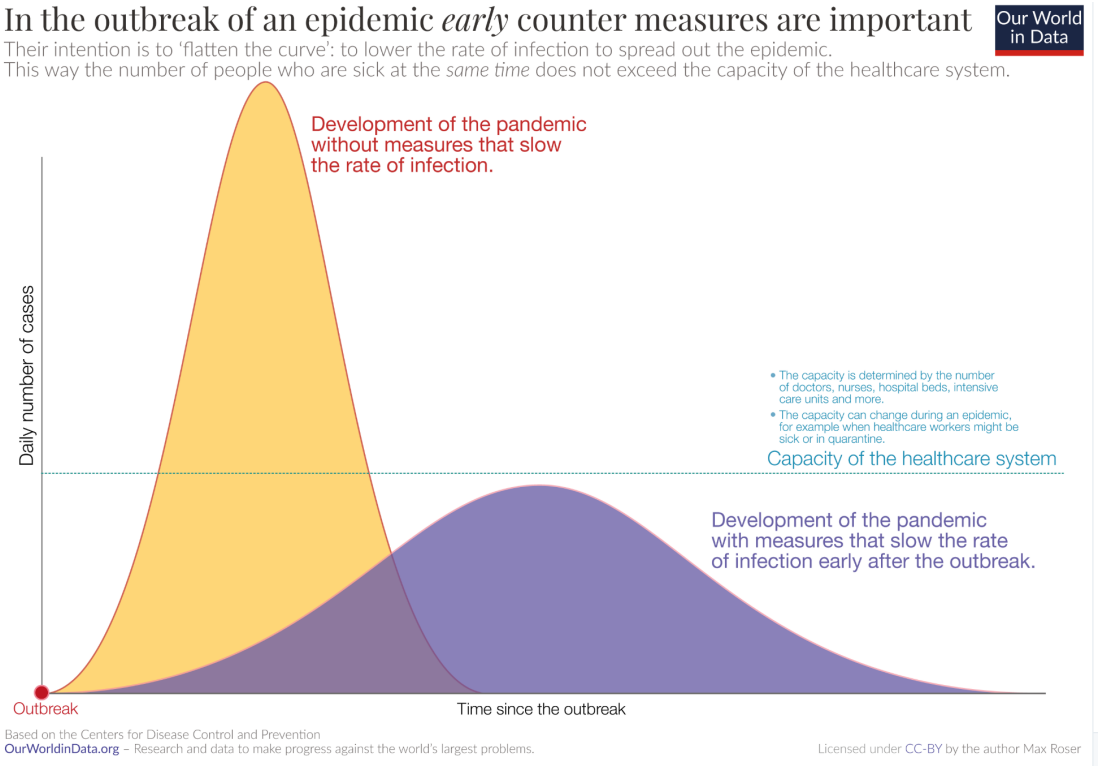
- We think
- Shut down Wuhan when 200 cases per day
- That seems to have been a good decision



The Goal

When Is It Appropriate to Move on This?

- Immediate social distancing…
- Self-isolate if you have a cough and a fever…
- Hope that warmer temperatures will do to this what they did to SARS…
- Otherwise, when do you want to start spreading out transmission. It seems that early is as good as later, so do it early…
  - I have no good intuition on why you want to move early
  - Plus your moving early will be wasted if you get reinfected
  - Plus the sparks you throw off making others' lives more difficult



References

- **Financial Times** (2020): Coronavirus Tracked: The Latest Figures as the Pandemic Spreads <https://www.ft.com/coronavirus-latest>
- **Nick Rowe** (2020): *Relative Supply Shocks, Unobtainium, Walras' Law, and the Coronavirus* <https://worthwhile.typepad.com/worthwhile_canadian_initi/2020/03/relative-supply-shocks-unobtainium-walras-law-and-the-coronavirus.html>
- **Jim Stock** (2020): *Coronavirus Data Gaps and the Policy Response* <https://drive.google.com/file/d/12MV466ZZy5xHir4xdPhoTrL1oO8CbZU-/view>

MOAR Coronavirus!

What I am watching:

- **Max Roser & Hannah Ritchie**: *Coronavirus Disease (COVID-19)* <https://ourworldindata.org/coronavirus>…
- **Worldometer**: *Coronavirus Update (Live)* <https://www.worldometers.info/coronavirus/>: '125,599 Cases and 4,605 Deaths from COVID-19 Virus Outbreak…
- *FT Coronavirus Tracker* <https://www.ft.com/content/a26fbf7e-48f8-11ea-aeb3-955839e06441>
- Josh Marshall's COVID Twitter List <https://twitter.com/i/lists/1233998285779632128>
- NEJM Group: Updates on the Covid-19 Pandemic <*http://m.n.nejm.org/nl/jsp/m.jsp?c=%40kxNtXckRDOq8oG0jJvAXsIzN4mPECIPhltxoTSdTU9k%3D&cid=DM89089_NEJM_COVID-19_Newsletter&bid=173498255*>: 'From the New England Journal of Medicine, NEJM Journal Watch, NEJM Catalyst, and other trusted sources...

Catch Our Breath…

- Ask a couple of questions?
- Make a couple of comments?
- Any more readings to recommend?

- <https://www.icloud.com/keynote/0YKEi7HeOrVGvKYtt9FEqH7nA>
- <https://www.bradford-delong.com/2020/04/coronavirus.html>

- github:<https://github.com/braddelong/public-files/blob/master/coronavirus.pptx>
- https://github.com/braddelong/public-files/blob/master/coronavirus.pdf>

- html File: <https://www.bradford-delong.com/2020/04/coronavirus.html>
- Edit This File: <https://www.typepad.com/site/blogs/6a00e551f08003883400e551f080068834/post/6a00e551f080038834025d9b3bd66a200c/edit>

- <https://delong.typepad.com/files/2020-04-01-coronavirus.pdf>

Coronavirus! (March 16)

~~**With 31 deaths in the U.S. as of March 11, a 1% death rate, and up to 4 weeks between infection and death, that means that as of Feb 12 there were 3100 coronavirus cases in the United States.**~~

With 87 deaths in the U.S. as of Mar 16, a 1% death rate, and up to 4 weeks between infection and death, that means that as of Feb 17 there were 8700 coronavirus cases in the United States

If it is doubling every seven days, then now about 150,000 people have and in the next week about 150,000 more people in the U.S. will catch coronavirus—which means 1/2200, currently 3500 of the 7.6 million inhabitants of San Francisco Bay. Touch a hard surface that any of those 3500 has touched in the last 48 hours, and the virus has a chance to jump to you…

These numbers could be five times too big. These numbers are probably not five times too small unless the thing is a lot less deadly, and there are a lot of asymptomatic cases…

- What is wrong with this analysis?

MOAR Coronavirus!

As of March 21: Things are not moving in the right direction:

- What is the R_0?
- How can the R_0 be changed?
- How will the R_0 change?
- What is the asymptote share of the population?
- What is the mortality rate?

Coronavirus Cases:

179,836

view by country

Deaths:

7,098

Recovered:

78,324

Country, Other	Total Cases	New Cases	Total Deaths	New Deaths	Total Recovered	Active Cases	Serious, Critical	Tot Cases/ 1M pop
China	80,880	+36	3,213	+14	67,819	9,848	3,226	56.2
Italy	27,980	+3,233	2,158	+349	2,749	23,073	1,851	462.8
Iran	14,991	+1,053	853	+129	4,590	9,548		178.5
Spain	9,428	+1,440	335	+41	530	8,563	272	201.6
S. Korea	8,236	+74	75		1,137	7,024	59	160.6
Germany	7,241	+1,428	15	+2	65	7,161	2	86.4
France	5,423		127		12	5,284	400	83.1
USA	4,186	+506	73	+5	73	4,040	12	12.6
Switzerland	2,353	+136	19	+5	4	2,330		271.9
UK	1,543	+152	55	+20	52	1,436	20	22.7
Netherlands	1,413	+278	24	+4	2	1,387	45	82.5
Norway	1,323	+67	3		1	1,319	27	244.0

ACTIVE CASES

94,414

Currently Infected Patients

88,252 (93%) in Mild Condition

6,162 (7%) Serious or Critical

Show Graph

CLOSED CASES

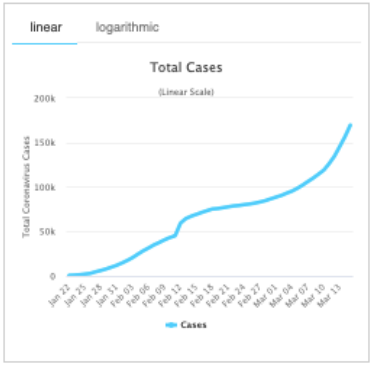
85,422

Cases which had an outcome:

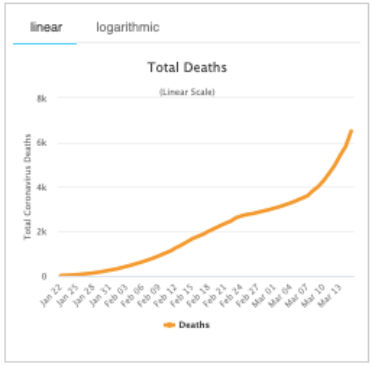
78,324 (92%) Recovered / Discharged

7,098 (8%) Deaths

Show Graph



More Case Statistics



More Death Statistics

MOAR Coronavirus!

As of March 10: Things are not moving in the right direction:

- What is the R_0?
- How can the R_0 be changed?
- How will the R_0 change?
- What is the asymptote share of the population?
- What is the mortality rate?

Coronavirus Cases:

125,599

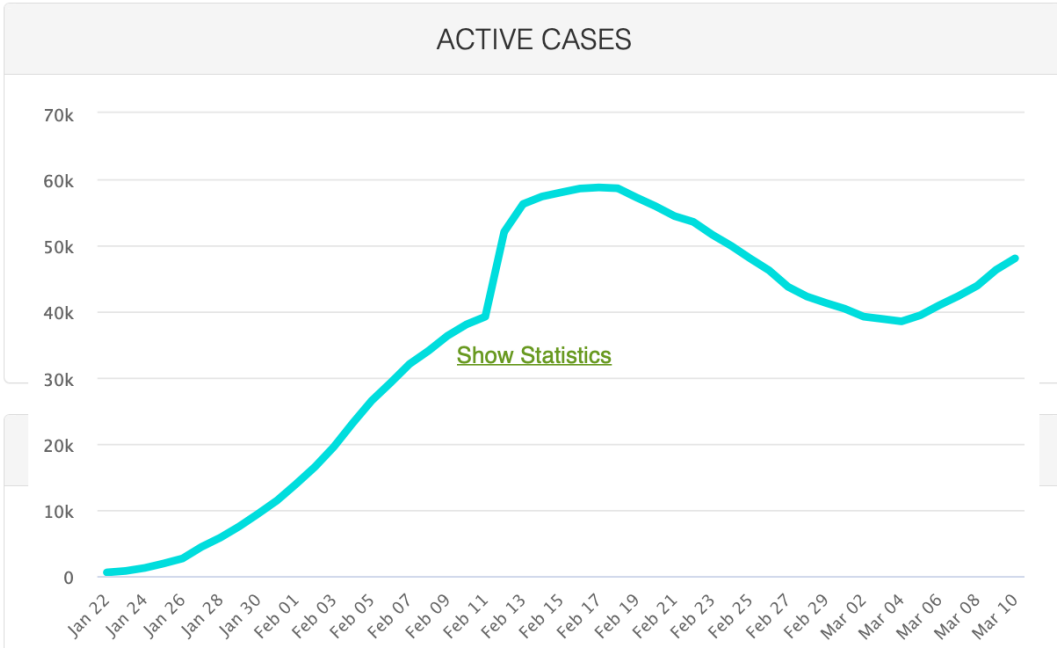
view by country

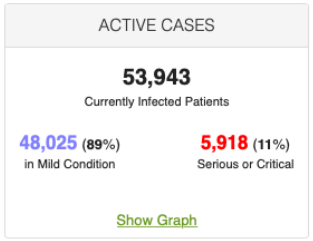
Deaths:

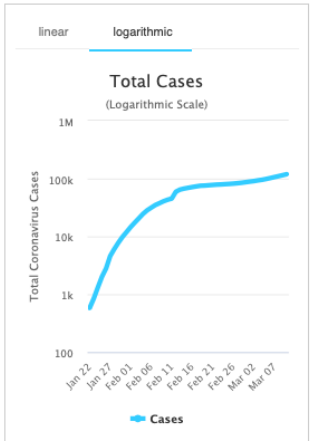
4,605

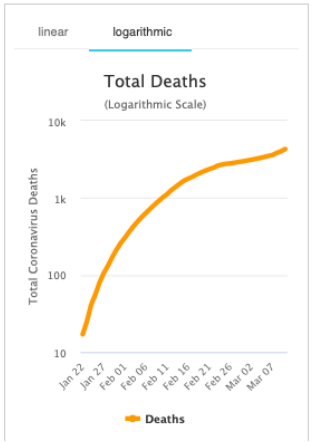
Recovered:

67,051









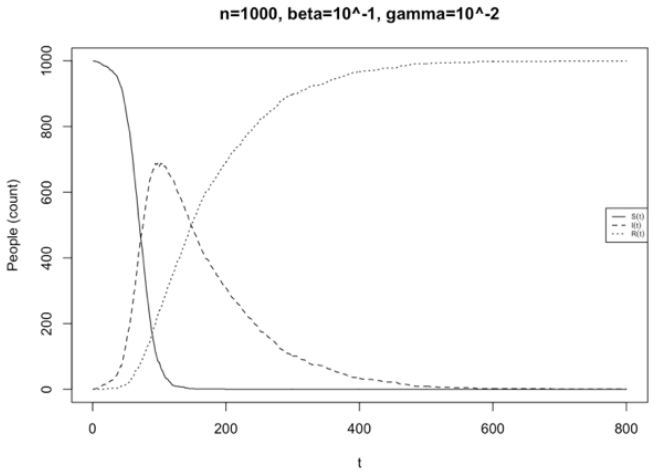
Notes

Epidemic Models

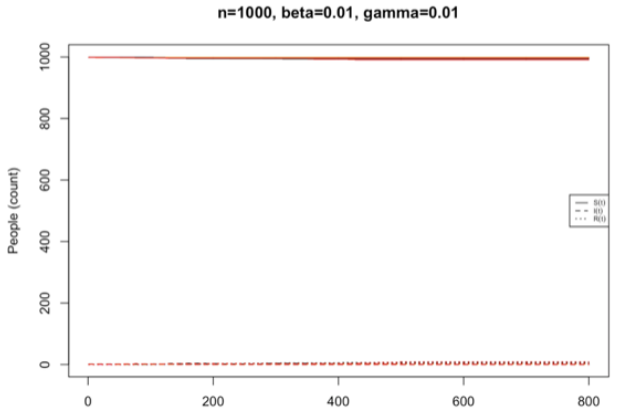
A requested special topic:

- Written and presented by Cosma Shalizi
- Of Carnegie-Mellon University
- <http://www.stat.cmu.edu/~cshalizi/dm/20/lectures/special/epidemics.html#(1)>
- 36-462/662, Spring 2020
- 16 April 2020 (Lecture 25)

What One Simulation Looks Like



What If We Make Contagion Harder?



audio time :: From Cosma Shalizi of Carnegie-Mellon: <http://www.stat.cmu.edu/~cshalizi/dm/20/lectures/special/epidemics.html#(1)>

Simple Epidemic Models

- **Compartments**: Every person can be in one of three states:
  - *Susceptible (S): not sick, could get sick*
  - *Infectious (I): sick, can make others sick*
  - *Removed (R): either recovered or dead; not sick, can't get sick, can't make others sick*
- **Contagion**: When an S meets an I, some probability of the S also becoming I
- **Removal**: Is spontaneously change into Rs
  - *Maybe after some random time*
  - *Maybe at some steady rate per unit time*
- **Mixing** or **mass action**: probability of an S meeting an I just depends on total numbers of Ss, Is and Rs

Stochastic Form of the SIR Model (1)

- $S(t)$ = number of Ss at time t, similarly for $I(t)$ and $R(t)$
- Total (initial) population is n
- Small time increment h, during which each S person encounters kh people
- The probability of contagion from an encounter between an S and an I is c
- Probability that a random person is infected is $I(t)/n$
- So the probability of an S becoming I is $kchI(t)/n$
  - *Strictly it's* $1-(1-cI(t)/n)^{hk} \approx kchI(t)/n$ *for small* h
- Number of *new* infections in time h is $\text{Binom}(S(t), kchI(t)/n)$
  - *If* h *is very small but* $S(t)$ *is very large, this is approximately* $\text{Poisson}(\frac{kch}{n}S(t)I(t))$
- Every I gets removed with probability γh so the number of removals in time h is $\text{Binom}(I(t), \gamma h)$
  - *If* h *is very small but* $I(t)$ *is very large, this is approximately* $\text{Poisson}(\gamma h I(t))$

Stochastic Form of the SIR Model (2)

- Over-all equations:

$$
\begin{aligned}
C(t+h) &= \text{Binom}(S(t), \frac{\beta}{n}hI(t)) \\
D(t+h) &= \text{Binom}(I(t), \gamma h) \\
S(t+h) &= S(t) - C(t+h) \\
I(t+h) &= I(t) + C(t+h) - D(t+h) \\
R(t+h) &= R(t) + D(t+h)
\end{aligned}
$$

- This bundles up multiple parameters we don't get to measure separately into some "effective" parameters β and γ
  - *I left in the factors of* h *and* n *for reasons which will become clear later*

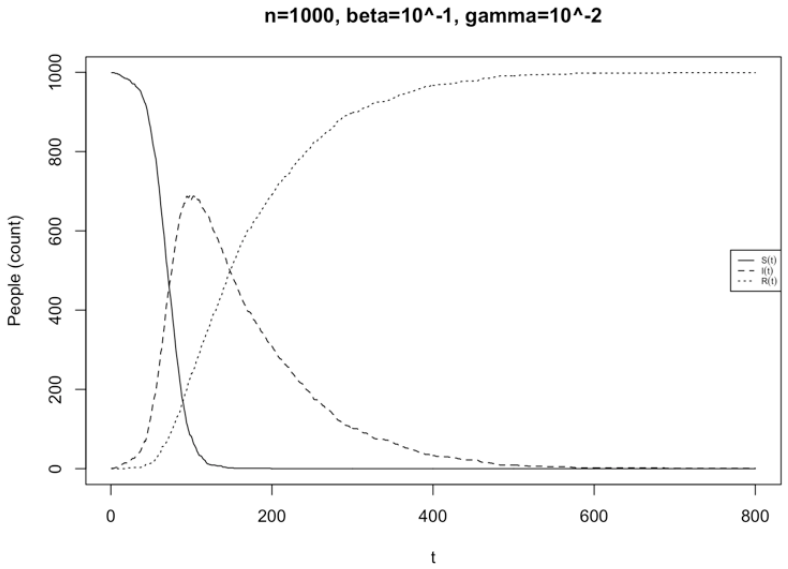
SIR is easy to simulate

```
sim.SIR <- function(n, beta, gamma, s.initial=n-1, i.initial=1, r.initial=0, T) {
    stopifnot(s.initial+i.initial+r.initial == n)
    states <- matrix(NA, nrow=3, ncol=T)
    rownames(states) <- c("S", "I", "R")
    states[,1] <- c(s.initial, i.initial, r.initial)
    for (t in 2:T) {
        contagions <- rbinom(n=1, size=states["S",t-1],
                             prob=beta*states["I",t-1]/n)
        removals <- rbinom(n=1, size=states["I",t-1],
                           prob=gamma)
        states["S",t] <- states["S",t-1] - contagions
        states["I",t] <- states["I",t-1] + contagions - removals
        states["R",t] <- states["R",t-1] + removals
    }
    return(states)
}
```

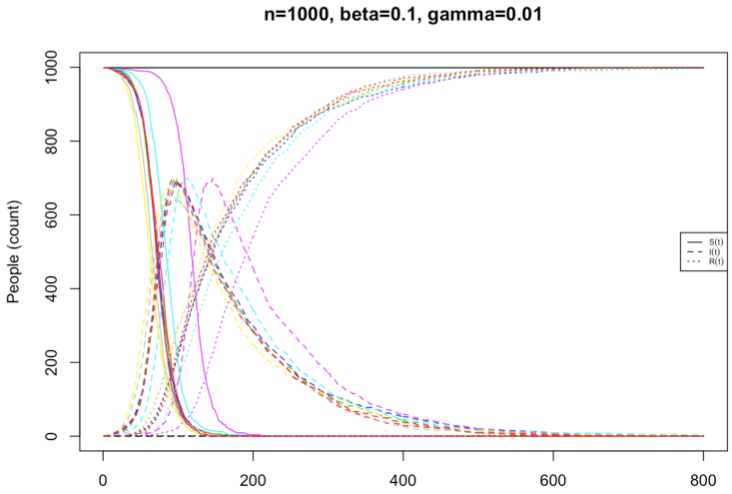
- The code doesn't need h here because it's (implicitly) taking $h = 1$

audio time :: From Cosma Shalizi of Carnegie-Mellon: <http://www.stat.cmu.edu/~cshalizi/dm/20/lectures/special/epidemics.html#(1)>

What One Simulation Looks Like



Multiple Simulations with the Same Settings



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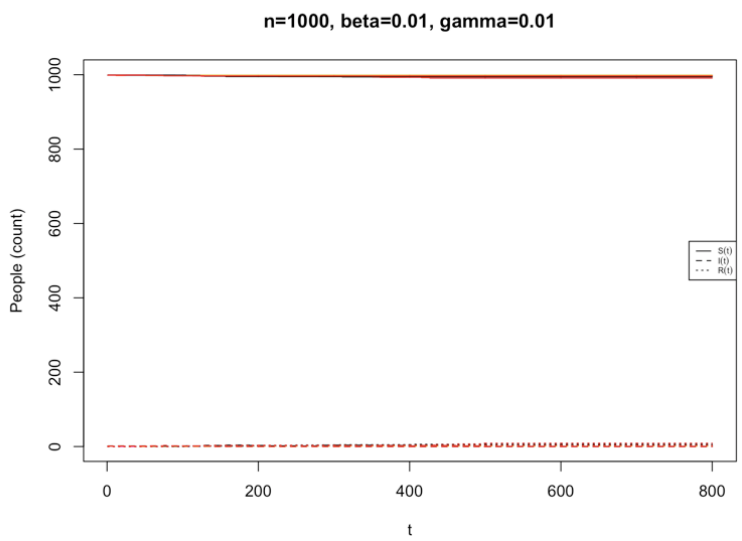
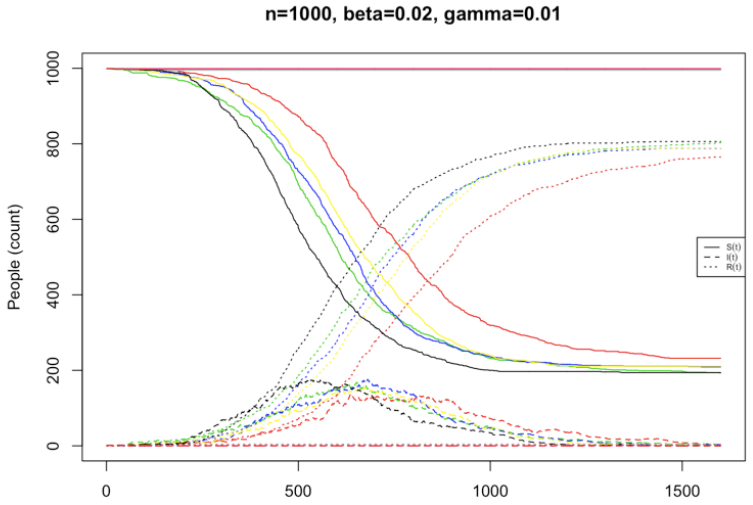
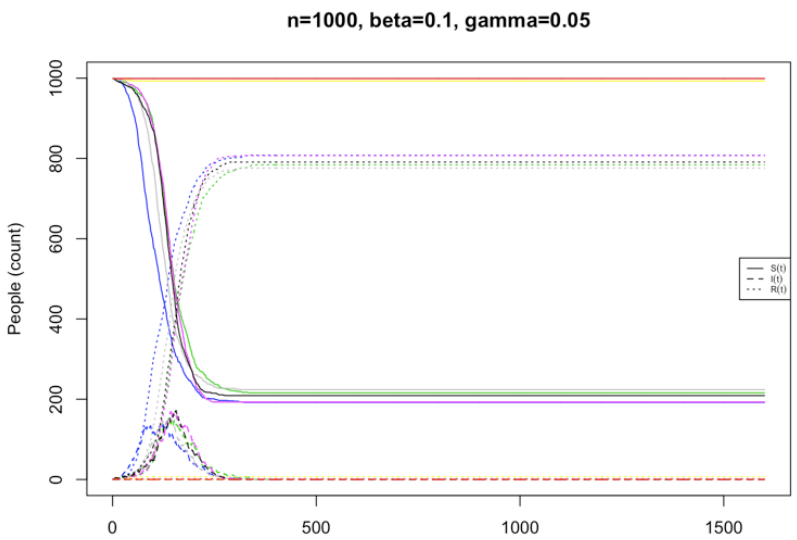


Maybe Not Quite That Much Harder?



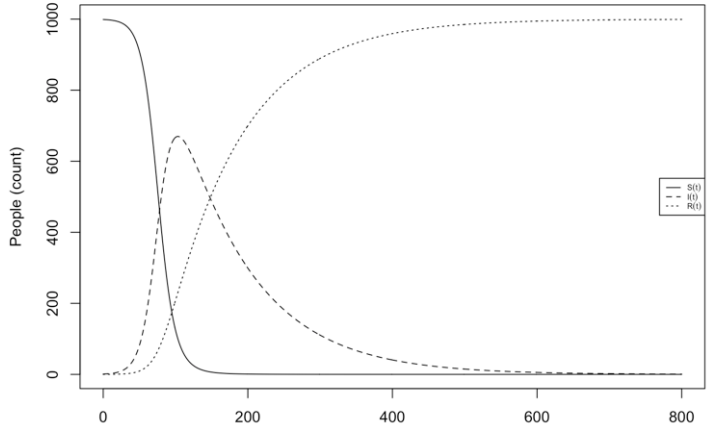
audio time :: From Cosma Shalizi of Carnegie-Mellon: <http://www.stat.cmu.edu/~cshalizi/dm/20/lectures/special/epidemics.html#(1)>

Go Back to the Original Ease of Contagion, But Make Removal Faster



Simulating the Deterministic Limit

Go back to the original parameter values:



Some Suggestions from Those Simulations

- Epidemic outbreak when β is sufficiently large, compared to γ
  - *At least, outbreaks with high probability*
- Epidemics don't have to affect everyone before they die out
- It may be the ratio β/γ is what matters for the probability of an outbreak and for the ultimate fraction ever infected
  - *Rather than, say, the difference* $\beta - \gamma$

Deterministic limit

- Imagine making the population size really big ($n \to \infty$), and the time step really small ($h \to 0$)
- The fluctuations get (relatively) negligible, and we're left with *deterministic* equations
  - *See backup*

$$
\begin{aligned}
S(0) + I(0) + R(0) &= n \\
\frac{dS}{dt} &= -\frac{\beta}{n} S(t) I(t) \\
\frac{dI}{dt} &= \frac{\beta}{n} I(t) S(t) - \gamma I(t) \\
\frac{dR}{dt} &= \gamma I(t)
\end{aligned}
$$

- When people talk about "*the* SIR model", it's often ambiguous between the stochastic model we started with and these ordinary differential equations (ODEs)
- See backup for manipulations to these equations

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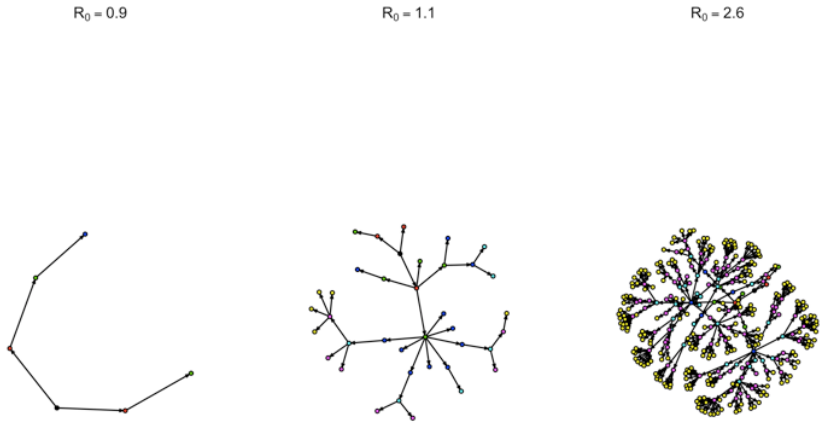
Is There Going to be an Epidemic?

- **Epidemic transition**: Typically, the contagion either dies out rapidly *or* it takes over a large fraction of the population
  - *We saw evidence for this in the simulation*
  - *More mathematically: As n grows, does the total number who are ever infected grow n or not?*
  - *I.e., is $R(\infty) = O(n)$ (an epidemic) or $R(\infty) = o(n)$ (no epidemic)?*
- One way to approach this is through the **basic reproductive number** R_0:

  $R_0 \equiv \mathbf{E}$ [number of new infections directly produced by adding one infected into a
  - *Don't confuse this with $R(0)$ = number removed at time 0!*
  - *Some people write $\mathcal{R}_0$ to avoid this confusion*
- Each of those R_0 new infections *also* faces an (almost) entirely susceptible population, so they'll cause R_0 new infections on average as well
  - *Obviously can't be true for ever, but is true initially*
- After k rounds of contagion, we expect R_0^k infected

The Epidemic Threshold, Illustrated



Relating R_0 to SIR Parameters (1)

- Start by guestimating
- $I(t) = 1, S(t) \approx n$, so expected number of infections per time step (of length is $\approx \beta$
- Expected number of time steps before the initial I gets removed is $1/\gamma$
- So (roughly!)

$$R_0 = \frac{\beta}{\gamma}$$

  - *Our initial simulations had $\beta = 10^{-1}, \gamma = 10^{-2}$ so $R_0 = 10$*
  - *For the second set of simulation, $R_0 = 1$*
  - *For the third and fourth sets, $R_0 = 2$*

Relating R_0 to SIR Parameters (2)

- There are more rigorous ways to come to the same conclusion…
  - *For the stochastic model: approximate it as a branching process*
  - *For the deterministic model: look at the stability of the all-susceptible state*
- Upshot: In the SIR model,

$$R_0 = \frac{\beta}{\gamma}$$

  - *Holds in both the stochastic and deterministic versions*

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Qualitative Results for the Deterministic Model

- $dS/dt \leq 0$ so the number of susceptibles never goes up
- $dR/dt \geq 0$ so the number removed never goes down
- If we begin with $I(0) \ll n, R(0) = 0, S(0) \approx n$, then at small times t,

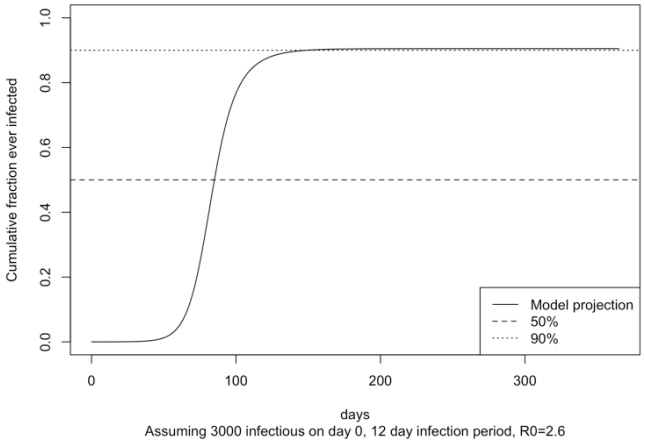
$$I(t) \approx I(0)e^{(\beta-\gamma)t}$$

  - *See backup for derivation*
- That is, early in an outbreak we expect to see exponential growth at the rate $\beta - \gamma$
  - *Notice: positive growth rate iff $R_0 > 1$*
- Once S gets small enough, $dI/dt < 0$
  - *Specifically, $dI/dt < 0$ once $\frac{S}{n} \leq \frac{\gamma}{\beta} = \frac{1}{R_0}$*
- So $I(t)$ will grow exponentially and then eventually decline
- $I(t)$ is going to be a one-humped curve, usually skewed to the right

Back-of-the-envelope SIR Modeling for Covid-19 in the USA

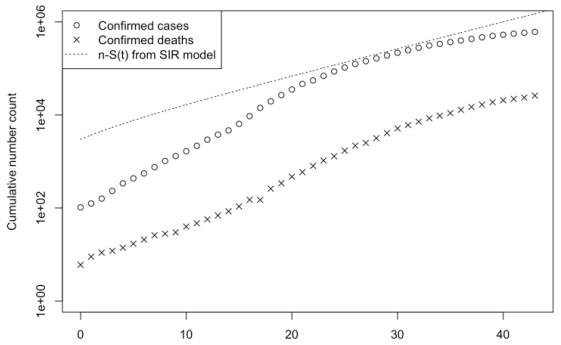
- Did this back in early March (file last updated 11 March)
- Initial state:
  - $S(0) = 3 \times 10^8$ *(approx. US population)*
  - $I(0) = 3 \times 10^3$ *(number of known US cases at the time, times a fudge factor of about 30)*
  - $R(0) = 1$ *just because I wanted to plot everything on a log scale*
- Parameters:
  - $1/\gamma =$ *average length of time someone is infectious, say 12 days*
    - An early estimate; we could adjust that now
  - $R_0 = \beta/\gamma$, *and one plausible estimate back then was* $R_0 \approx 2.6$ *(Imai et al. 2020)*
  - *I backed out* β *from* R_0 *and* γ

What Did This Predict?



How Well Did This Do?

- Use Kieran Healy's `covdata` package to get data on *reported* cases and deaths for the US
- The 100th confirmed case in the US was reported on 2020-03-03, abou when I did the simple model



Extending the Basic SIR Model

- Reinfection: Change the $I \to R$ transition to be $I \to S$ (SIS model)
  - *or $I \to R \to S$ (SIRS model) if there's a period of immunity after infection*
- Can add an "exposed" compartment E for "have the disease and will become I, but not yet"
  - *SEIR models are very standard when the disease takes some time to develop*
- Can add an "infectious but not showing symptoms" (A for "asymptotmatic") compartment that acts like I
  - *Might be less (or more!) effective at spreading than the classic Is*
- Can make the basic coefficients β and γ functions of time, to account for seasonal effects
- Can divide space into multiple regions, give each region its own count of each compartment, and include movement between regions
  - *E.g., we might have two regions A and B, with $S_A(t), S_B(t), I_A(t), I_B(t)$, etc., and equations like*

$$I_A(t) = \frac{\beta}{n} S_A(t) I_A(t) - \gamma I_A(t) - \mu_{AB} I_A(t) + \mu_{BA} I_B(t)$$

where the μ coefficients represent movement from region to region

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Aside: Why diseases do *not* always evolve to be less deadly

- Many biologists used to think diseases would tend to evolve to be more benign on their hosts
  - *Killing the hosts seems bad for the pathogen's own reproduction!*
  - *It's explicit in Zinsser (1935) (a wonderful, if eccentric, old book about epidemics, along with many other things)*
    - Zinsser was kind of eccentric but not about this idea
  - *You still find non-biologists (often economists or legal academics influenced by economics…) making this argument*
- More mathematically:
  - *if we have two variant strains of the disease, the one with the higher R_0 is going to dominate*
    - Because: exponential growth
  - *The longer the disease leaves the host alive, the smaller γ is*
  - *Smaller γ means larger R_0 (all else being equal)*
  - *So, shouldn't evolution favor less-lethal variants of the disease?*
- Biologists don't believe this any more for a very simple reason:

$$R_0 = \frac{\beta}{\gamma}$$

  - *A mutation which kills off hosts faster (increases γ) but also makes the disease easier to spread (increases β) can raise R_0!*
  - *Lots of what diseases do to their hosts look like adaptations which increase spread at the cost of killing off the host faster (Ewald 1996)*
  - *I.e., they are adaptations which increase both β and γ*
- Moral: pathogen evolution is not our friend

Social Network Structure

- When we derived the SIR model, we said each S encounters k other individuals in a time-step of length h
- Some people have a lot more contacts than others!
- Use a **social network** to represent this
- $a_{ij} = 1$ if person i knows person j (this $i \neq I$!), otherwise $a_{ij} = 0$
- $k_i = \sum_{j=1}^{n} a_{ij}$ = number of people i knows, **degree** of i
- $p(k)$ = fraction of people with degree k, the **degree distribution**

R_0 on Networks

- If you get infectious, you're only infectious for so long, and you have some *limited* probability of passing on the disease to your contacts, call this τ (for "transmission")
- We start with *one* transmission event, where Irene i gives the disease to Joey j
- R_0 = How many *new* infections does Joey cause, on average?

$$R_0 = \tau \mathbf{E}\left[\text{degree of Joey} - 1\right]$$

  - *Why -1?*

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The Degree Distribution for a Random Friend

- Might think
  $\mathbf{E}\left[\text{degree of Joey}\right] = \mathbf{E}\left[\text{degree of random node}\right] = \mathbf{E}\left[K\right] = \sum_{k=0}^{\infty} kp(k)$
- BUT *Joey is not a random node*
- Joey is a node reached by a random *edge*
- High degree nodes are extra likely to be reached by following edges
  - *If Joey has twice the degree of James, Joey is twice as likely to be reached as James*
  - *But there are only so many nodes of high degree*
- So $\Pr\left(K_{\text{Joey}} = k\right) \propto kp(k)$, and, to normalize,
  $\Pr\left(K_{\text{Joey}} = k\right) = kp(k) / \sum_{k=1}^{\infty} kp(k)$
- The expected value of this distribution is going to be $> \mathbf{E}\left[K\right]$
- **The friendship paradox**: "On average, your friends have more friends than you do"

Back to R_0 on Networks

- Plug in to the equation from two slides ago:

$$\begin{aligned} R_0 &= \tau \mathbf{E}\left[\text{degree of Joey} - 1\right] \\ &= \tau \frac{\sum_{k=1}^{\infty} (k-1)kp(k)}{\sum_{k=1}^{\infty} kp(k)} \\ &= \tau \frac{\mathbf{E}\left[K^2 - K\right]}{\mathbf{E}\left[K\right]} \\ &= \tau \frac{\mathbf{E}\left[K^2\right] - \mathbf{E}\left[K\right]}{\mathbf{E}\left[K\right]} \\ &= \tau \frac{\mathrm{Var}\left[K\right] + \mathbf{E}[K]^2 - \mathbf{E}\left[K\right]}{\mathbf{E}\left[K\right]} \end{aligned}$$

(because $\mathrm{Var}\left[K\right] = \mathbf{E}\left[K^2\right] - \mathbf{E}[K]^2$ for any variable)

Epidemic Threshold on Networks

- We're above the epidemic threshold when $R_0 > 1$, or

$$\tau\left(\frac{\mathrm{Var}\left[K\right]}{\mathbf{E}\left[K\right]} + \mathbf{E}\left[K\right] - 1\right) > 1$$

- So 3 things help the epidemic take off:
  - *High transmissibility (large τ)*
  - *High average degree ($\mathbf{E}\left[K\right]$ big)*
  - *High variance in degree ($\mathrm{Var}\left[K\right]$ big)*
- Lots of social networks have *very* high degree variance

Implications for Disease Control

- Removing the highest-degree nodes is *especially* effective for blocking epidemics
  - *Drives down $\mathbf{E}\left[K\right]$*
  - *Even more effective at driving down $\mathrm{Var}\left[K\right]$*
  - *Idea goes back to Pastor-Satorras and Vespignani (2002), building off Cohen et al. (2000);Cohen et al. (2001)*
- "Remove" could mean vaccinating
- "Remove" could mean isolating

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Complications to the Basic Network Analysis

- **Community structure**: Different sorts of people have different probabilities of knowing each other
  - *Usually high probability of ties within communities compared to across communities*
  - *Tight communities tend to favor localized outbreaks (Smith et al. 2013)*
    - everyone in the community gets sick
    - other communities not as affected
    - still some transmission across communities so still _pan_demic outbreaks
- **Higher-order interactions**: Everyone in the same cafeteria, airplane, classroom, office… is exposed to each other, even if they don't directly know each other
  - *One approach: treat these locations as special nodes, with ties to the people who go there (Saint-Onge et al. 2020)*
  - *The locations will have very high degree*
- More detailed dynamics instead of just "what's R_0"
  - *"Agent-based" or "individual-based" models: Simulate!*
  - *"Mean-field" approximations: see backup*

Some implications for the present situation

- Do things to reduce τ
  - *Reduce the amount of time people spend near each other*
  - *Increase physical distancing*
  - *Wear masks (which make it harder for what comes out of you when you sneeze to spread)*
- Do things to reduce $\mathbf{E}[K]$ and $\mathrm{Var}[K]$
  - *Close down events and public places*
  - *Stay home*
- "Contact tracing" (= isolating those who are tied to those known to have been infected) could be effective, *if* it could be implemented well

Connecting to Data

- The stochastic model has a likelihood, so if we could measure $S(t), I(t), R(t)$ we could estimate the parameters
  - *Or any two of them, along with a knowledge of n*
  - *Initially, everything just looks like exponential growth, so it's hard to discriminate between models*
  - *Initially, everything just looks like exponential growth, so even assuming an SIR model, it's easier to estimate $\beta - \gamma$ than (β, γ)*
- Without widespread *and accurate* testing, measurements of S, I, R are all very noisy
  - *Need to model sheer test error (false positives, false negatives)*
  - *Need to model who gets tested*
  - *A good example for COVID-19: Javan, Fox, and Meyers (2020)*
- Can sometimes **calibrate** the parameters from other sources
  - *E.g., $1/\gamma$ = average time someone is infectious, which could be determined from clinical studies / observations*

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Backup: Non-basic reproductive numbers

- If R_0 is the *basic* reproductive number, what are the *other* reproductive numbers?
- Remember that R_0 is the number of new infections directly caused by introducing one infected individual at time 0 of the epidemic
- R_t = the number of extra infections directly caused by increasing $I(t)$ by 1
- Generally, R_t declines with t as there are fewer susceptibles to infect

Backup: From the stochastic to the deterministic SIR model

- Rate of change in susceptibles is

$$\frac{S(t+h)-S(t)}{h} = \frac{-C(t+h)}{h} \sim -\frac{1}{h}\text{Binom}(S(t), \beta h I(t)/n)$$

- Similarly

$$\frac{I(t+h)-I(t)}{h} = \frac{C(t+h)-D(t+h)}{h} \sim \frac{1}{h}\text{Binom}(S(t), \beta h I(t)/n) - \frac{1}{h}\text{Binom}(I(t), \gamma h)$$

- So the *expected* rates of change are

$$\mathbf{E}\left[\frac{S(t+h)-S(t)}{h}|S(t), I(t)\right] = -\frac{\beta}{n}S(t)I(t)$$
$$\mathbf{E}\left[\frac{I(t+h)-I(t)}{h}|S(t), I(t)\right] = \frac{\beta}{n}S(t)I(t) - \gamma I(t)$$

- The variance of a binomial, $\text{Binom}(n,p)$ is $np(1-p)$, so as $n \to \infty$, the fluctuations around the expected values become negligible in comparison
  - *This is easy to say, but the real work of a proof goes here*
- Take the limit as $n \to \infty, h \to 0$:

$$\frac{dS}{dt} = -\frac{\beta}{n}S(t)I(t)$$
$$\frac{dI}{dt} = \frac{\beta}{n}S(t)I(t) - \gamma I(t)$$
$$\frac{dR}{dt} = \gamma I(t)$$

Backup: Slightly more rigorous calculation of the epidemic threshold on networks

(Adapted from Newman (2002), with fewer generating functions)

- Start by infecting a single random node, Irene
- Irene is connected to a susceptible node, Joey
- Define α_d as the probability that this connection starts a chain of infections of length $\leq d$
- So $1-\alpha_d$ is the probability that the chain goes for *more* than d steps
- The probability that there's an epidemic = the probability that the chain goes forever = $\lim_{d\to\infty}(1-\alpha_d)$
- We'll figure this out by recursively writing α_d in terms of α_{d-1} and taking the limit

Backup: Exponential growth in the early start of the epidemic in the deterministic SIR model

- Suppose that $I(0) \ll n, R(0) = 0$ and so $S(0) = n-1$, and n is big
- Then initially

$$\begin{aligned}\frac{dI}{dt} &= \frac{\beta}{n}S(t)I(t) - \gamma I(t)\\ &= \left(\beta\frac{S(t)}{n} - \gamma\right)I(t)\\ &\approx (\beta-\gamma)I(t)\end{aligned}$$

  and we know how to solve this differential equation:

$$I(t) \approx I(0)e^{(\beta-\gamma)t}$$

- So we'll get exponential *growth* just when $\beta > \gamma$, i.e., when $R_0 > 1$
  - *If $R_0 < 1$, we'll get exponential decay*
- If we have data on $I(t)$ over time, we can use that to estimate $\beta - \gamma$
  - *… but not β or γ separately*
  - *Works best if $I(0)$ is big enough that the deterministic approximation is holding well, so you often need to wait until there are (say) 100 cases, rather than 1*

Backup: Slightly more rigorous calculation of the epidemic threshold on networks

- So let's try to come up with the recursion for α_d
- Irene's connection to Joey starts a chain of length $\leq d$ in one of two ways:
  1. *Irene doesn't infect Joey*
  2. *Irene does infect Joey, but all chains from Joey have length $\leq d-1$*
- The average probability of an S being infected by a neighboring I is τ, so

$$\alpha_d = (1-\tau) + \Pr(\text{Joey gets infected but only starts chains of length } \leq d-1)$$

- 2nd term: Joey has $K_{\text{Joey}} - 1$ friends other than Irene (Kalpana, Karl, Kryztof), and *none* of those potential transmissions can start a chain more than $d-1$ steps long
- Those events each have probability α_{d-1}
- We worked out Joey's degree distribution earlier as $\Pr(\text{Joey has degree } k) = \frac{kp(k)}{\mathbf{E}[K]}$
- Plugging in,

$$\alpha_d = (1-\tau) + \tau\sum_{k=1}^{\infty}\frac{kp(k)}{\mathbf{E}[K]}\alpha_{d-1}^{k-1}$$

- Now *define* the right-hand side as $f(\alpha_{d-1})$, i.e.,,

$$f(x) \equiv (1-\tau) + \tau\sum_{k=1}^{\infty}\frac{kp(k)}{\mathbf{E}[K]}x^{k-1}$$

so we can say that

$$\alpha_d = f(\alpha_{d-1})$$

Backup: Eliminating parameters from the deterministic SIR model

- We can change our units for time to whatever we like, i.e., define $u = t\gamma$, so $t = u/\gamma$
- Then (chain rule of derivatives)

$$\begin{aligned}\frac{dR}{du} &= \left(\frac{dR}{dt}\right)\left(\frac{dt}{du}\right)\\ &= (\gamma I)\left(\frac{1}{\gamma}\right)\\ &= I\end{aligned}$$

- Doing the same thing for all the variables,

$$\frac{dS}{du} = -\frac{\beta}{n\gamma}SI$$
$$\frac{dI}{du} = \frac{\beta}{n\gamma}SI - I$$
$$\frac{dR}{du} = I$$

- Now re-scale our counts so they're relative to the total population, so $s = S/n$, $i = I/n$, $r = R/n$:

$$\begin{aligned}\frac{ds}{du} &= \left(\frac{ds}{dS}\right)\left(\frac{dS}{du}\right)\\ &= \left(\frac{1}{n}\right)\left(-\frac{\beta}{\gamma}\frac{S}{n}I\right)\\ &= -\frac{\beta}{\gamma}si\end{aligned}$$

- Doing the same thing for all the variables,

$$\frac{ds}{du} = -\frac{\beta}{\gamma}si$$
$$\frac{di}{du} = \frac{\beta}{\gamma}si - i$$
$$\frac{dr}{du} = i$$

- So the *only* parameter left is $\beta/\gamma = R_0$
  - *Units: dR/dt has units of* [people]/[time], *so γ must have units of* 1/[time]
  - *dS/dt also has units of* [people]/[time], *but SI/n has units of* [people]^2/[people] = [people], *so β must also have units of* 1/[time]
  - *β/γ is a unitless ratio, which makes sense for interpreting it as the number of new infections directly caused by an initial infection*
- The trick of manipulating variables so that parameters are combined into unitless ratios is a common way of simplifying dynamical systems
  - *Often called "dimensional analysis"*
  - *Boccara (2004) has many good examples*

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Backup: Slightly more rigorous calculation of the epidemic threshold on networks

How does any of this help???

- "Starts a chain of length $\leq d-1$" implies "Starts a chain of length $\leq d$", so $\alpha_{d-1} \leq \alpha_d$, and α_d is non-decreasing as $d \to \infty$
  - *Alternately: use algebra to check that $f(x) \geq x$*
- But α_d is a probability so $\alpha_d \leq 1$ for all d
- Since α_d is non-decreasing and bounded above, $\lim_{d\to\infty} \alpha_d \equiv \alpha_\infty$ must exist and be ≤ 1
- The limit must be a fixed point of f:

$$\alpha_\infty = f(\alpha_\infty)$$

- It's easy to check that $f(1) = 1$ always
  - *If $\alpha_\infty = 1$, then any chain of infections must stop in a finite number of steps, and the probability of an infinite epidemic is 0*
- If $f'(1) < 1$, then the $f(1) = 1$ solution is stable, and this is what α_∞ will converge to
- If $f'(1) > 1$, then the fixed point $f(1) = 1$ is unstable, and α_d will converge to the *other* solution of $f(x) = x$
  - *Proof that there is another solution: what is this, a math class?*
- The derivative is

$$\frac{df}{dx} = \tau \sum_{k=1}^{\infty} (k-1) \frac{kp(k)}{\mathbf{E}[K]} x^{k-2}$$

- So the epidemic criterion is

$$f'(1) = \tau \sum_{k=1}^{\infty} (k-1) \frac{kp(k)}{\mathbf{E}[K]} > 1$$

or

$$\tau \left(\frac{\mathbf{E}[K^2] - \mathbf{E}[K]}{\mathbf{E}[K]} \right) > 1$$

exactly as we got before

Backup: "Mean-field" approximations to epidemic models on networks

- Keep track of number in each compartment with each degree, so $S_2(t)$ or $I_1(t)$
  - *Idea goes back to May and Anderson (1988)*
- Similarly say $S_k I_l(t)$ is the number of Ss who have degree k and are connected to Is of degree l at time t
- Then $\frac{dS_k}{dt} = -\sum_l \beta S_k I_l(t)$ and similarly for the other first-order variables
- But now we need to know $S_k I_l(t)$
- Option 1, the "mean-field" approximation: $S_k I_l \approx \frac{kl}{n\mathbf{E}[K]} S_k I_l$
  - *The susceptibles of degree k "send out" kS_k edges at random*
  - *There are $n\mathbf{E}[K]$ incoming edges those could match*
  - *lI_l of those incoming edges belong to infectious of degree l*
- Option 2, the "pairwise mean-field" approximation
  - *Introduce $S_k S_l I_m$ (and so forth), so*

$$\frac{dS_k I_l}{dt} = -\gamma S_k I_l + \tau \sum_m S_k S_l I_m - I_m S_k I_l - S_k I_l$$

  - *Now approximate triples like $S_k S_l I_m$ in terms of pairs and singles*
    - similar, if more elaborate, counting arguments for the simple mean-field approach above
- The pairwise mean-field approximation often gives pretty good matches to individual-level simulations, with a lot less computational work
- Details: Kiss, Miller, and Simon (2017)

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Further Reading

- SIR or "compartment" type models of epidemics go back to the 1920s, especially to work on malaria
  - *See Bacaër (2011), chapters 12 and 16, for some of the history*
- For a modern textbook treatment of epidemic models, see Ellner and Guckenheimer (2006)
- **Branching processes** (which I used to derive R_0 from the SIR model) are an important part of applied probability theory; there's a good treatment in Grimmett and Stirzaker (1992), among many other places
  - *See also Bacaër (2011), chapter 9, on their origin in the 19th century*
  - *Guttorp (1995) covers statistical inference for branching processes, and many other sorts of stochastic process*
- The way I derived R_0 for the network model follows Newman (2002), but without (explicitly) using generating functions
  - *It's an example of using **percolation theory**, another important topic in applied probability (Grimmett 1999), with many surprising applications to epidemiology (Davis et al. 2008)*
  - *See Bacaër (2011), chapter 22 for some of the 20th century history*
- Kiss, Miller, and Simon (2017) is an excellent textbook on epidemics on networks, but assumes more knowledge of differential equations than is usual for statistics students

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audio time :: From Cosma Shalizi of Carnegie-Mellon: <http://www.stat.cmu.edu/~cshalizi/dm/20/lectures/special/epidemics.html#(1)>

2020-04-06 Coronavirus

Where we think we are, as of Mo Apr 6:

- We really do not know
- No random samples…
- If we extrapolate out the past week straight-line log:
  - We will have 440,000 deaths in three weeks
  - But it is unlikely to be that bad
- Best thing I have read comes from Jim Stock <https://drive.google.com/file/d/12MV466ZZy5xHir4xdPhoTrL1oO8CbZU-/view>:
  - The basic SIR epidemiological model of contagion
  - The effect of social distancing and business shutdowns on epidemic dynamics enters the model through a single parameter: the case transmission rate β
  - Re-express the model in terms of β and the asymptomatic (or not very symptomatic) hence non-tested rate—the fraction of the infected who are not tested
  - The COVID-19 non-testing rate is unidentified in our model
  - Estimates in the epidemiological literature range from 0.18 to 0.86.
    - The asymptomatic rate could be estimated accurately and quickly by testing a random sample
- The optimal policy response and its economic consequences hinge critically on the asymptomatic rate

Coronavirus Extrapolations

Date	Deaths	Cases = Deaths x 100	Constant Weekly New Cases	Cases = 5 x Cases(-3)	Cases = 20 x Cases (-3)	Cases = Cases (-3) x exp(3 x week ch)
2020-04-05	9618		3,102,000	4,809,000	19,236,000	55,832,145
2020-03-29	2484		869,400	1,242,000	4,968,000	53,654,400
2020-03-22	414		144,900	207,000	828,000	8,942,400
2020-03-15	69	961,800	19,800	34,500	138,000	128,966
2020-03-08	26	248,400	10,100	13,000	52,000	45,697,600
2020-03-01	1	41,400	370	500	2,000	100,000
2020-02-23		6,900	37	50	200	10,000
2020-02-16		2,600	4	5	20	
2020-02-09		100				
2020-02-02		10				
2020-01-26		1				
		0				
	https://www.icloud.com/numbers/0Ez8EAgAQoiAip4VJWYWIWiCQ					

Coronavirus Cases:

1,342,235

view by country

Deaths:

74,554

Recovered:

278,182

United States

Coronavirus Cases:

364,059

Deaths:

10,792

Recovered:

19,536

USA State	Tot Cases/ 1M pop	Deaths/ 1M pop
USA Total	1,100	33
New York	6,662	243
New Jersey	4,626	113
Michigan	1,729	73
California	404	10
Louisiana	3,188	110
Massachusetts	2,026	38
Florida	662	12
Pennsylvania	1,016	13
Illinois	956	24
Washington	1,095	46
Texas	263	5
Georgia	710	22

Coronavirus II

We do not really know where we are, as of Mo Apr 6:

- Best thing I have read comes from Jim Stock <https://drive.google.com/file/d/12MV466ZZy5xHir4xdPhoTrL1oO8CbZU-/view>:
  - The basic SIR epidemiological model of contagion
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1,342,235

view by country

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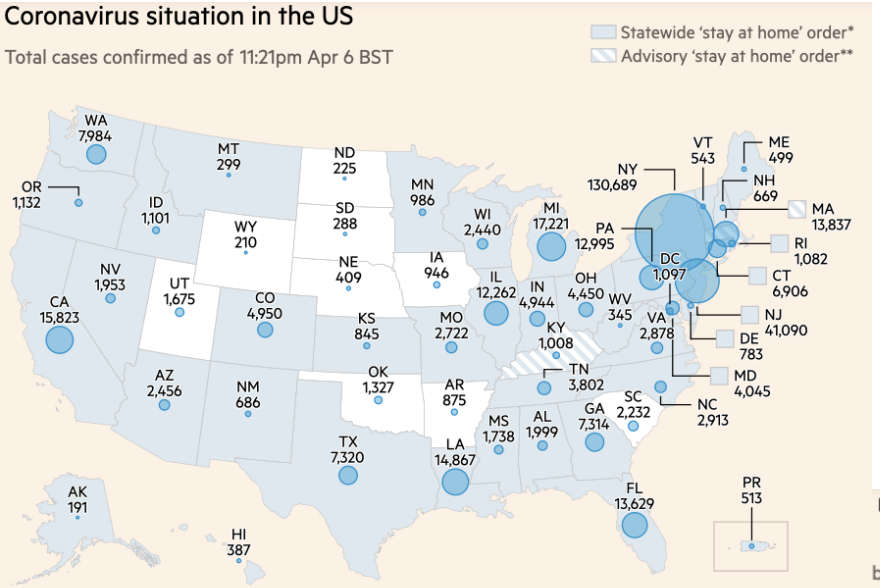
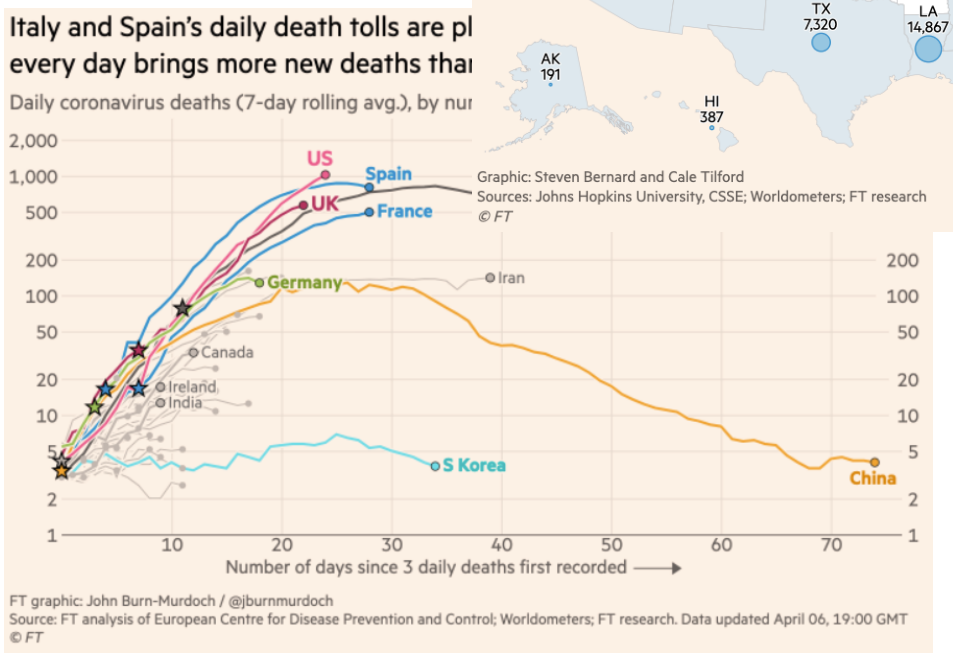
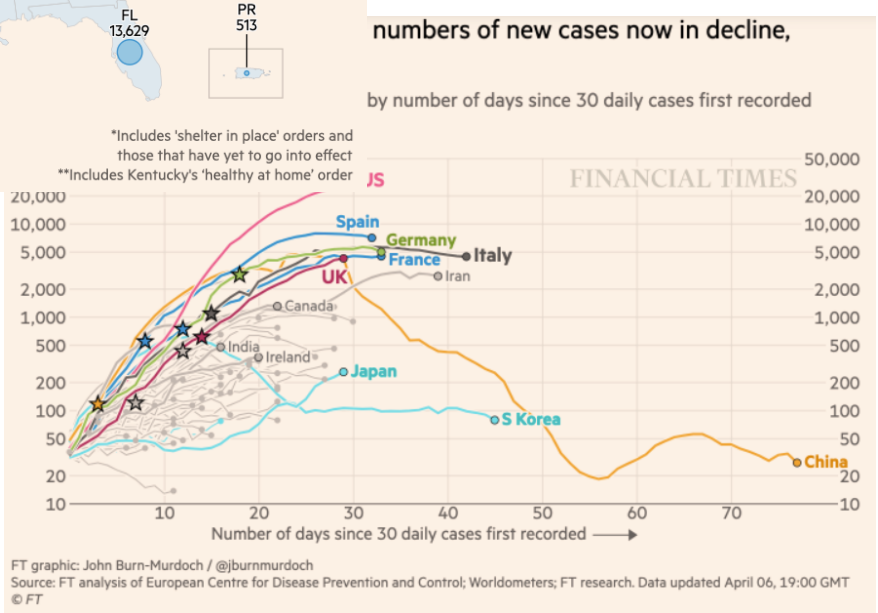
Financial Times Graphs Blown Up...

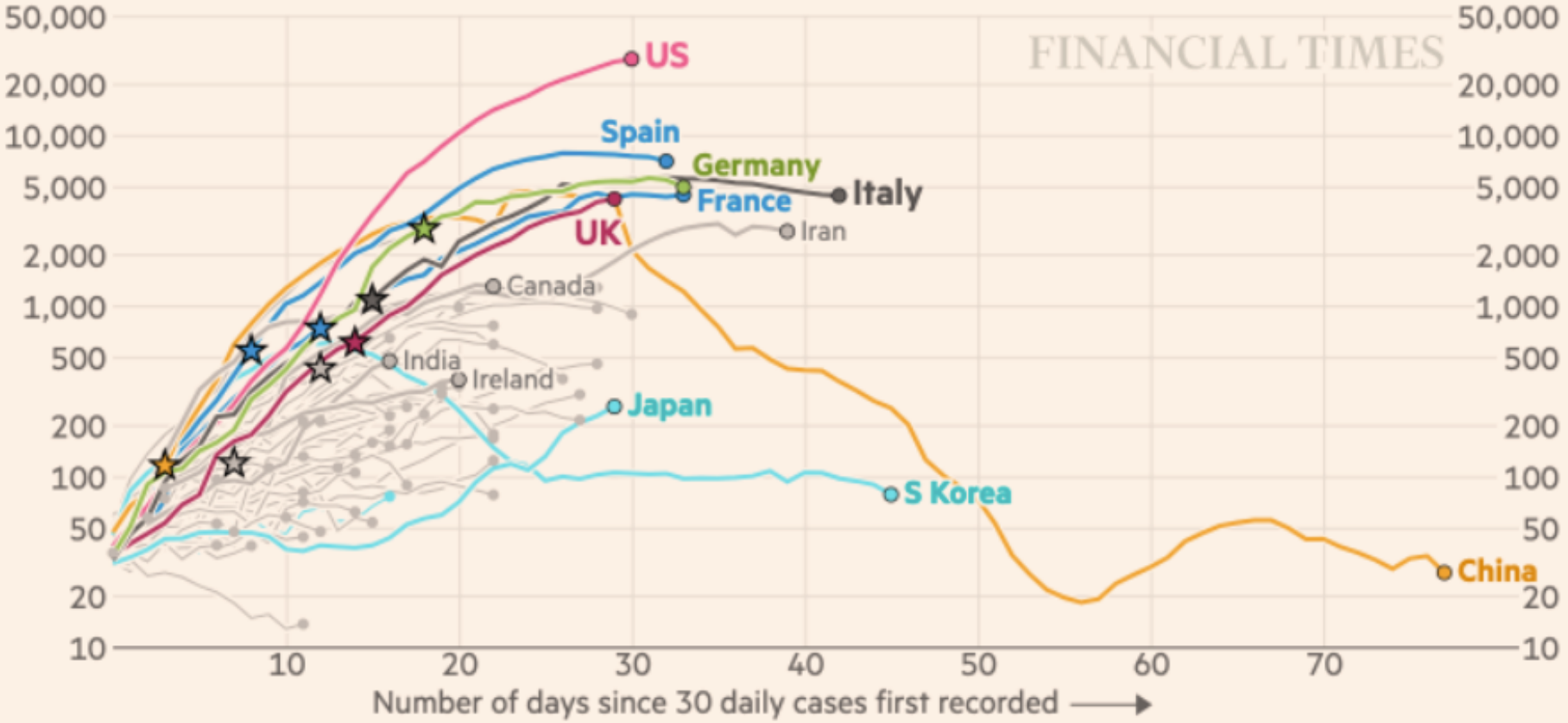






Italy has turned the corner, with numbers of new cases now in decline, following in China's footsteps

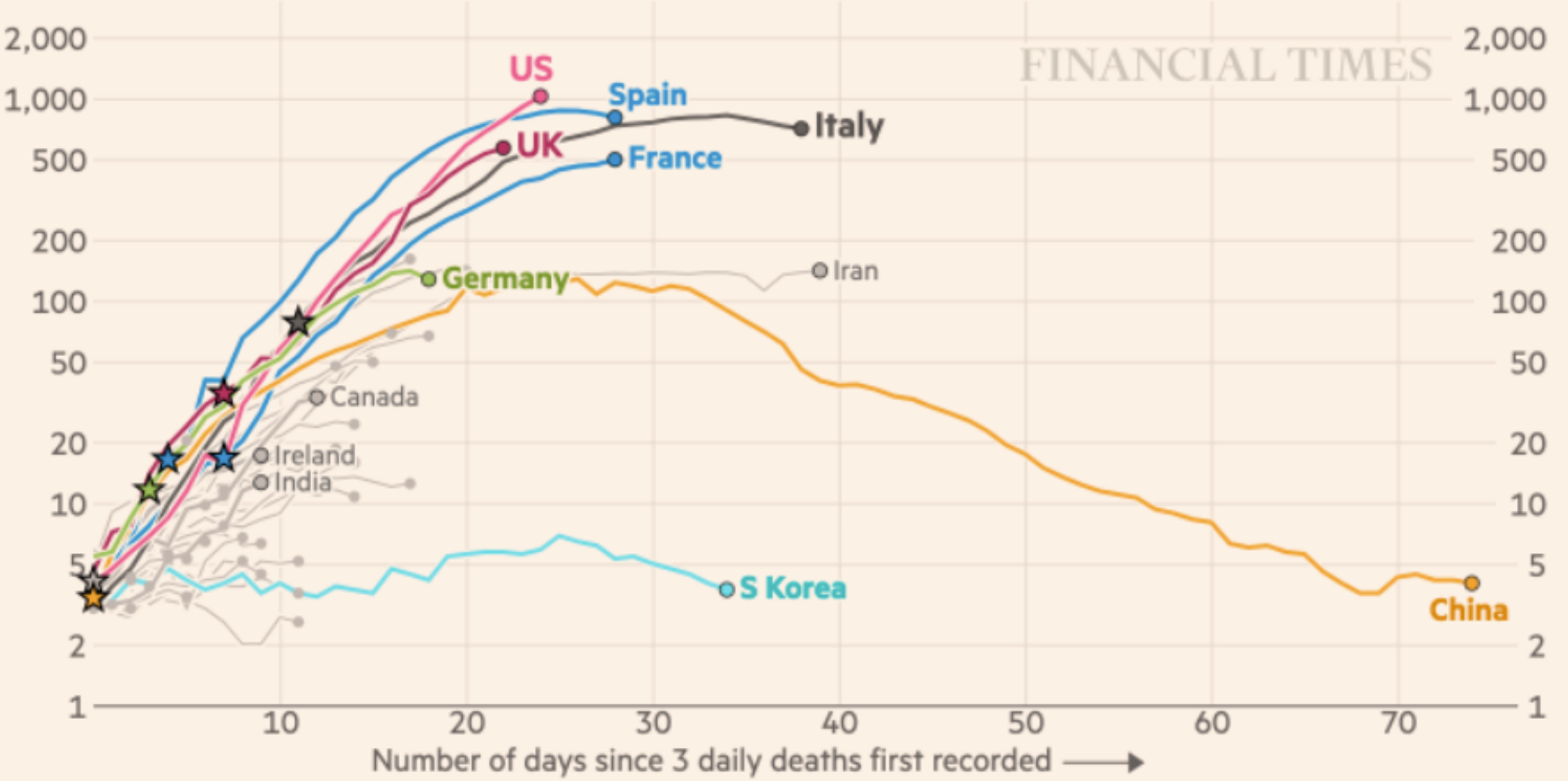
Daily confirmed cases (7-day rolling avg.), by number of days since 30 daily cases first recorded
Stars represent national lockdowns ★



FT graphic: John Burn-Murdoch / @jburnmurdoch
Source: FT analysis of European Centre for Disease Prevention and Control; Worldometers; FT research. Data updated April 06, 19:00 GMT

Italy and Spain's daily death tolls are plateauing, but in the UK and US every day brings more new deaths than the last

Daily coronavirus deaths (7-day rolling avg.), by number of days since 3 daily deaths first recorded

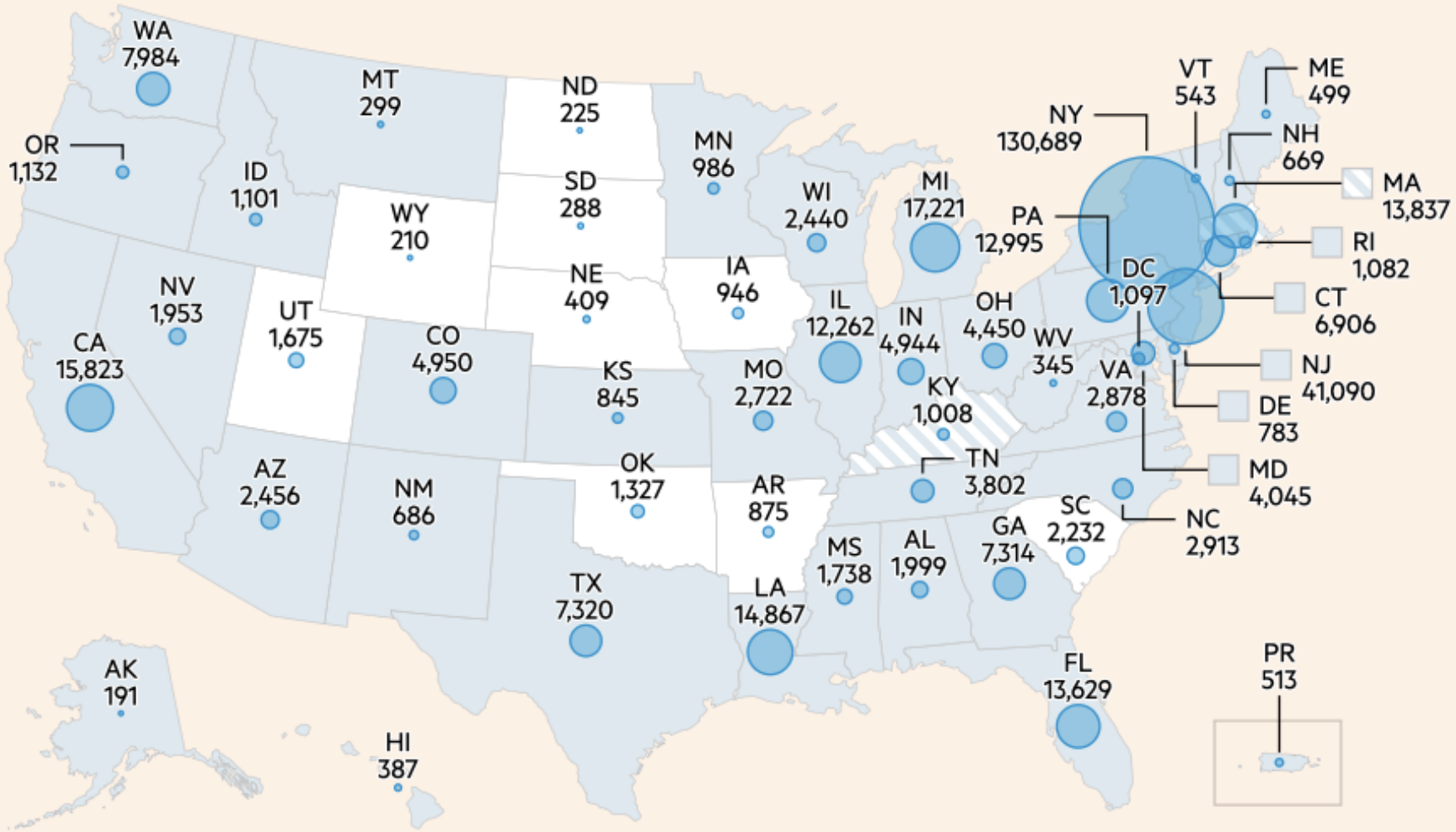


FT graphic: John Burn-Murdoch / @jburnmurdoch

Source: FT analysis of European Centre for Disease Prevention and Control; Worldometers; FT research. Data updated April 06, 19:00 GMT

Coronavirus situation in the US

Total cases confirmed as of 11:21pm Apr 6 BST



Graphic: Steven Bernard and Cale Tilford

Sources: Johns Hopkins University, CSSE; Worldometers; FT research

*Includes 'shelter in place' orders and those that have yet to go into effect

**Includes Kentucky's 'healthy at home' order

James Stock (2020)

Standard SIR model:<https://drive.google.com/file/d/12MV466ZZy5xHir4xdPhoTrL1oO8CbZU-/view>:

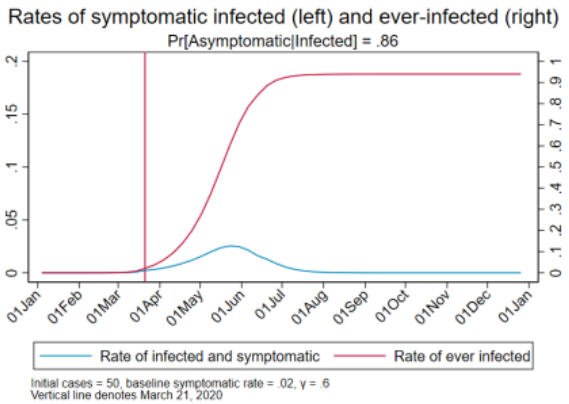
- **S**usceptible, **I**nfected, **R**ecovered (& immune), transmission rate β, recovery rate γ, reproduction number R_0, asymptomatic hence non-tested rate π_0
- Calibration: half-life of infection one week: $\gamma = 0.5$, $s_0 = 0.02$, 50 cases on Jan 24
- For March 21, 2020, the positive test

$$\Delta S_t = -\beta I_{t-1} \frac{S_{t-1}}{N}$$

$$\Delta R_t = \gamma I_{t-1},$$

$$\Delta I_t = \beta I_{t-1} \frac{S_{t-1}}{N} - \gamma I_{t-1}$$

Figure 2. High asymptomatic rate, short-duration policy



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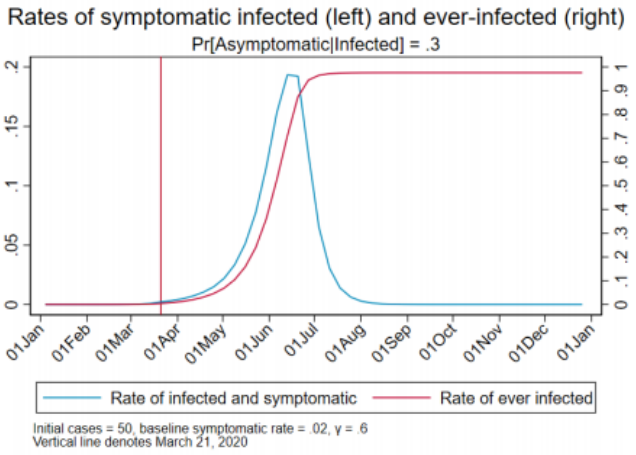
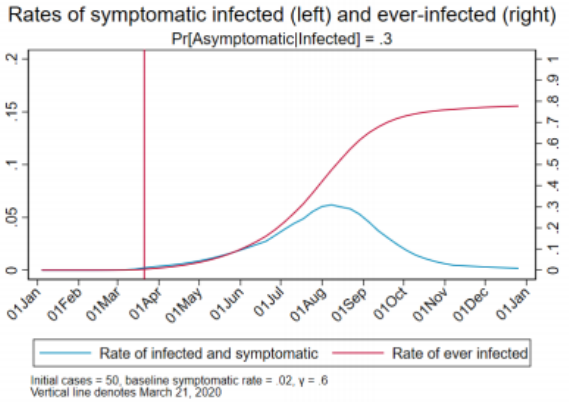


Figure 4. Low asymptomatic rate, severe long-duration policy



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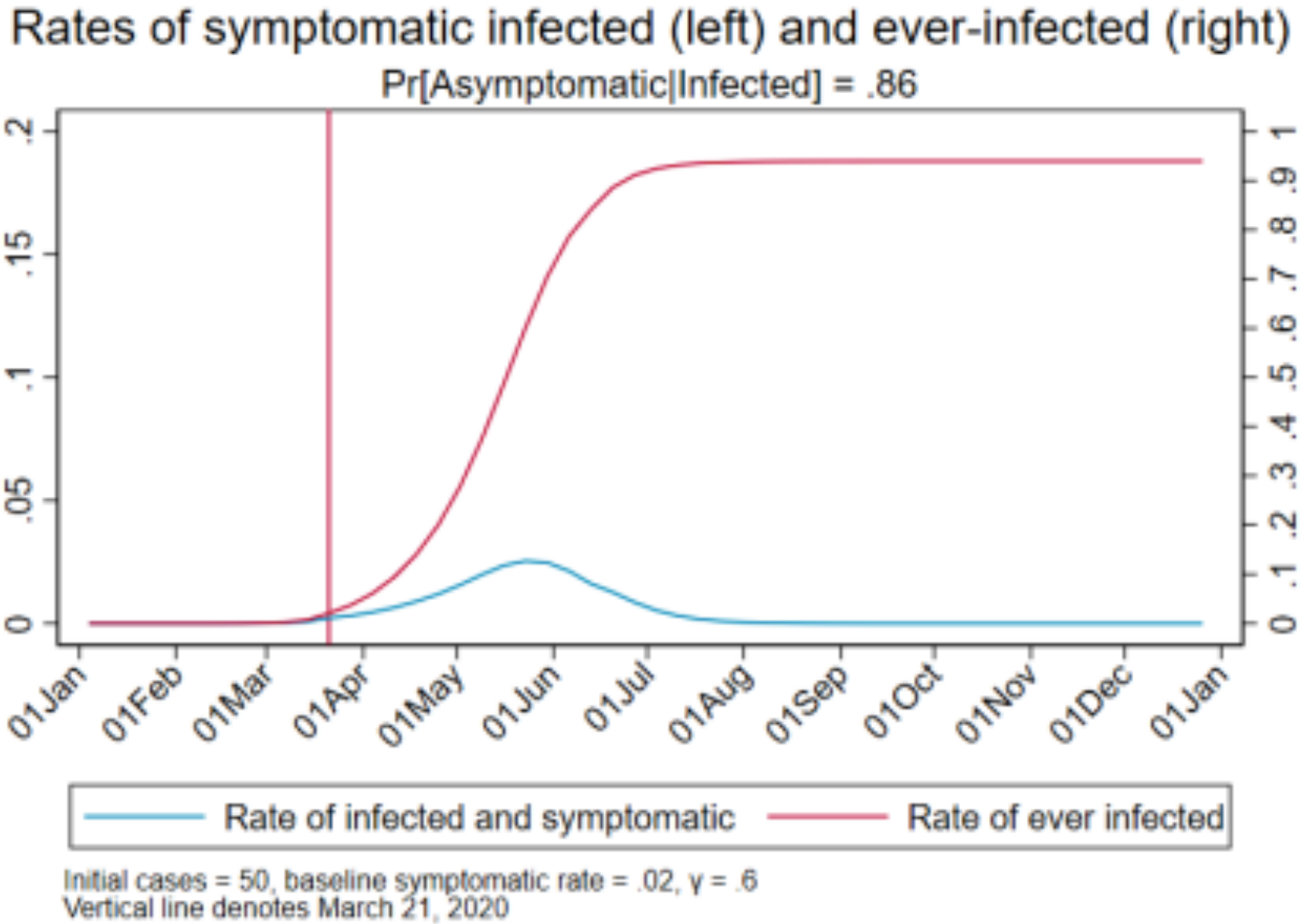

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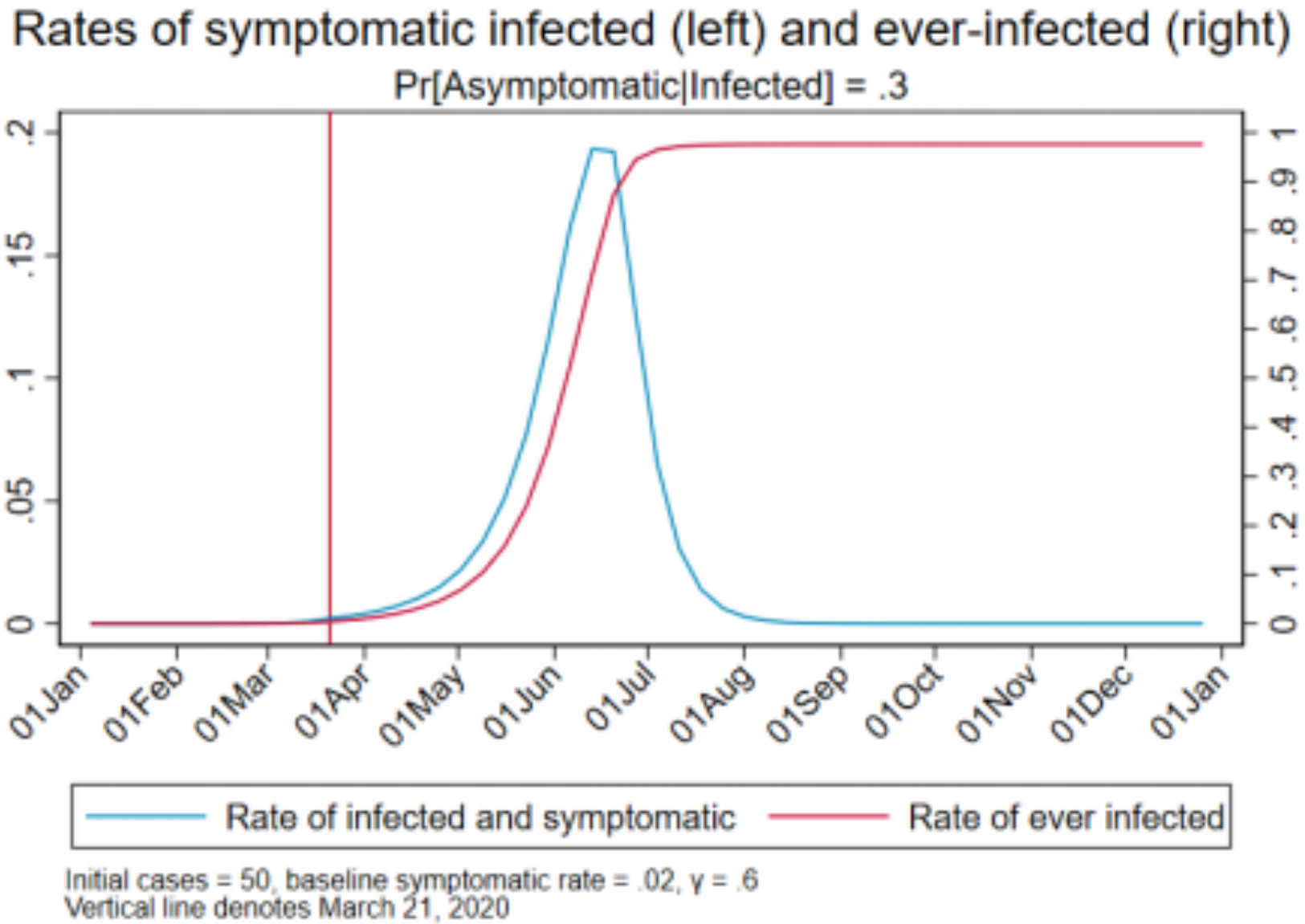

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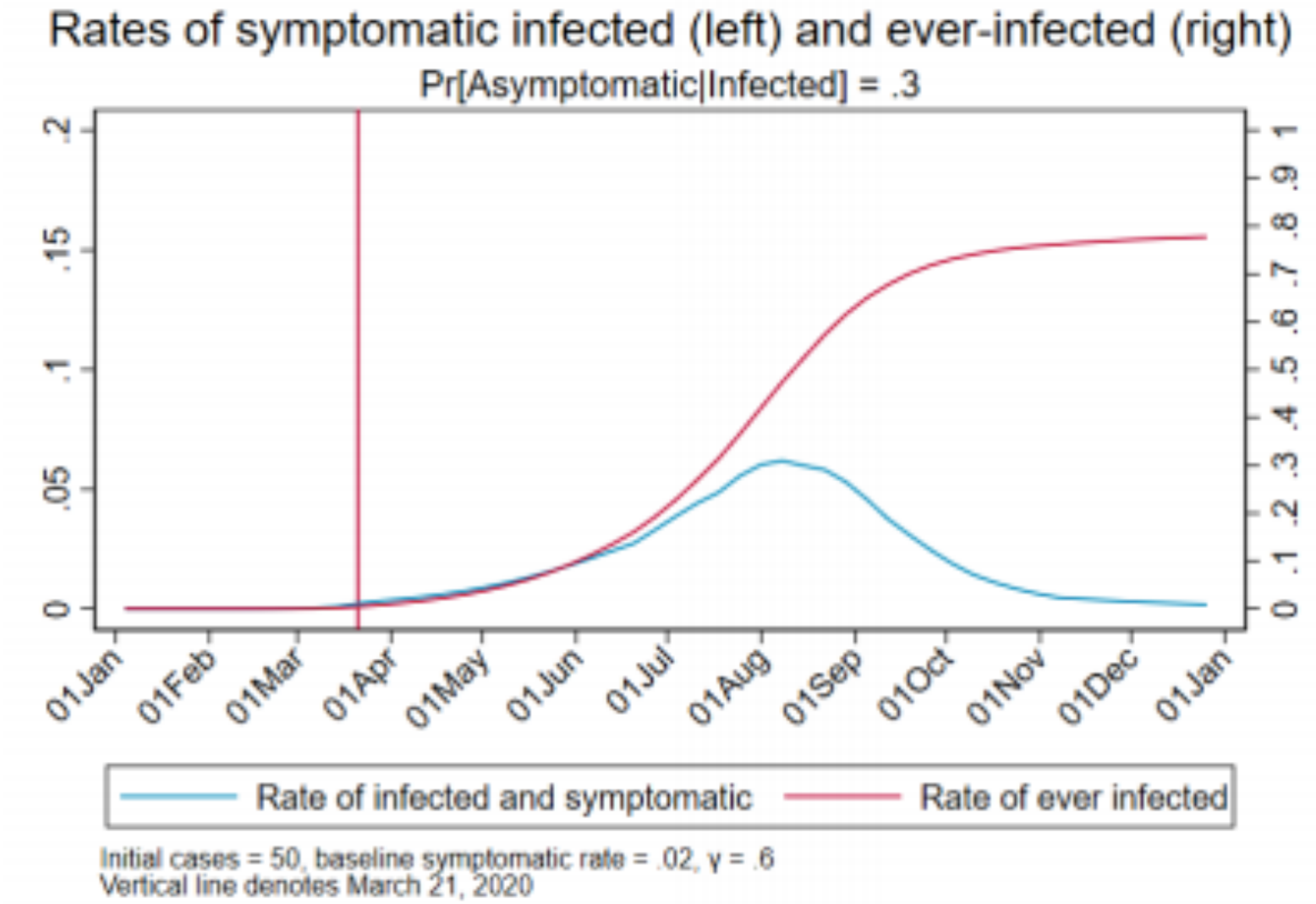

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$$\Delta I_t = \beta I_{t-1} \frac{S_{t-1}}{N} - \gamma I_{t-1}$$

Bringing the Economy Back Up from Anæsthesia

Major issues:

- Certificates of immunity:
    - Which requires test, test, test:
        - And not just disease virus tests
        - Presence-of-antibodies tests
- How quickly can we match the immune with public-contact jobs?
- What jobs can be done with minimal infection risk?
- What minimal-infection substitutes can we find for previous jobs?
- How quickly can restrictions be relaxed without the virus coming roaring back?
- How do we avoid having the market give a “shutdown” signal to enterprises we in fact want restarted?
    - Which is pretty much all of them
- How much of the potential caseload do we want to push out beyond the vaccine-arrival date?

ALL THESE QUESTIONS ARE ANSWERABLE IF WE LEARN THE ASYMPTOMATIC HENCE NON-TESTED RATE!!

Keeping the Economy from Crashing During the Lockdown

Nick Rowe: We have a 50% output cut in 100% of the sectors:

- A temporary 100% output cut in 50% of the sectors (what the Coronavirus does) is very different from a 50% output cut in 100% of the sectors
- Nick's thought experiment:
  - In three months we are going to invent unobtanium:
    - Substantial intertemporal substitutibility
    - Plus lower cross-good contemporaneous substitutitbility
    - Hence high desired savings rate now
  - Flex-price market thus produces a nominal rate at the zero lower bound and a high inflation rate over the next three to six months
  - Plus liquidity-constrained workers in affected sectors see their demand go to zero immediately
  - Can we get there? Should we get there? What should we do instead?
  - We need a good RBC economist: are there any?…

<https://worthwhile.typepad.com/worthwhile_canadian_initi/2020/03/relative-supply-shocks-unobtainium-walras-law-and-the-coronavirus.html>

Keeping the Economy from Crashing During the Lockdown II

Nick Rowe:

- <https://worthwhile.typepad.com/worthwhile_canadian_initi/2020/03/relative-supply-shocks-unobtainium-walras-law-and-the-coronavirus.html>
- Plus: to extend the thought experiment:
  - We just lost the ability to make "unobtainium"
  - So we *should* be substituting leisure for work, and moving workers into relatively unproductive labor, making the commodities we can still produce right now
  - How should relative prices move as a result? How should we make them move?

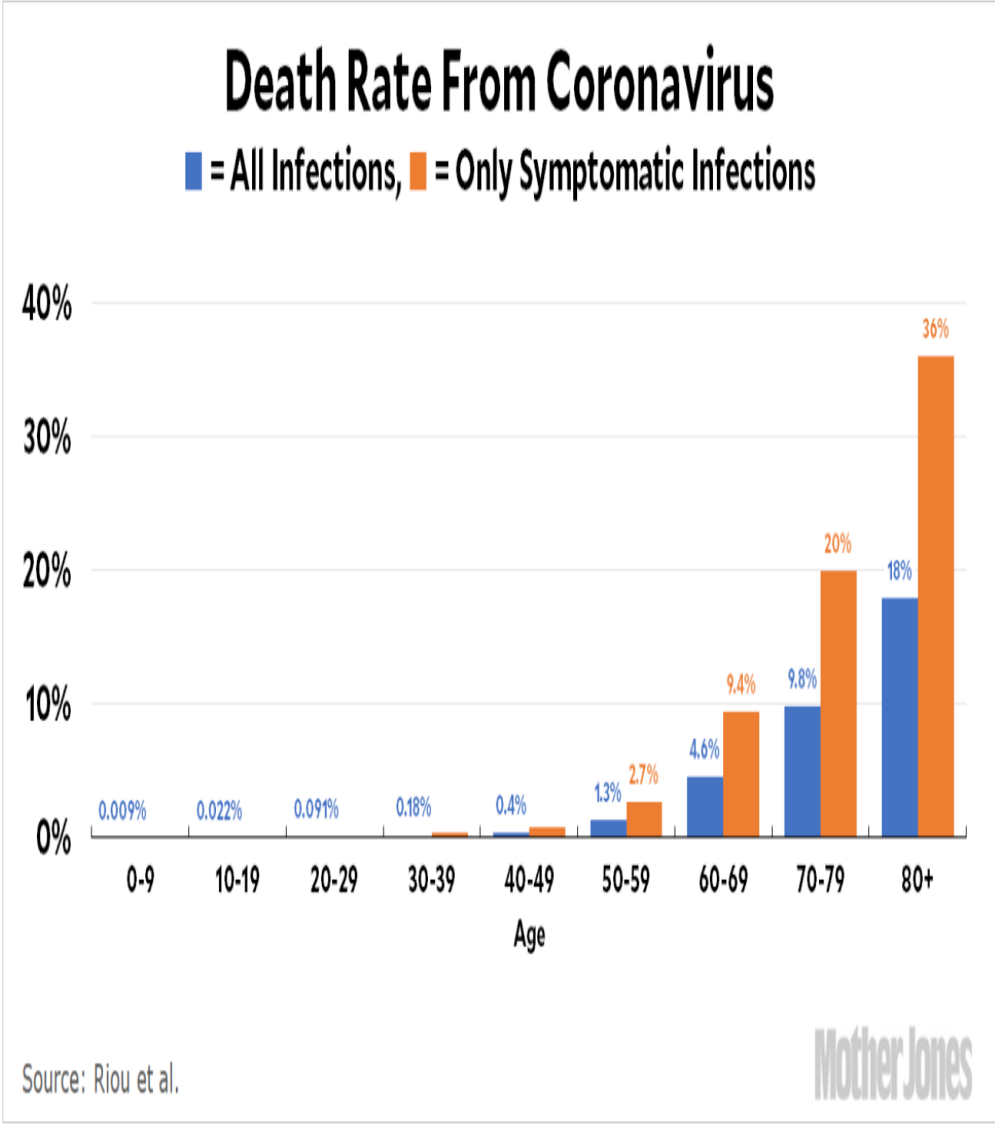
Plus: distributional issues

Plus: bankruptcy and credit chain issues

MOAR Coronavirus!

Death for Geezers!

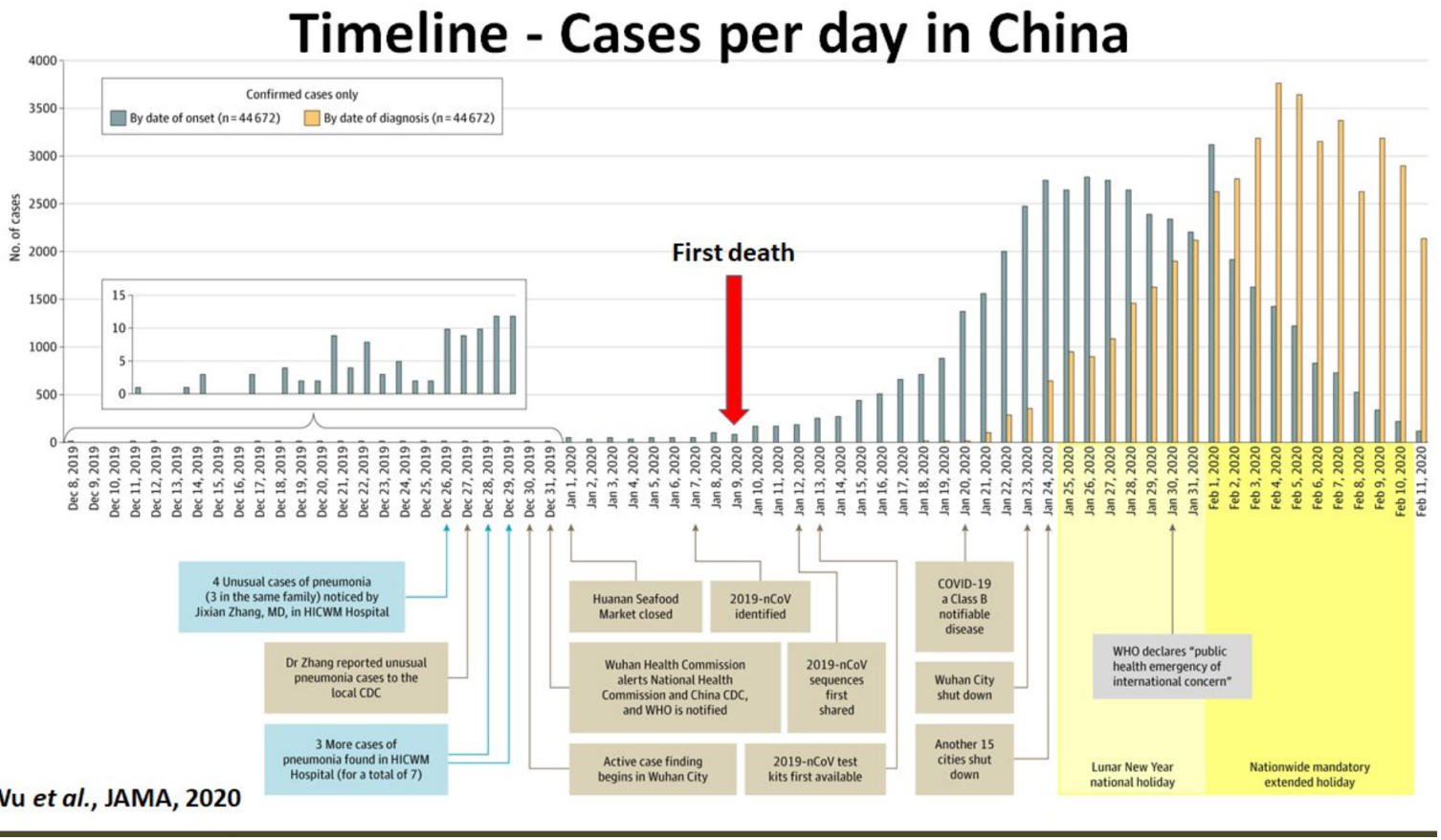
- Mortality for the Youngs very low…
- It's the flu for them—for you…
- And an extra doubling—or is it 5%?—mortality for the asthmatic
- And an extra doubling—or is it 5%?—mortality for the overweight



What We Think Happened in Wuhan

China beat it quickly & relatively easily!

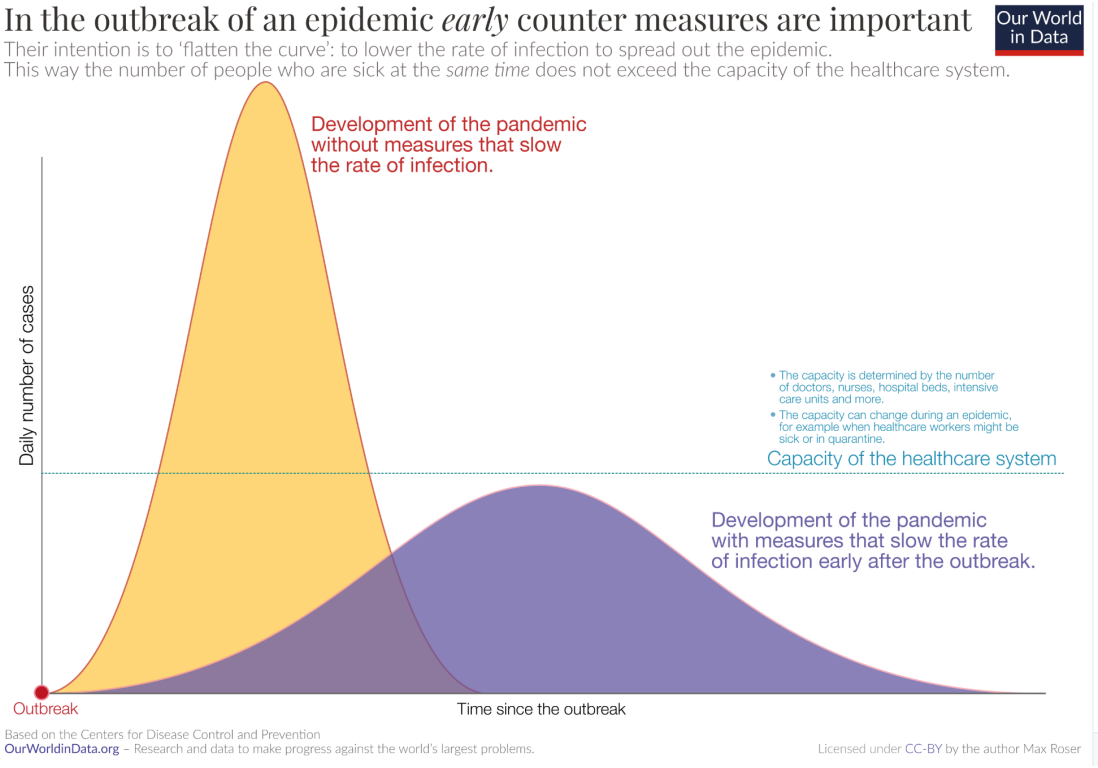
- We think
- Shut down Wuhan when 200 cases per day
- That seems to have been a good decision



The Goal

When Is It Appropriate to Move on This?

- Immediate social distancing…
- Self-isolate if you have a cough and a fever…
- Hope that warmer temperatures will do to this what they did to SARS…
- Otherwise, when do you want to start spreading out transmission. It seems that early is as good as later, so do it early…
  - I have no good intuition on why you want to move early
  - Plus your moving early will be wasted if you get reinfected
  - Plus the sparks you throw off making others' lives more difficult



References

- **Financial Times** (2020): Coronavirus Tracked: The Latest Figures as the Pandemic Spreads <https://www.ft.com/coronavirus-latest>
- **Nick Rowe** (2020): *Relative Supply Shocks, Unobtainium, Walras' Law, and the Coronavirus* <https://worthwhile.typepad.com/worthwhile_canadian_initi/2020/03/relative-supply-shocks-unobtainium-walras-law-and-the-coronavirus.html>
- **Jim Stock** (2020): *Coronavirus Data Gaps and the Policy Response* <https://drive.google.com/file/d/12MV466ZZy5xHir4xdPhoTrL1oO8CbZU-/view>

MOAR Coronavirus!

What I am watching:

- **Max Roser & Hannah Ritchie**: *Coronavirus Disease (COVID-19)* <https://ourworldindata.org/coronavirus>…
- **Worldometer**: *Coronavirus Update (Live)* <https://www.worldometers.info/coronavirus/>: '125,599 Cases and 4,605 Deaths from COVID-19 Virus Outbreak…
- *FT Coronavirus Tracker* <https://www.ft.com/content/a26fbf7e-48f8-11ea-aeb3-955839e06441>
- Josh Marshall's COVID Twitter List <https://twitter.com/i/lists/1233998285779632128>
- NEJM Group: Updates on the Covid-19 Pandemic <*http://m.n.nejm.org/nl/jsp/m.jsp?c=%40kxNtXckRDOq8oG0jJvAXsIzN4mPECIPhltxoTSdTU9k%3D&cid=DM89089_NEJM_COVID-19_Newsletter&bid=173498255*>: 'From the New England Journal of Medicine, NEJM Journal Watch, NEJM Catalyst, and other trusted sources...

Catch Our Breath…

- Ask a couple of questions?
- Make a couple of comments?
- Any more readings to recommend?

- <https://www.icloud.com/keynote/0YKEi7HeOrVGvKYtt9FEqH7nA>
- <https://www.bradford-delong.com/2020/04/coronavirus.html>

- github:<https://github.com/braddelong/public-files/blob/master/coronavirus.pptx>
- https://github.com/braddelong/public-files/blob/master/coronavirus.pdf>

- html File: <https://www.bradford-delong.com/2020/04/coronavirus.html>
- Edit This File: <https://www.typepad.com/site/blogs/6a00e551f08003883400e551f080068834/post/6a00e551f080038834025d9b3bd66a200c/edit>

- <https://delong.typepad.com/files/2020-04-01-coronavirus.pdf>

Coronavirus! (March 16)

~~**With 31 deaths in the U.S. as of March 11, a 1% death rate, and up to 4 weeks between infection and death, that means that as of Feb 12 there were 3100 coronavirus cases in the United States.**~~

With 87 deaths in the U.S. as of Mar 16, a 1% death rate, and up to 4 weeks between infection and death, that means that as of Feb 17 there were 8700 coronavirus cases in the United States

If it is doubling every seven days, then now about 150,000 people have and in the next week about 150,000 more people in the U.S. will catch coronavirus—which means 1/2200, currently 3500 of the 7.6 million inhabitants of San Francisco Bay. Touch a hard surface that any of those 3500 has touched in the last 48 hours, and the virus has a chance to jump to you…

These numbers could be five times too big. These numbers are probably not five times too small unless the thing is a lot less deadly, and there are a lot of asymptomatic cases…

- What is wrong with this analysis?

MOAR Coronavirus!

As of March 21: Things are not moving in the right direction:

- What is the R_0?
- How can the R_0 be changed?
- How will the R_0 change?
- What is the asymptote share of the population?
- What is the mortality rate?

Coronavirus Cases:

179,836

view by country

Deaths:

7,098

Recovered:

78,324

Country, Other	Total Cases	New Cases	Total Deaths	New Deaths	Total Recovered	Active Cases	Serious, Critical	Tot Cases/ 1M pop
China	80,880	+36	3,213	+14	67,819	9,848	3,226	56.2
Italy	27,980	+3,233	2,158	+349	2,749	23,073	1,851	462.8
Iran	14,991	+1,053	853	+129	4,590	9,548		178.5
Spain	9,428	+1,440	335	+41	530	8,563	272	201.6
S. Korea	8,236	+74	75		1,137	7,024	59	160.6
Germany	7,241	+1,428	15	+2	65	7,161	2	86.4
France	5,423		127		12	5,284	400	83.1
USA	4,186	+506	73	+5	73	4,040	12	12.6
Switzerland	2,353	+136	19	+5	4	2,330		271.9
UK	1,543	+152	55	+20	52	1,436	20	22.7
Netherlands	1,413	+278	24	+4	2	1,387	45	82.5
Norway	1,323	+67	3		1	1,319	27	244.0

ACTIVE CASES

94,414

Currently Infected Patients

88,252 (93%) in Mild Condition

6,162 (7%) Serious or Critical

Show Graph

CLOSED CASES

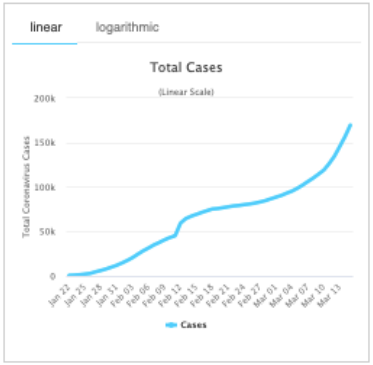
85,422

Cases which had an outcome:

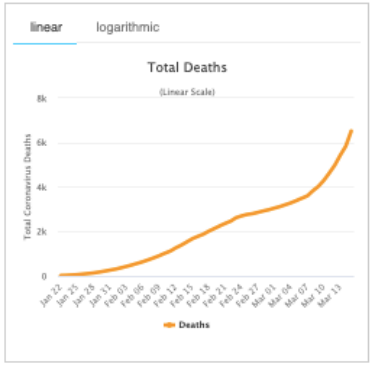
78,324 (92%) Recovered / Discharged

7,098 (8%) Deaths

Show Graph



More Case Statistics



More Death Statistics

MOAR Coronavirus!

As of March 10: Things are not moving in the right direction:

- What is the R_0?
- How can the R_0 be changed?
- How will the R_0 change?
- What is the asymptote share of the population?
- What is the mortality rate?

Coronavirus Cases:

125,599

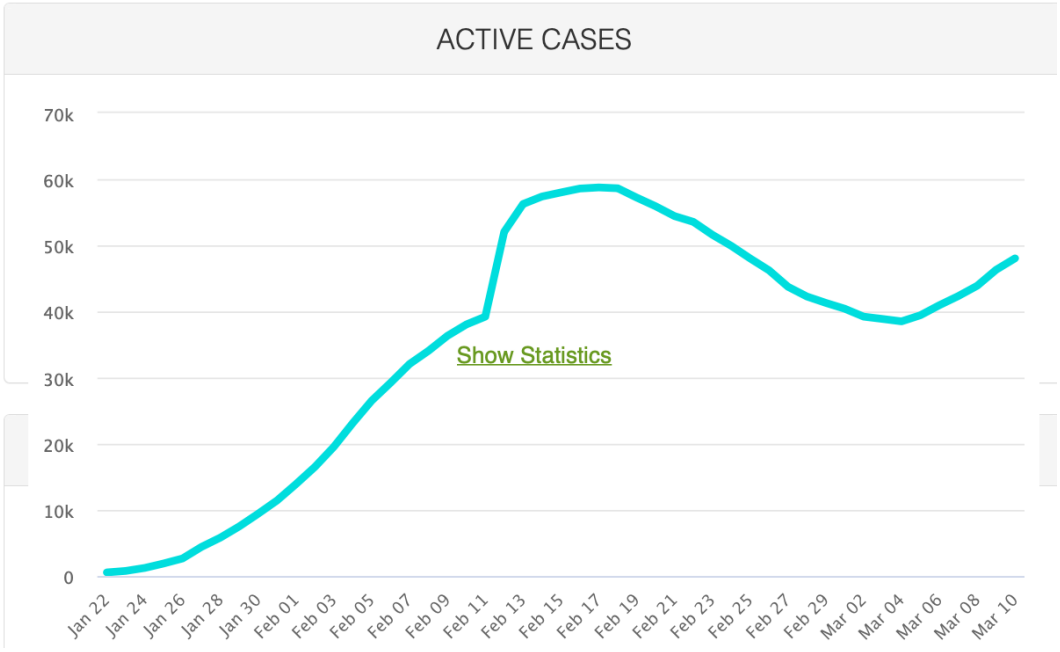
view by country

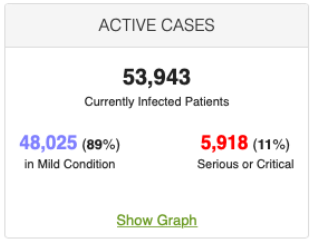
Deaths:

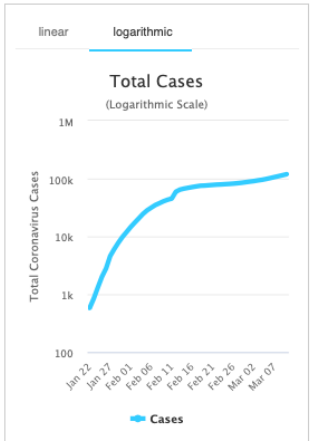
4,605

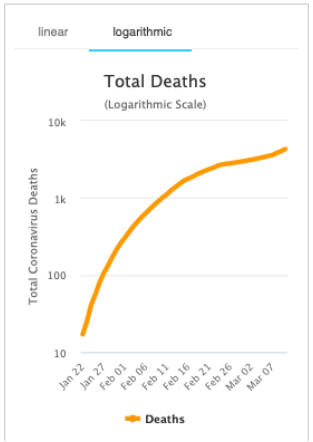
Recovered:

67,051









Notes

Catch Our Breath…

Continue the Discussion:

- Ask a couple of questions?
- Make a couple of comments?
- Any more readings to recommend?

Files:

audio time

Notes