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Biotechnology | North America

COVID-19 Outbreak Dynamics - Daily Update Vs Our Model

We provide daily updates for actual confirmed COVID-19 cases versus our tracking models for the US, Italy, Japan, South Korea, France, Germany and Spain. We also provide daily evolution of key epidemiological variables including reproduction rate and doubling time, and updates on testing coverage.

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Background on our models: Our models are empiric and based on the disease dynamics observed in China. Our models will yield different outcomes than traditional epidemiologic models which use fixed parameters for infection rates and doubling time. We believe this empiric approach is more reasonable given the significant intervention occurring to stem the viral spread. We use data from six Chinese provinces, all of which have the infection dynamics and time to peak cases, to build a "consensus" model. We then apply that model to the trajectory of the disease dynamics in other countries to see if their outbreak aligns with China or diverges. For the US, we took an incremental approach and combined both the trends in Italy and China to derive our assumptions. It is important to note that we believe our models are most useful from the date countries impose strict social distancing measures as that most closely resembles the aggressive containment in China. **See detailed information on our methodology for the US (here) or exUS (here and here).**

For all plots: *Please note the blue line is actual cumulative confirmed cases and should be compared against the maroon line. The red vertical line indicates when the prediction model was built.*

United States - Next 4 days are key as we watch to see if the US follows or diverges from Italy's trajectory: The US trend is tracking in-line with Italy, but ~11 days behind. However, the US introduced stronger social distancing measures ~5 days ahead of Italy. Thus, we are watching to see if the US follows Italy's trajectory or diverges in the next 4 days. **We want to highlight that California's governor issued a statewide 'stay at home' order effective 3/19 evening asking all residents to stay inside amid the coronavirus outbreak till further notice, except that essential services such as pharmacies, grocery stores, and delivery restaurants will stay open. We believe this is an important step toward our BASE case scenario.** We provide tracking curves (after scaling for adjustment for testing coverage and population size) against our potential BULL, BASE and BEAR case scenarios as follows. Please note that we initially plotted the U.S. reported data with 5x scaling, which was estimated a few days ago due to the limited testing capacity. We are now rescaling gradually toward the reported given the improving testing coverage over time and expect to reduce to the

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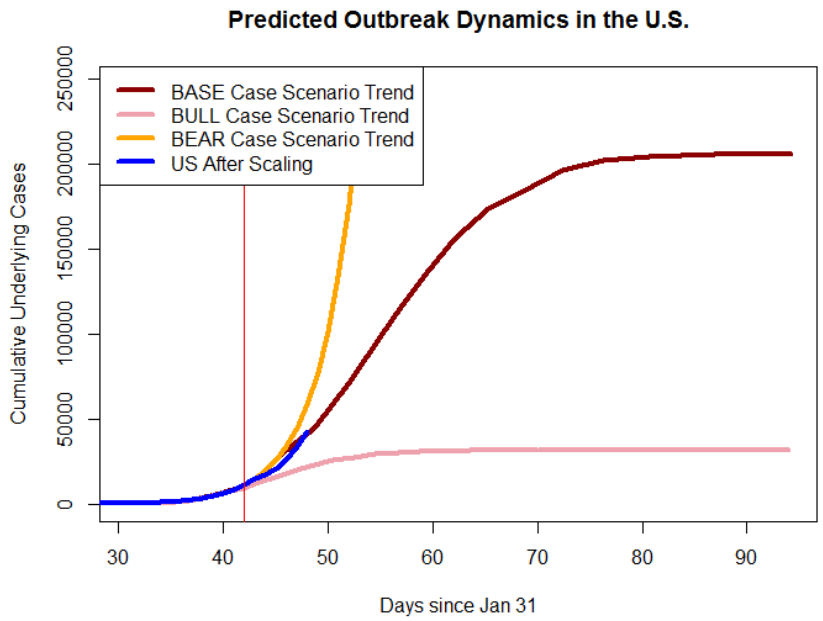
actual without scaling by early next week. Also, note that our overall peak cases and timing of peak cases remains unchanged despite the scaling/rescaling. We expect greater clarity on the trend vs our different scenarios over the next week.

Exhibit 1: U.S. Potential Scenarios vs Actual



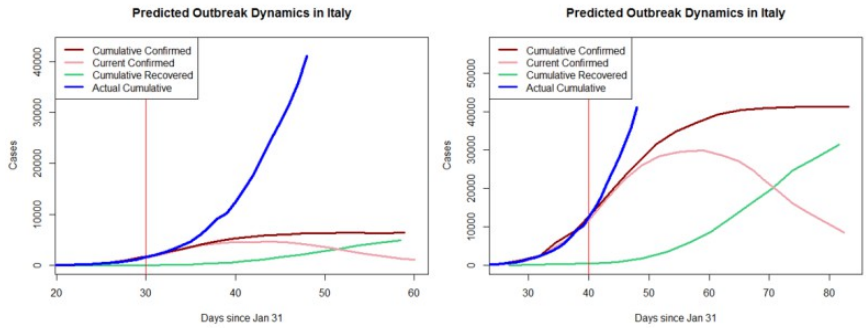
Source: Morgan Stanley Research, China CDC, U.S. State Level Updates

Europe

We currently model Europe as individual countries given the different disease dynamics. Below, we focus on how Italy is tracking and how the key other countries, including German, France and Spain, are tracking versus Italy's trajectory. Importantly, we currently do not model the UK given they are not expected to implement significant social distancing measures until 3/21.

Italy - Next 4 days are key: Italy is now 6 days into its country-wide lock down. Other countries with a similar lock down have taken ~10-15 days to start to stem the rise in new cases. Italy implemented a nationwide quarantine on ~60M people on 3/9, and announced further lock down measures on 3/11, including closing all nonessential shops, bars and restaurants. With these strict measures, we believe the outbreak in Italy will start to track more closely with China model going forward. Italy's new confirmed cases have been hovering around ~3,500/day, with the number of tests between 11,000 and 15,000. In the past two days, the number of tests jumped to ~17,000 and the reported new cases also increased to ~4,200 and ~5,300. We believe part of the rise in cases is due to increased testing and a catch-up phase.

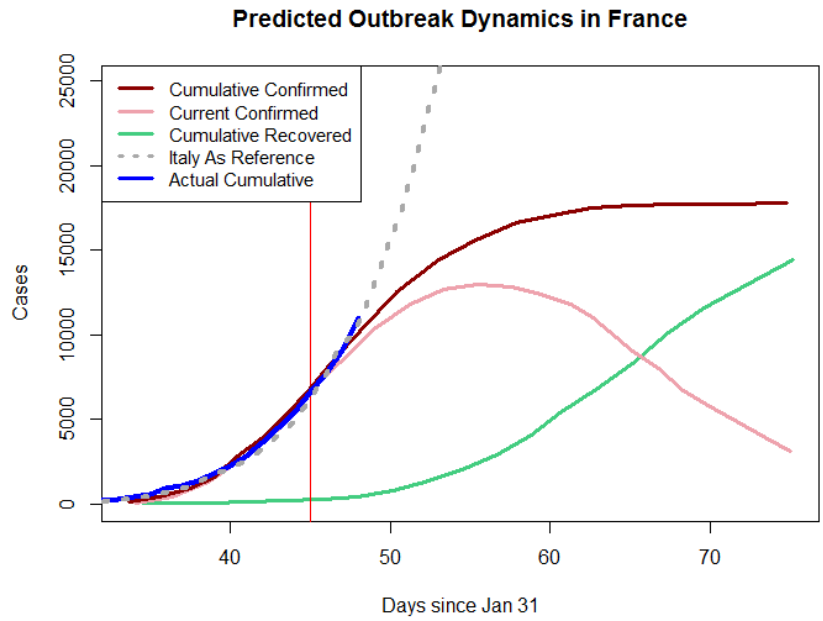
Exhibit 2: Italy Previous Model (Left) & New Model (Right) vs Actual



Source: Morgan Stanley Research, Johns Hopkins CSSE

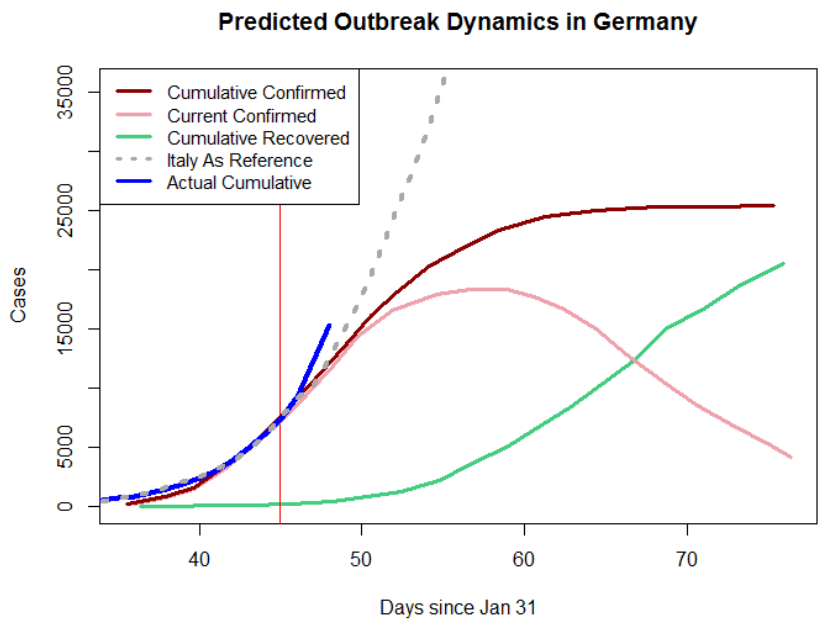
France, Germany and Spain - continuing to track more like Italy than China: As we have seen the trend being broken in all the three countries and each of has started escalating containment levels, we refitted models and updated the curves. Although we expect the actuals to track closer against the new models, the lags in testing and potentially less strict measures implemented in certain areas may lead to higher numbers than predicted.

Exhibit 3: France New Model vs Actual



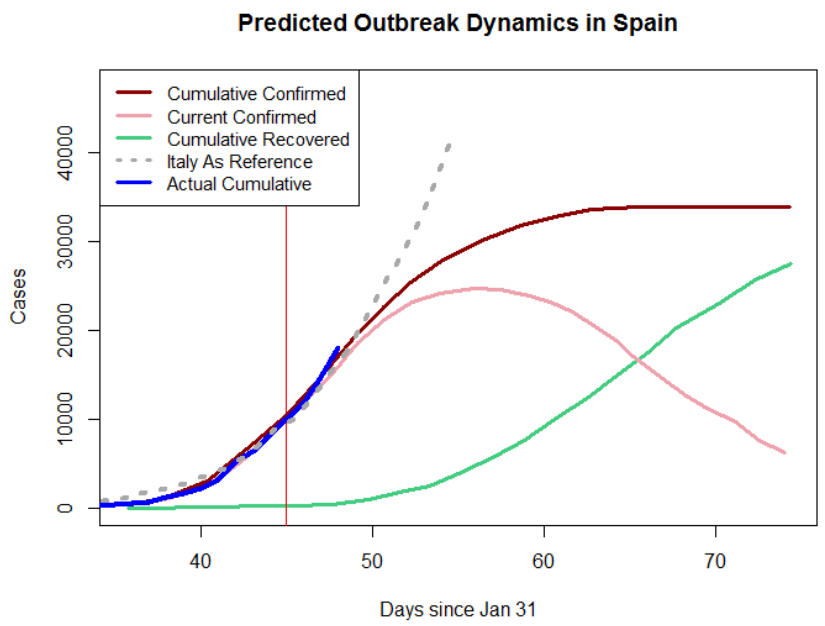
Source: Morgan Stanley Research, Johns Hopkins CSSE

Exhibit 4: Germany New Model vs Actual



Source: Morgan Stanley Research, Johns Hopkins CSSE

Exhibit 5: Spain New Model vs Actual



Source: Morgan Stanley Research, Johns Hopkins CSSE

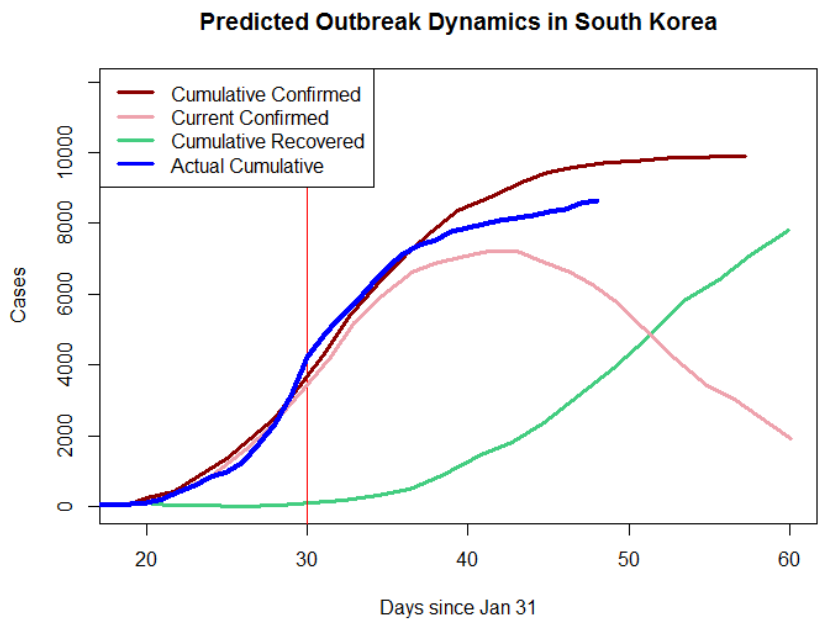
Asia

Most asian geographies are now stable with South Korea representing the best case in terms of how to contain the viral spread. In addition to our overall tracking curves which we provide for South Korea and Japan, we are also following actual cases closely for all asian countries to look for a possible "second wave" of spread.

South Korea: The data is tracking with our model and appears to be reaching a

slightly lower plateau at ~8,500.

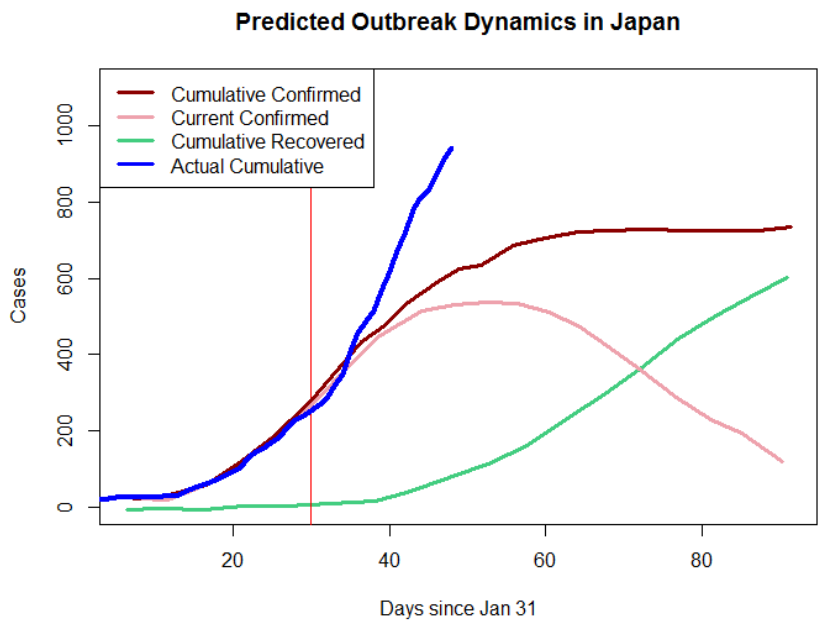
Exhibit 6: South Korea Model vs Actual



Source: Morgan Stanley Research, KCDC

Japan: We continue to expect the changes in testing criteria to impact the trend of reported cases in Japan and believe the trend against our model based on China data has been broken.

Exhibit 7: Japan Model vs Actual

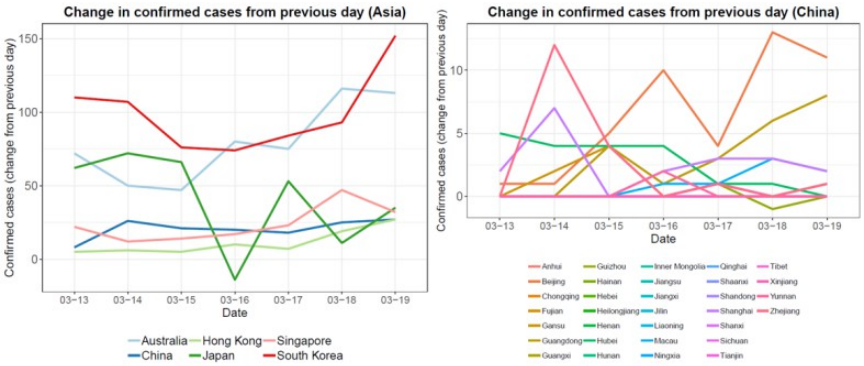


Source: Morgan Stanley Research, World Health Organization, Johns Hopkins CSSE

Tracking the dynamics of COVID-19 in ASIA to watch for a potential second wave of cases: Despite the significant slow down of COVID-19 spread in Asian

countries, a rebound of the cases number may be possible. We are, therefore, monitoring day-to-day changes in the cases reported in Asia/China over the past week. As Exhibit 8shows, the maximum day-to-day change amongst Asian countries was exhibited by S. Korea (~150 cases) and Australia (~110 cases), while the day-to-day change in all other Asia countries we follow lies ~25 cases. In China (right panel), we note that the day-to-day change in reported cases was near zero for all areas, with only Beijing demonstrating a day-to-day change of >10 cases.

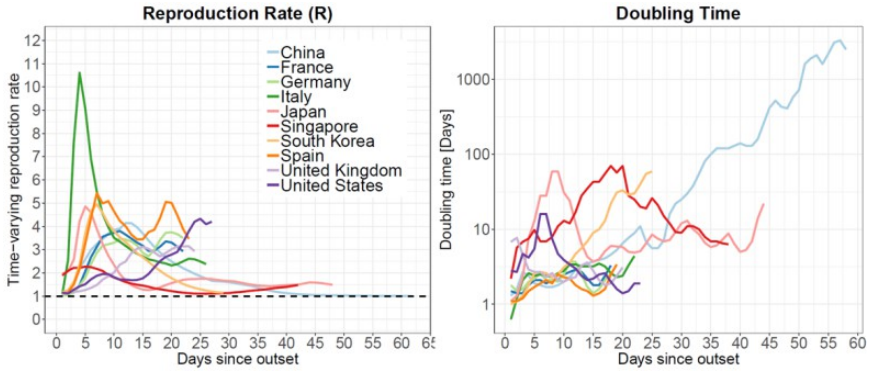
Exhibit 8: Day-to-day change in the cases reported in major Asian countries (left) or major China cities/provinces (right).



Source: Morgan Stanley Research, Johns Hopkins CSSE.

R and doubling times of cases: In Exhibit 9, we present plots from 10 countries with a cutoff date of March 19th (for our methodology see here). Based on the data below, we highlight that the R for Italy is 2.4 (doubling time of 4.4 days), for Spain is 3.5 (doubling time of 3.4), while for S. Korea is 1.14 (doubling time of 59 days). We underscore that S. Korea is approaching R=1, which reflects that COVID-19 is switching from epidemic to endemic (during R>1), driven by the broad testing in combination with strict containment measures. In the US, given that Thermo Fisher and Roche introduced ~2M tests this week, we expect the R to increase and doubling time to decrease in the next days mainly driven by the diagnosis of already existing but undiagnosed cases. For individual country plots see inside the Individual R and Doubling Time Plots .

Exhibit 9: Time-varying reproduction rate R and doubling time of COVID-19 cases. *Note that the R in the plots refers to the time-varying effective R, which differs from the basic reproduction number (R0) that reflects R under ideal transmission conditions without any intervention. We also caution that our calculations are based on daily reported data and may be confounded by testing capacity, reporting timing, and different sources of data.*

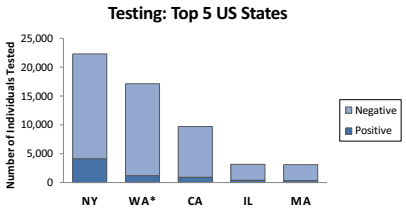


Source: Morgan Stanley Research, Johns Hopkins CSSE

Testing by Country and Top 5 US States: In Exhibit 10, we present graphs from 4 countries (left) and the top 5 US states (right) with a cutoff date of March 19th. We highlight that total tests performed in the US increased by 36% D/D. Exhibit 10

Exhibit 10: Total COVID-19 Tests by Country and Top 5 US States

As of 03/19/2020	Number of tests completed	Number of confirmed cases	Confirmed as a % of tests completed
South Korea	307,024	8,565	2.8%
Italy	182,777	41,035	22.5%
United Kingdom	64,621	3,269	5.1%
United States	103,945	13,159	12.7%
Total	658,367	66,028	



*Washington State testing figures are from 3/18/20

Source: Max Roser, Hannah Ritchie and Esteban Ortiz-Ospina (2020) - "Coronavirus Disease (COVID-19) – Statistics and Research". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/coronavirus' [Online Resource], Morgan Stanley Research

Recent COVID-19 research

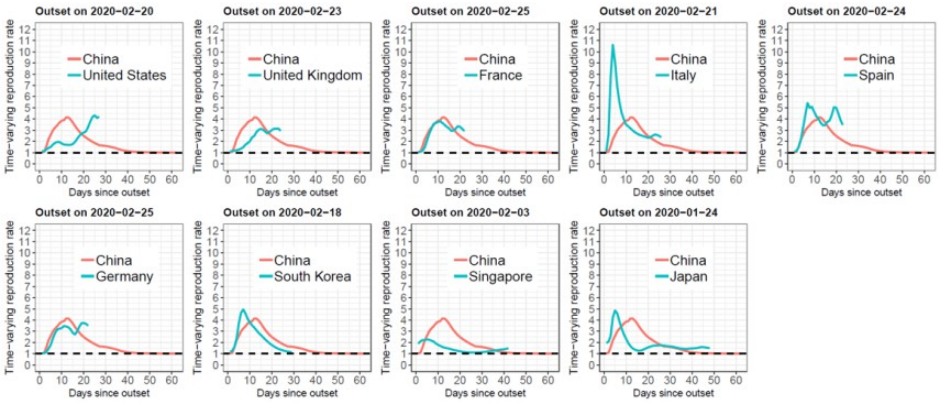
- Biotechnology: Introducing Two Key Epidemiologic Variables in Our COVID-19 Reports (17 Mar 2020)
- Gilead Sciences Inc.: Is Remdesivir A Market Catalyst? (17 March 2020)
- Moderna Inc: First Patient Dosed in COVID-19 Vaccine Trial (16 March 2020)
- Biotechnology: Potential U.S. COVID-19 Outbreak Dynamics (15 March 2020)
- Biotechnology: COVID-19 Outbreak Dynamics - An Update On Actuals Vs Our Model + New EU Countries (9 Mar 2020)
- Biotechnology: Current Status of COVID-19 Diagnostics (5 Mar 2020)
- Moderna Inc: COVID-19 Vaccine Patient Dosing Expected Soon (4 Mar

2020)

- Biotechnology: Key Takeaways From COVID-19 Expert Call (3 Mar 2020)
- Biotechnology: COVID-19 Potential Outbreak Dynamics - Using China As A Model (2 Mar 2020)
- Moderna Inc: Next Steps For COVID-19 Vaccine Development (1 Mar 2020)
- Biotechnology: COVID-19 Potential Therapeutic Options from Ongoing Clinical Trials (28 Feb 2020)

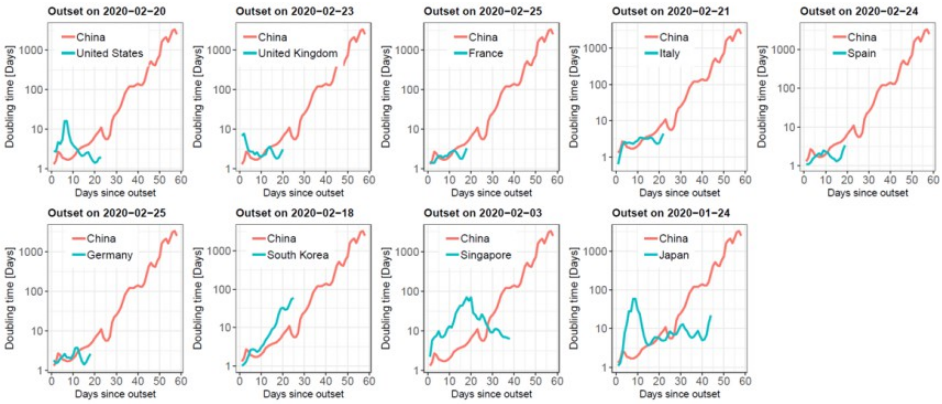
Individual R and Doubling Time Plots

Exhibit 11: Time-varying reproduction rate R for each country overlaid with China's R as a comparison. *Note that the R in the plots refers to the time-varying effective R, which differs from the basic reproduction number (R0) that reflects R under ideal transmission conditions without any intervention. We also caution that our calculations are based on daily reported data and may be confounded by testing capacity, reporting timing, and different sources of data.*



Source: Morgan Stanley Research, Johns Hopkins CSSE.

Exhibit 12: Doubling time of case number for each country overlaid with China's doubling time as a comparison.



Source: Morgan Stanley Research, Johns Hopkins CSSE.

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(as of February 29, 2020)
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Overweight/Buy	**1194**	**37%**	**311**	**43%**	**26%**	**534**	**37%**
Equal-weight/Hold	**1457**	**45%**	**332**	**46%**	**23%**	**697**	**48%**
Not-Rated/Hold	**2**	**0%**	**1**	**0%**	**50%**	**2**	**0%**
Underweight/Sell	**572**	**18%**	**77**	**11%**	**13%**	**224**	**15%**
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INDUSTRY COVERAGE: Biotechnology

COMPANY (TICKER)	RATING (AS OF)	PRICE* (03/19/2020)
David N Lebowitz, CFA, MPH		
Akebia Therapeutics Inc (AKBA.O)	E (09/07/2018)	$5.53
Alnylam Pharmaceuticals Inc (ALNY.O)	O (03/05/2019)	$105.97
Ascendis Pharma A/S (ASND.O)	O (10/11/2019)	$101.04
AVROBIO Inc (AVRO.O)	O (07/16/2018)	$13.76
Blueprint Medicines Corporation (BPMC.O)	O (04/03/2019)	$58.34
Epizyme Inc (EPZM.O)	O (12/05/2019)	$16.02
Ionis Pharmaceuticals Inc (IONS.O)	U (11/07/2019)	$46.07
Ironwood Pharmaceuticals, Inc. (IRWD.O)	E (03/27/2019)	$9.41
MacroGenics Inc (MGNX.O)	U (11/21/2019)	$4.78
Nabriva Therapeutics PLC (NBRV.O)	E (03/17/2020)	$0.57
Rhythm Pharmaceuticals Inc (RYTM.O)	O (09/07/2018)	$14.66
Schrodinger Inc. (SDGR.O)	E (03/02/2020)	$33.44
Syndax Pharmaceuticals Inc (SNDX.O)	E (10/29/2018)	$8.53
Zealand Pharma A/S (ZEAL.O)	O (09/12/2018)	$29.04
Jeffrey Hung		
Acceleron Pharma Inc (XLRN.O)	O (02/03/2020)	$74.62
Aprea Therapeutics Inc (APRE.O)	E (10/28/2019)	$35.63
Cytokinetics Inc (CYTK.O)	E (09/10/2018)	$9.00
Exelixis Inc. (EXEL.O)	E (03/18/2019)	$15.17
MyoKardia Inc (MYOK.O)	O (09/10/2018)	$46.94
Neurocrine Biosciences Inc (NBIX.O)	O (09/10/2018)	$79.00
NextCure Inc. (NXTC.O)	O (06/03/2019)	$34.41
Prevail Therapeutics Inc (PRVL.O)	O (07/15/2019)	$12.35
Ultragenyx Pharmaceutical Inc (RARE.O)	O (03/27/2019)	$38.24
Viela Bio (VIE.O)	O (10/28/2019)	$31.85
Voyager Therapeutics Inc (VYGR.O)	E (09/10/2018)	$7.56
Matthew Harrison		

Alector Inc (ALEC.O)	O (03/04/2019)	$27.89
Alexion Pharmaceuticals (ALXN.O)	E (12/17/2019)	$83.50
Amgen Inc. (AMGN.O)	O (12/17/2019)	$198.76
argenx SE (ARGX.O)	O (01/04/2019)	$121.00
BeiGene Ltd (6160.HK)		HK$89.55
BeiGene Ltd (BGNE.O)	O (01/17/2020)	$148.37
Biogen Inc (BIIB.O)	U (03/22/2019)	$288.02
Biohaven Pharmaceutical Holding Company (BHVN.N)	E (04/09/2019)	$30.47
Biomarin Pharmaceutical Inc (BMRN.O)	O (02/07/2017)	$74.28
Bluebird Bio Inc (BLUE.O)	E (11/03/2017)	$46.43
Cabaletta Bio Inc (CABA.O)	O (11/19/2019)	$6.24
Denali Therapeutics Inc (DNLI.O)	O (01/02/2018)	$17.82
Editas Medicine (EDIT.O)	E (02/29/2016)	$20.00
Evelo Biosciences Inc (EVLO.O)	O (06/04/2018)	$4.55
Forty Seven Inc. (FTSV.O)	E (03/03/2020)	$91.39
Fulcrum Therapeutics Inc (FULC.O)	O (08/12/2019)	$11.00
Galapagos NV (GLPG.O)	E (12/17/2019)	$143.00
Genmab A/S (GMAB.CO)	O (08/12/2019)	DKr 1,293.50
Genmab A/S (GMAB.O)	O (08/12/2019)	$18.51
Gilead Sciences Inc. (GILD.O)	E (10/01/2015)	$78.55
Global Blood Therapeutics Inc (GBT.O)	E (03/21/2018)	$45.76
Immunomedics Inc (IMMU.O)	E (01/22/2019)	$10.30
Innoviva Inc (INVA.O)	U (08/14/2014)	$8.73
Insmed Inc (INSM.O)	O (03/21/2018)	$15.09
Kaleido Biosciences Inc. (KLDO.O)	O (03/25/2019)	$4.99
Kodiak Sciences Inc (KOD.O)	O (10/29/2018)	$42.97
Moderna Inc (MRNA.O)	O (01/02/2019)	$28.27
Regeneron Pharmaceuticals Inc. (REGN.O)	E (10/01/2015)	$489.83
Regenxbio Inc (RGNX.O)	O (11/09/2017)	$25.61
Rubius Therapeutics Inc. (RUBY.O)	E (03/13/2020)	$4.20
SAGE Therapeutics Inc (SAGE.O)	O (02/26/2018)	$28.19
Sarepta Therapeutics Inc (SRPT.O)	O (08/01/2018)	$87.22
Seattle Genetics Inc. (SGEN.O)	E (12/10/2019)	$100.01
Unity Biotechnology Inc. (UBX.O)	O (05/29/2018)	$5.13
Vertex Pharmaceuticals (VRTX.O)	O (10/01/2015)	$215.69

Vikram Purohit

DBV Technologies SA (DBVT.O)	E (10/23/2017)	$3.39
Incyte Corp (INCY.O)	E (09/05/2019)	$66.51
Neon Therapeutics Inc (NTGN.O)	E (01/16/2020)	$2.20
Portola Pharmaceuticals Inc (PTLA.O)	E (09/05/2019)	$7.21
Radius Health Inc (RDUS.O)	O (09/05/2019)	$13.43
Unum Therapeutics Inc (UMRX.O)	E (03/03/2020)	$0.36

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