*March 23, 2020*

**Public Note 4:**

# Analysis of COVID-19 Contagion & Outlook

This report provides both US financial market analysis and data analysis of COVID-19 cases across all global jurisdictions.

The accelerating epidemiological trajectory of COVID-19 infections globally and in the US (broken out by region and state) is covered, as are policies that can be expected to address these dynamics and related economic and financial pressures.

**Charts highlighting epidemiological trends for every global region are provided at the end of this note.**

## SUMMARY

*A recent focus on liquidity has led to the scale of international and US domestic epidemiological shifts being underestimated.*

In our March 16 note, we highlighted that current market and policy developments can best be understood in terms of **systemic pressures building in phases as the COVID-19 situation evolves**.

This framework offers a clear understanding of how market pressures are likely to continue to develop and also provides a means to anticipate policy direction. Per that March 16 note, **phased drivers of systemic pressure** have been:

1. **International pressures.** The initial impact of COVID-19 on US markets focused on the virus's impact on international data. A sense of growing headwinds to global growth developed as mass coronavirus infections emerged in China and hit economic activity there. The initial catalyst of the market selloff that began on Feb. 20 was a rapid acceleration of cases in NE Asia, Europe, and the Middle East.
    - Our assessment is that these **"global growth headwinds" have been significantly underestimated** amidst a recent turn in market focus towards the second and third phases of COVID-19 systemic pressures.
2. **Deterioration in the US epidemiological trajectory.** As the number of cases of COVID-19 has accelerated in the US, a substantial reassessment of earnings expectations has been necessary due to the negative impact of COVID-19 mitigation measures on economic activity.
3. **Liquidity pressures.** Financial liquidity has emerged as a significant concern due to a rapid evaporation of cash flows and reduced economic activity as COVID-19 mitigation measures are implemented.

*Our assessment is that success addressing liquidity concerns is poised to buy the market some breathing room. Unless the international and US epidemiological situation are stabilized aggressively, however, liquidity pressures can be expected to resurface.*

**This report highlights what aggressive stabilization measures are likely to evolve and details the epidemiological data trends that make such measures necessary.**

## LIQUIDITY STABILIZATION

**The most effective short-term policy responses in the US have been focused on liquidity pressures**.

Two related categories of liquidity pressure have demanded action:

- **Financial system liquidity.** Markets have rapidly shifted to risk off assets and re-allocated capital in preparation for a significantly deteriorated economic environment. Amidst this shift, **the Federal Reserve has initiated multiple extraordinary monetary measures** to maintain liquidity in the financial markets and banking system.
- **Individual income liquidity.** As economic activity has scaled back drastically due to COVID-19 containment measures, **the US Congress and White House are pursuing unprecedented fiscal stimulus** to address "Main Street" liquidity concerns and bolster macroeconomic growth.

**The liquidity phase of the COVID-19 impact appears to at least temporarily be stabilizing in the US (at least in terms of financial market liquidity).**

- the Federal Reserve has committed to "infinite" quantitative easing to prevent liquidity emerging as a debilitating systemic pressure in the financial system
- Congress appears on the verge of passing a multi-trillion-dollar stimulus package to transfer payments to individual taxpayers and help bridge cash flow evaporation

**Our assessment is that there are significant reasons to be concerned about the medium and long-term impact of these stabilization measures.** Of particular concern:

- to what extent cash flow evaporation at the individual level is best responded to via one-time transfers on a scale that can significantly undermine the financial position of the US federal government
- whether a more indirect role of US authorities committing to maintain personal liquidity via back stopping of no-interest loans, payroll loans for businesses, etc. might represent a more effective leverage of resources
- what options will exist if further liquidity stabilization is needed

With the liquidity phase of the crisis at least temporarily stabilized, however, **the most critical concern for assessment is the US epidemiological and international situation**.

In this context, markets appear poised to continue the cyclical pattern we suggested in our March 1 and March 16 reports:

- **epidemiological deterioration** in the US and globally
- **counterbalanced cyclically** by policy expectations of economic stimulus and the implementation of aggressive policy to stabilize the epidemiological trajectory

The Fed and Congress's exceptionally aggressive liquidity measures likely represent significant cyclical support within this pattern. **However, while market and policy focus has been on liquidity issues there has not been an equivalent aggressive policy response to address the epidemiological trajectory.**

*The scale of epidemiological deterioration has in our assessment been significantly underestimated, especially at the international level.*

## US Policy Focus

**US policy appears to be focused on minimizing symptoms of COVID-19 prevalence rather than eradicating COVID-19 infections.**

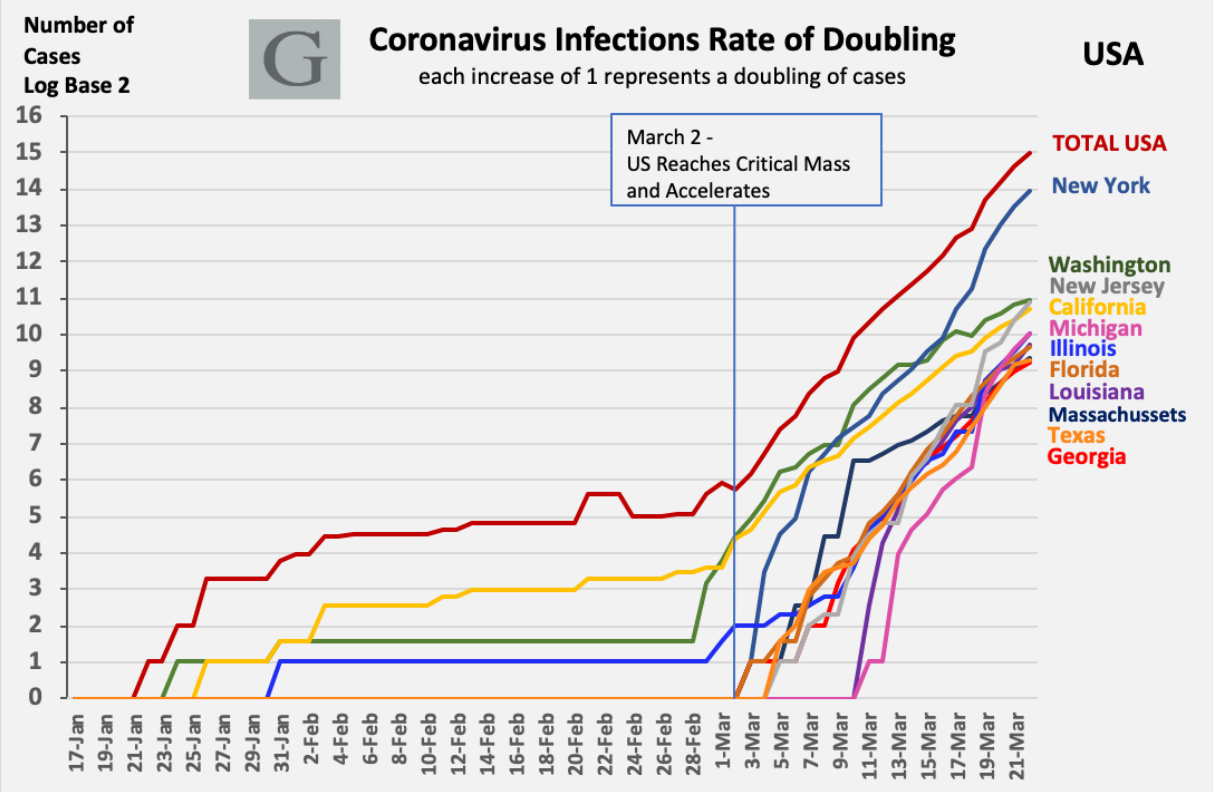
In addition to financial stabilization measures and economic stimulus, the goal seems to be increasing hospital capacity to deal with increased prevalence of COVID-19, while slowing the rate of infection to a level that is manageable systemically via social-distancing guidelines that are largely unenforced.

**This differs markedly from the approaches taken in countries where COVID-19 has actually been subdued.** Our assessment is that this approach both underestimates COVID-19 virulence and the suffering associated with a higher incidence of COVID-19 (both economic and personal). It also appears dependent on an assessment that mortality levels in the US might be reduced due to a higher standard of health care. Should any of these assumptions prove untrue, the potential political and economic repercussions are very significant.

Under such a policy trajectory, the best-case scenario is stabilization of new COVID-19 cases thanks to recent social distancing measures, with increased health care system capacity absorbing any temporary increase in resource demands.

As the graph below highlights, **this expectation does not match the current COVID-19 infection trajectory in the US as of March 22 data.**

**Chart 1:**
US Epidemiological Trajectory



## Will Social Distancing Work?

The above trajectory of continued exponential growth in infections within the US might be considered to simply reflect that social distancing measures have yet to take hold. However, there exist some fundamental differences between social distancing measures as being applied in the US versus strategies that have proven successful in stopping COVID-19 infections elsewhere. These differences and the **deteriorating COVID-19 epidemiological trajectory in the US across all states and regions** are detailed later in this note.

## International Risks Accelerating

Prior to detailing dynamics of the US epidemiological trajectory, a full understanding of the scale of international epidemiological pressures is in order. This **global deterioration has been far more rapid than seems to have been publicly appreciated** and not only represents a major economic, financial, and humanitarian threat, as well as a destabilizing geopolitical factor.

The significant development of COVID-19 infection clusters in all nations around the world now makes **all inbound international travel an epidemiological threat** to spark infection clusters in the US.

This **significantly increased risk of international travel continues to be under-addressed at the US and global level**. It represents the central factor sparking initial COVID-19 cases and leading towards domestic community transmission across nations.

*Failure to effectively reduce the threat of inbound international travel continues to spark local infection clusters and significantly undermines domestic stabilization.*

## Further Limits on International Travel

**Significant further restrictions on international travel can be expected to develop.** Though academic computer models have minimized the impact of such restrictions on stopping vs. simply delaying COVID-19 contagion, in actual practice **travel restrictions have proven a critical factor in stabilizing infection trajectories in multiple countries.**

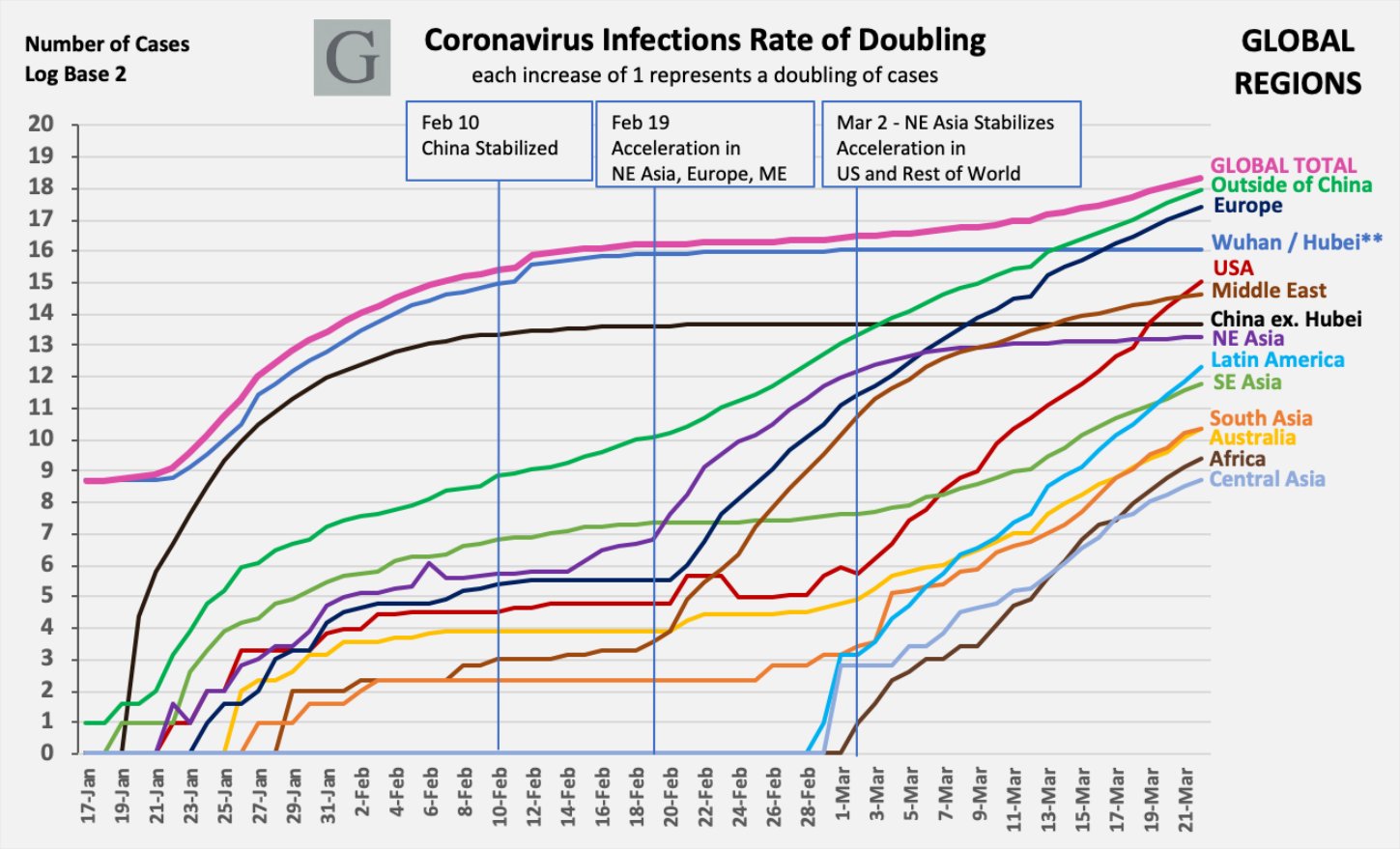
**Globally coordinated restrictions on international travel can be expected** as an eventual policy outcome given the global scale of COVID-19 pressures.

## Charting International Pressures

The following chart highlights the scale of international epidemiological pressures. These charts (provided for every global region, US state, and European nation later in this report) look at global COVID-19 infection rates in terms of their rate of doubling, with each increase of 1 representing a doubling of case numbers from previous levels.

- **The overall number indicates where the most cases have emerged** – for example, the US now has over double the number of diagnosed cases that China had outside of the Wuhan/Hubei epicenter (2 to the $15^{th}$ power vs. 2 to the $14^{th}$ power).
- **The slope of the curve indicates the speed at which cases are doubling** and offers significant insight into the effectiveness of policies. As noted, after infection rates began to accelerate dramatically Feb 19th in the Middle East, Europe, and NE Asia outside China, on March 2 they began to accelerate dramatically in all other regions of the globe, too.

**CHART 2: GLOBAL DIAGNOSES TRAJECTORIES**




## INTERNATIONAL RISKS HAVE DRAMATICALLY ACCELERATED

The trajectories above highlight the scale of **an international threat that in our assessment has been vastly underestimated** as nations and markets under siege have been focused on domestic stabilization.

The progressive evolution and timing of international pressures not only track the epidemiological trajectory highlighted in our March 1 report but emphasize the **critical need for international coordination of policy responses** to prevent this pandemic from accelerating uncontrolled across the globe.

## EMERGENCE OF INTERNATIONAL COORDINATION

Leadership at the global level has been slow to respond to this crisis given national authorities' focus on domestic concerns. We expect this to shift soon.

Though the World Health Organization (WHO) has failed in its operational mission of preventing a global pandemic from spreading, we expect it and other UN agencies to begin leading **efforts to coordinate a reduction in air travel and other vectors of infection**. This might be achieved in coordination with the International Civil Aviation Organization (ICAO), though this would be significantly different than its standard operational mandate. **Such efforts can be expected to lead to significant geopolitical tension.**

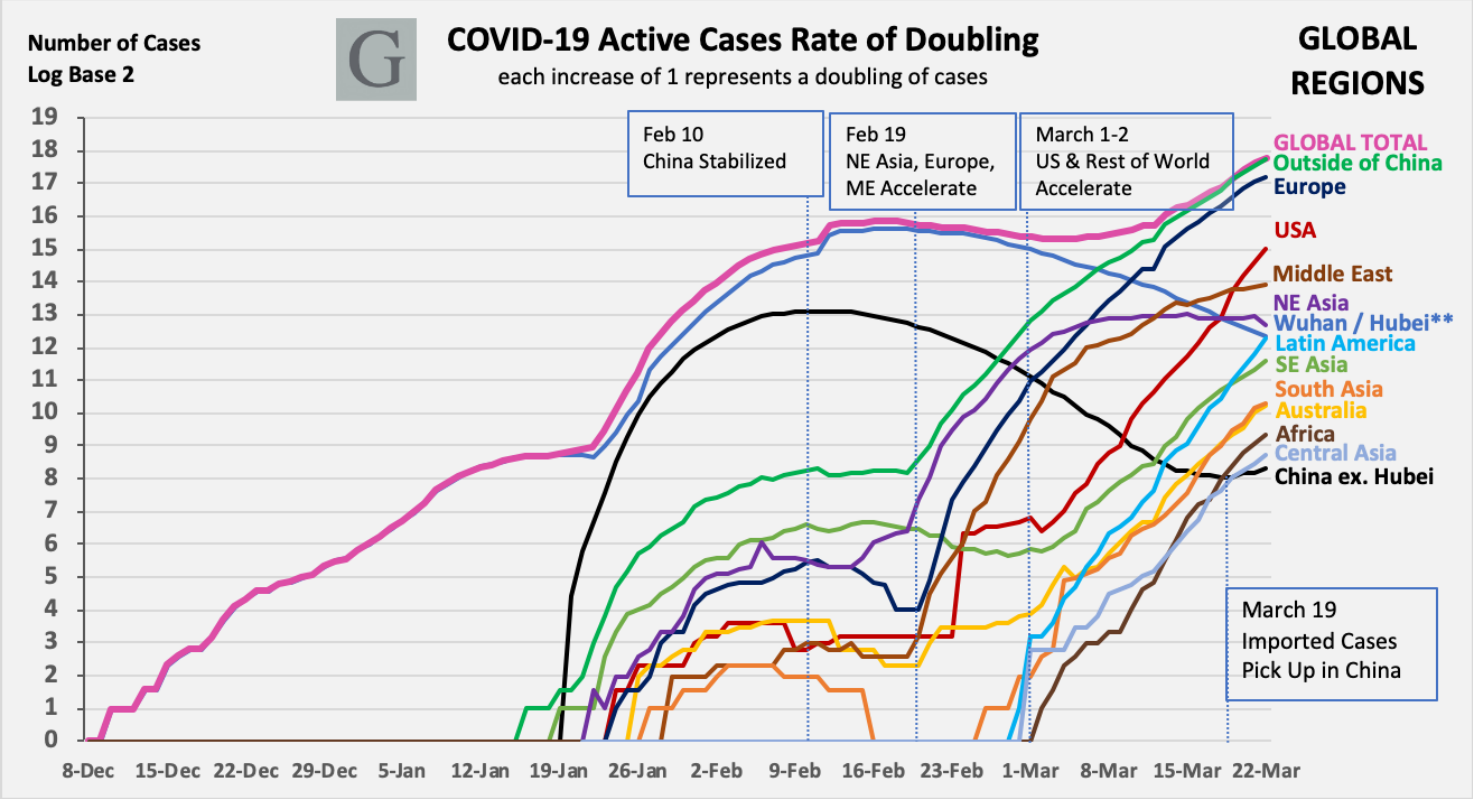
The **leverage of financial mechanisms** similar to the Global Fund to Fight AIDS,

Tuberculosis, and Malaria can also be expected to finance and encourage best practices in virus containment and treatment. These efforts **will require extraordinary financial resources in addition to economic and financial stabilization mechanisms**.

## Insight from Active Cases Data

To better understand timing and policy responses related to epidemiological curves, **the below chart focuses not on diagnoses of infection as tracked above but actual active cases of COVID-19 patients**. "Active cases" are the number of diagnosed infections minus cases that have been "resolved" - either because earlier infections have recovered and been cleared or the much smaller number of cases where patients have died.

**Chart 3:** Global Active Case Trajectories




Though this chart highlights similar international dynamics as the above data analysis of the trajectory of infection diagnoses, it offers **significant hope for the pressure on systems to diminish over time once the epidemiological curve of new infections is brought under control.**

This is particularly apparent in China outside of Hubei (black line above). Despite questions about the full veracity of data – there is a clear trend of:

- rapid expansion in cases as diagnoses exploded
- stabilization as containment measures lead to a drop in new cases
- reducing health care system loads as existing cases are treated and typically resolved quickly

**This pattern offers significant cause for optimism *if effective containment measures can be implemented.***

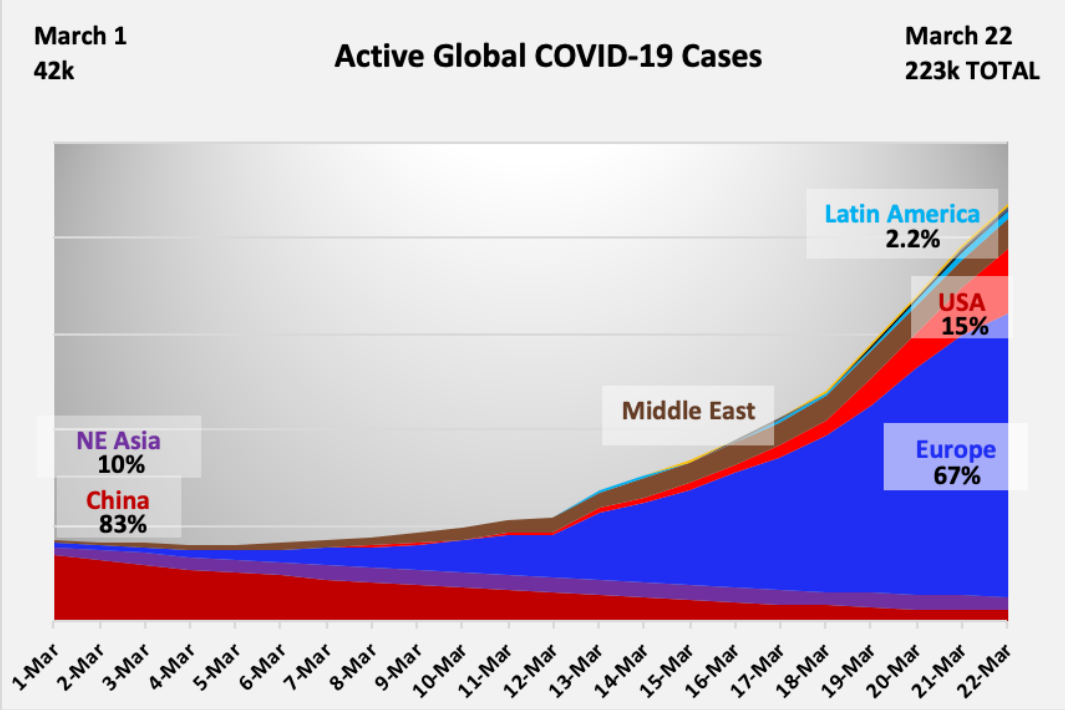
*A recent resurgence of cases in China reinforces the importance of international travel restrictions, as this resurgence is tied to inbound traffic into China.*

Even as a system is able to stabilize internal dynamics related to COVID-19 community infections**, strict controls and quarantines of inbound travel are essential to prevent the development of further infection clusters.**

## Cumulative Burden of Active Cases

The previous graphs have highlighted **the rapid expansion of COVID-19 infections in virtually all jurisdictions – other than its defeat in China and the trend towards defeat elsewhere in East Asia.** To better understand what these different trajectories mean cumulatively in terms of the global impact of COVID-19, the below chart tracks the evolving cumulative sum of active cases.

**Chart 4:**
**Global Active Case Distribution**




Exponential epidemiological trajectories across nearly all global regions have meant **an increase in the total number of global active cases by nearly 6-fold in the last three weeks** – from 42k active cases globally to 223k as of March 22. Note that this active case data differs from commonly cited data on total diagnoses but has also expanded exponentially.

This growth is despite the fact that **the number of active cases in China decreased by nearly 30k over the same period** as earlier diagnoses were either resolved and cleared through clinical treatment or resulted in death (400 new deaths reported in China from

March 1-22). *This data may be suspect, but the trend is clear.*

As COVID-19 has expanded exponentially internationally, **the global burden of active cases has shifted markedly away from China and East Asia.** On March 1, Northeast Asia together accounted for 93% of all active COVID-19 cases, but only 5.5% of global active cases as of March 22 (China 2.5%; other NE Asia 3%).

**The burden of active cases has shifted rapidly to Europe and the US.**

- This shift represents the epidemiological trajectory we outlined in our March 1 report and highlights a fundamental evolutionary characteristic of COVID-19.

## Understanding the Nature of COVID-19

**The COVID-19 virus is best understood as a parasitic organism that moves from jurisdiction to jurisdiction, taking advantage of environments where there are limited barriers to its movement.**

The virus does not move on its own. It depends upon:

- the movement of people to cross jurisdictional lines
- the movement of respiratory particles to move from one infected human to another

This understanding of COVID-19's nature makes it clear why:

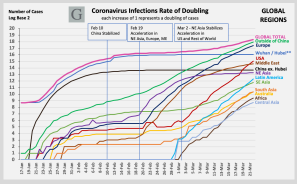
- limits to human movement are essential to prevent the virus's movement from jurisdiction to jurisdiction
- face masks that limit the virus's movement out of infected humans via respiratory particles are critical

**These principles were the foundation of success in the fight against COVID-19 in China** but appear fundamentally ignored in policy in the US and elsewhere.

## The Coming Explosion of COVID-19 Cases

*Failure to implement policies in line with these principles globally has led to exponential explosion of COVID-19 cases outside East Asia.*

This is most marked in terms of the exponential growth of cases in Europe, as highlighted in Chart 4: "Global Active Case Distribution." In only three weeks, Europe has evolved from 2k active cases to nearly 150k as of March 22 - from 5% of the global total to 67%.




**The US is on a similar trajectory to Europe, only approximately two weeks behind.** Note that Chart 2: "Global Diagnoses Trajectories" indicates that the epidemiological trajectories of Europe and the US are parallel but the US lags by approx. 14 days. This progression is reflected in the fact that on March 1 the US had only 0.3% of COVID-19 active cases globally but now has 15%.

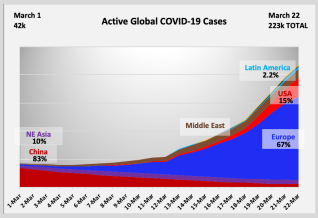



Chart 4's visualization of the percentage of global active cases by jurisdiction is helpful not only for gauging relative policy performance: **if your jurisdiction is growing as a share of total cases, it is failing in terms of policies.** In this context, China is clearly the "winner." Yet Chart 4 also documents something else clearly: COVID-19 is evolving towards a coming exponential explosion in global cases.

**Nearly every single region has a similar epidemiological trajectory even as they differ**

**in where they are on the epidemiological timeline.** As other regions advance on this timeline, the size of each region's slice in the Active Cases Chart 4 is poised to grow substantially (similar to how Europe's grew, then the US, and recently Latin America). As this evolution progresses, **the overall number of active cases globally is poised to cumulatively explode.**

*This international evolution is poised to happen in virtual unison over the next 3 weeks, even if the European and US trajectories should stabilize from their current exponential acceleration.*

**The scale of this international threat is immense but does not appear to be priced into US markets currently focused on domestic liquidity dynamics.**

## The Importance of International Action

**Addressing the international spread of COVID-19 should be top priority for policymakers** not only from a short-term stabilization and long-term recovery perspective. Stemming the international element of phased systemic pressures can help stem the development of US epidemiological and liquidity pressures. International intervention:

- offers outsized benefits because it can be applied early in the epidemiological cycle – a critical factor highlighted in our March 1 report
- offers the greatest maximum benefit in terms of reducing human deaths given poor health resources available to respond to further explosion in COVID-19 cases overseas

While policy and market focus has clearly been on the domestic US epidemiological trajectory and domestic liquidity issues, **the evolution of international efforts is a central factor to expect and follow in terms of systemic pressure mitigation.** Failure to pursue such efforts will have major economic, health, and geopolitical ramifications.

## International Impact on Recovery Potential

**The impact of the international environment on even a nation that has domestic success defeating COVID-19 is demonstrated by China's experience** and reflected in recent shifts in the Chinese stock market.


- as COVID-19 infections began to explode across China and drastic limits on travel

and economic activity were introduced, **Chinese stocks collapsed beginning Jan. 20**
- as it became clear not only that Chinese authorities were willing to enact extensive monetary and fiscal stimulus but also that severe policies were shifting the epidemiological curve in country, **Chinese stocks rallied strongly beginning Feb. 3**
- despite continued epidemiological success in China, the rapidly deteriorating international environment led Chinese stocks to **another dramatic downward shift beginning March 5**

## Market Tea Leaves from China

There are significant structural differences between China's stock market, economic policy frameworks, and political system vs. other nations, but **the Chinese experience highlights two critical lessons:**

1. strong, immediate responses to COVID-19 on the epidemiological front not only result in dramatic rapid improvements in epidemiological curves but also in market conditions
2. even with domestic success in defeating COVID-19, if COVID-19's international threat is not comprehensively addressed the net result will not be positive

**This dynamic calls for aggressive immediate action at the global level to fight COVID-19**. This entails not only public health measures but also provision of liquidity and stimulus to prevent needed COVID-19 mitigation measures from resulting in catastrophic economic and financial consequences.

*A failure to rapidly implement policy measures that halt COVID-19's exponential trajectory globally will undermine the ability of the US and other economies to domestically stabilize their economic and epidemiological trajectories.*

## Southern Hemisphere Action Essential

As highlighted in our March 1 note, **the establishment of COVID-19 infection clusters in South America (and now Sub-Saharan Africa, too) represents a major turning point in the global battle against the virus**. Not only have infections spread rapidly in both regions along an exponential trajectory, which has led to an increase in Latin America's share of the global COVID-19 load and reinforced the ongoing exponential increase in global cases. *The establishment of COVID-19 in the Southern Hemisphere climate has fundamentally shifted virus dynamics.*

Determining what share of this exponential explosion is attributable to inbound travel vs. local transmission is difficult, but **COVID-19 appears to have firmly established it can spread and survive in warm weather climates, undermining seasonal expectations** that the virus would dissipate as summer months arrived in the Northern Hemisphere. **The ability of the virus to exist year-round in either hemisphere will negate normal seasonal weather constraints** that might have enabled its eradication and has the strong potential to turn COVID-19 into a persistent sustained health and economic threat.

## Organize Don't Agonize

International organization is urgently needed to thwart further global epidemiological deterioration, not only as a public health and economic threat domestically in foreign nations but also as **a public health and economic defense measure relevant to the US and other advanced economies.**

This coordination will require **significant economic resources and financial stabilization initiatives on a scale far in excess of what has already been discussed to stabilize the US economy.**

## PHASE 2 SYSTEMIC PRESSURES: US EPIDEMIOLOGICAL DETERIORATION

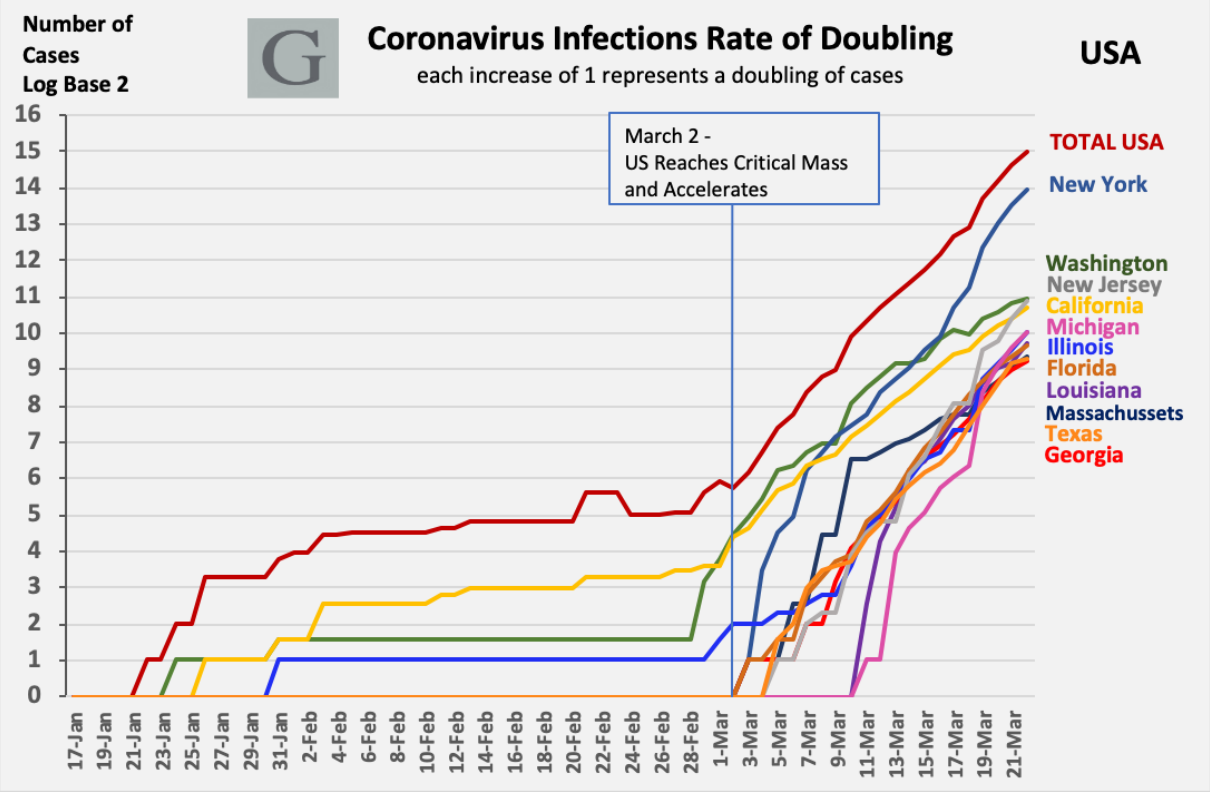
While attention has focused on liquidity pressures and economic stabilization efforts, the US epidemiological trajectory has deteriorated markedly.

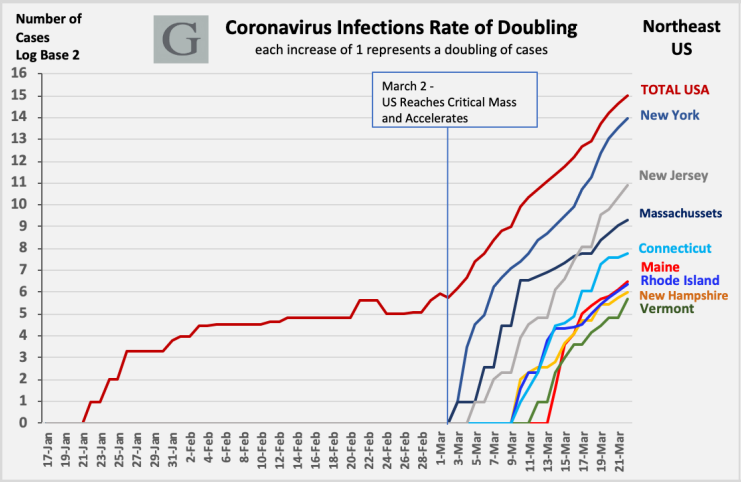
Returning to the chart introduced early in this report, the rate of doubling of infections in the US has continued to accelerate unabated since March 2nd. **The overwhelming contributor to this acceleration has been cases in New York,** which have doubled 14 times since the first diagnosed case on March 2nd.

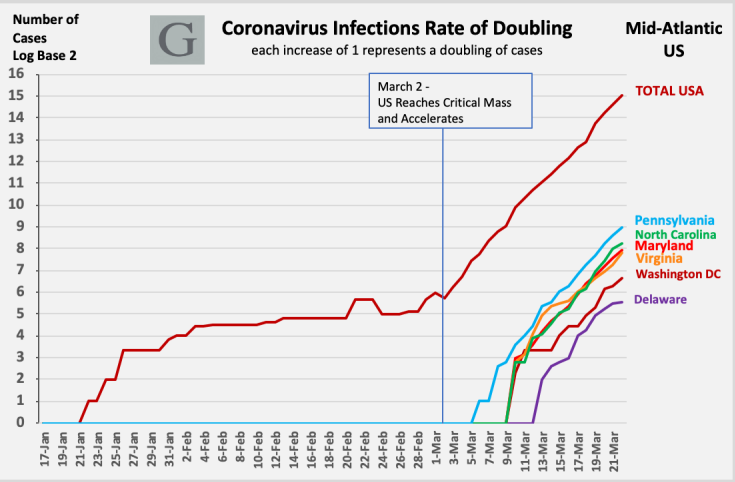
Multiple states, however, have seen similar and even steeper trajectories - though they are currently earlier in the epidemiological cycle. As with the international dynamic, **as different jurisdictions advance on the epidemiological timeline along a steep trajectory, the cumulative effect will be an explosion of US cases.**

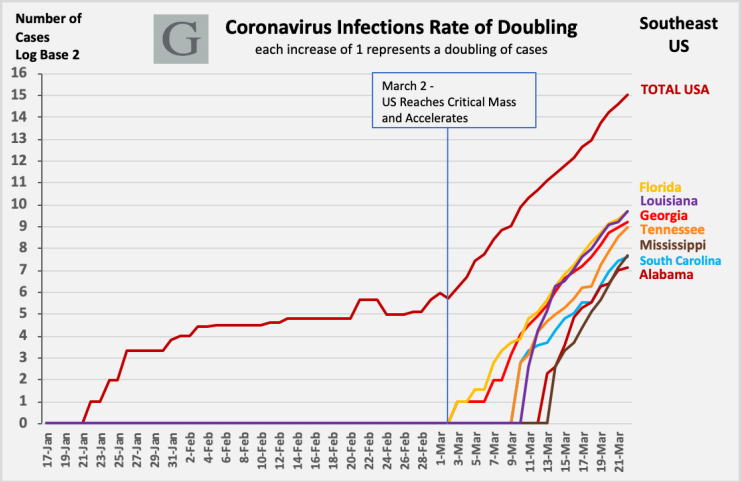
The chart below highlights key state contributors to US epidemiological deterioration. The following pages present this data for all US states and regions.

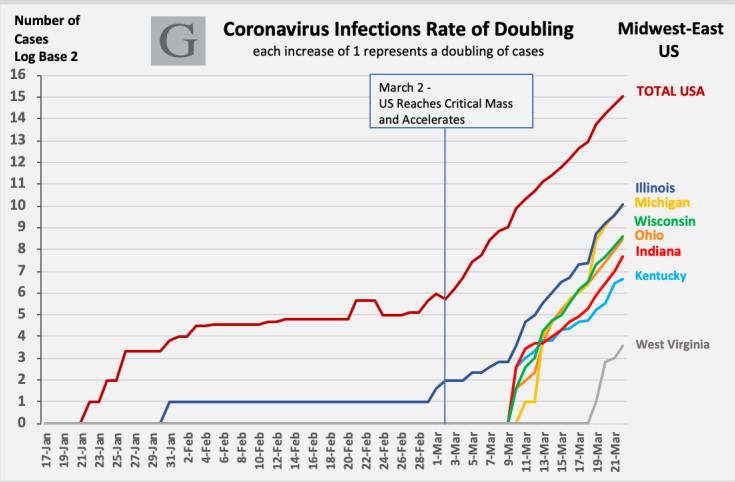
**CHART 1:**
US EPIDEMIOLOGICAL TRAJECTORY

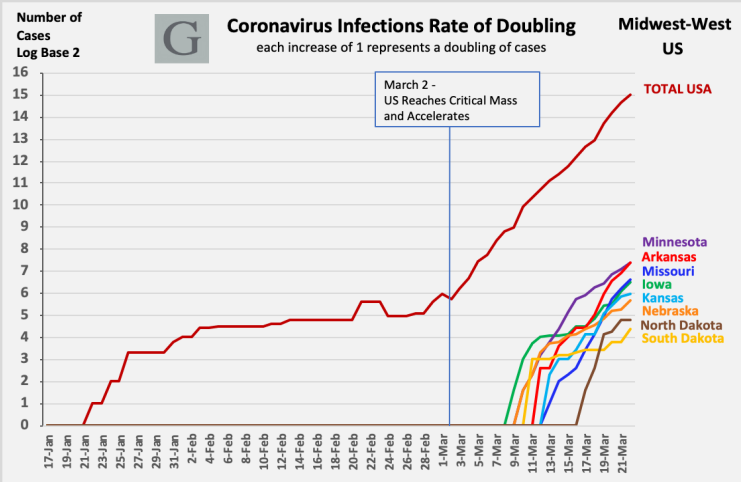


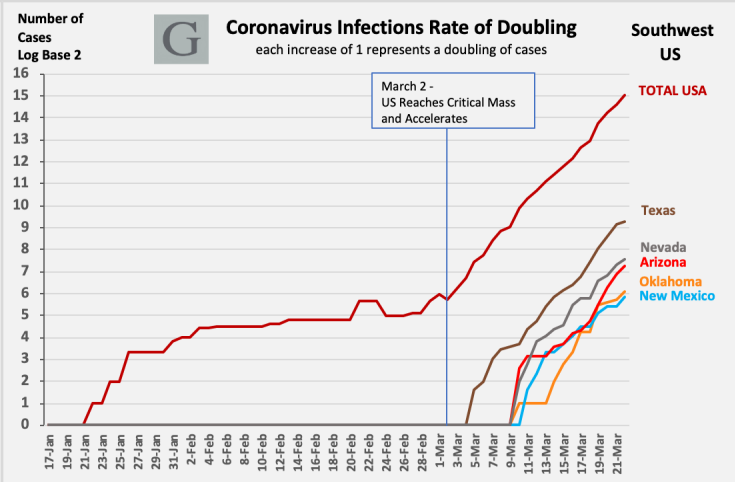

Number of Cases Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
Northeast US
March 2 - US Reaches Critical Mass and Accelerates
TOTAL USA
New York
New Jersey
Massachussets
Connecticut
Maine
Rhode Island
New Hampshire
Vermont

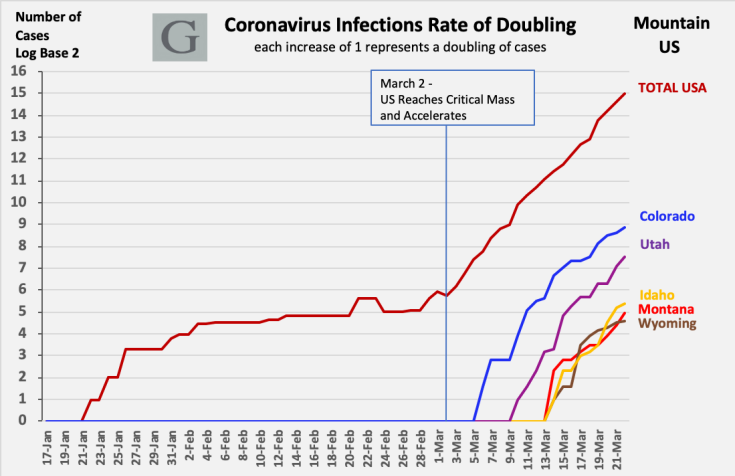

Number of Cases Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
Mid-Atlantic US
March 2 - US Reaches Critical Mass and Accelerates
TOTAL USA
Pennsylvania
North Carolina
Maryland
Virginia
Washington DC
Delaware

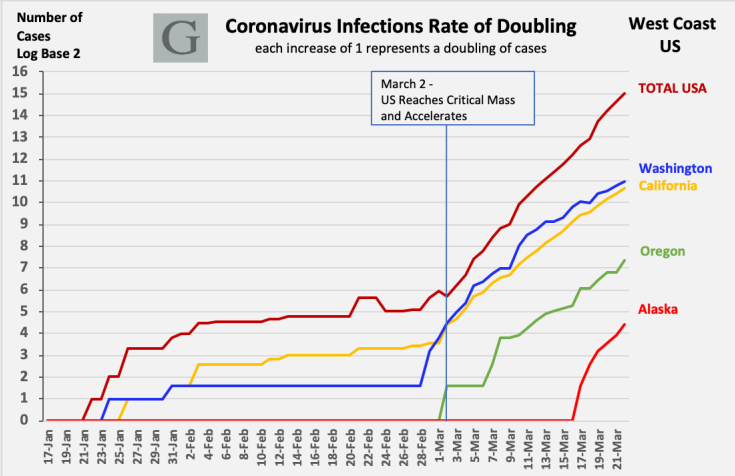

Number of Cases Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
Southeast US
March 2 - US Reaches Critical Mass and Accelerates
TOTAL USA
Florida
Louisiana
Georgia
Tennessee
Mississippi
South Carolina
Alabama


Number of Cases Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
Midwest-East US
March 2 - US Reaches Critical Mass and Accelerates
TOTAL USA
Illinois
Michigan
Wisconsin
Ohio
Indiana
Kentucky
West Virginia


Number of Cases Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
Midwest-West US
March 2 - US Reaches Critical Mass and Accelerates
TOTAL USA
Minnesota
Arkansas
Missouri
Iowa
Kansas
Nebraska
North Dakota
South Dakota


Number of Cases Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
Southwest US
March 2 - US Reaches Critical Mass and Accelerates
TOTAL USA
Texas
Nevada
Arizona
Oklahoma
New Mexico




As the above charts highlight, *every US state has COVID-19 infections, and nearly all are following an epidemiological trajectory similar to the US as a whole*. This trajectory is similar to what has been seen globally in other regions regarding COVID-19 infections.

Our assessment is that **this nearly universal trajectory is indicative of the nature of COVID-19 and its contagion pattern.** Jurisdictions that have seen the trajectory flatten have implemented policies that effectively address COVID-19's nature. China and South Korea have been most successful in this regard.

This assessment casts serious doubt on prevailing wisdom that recent spikes in US cases merely reflect increased testing. Even if limited testing has meant cases have been significantly underdiagnosed, **the trajectory of infections in the US tracks what appears to represent the fundamental nature of COVID-19 contagion** rather than a testing gap.

In reviewing the data of US states, **the unusually steep curves of New York and other states in the northeast are noteworthy.** This reflects the nature of COVID-19 and failure to implement effective policies, as discussed below.

## BREAKING THE COVID-19 TRAJECTORY

In the face of these deteriorating epidemiological dynamics, the US response has been to:

- encourage voluntary "social distancing"
- implement fairly limited travel restrictions targeted at travelers of countries identified as COVID-19 infection hotspots (China initially, recently Europe)
    - while allowing US citizens that had visited those countries to enter on expectations of a "voluntary self-quarantine"

Public health guidance has advised:

- healthy people not to wear face masks
- washing of hands as the primary preventive measure
- avoiding touching one's face
- remaining home if sick

**These policies have failed to stop COVID-19 from establishing itself on an exponential epidemiological trajectory in the US.** They also differ substantially from nations that have successfully halted COVID-19's exponential trajectory.

## Breaking the COVID-19 Trajectory

Such policies have seemed to ignore the fundamental epidemiological nature of COVID-19 in favor of computer models that indicate:

- travel restrictions could delay but not halt the entry of COVID-19 into the US
- widespread face mask usage is not only infeasible due to supply concerns but would not fully prevent infection of wearers
- voluntary social distancing could reduce infection rates to systemically manageable levels over a few life cycles of COVID-19 (approx. the 14-day quarantine period)

As the US epidemiological trajectory continues to deteriorate, **we expect immense political pressure to emerge and lead to a turnaround in these policies** in favor of a focus on the principles that proved essential to the defeat of COVID-19 in East Asia:

- limits to human movement are essential to prevent the virus's movement from jurisdiction to jurisdiction
- face masks that limit the virus's movement out of infected humans via respiratory particles are critical

**Such a turnaround would have significant implications for internal US travel and commerce.**

The development of "containment zones" that severely limit travel from and within areas where the epidemiological trajectory has advanced most aggressively (highlighted in our above data analysis) – is a likely evolutionary policy outcome. Even if not introduced by Federal authorities, **containment pressure at the state level can be expected to increase despite constitutional limits on restricting interstate commerce.**

**This would represent a marked turnaround from current expectations.** Any initial shock, however, could be expected to rapidly turn positive as such policies offer the prospect of success in defeating COVID-19. The economic and financial benefits of quick stabilization and recovery were demonstrated in China - until international deterioration pulled the Chinese market back down.

## US Policy Delays as a Threat

Current policies represent a path of least resistance politically in terms of limiting US authorities' direct restriction of citizens' movement. However, **further delay of effective measures as applied elsewhere is likely to significantly increase both epidemiological deterioration and the scale and duration of US economic disruption.**

This dynamic was highlighted in our March 1 note, and below we provide detail on why social distancing is likely to prove inadequate. Current efforts might be expected to offer a temporary reduction in the slope of the epidemiological curve. But based upon our assessment of COVID-19 contagion dynamics, **these policies appear unlikely to enable the virus to be eliminated as a public health threat that severely curtails economic activity in the US.**

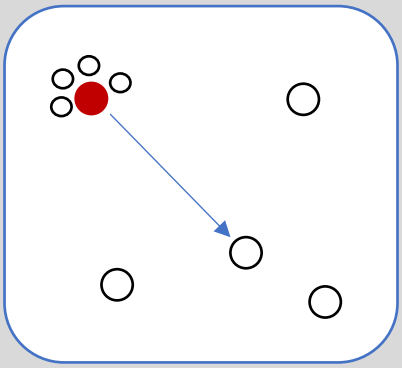
**The following illustrative model highlights the weakness of US "social distancing" vs. policies pursued in East Asia that focus on compartmentalization.**

By focusing on discouraging individuals from congregating in groups of 10 or more, US social distancing guidelines do help prevent "super-spreader" dynamics**.** However, **continued social interaction in even small groups can drive sustained community transmission.**

## Why Social Distancing is Insufficient

To demonstrate this dynamic of COVID-19 contagion under current US guidelines, the following illustrative model begins with **one person infected with COVID-19.** Such an index case has typically introduced the virus into a community via inward travel after being exposed in another jurisdiction.

## Step 1



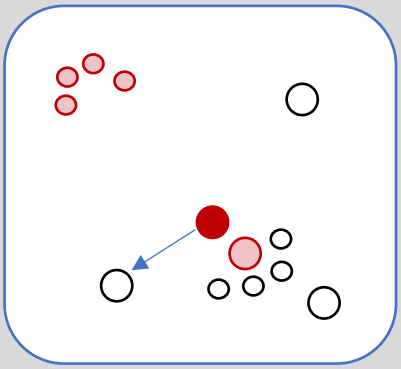
The initial case in this modeled scenario is only recently infected and is **asymptomatic but infectious.** Note that:

- though this person may be a US citizen traveling from a known COVID-19 hotspot and thus expected to self-quarantine, such quarantines are not enforced
- close personal family members are not advised to quarantine (which is key in limiting transmission dynamics in the real world and in this model)
- given the current prevalence of COVID-19 across the world and US, defining "hotspots" as high risk vs. low risk is nearly meaningless

## Step 2

Per the next model illustration, the initial case remains at home per guidelines then travels to visit one close personal contact (allowed per current US guidelines). As a result, **COVID-19 spreads to infect both the initial person's family cluster and one close personal contact**. None of the individuals wears personal protective gear since none believes they are sick (in keeping with US guidelines).

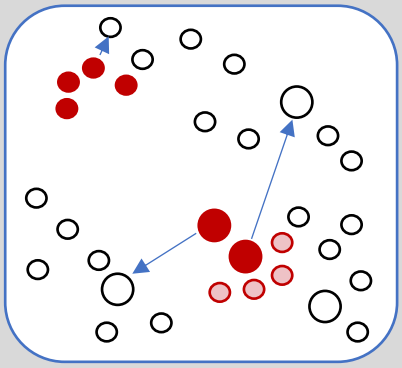
**1 case generates 5 more cases**



## STEP 3

As **the index case then moves on to visit another friend**, the **five initially infected persons become contagious (typically within a couple of days) and begin their own chains of transmission**. The visited friend infects her family cluster. The visited friend then travels to visit one of her friends, as does a contagious member of the index case's family cluster.

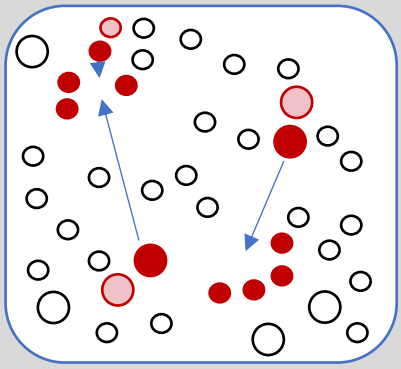
**1 case becomes**
- **6 infectious cases**
- **4 new developing cases** (the second individual's family cluster)



## STEP 4

As **the index individual returns home** (perhaps because he is beginning to feel ill) and his first infected friend returns home after infecting her friend, too, **the contagion contact chain continues to evolve**. The family cluster of the first visited friend is now contagious but asymptomatic.

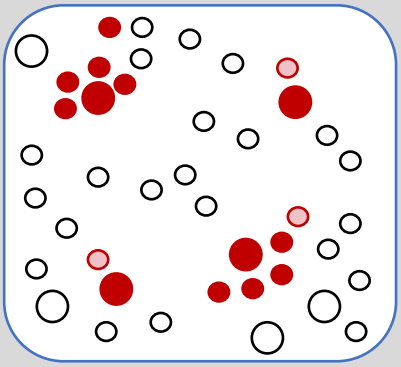
**6 infectious cases become**
- **10 infectious cases**
- **3 developing cases**



## STEP 5

Even with no further movement, infected individuals infect their close family clusters and the number of COVID-19 infections increases.

**1 case has evolved into 16 cases in a few days**



## OUTCOME

The above scenario may seem contrived, but **this pattern of contagion of COVID-19** cases doubling by a factor of 4 (16 cases = 2 to the 4th power) over just a few days **matches real world COVID-19 epidemiological trajectories.**

In this scenario, **all of these infections take place while the infected individuals present no symptoms**, and their behavior represents limited social interaction that **fully follows current US guidelines.**

*The above modeled scenario looks only at close social interaction and does not factor in group interaction at shopping and other business activities - which under current US guidelines continue to occur without face mask usage.*

## WHAT IS NEEDED BEYOND SOCIAL DISTANCING

Voluntary social distancing measures may reduce the slope of the US's epidemiological curve, but **the probability of these measures preventing sustained community transmission appears low.**

Current **US policy seems geared towards such a flattening of the epidemiological curve happening progressively over successive COVID-19 infection "life cycles"** (the approx. 14-day periods during which infected individuals are asymptomatic but contagious, which is the basis of quarantine measures). This approach – particularly if it proves less effective than expected as per our above model - **implies that social distancing measures will be necessary much longer than current public perception**.

The sustained economic impact of such policies - particularly when combined with what we expect to be their disappointing results per the model above and experience elsewhere globally - leads us to **expect significant pressures to tighten COVID-19 mitigation measures in the US.**

## PRINCIPLES PROVEN SUCCESSFUL

To understand the likely direction of such measures, it is worth revisiting the principles that have formed the foundation to successfully defeat the virus in East Asia.

**Successful COVID-19 reversal can fundamentally be summed up in the principle of "compartmentalization."** Barriers must be established to enforce compartmentalization.

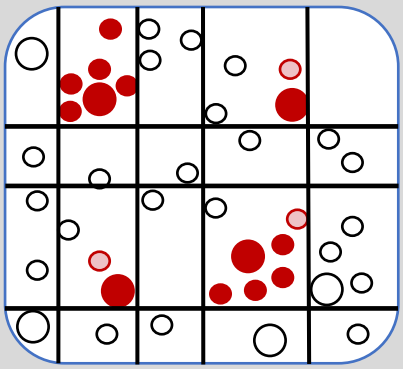
- compartmentalize the virus within the infected person's body
  - by having them wear a face mask so that the virus cannot escape via respiratory particles
- compartmentalize infected individuals and nodes of infection
  - by limiting their movement and ability to interact with other humans

## Principles Applied to Scenario

It is worth noting that had the initially infected index case in the above scenario been **wearing a face mask at all times, the train of transmission would have been immediately broken.**

However, even if that index case had access to a face mask, they would not have been wearing one per existing US guidelines because they were asymptomatic.

The below illustration demonstrates the principle of compartmentalization as applied to movement in the above scenario. **By erecting barriers to prevent social interaction between individuals, not only can further infection be limited; clusters of cases can be identified for intervention and treatment.**



Such compartmentalization can allow relatively free movement amongst compartments where infections are not present. This **can encourage sustained economic activity even as the COVID-19 threat is aggressively addressed**.

## Real World Success

These two principles: compartmentalization of infections within individuals via masks, and compartmentalization of individuals by enforcing barriers to travel, represent **the fundamental foundations of success in defeating COVID-19 in East Asia.**

The difficulty of enforcing compartmentalization in the US vs. China has led to the strategy being dismissed as impractical and politically impossible. Compartmentalization, however, **may be the only effective strategy to defeat COVID-19 and reduce economic dislocation rapidly**.

Much analysis of China's success in defeating COVID-19 has focused on invasive, authoritarian aspects of its policies and doubts about data. Despite these criticisms, at a fundamental level **the two critical components of success were face mask supply and the rapid implementation of compartmentalization.**

Compartmentalization in China did take advantage of existing social and political

structures - China has long been organized hierarchically into successive units to allow compartmentalization of threats and distribution of resources. This system was mobilized aggressively in response to COVID-19 - most notably using the lowest level of organization in the Chinese system: local neighborhood committees.

**Local committees were mobilized rapidly to compartmentalize areas of existing and potential infection**. Neighborhood officials:

- prevented movement in or out of their compartmentalized areas other than by individuals who resided within (managed by an ID and permit system)
- monitored all individuals entering and within any compartmentalized area to identify COVID-19 cases (usually with infrared thermometer checks)

*This organizational aspect – as well as its combination with face mask usage – was the reason China was able to stop COVID-19 infections and reduce active cases at an incredibly rapid rate.*

## CONCLUSION

Despite academic studies that have been used to support perspectives (often with political and economic motivations) that travel restrictions cannot be expected to stop COVID-19 contagion and that masks cannot be expected to stop contagion either, **the fundamental lessons of success in East Asia indicate otherwise.**

In the modeled scenario above, only one index case drove exponential infection growth. In reality**, the most rapid infection cluster expansion is driven by multiple cases entering a jurisdiction and sparking multiple clusters of infection**.

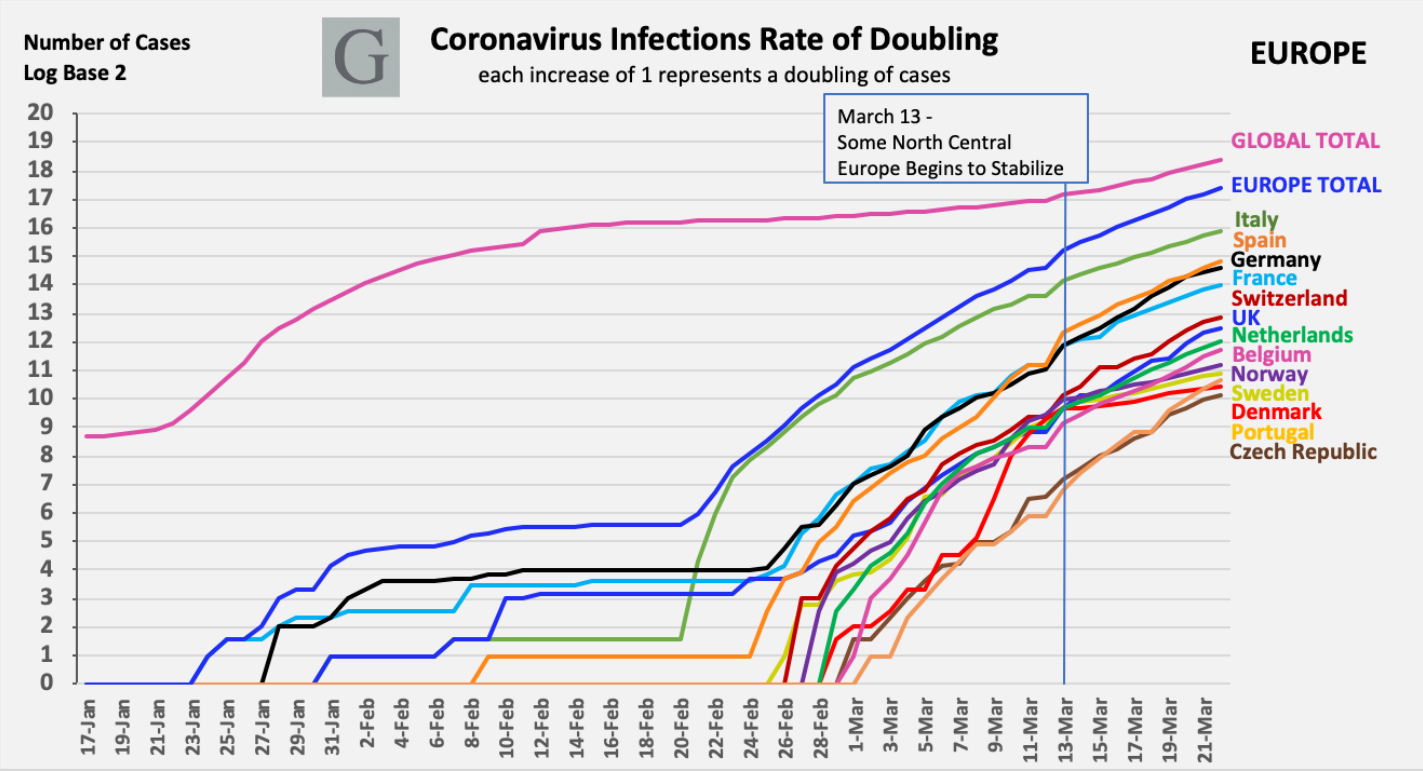
This dynamic is demonstrated in jurisdictions that have the steepest epidemiological trajectories in the US and globally.

- China outside of Hubei had the steepest initial epidemiological explosion due to massive amounts of travelers from and through Wuhan (a central national transit hub) during the Chinese New Year
- the exponential growth in South America was sparked initially by multiple travelers returning from Italy (Europe's epicenter, and where initial coronavirus cases were linked to inbound travel from China)
- New York, New Jersey, and Connecticut have likely had exceptionally steep exponential infection curves due to New York City's extensive travel links and high population density
    - initial travel-related infections have rapidly spread into secondary and tertiary infection clusters and into neighboring states
    - driving a rapid local epidemic that threatens to spread unless drastic compartmentalization measures are implemented

**Directly addressing these dynamics of COVID-19 contagion will require a dramatic shift in US policy approaches.** In this context, the extensive data analysis provided on US jurisdiction offers insight into areas where containment zones are likely to be sought.

Such containment zones, though politically very contentious, are already being established **in Europe. This has had a significant impact on infection curves.**

# EUROPE COVID-19 INFECTIONS DATA ANALYSIS




Faced with significant explosion of epidemics across the continent, **multiple European nations have enacted tighter border controls and/or enforced extensive internal travel limits.**

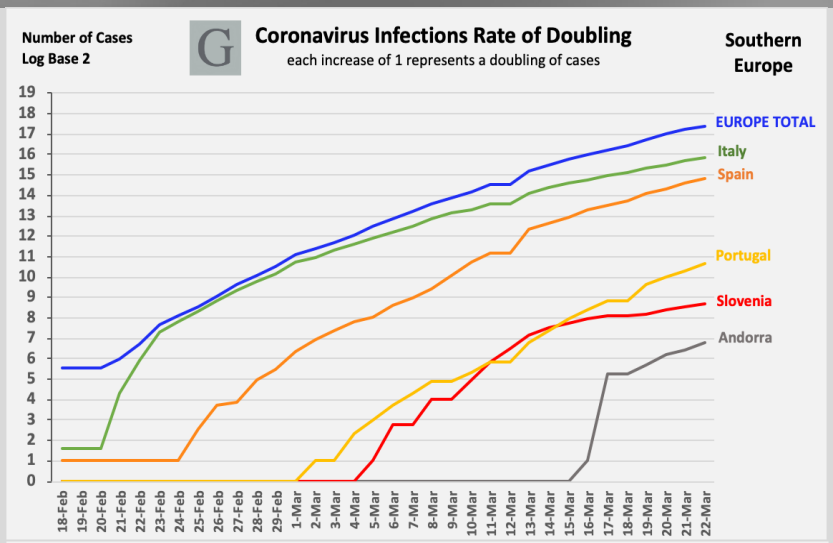
The most extreme of these measures have been initially in **Italy**, which **has progressively tightened domestic movement** after failing to prevent international inbound travel from leading to the rapid development of domestic clusters.

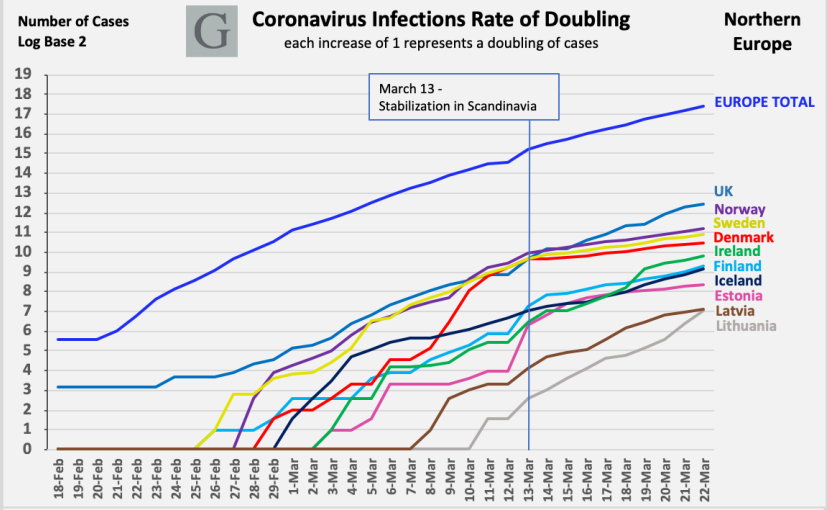
Failure to implement effective travel restrictions elsewhere in Europe – including on travel to and from Italy - led to **domestic infection clusters developing across the continent 1 to 2 weeks after Italian infections exploded**. This matches the COVID-19 "life cycle."

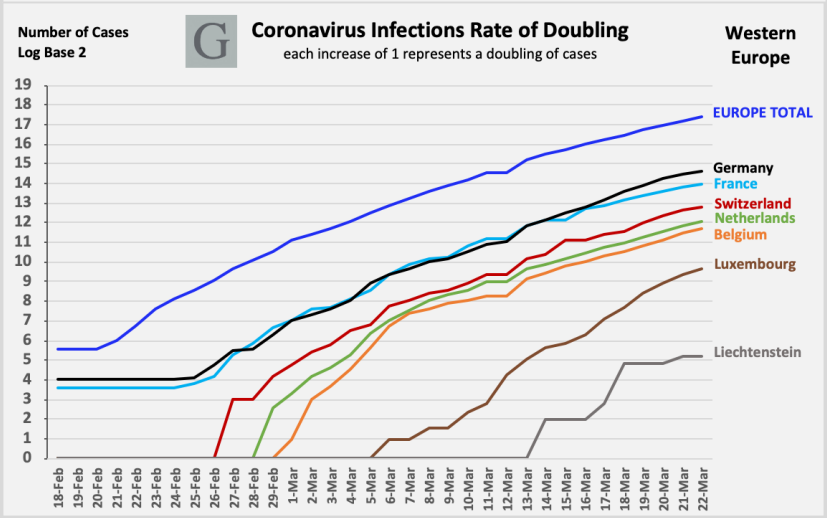
Following two weeks of local COVID-19 infection clusters increasing exponentially across Europe, policy began to rapidly shift. The sudden flattening of the infection curve in Denmark beginning March 13 is notable as it coincides with the implementation of tight border controls closing Danish borders to all non-resident travelers.

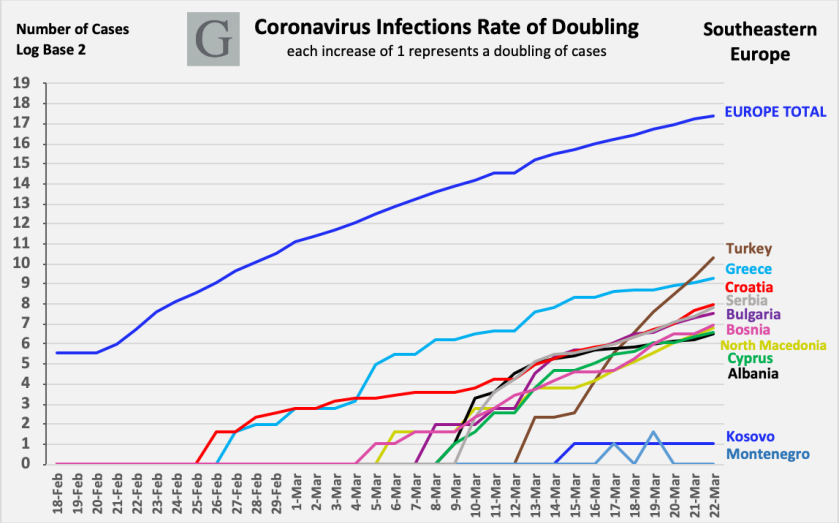
**This policy direction should be expected to evolve further not only in Europe but in the US and globally.**

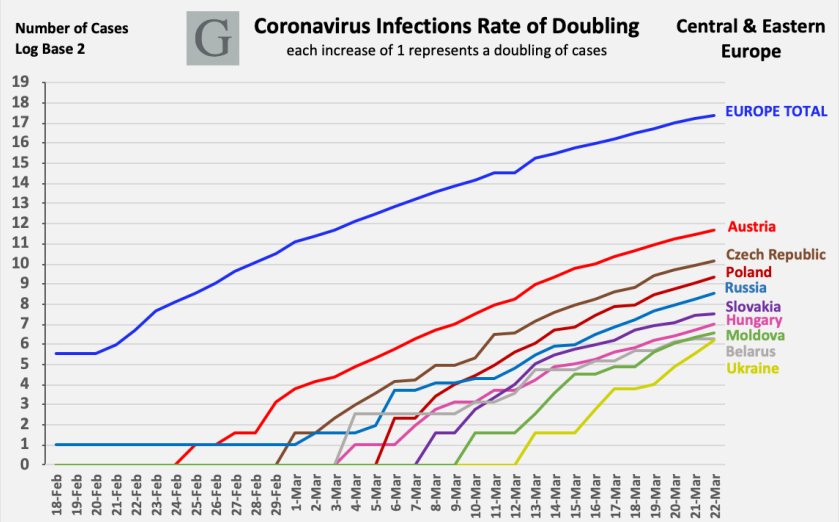
*The following pages detail infection curves for all of Europe by region and state, as well as other global regions, including at the state/province level in Canada and Australia.*


Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
Southern Europe
EUROPE TOTAL
Italy
Spain
Portugal
Slovenia
Andorra

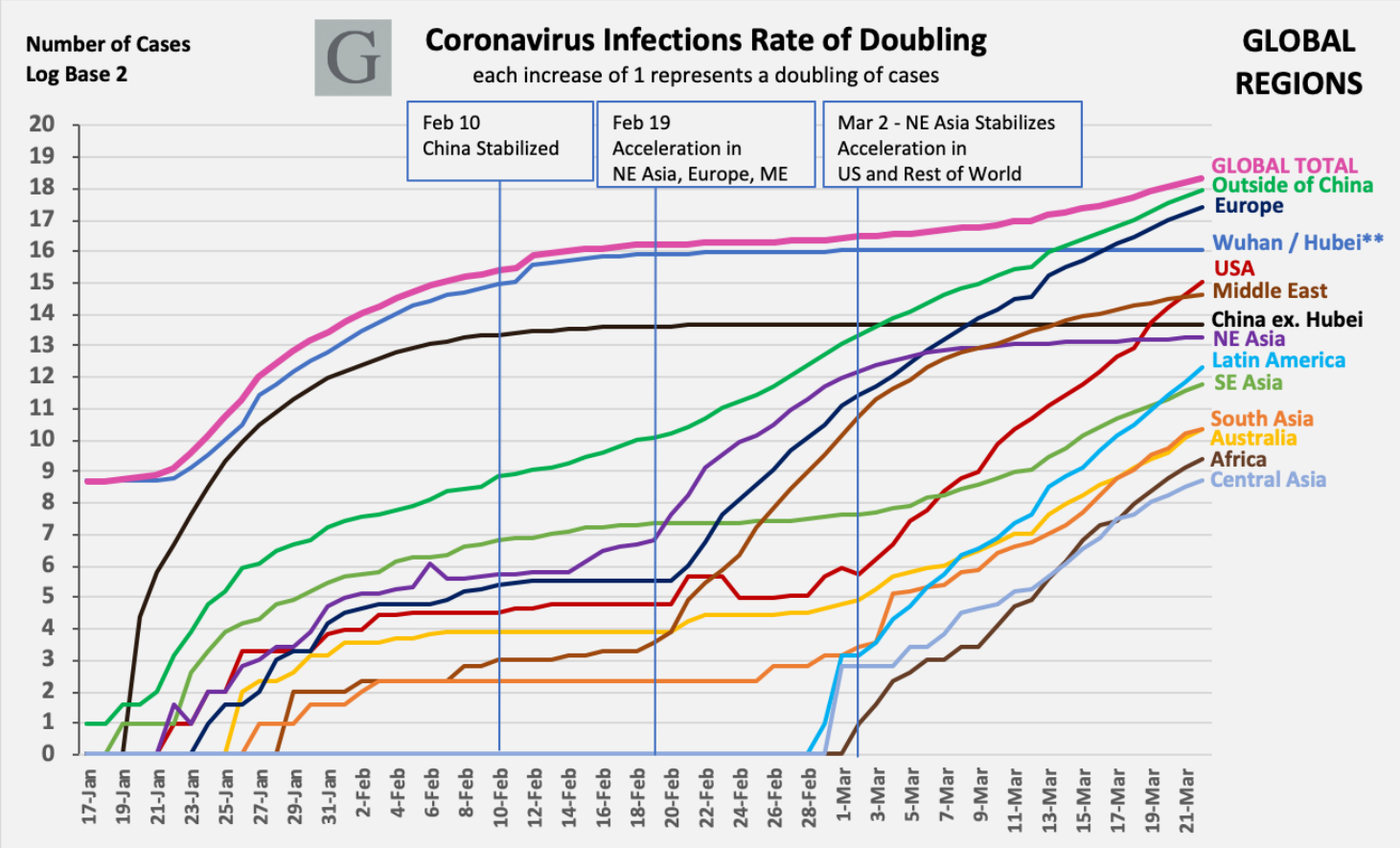

Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
Northern Europe
March 13 -
Stabilization in Scandinavia
EUROPE TOTAL
UK
Norway
Sweden
Denmark
Ireland
Finland
Iceland
Estonia
Latvia
Lithuania


Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
Western Europe
EUROPE TOTAL
Germany
France
Switzerland
Netherlands
Belgium
Luxembourg
Liechtenstein


Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
Southeastern Europe
EUROPE TOTAL
Turkey
Greece
Croatia
Serbia
Bulgaria
Bosnia
North Macedonia
Cyprus
Albania
Kosovo
Montenegro

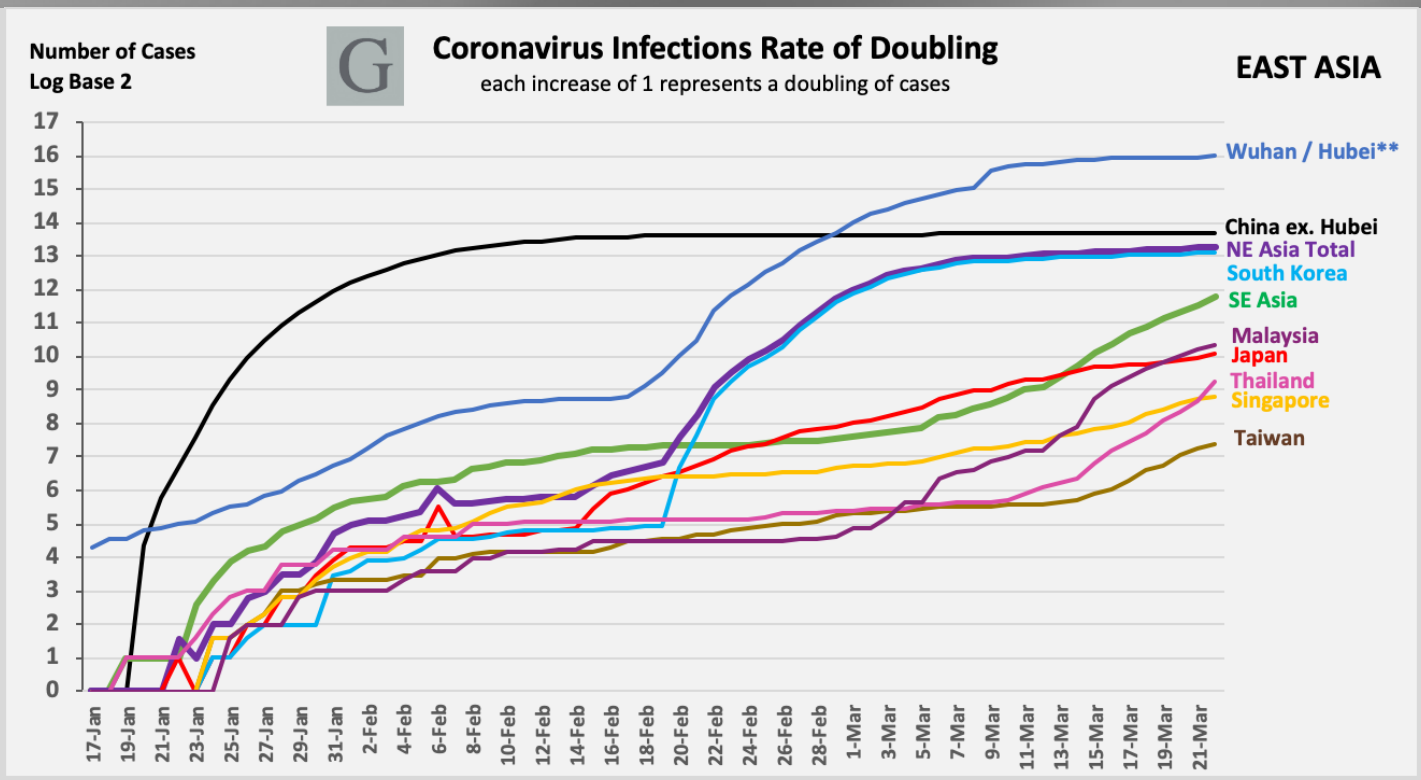

Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
Central & Eastern Europe
EUROPE TOTAL
Austria
Czech Republic
Poland
Russia
Slovakia
Hungary
Moldova
Belarus
Ukraine

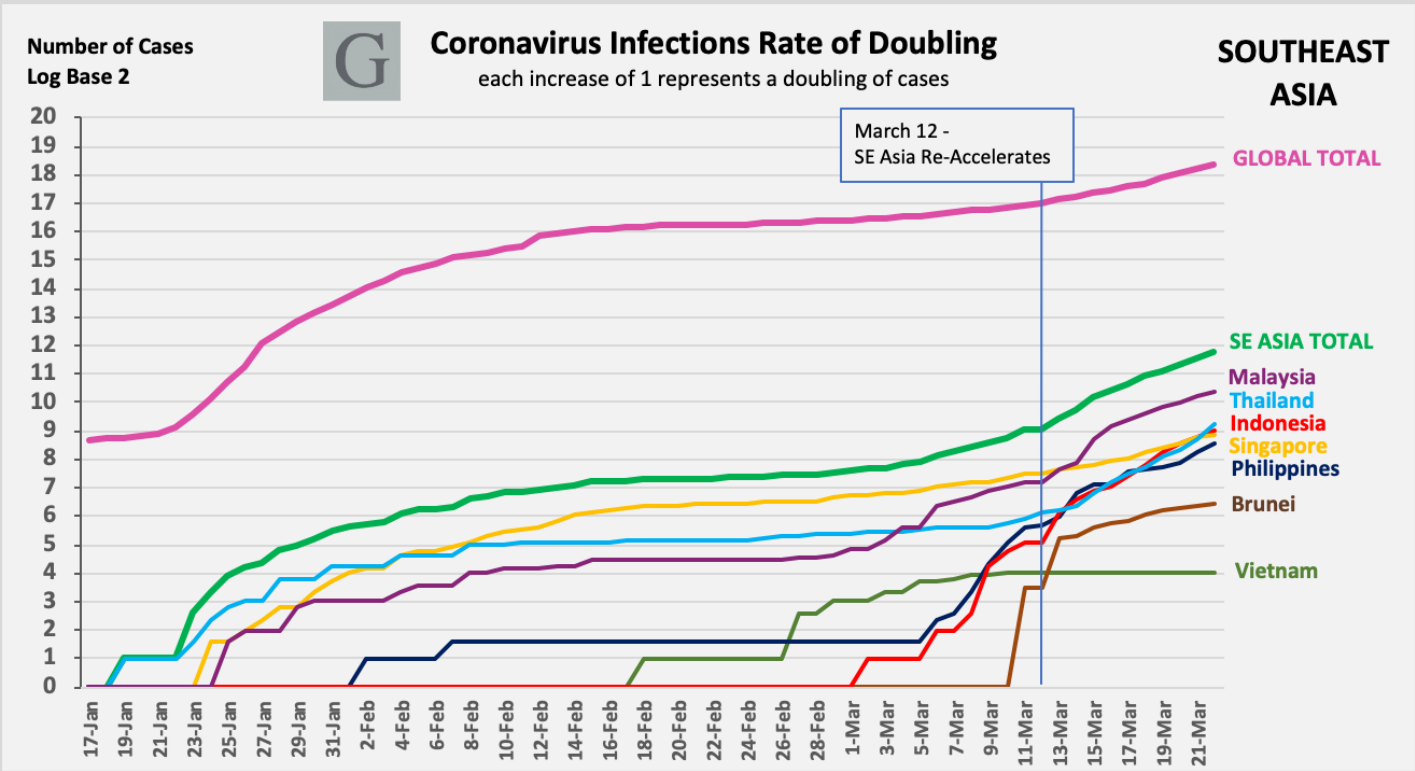
# GLOBAL COVID-19 INFECTIONS DATA ANALYSIS

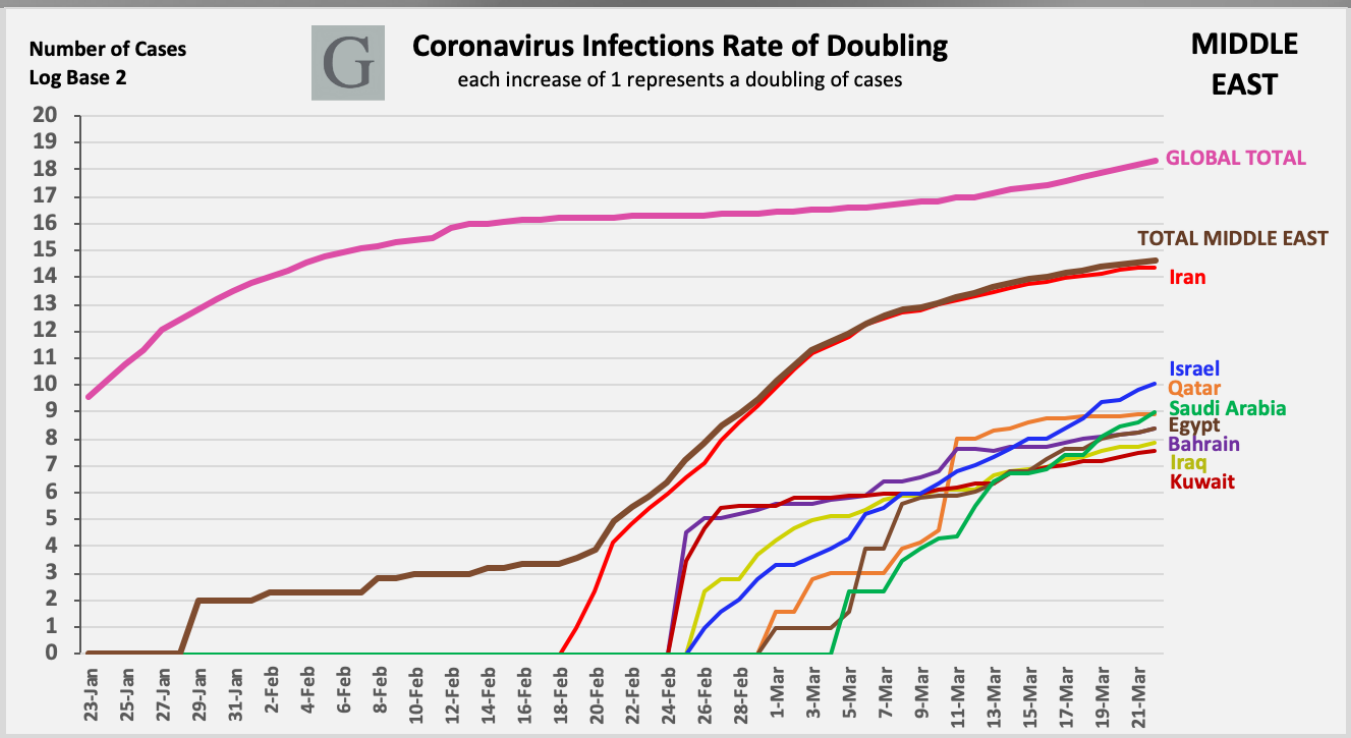


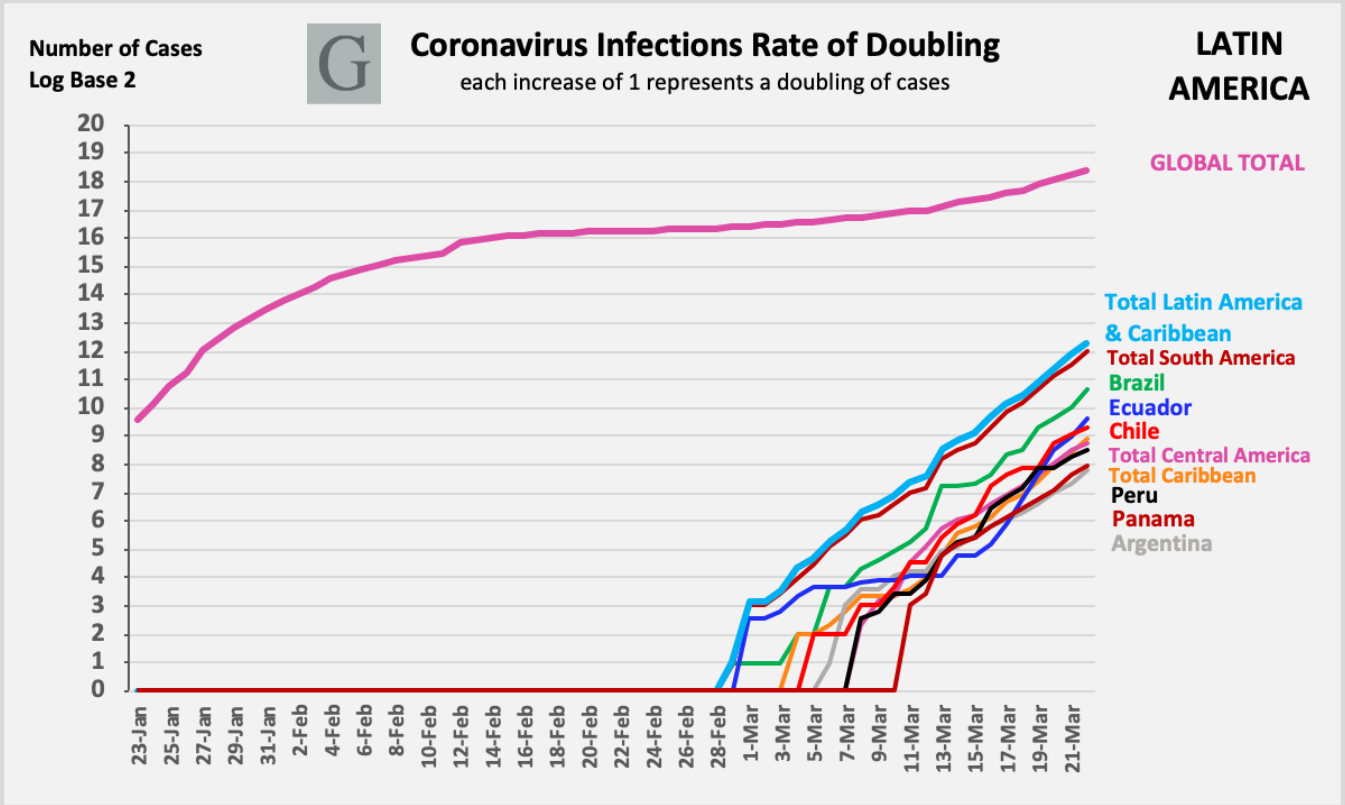

Note:

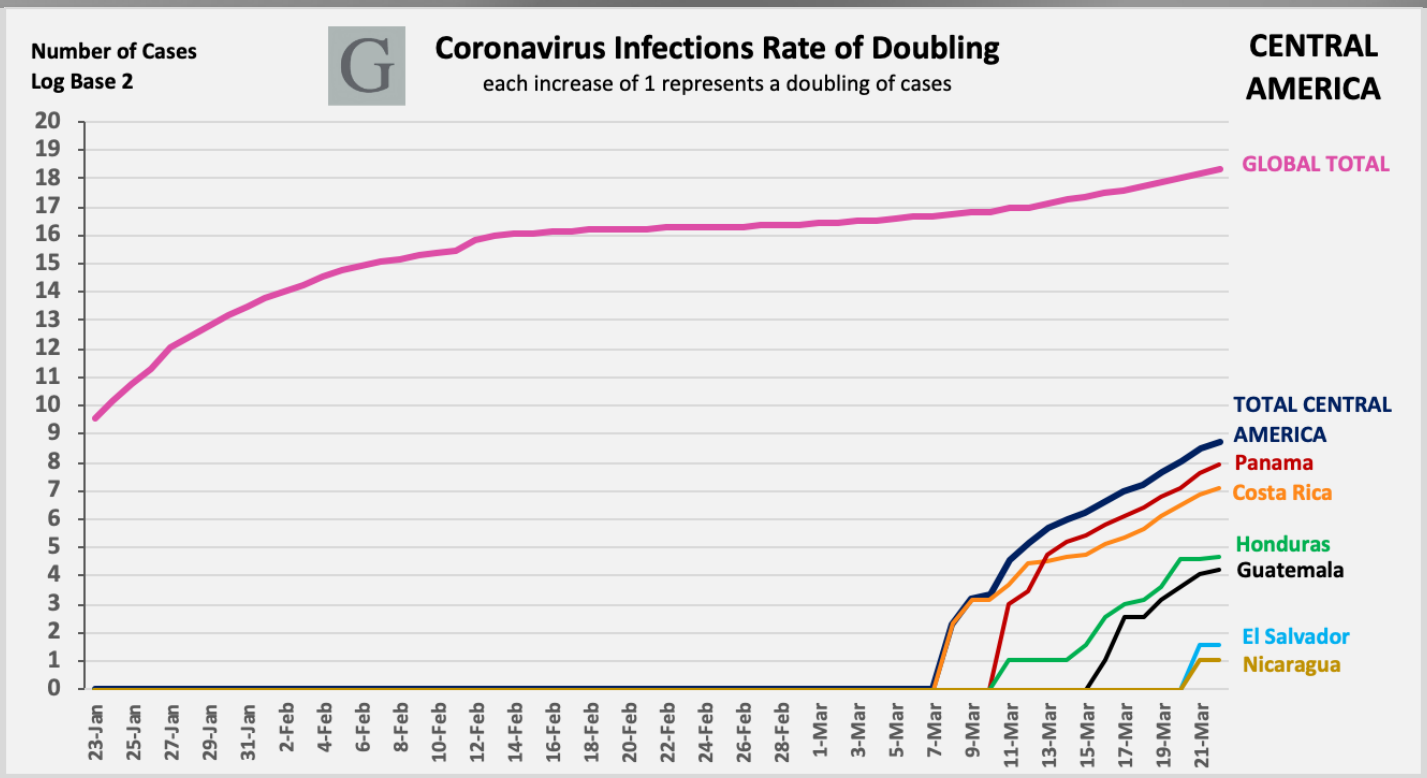
- **the slope of the curve indicates the speed at which infections are doubling**
- **the overall number indicates where the most cases have emerged**
  - the closer a jurisdiction's curve is to the bottom right hand corner, the smaller that jurisdiction's contribution to global totals
  - numbers are not on a proportional but an exponential scale
    - the difference between South Asia and Africa is 1 on the chart but this indicates South Asia has DOUBLE the infections of Africa ($2^1$)
    - the difference of 2 between Europe and the US indicates Europe has FOUR TIMES ($2^2$) the number of cases of the US

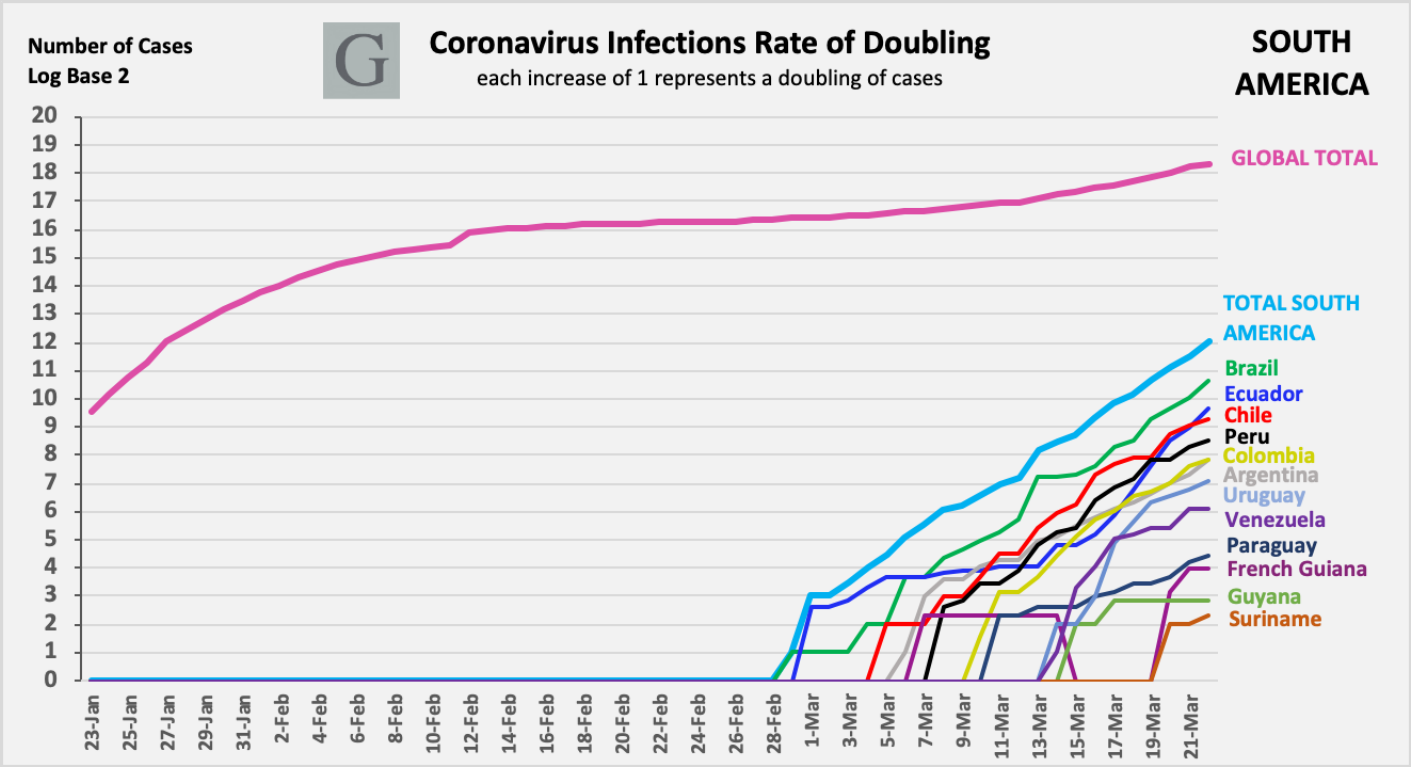

Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
EAST ASIA
Wuhan / Hubei**
China ex. Hubei
NE Asia Total
South Korea
SE Asia
Malaysia
Japan
Thailand
Singapore
Taiwan

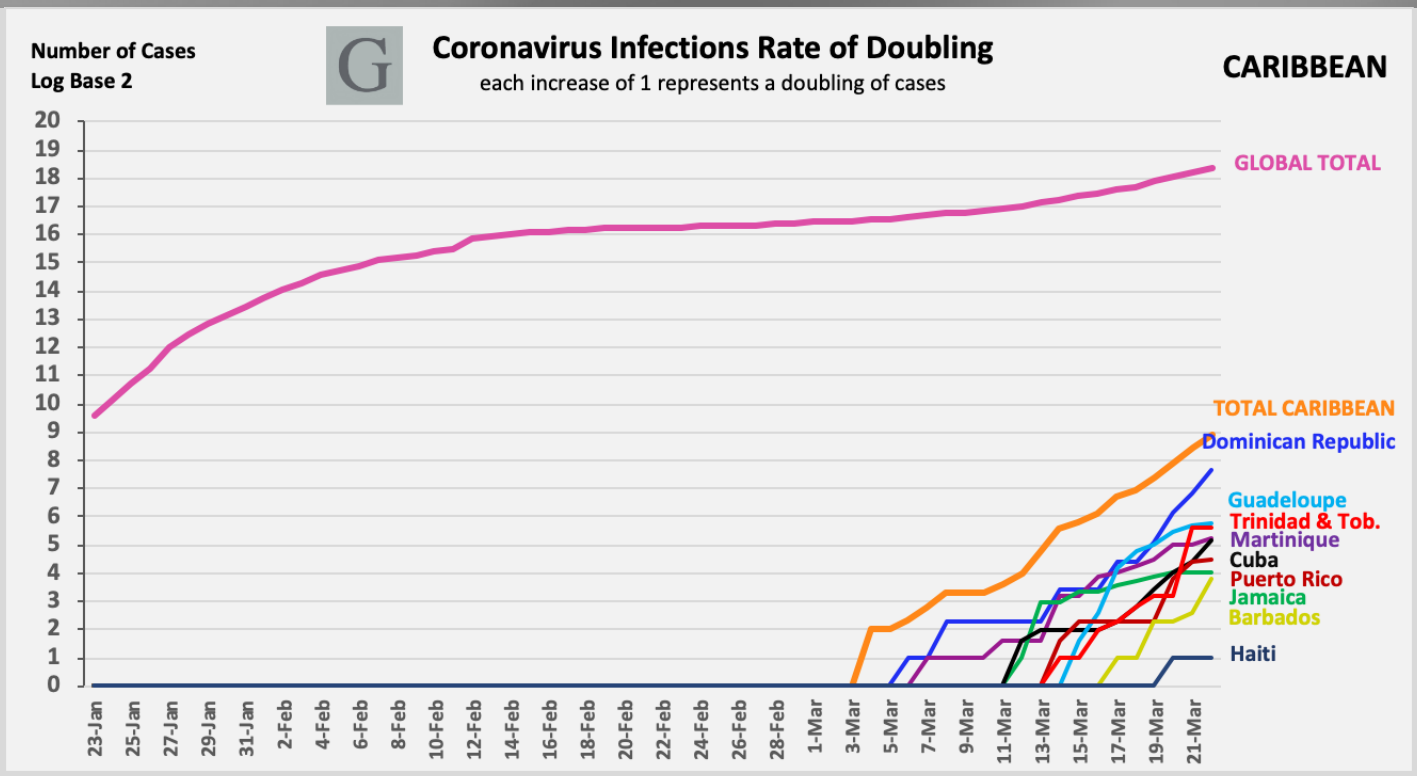

Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
SOUTHEAST ASIA
March 12 -
SE Asia Re-Accelerates
GLOBAL TOTAL
SE ASIA TOTAL
Malaysia
Thailand
Indonesia
Singapore
Philippines
Brunei
Vietnam

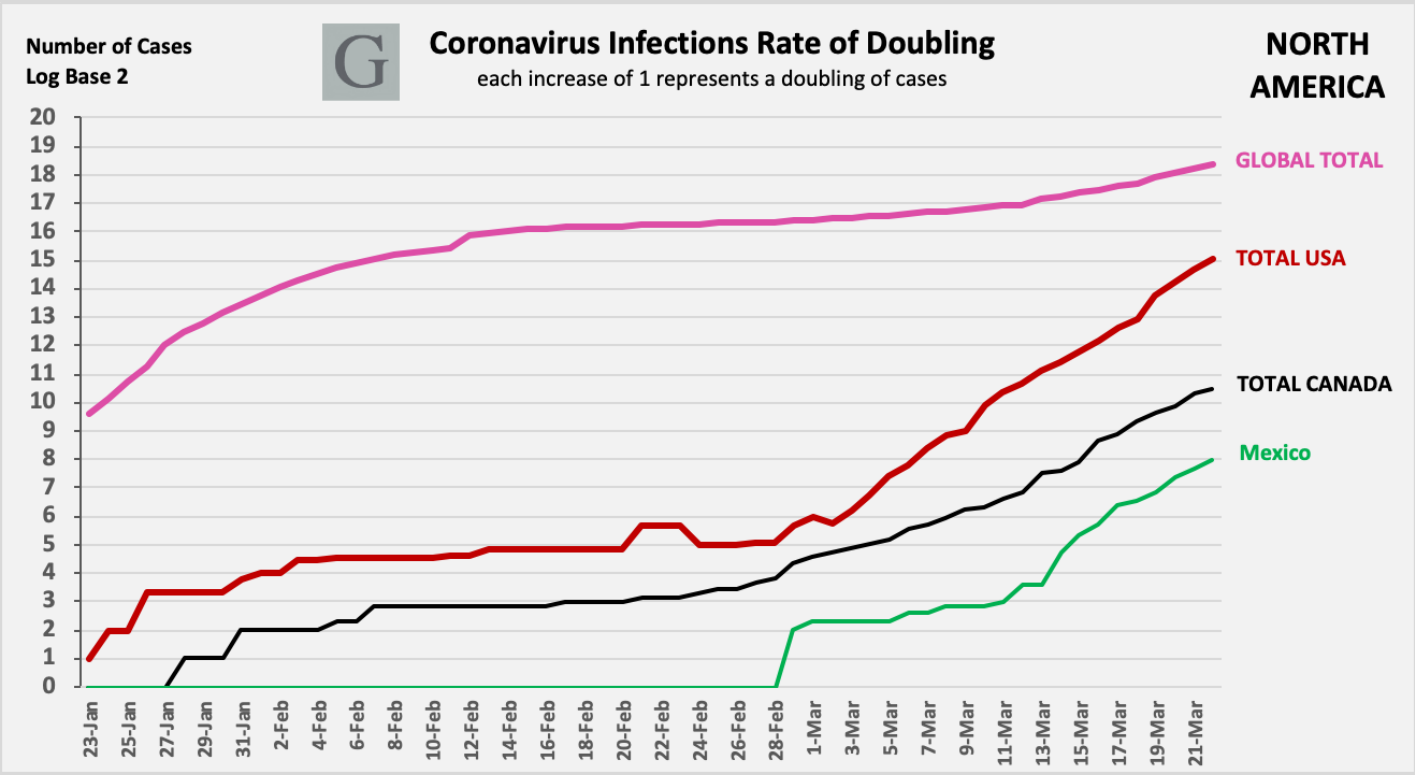

Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
MIDDLE EAST
GLOBAL TOTAL
TOTAL MIDDLE EAST
Iran
Israel
Qatar
Saudi Arabia
Egypt
Bahrain
Iraq
Kuwait

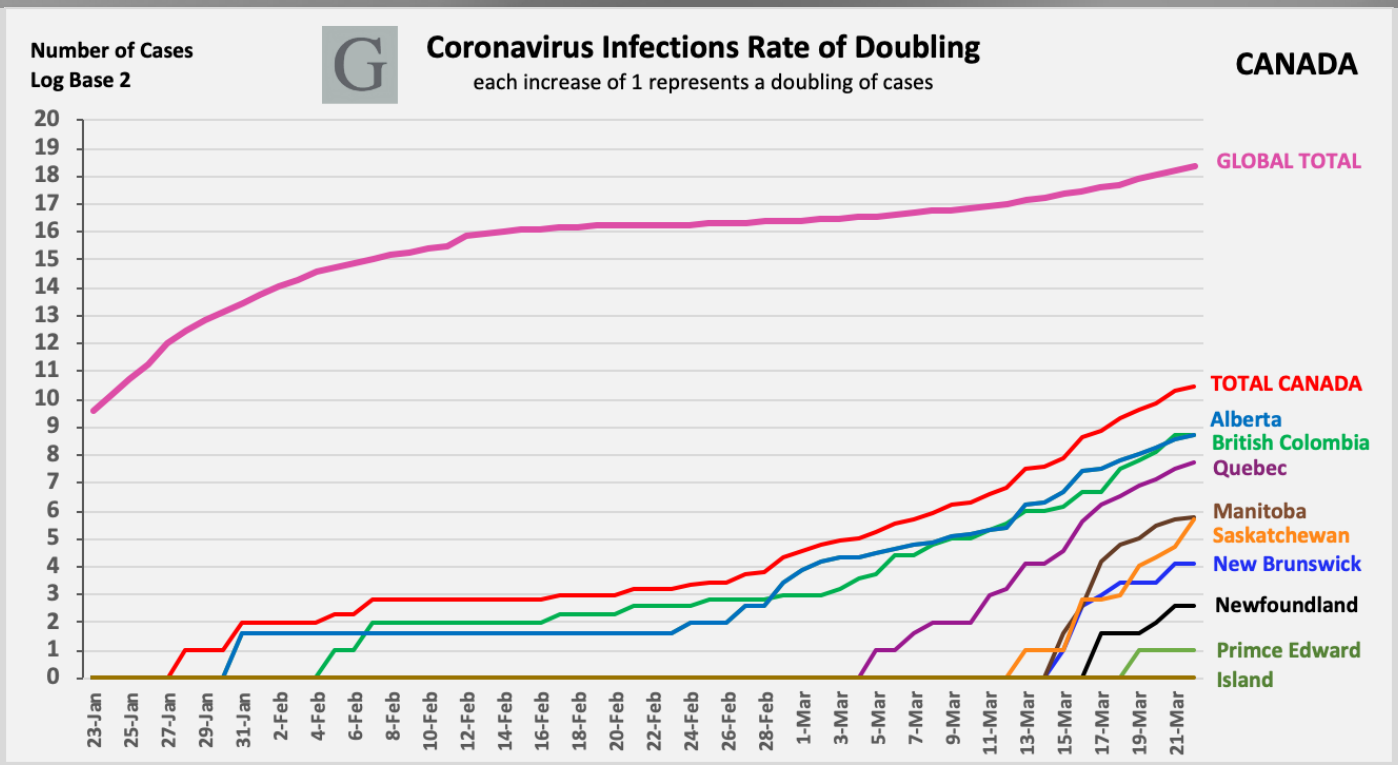

Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
LATIN AMERICA
GLOBAL TOTAL
Total Latin America & Caribbean
Total South America
Brazil
Ecuador
Chile
Total Central America
Total Caribbean
Peru
Panama
Argentina

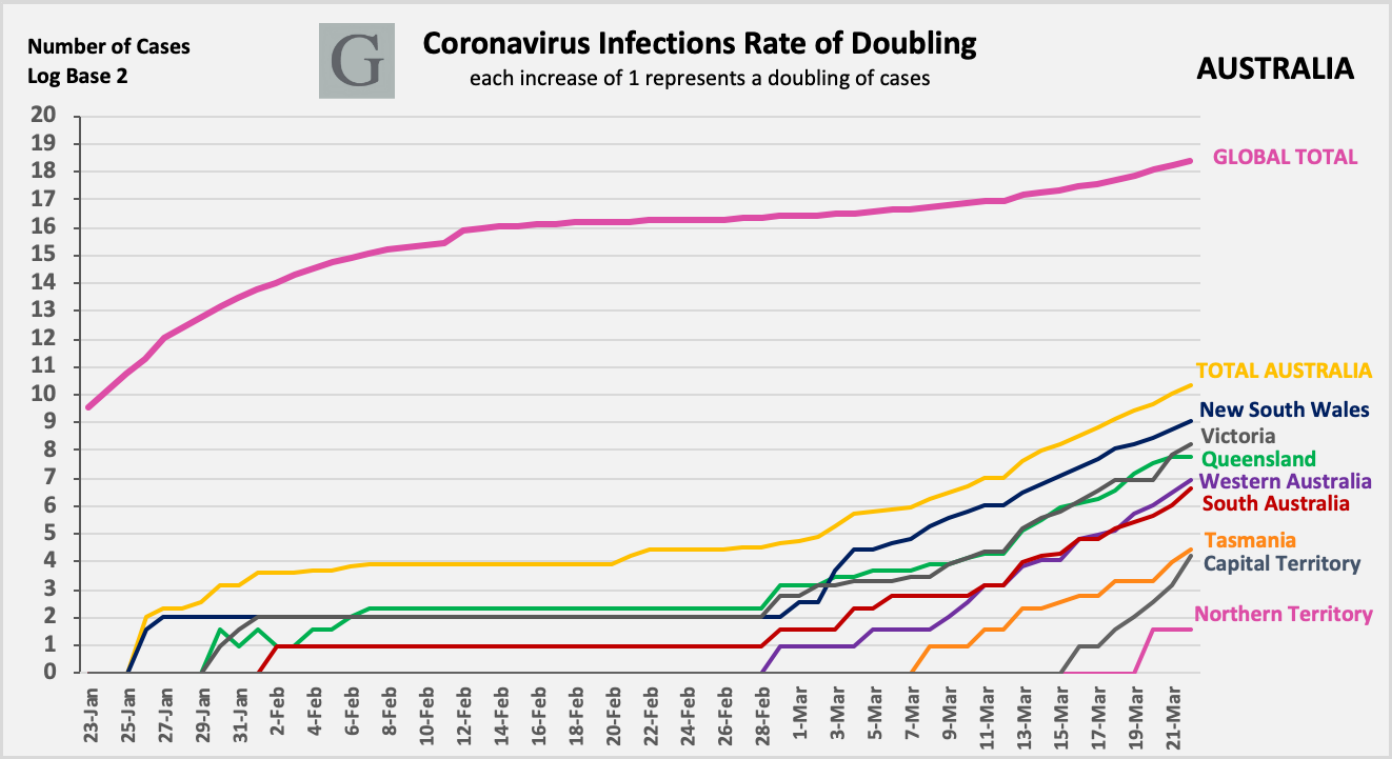

Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
CENTRAL AMERICA
GLOBAL TOTAL
TOTAL CENTRAL AMERICA
Panama
Costa Rica
Honduras
Guatemala
El Salvador
Nicaragua
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
23-Jan 25-Jan 27-Jan 29-Jan 31-Jan 2-Feb 4-Feb 6-Feb 8-Feb 10-Feb 12-Feb 14-Feb 16-Feb 18-Feb 20-Feb 22-Feb 24-Feb 26-Feb 28-Feb 1-Mar 3-Mar 5-Mar 7-Mar 9-Mar 11-Mar 13-Mar 15-Mar 17-Mar 19-Mar 21-Mar

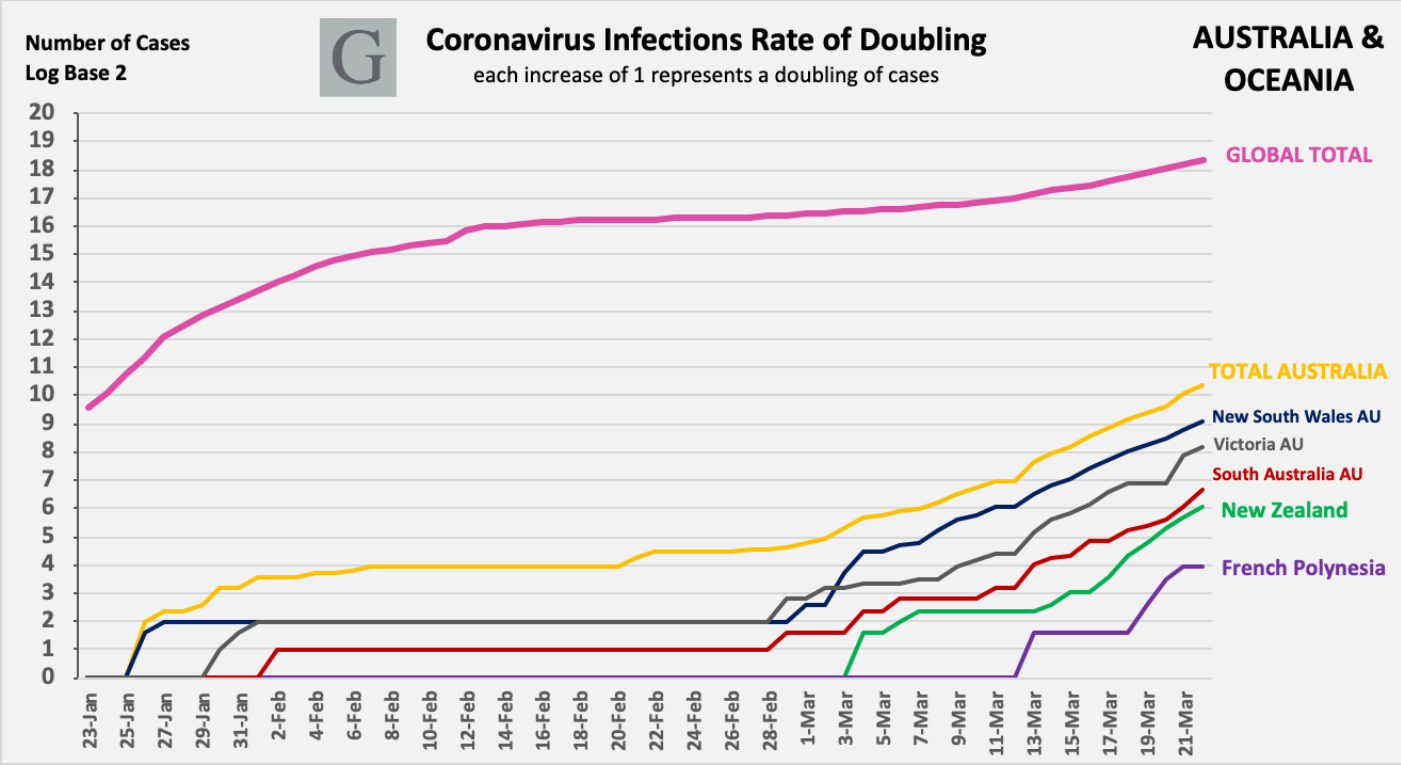

Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
SOUTH AMERICA
GLOBAL TOTAL
TOTAL SOUTH AMERICA
Brazil
Ecuador
Chile
Peru
Colombia
Argentina
Uruguay
Venezuela
Paraguay
French Guiana
Guyana
Suriname
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
23-Jan 25-Jan 27-Jan 29-Jan 31-Jan 2-Feb 4-Feb 6-Feb 8-Feb 10-Feb 12-Feb 14-Feb 16-Feb 18-Feb 20-Feb 22-Feb 24-Feb 26-Feb 28-Feb 1-Mar 3-Mar 5-Mar 7-Mar 9-Mar 11-Mar 13-Mar 15-Mar 17-Mar 19-Mar 21-Mar

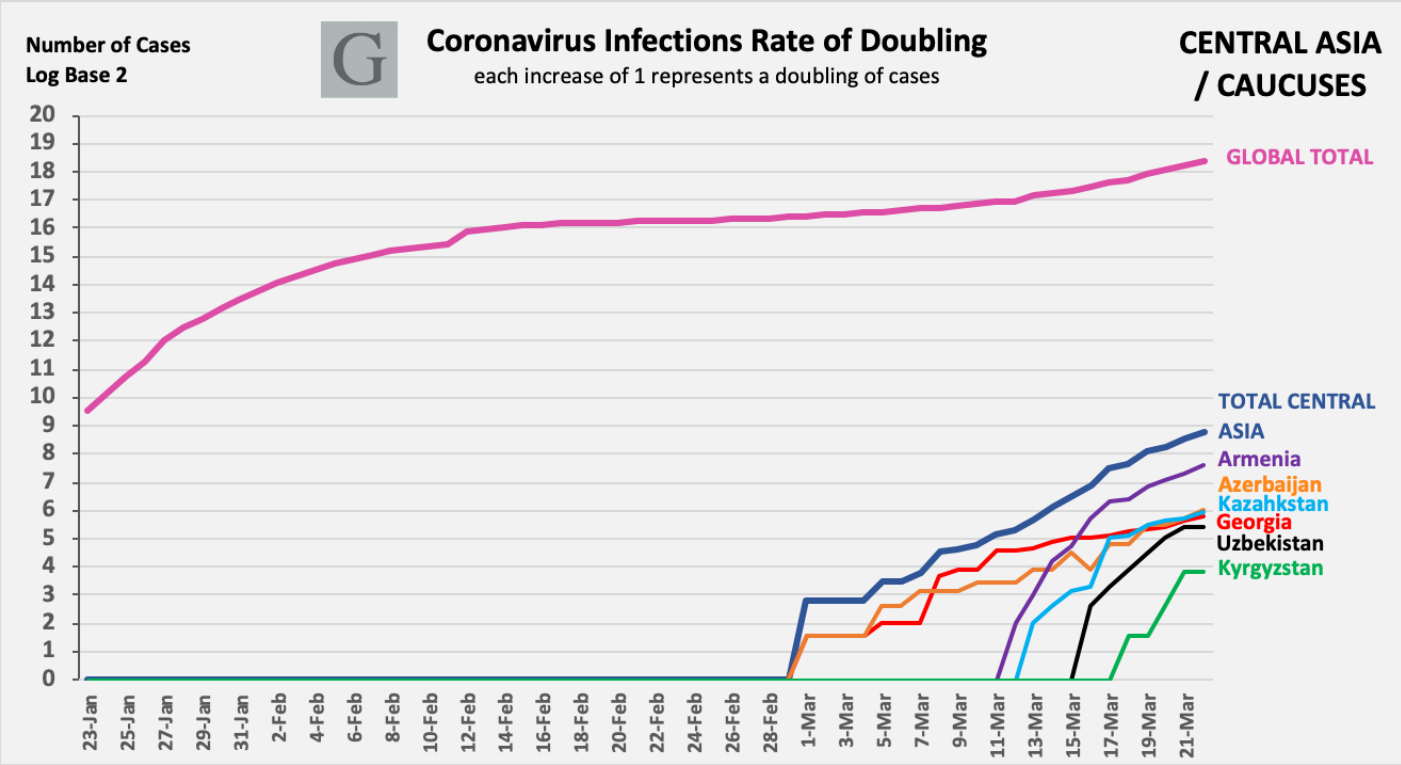

Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
CARIBBEAN
GLOBAL TOTAL
TOTAL CARIBBEAN
Dominican Republic
Guadeloupe
Trinidad & Tob.
Martinique
Cuba
Puerto Rico
Jamaica
Barbados
Haiti

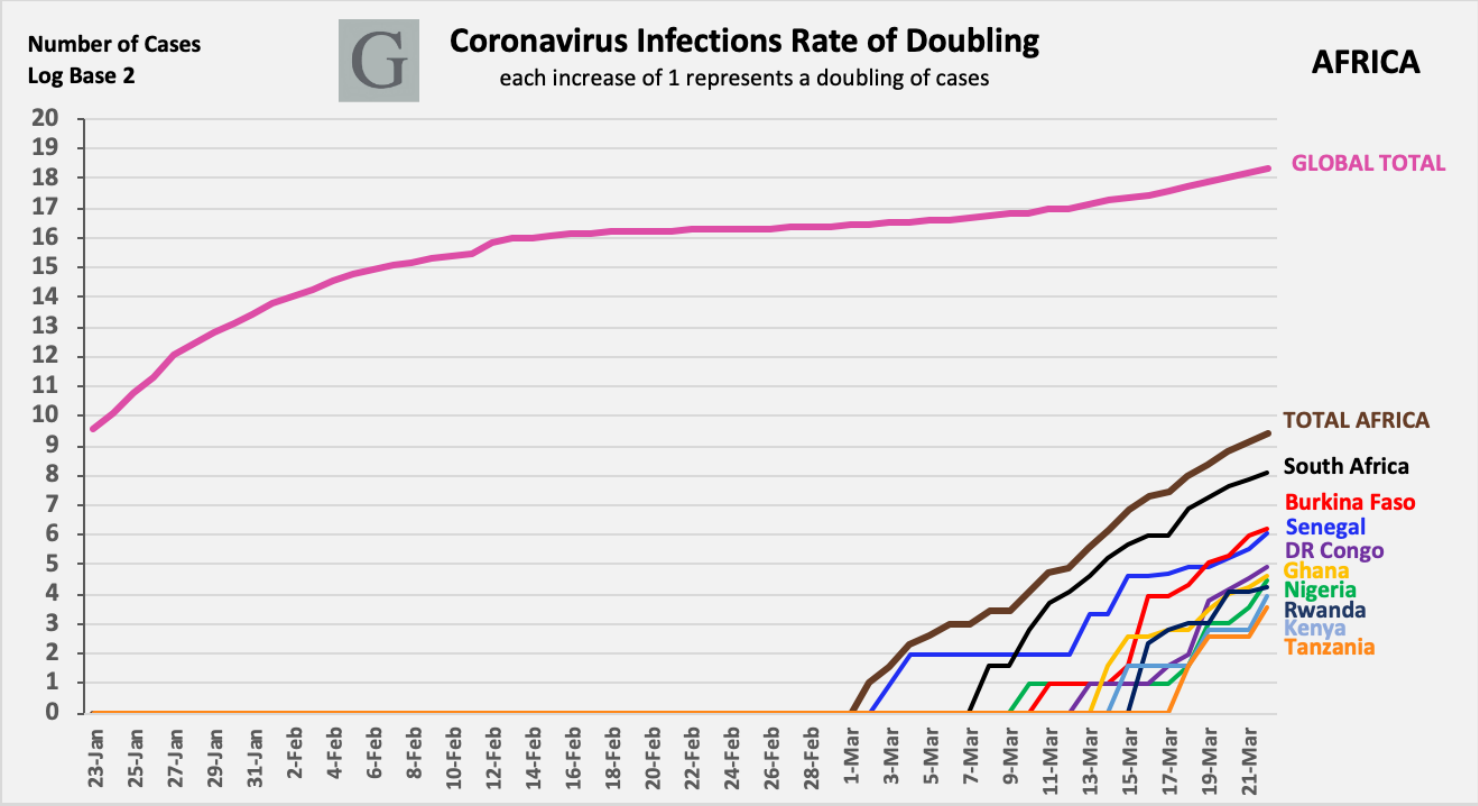

Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
NORTH AMERICA
GLOBAL TOTAL
TOTAL USA
TOTAL CANADA
Mexico


Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
CANADA
GLOBAL TOTAL
TOTAL CANADA
Alberta
British Colombia
Quebec
Manitoba
Saskatchewan
New Brunswick
Newfoundland
Primce Edward Island


Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
AUSTRALIA
GLOBAL TOTAL
TOTAL AUSTRALIA
New South Wales
Victoria
Queensland
Western Australia
South Australia
Tasmania
Capital Territory
Northern Territory


Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
AUSTRALIA & OCEANIA
GLOBAL TOTAL
TOTAL AUSTRALIA
New South Wales AU
Victoria AU
South Australia AU
New Zealand
French Polynesia
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
23-Jan 25-Jan 27-Jan 29-Jan 31-Jan 2-Feb 4-Feb 6-Feb 8-Feb 10-Feb 12-Feb 14-Feb 16-Feb 18-Feb 20-Feb 22-Feb 24-Feb 26-Feb 28-Feb 1-Mar 3-Mar 5-Mar 7-Mar 9-Mar 11-Mar 13-Mar 15-Mar 17-Mar 19-Mar 21-Mar


Number of Cases
Log Base 2
Coronavirus Infections Rate of Doubling
each increase of 1 represents a doubling of cases
CENTRAL ASIA / CAUCUSES
GLOBAL TOTAL
TOTAL CENTRAL ASIA
Armenia
Azerbaijan
Kazahkstan
Georgia
Uzbekistan
Kyrgyzstan
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
23-Jan 25-Jan 27-Jan 29-Jan 31-Jan 2-Feb 4-Feb 6-Feb 8-Feb 10-Feb 12-Feb 14-Feb 16-Feb 18-Feb 20-Feb 22-Feb 24-Feb 26-Feb 28-Feb 1-Mar 3-Mar 5-Mar 7-Mar 9-Mar 11-Mar 13-Mar 15-Mar 17-Mar 19-Mar 21-Mar




*This report is part of the analysis and advisory service we provide clients on COVID-19 dynamics. That service and access to all of our data is available to private sector clients for a $375 monthly subscription, and to government and public health entities for free. Bespoke research tailored to client interests and portfolios is also available on contract. Contact us at client.relations@greygcapital.com for further details.*

## About our Background in Preparing this Report

In leading the preparation of our COVID-19 analysis, Director of Research Mark Reedy draws on extensive field and analytical experience with pandemic prevention programs.

Mr. Reedy was a team leader for the United Nations on the ground in Equatorial Guinea, Central Africa, where he led the development of infectious-disease prevention and treatment programs on behalf of the Global Fund to Fight AIDS, Tuberculosis, and Malaria. Following this field leadership experience, he worked on a Gates Foundation / Clinton HIV-AIDS Initiative co-project called the Consortium for Strategic HIV Operations Research, where he designed systems to apply advanced data analysis for the assessment of epidemiological trajectory, clinical operations, and best practices in the fight against the Human Immunodeficiency Virus pandemic.

For details on material in this report, or to contract specific bespoke research of interest to you, please contact reedy@greygcapital.com