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The Corona Virus Emergency: A Quantitative View

Northfield Information Services Essay

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"For every bad, there is a worse"

Thomas Hardy

Preface

The corona virus pandemic represents an unprecedented challenge to all investors. The global situation is deeply uncertain and subject to change in conditions by the hour. However, Northfield owes it to our clients to say something we believe substantive and sensible about the crisis, rather than stay silent. It is likely that some readers will find the following discussion unpleasant and or even emotionally disconcerting. While the content has not been subjected to any formal peer review, multiple drafts of this document have been circulated to about sixty individuals, about half of whom are outside the Northfield staff. The thirty outsiders are a cross-section of experts in economics, risk management, actuarial science, financial regulation, and medicine. Many commentators both internal and external have made useful suggestions that have iteratively improved the article as new drafts were circulated on a daily basis this week. I thank everyone for their useful input and take responsibility for any remaining errors and omissions. We will distribute a formal version at a later date inclusive of the usual citation of background material and references.

Introduction

In the current atmosphere of crisis, it is critical that we help institutional investors have a logical rather than emotional basis for their actions. The first purpose of this article is to examine the likely outcomes from the current pandemic through a simple first order model. This model is not intended to compete with forecasts arising from public health authorities, but rather to frame the problem in a way that is transparent to financial rather than medical professionals, so that the output can be can easily integrated into their investment decision making. Many parameters of the pandemic model are highly uncertain and the available body of statistical data is changing from hour to hour.

The worst-case scenarios for global corona virus mortality are certainly unimaginable as a human tragedy. However, in the course of the twentieth century, humanity survived several incidents that were even more extreme (World

War I, 1918 Spanish Flu Epidemic, World War II). Our estimate of the worst case is that the entire world ignores the pandemic (obviously already untrue) *in which everyone in the world becomes infected with the corona virus,* leading to mass mortality of around 60 million. The estimate of 60 million deaths reflects the fact that the 3.4% mortality rate (current estimate of the World Health Organization) is highly skewed to an elder population which is large in the countries impacted to date. For example, the United States is about 4.3% of the world population but about 12% of the world population over age 65. When you break the observed mortality rate into the "under 60" and "over 60" subsets, you capture the fact that the percentage of persons over 60 in the developing world is quite small. There are approximately 815 million people 65 and over in the world or about 10.5% of the total population, so if the daily growth rate of new infections *within the sixty-five and over age group only* can be brought down to a low level (e.g. < 2%) the total mortality from corona virus reduces to a very low level. Later in our discussion, we will consider several different ways in which the 3.4% mortality rate might be influenced to be either very much lower (a small fraction of 3.4%) or as high as 14%.

While terrifying, the 60 million casualty estimate is about .8% of the current world population. While casualties of war are hard to tally with precision, that figure of .8% is around the higher end of the estimated range for each of the eight plus years of the World Wars. When we add in the massive number of deaths (median estimate 35 million) from the Spanish Flu epidemic of 1918, the maximum likelihood estimate for abnormal mortality for that year was about 1.9% of the then global population.

Let me try to put the corona virus emergency into this context. As of today, about ***10,000 people have presumptively died from the corona virus*** since first apparent case on November 17, 2019 in Wuhan. Over that same span of about four months about ***19 million people have died from routine causes*** (old age, disease, traffic accidents, military conflict) unrelated to the corona virus, out of the current global population of about 7.7 billion. As such, the *current impact of the virus* on mortality has been almost unmeasurably small. From a human perspective, the vast majority of *risk* is how great the loss of life will be if the virus is left completely unchecked and how soon. At a geometric growth rate of 8% per day (see discussion below for description and distinction from related statistical parameters), the entire world population would be exposed in approximately four and a half months. *If the growth rate* of exposure *is reduced to 1% per day, less than one in a thousand people would be exposed in the next year and roughly one in thirty people in the next two years, which is the widely suggested estimate of time to availability of a vaccine.*

As measured by the decline of the S&P 500 since the recognition of the pandemic implies that equity investors believe that the expected duration of the crisis is *on the order of seven months,* which is materially longer than has been the limited experience to date in China.

A First Order Model for the Pandemic

In Appendix 1, I present a simple "first order" model for tracking the pandemic. There is a key subtlety that must be understood about the model and why it is different than the range of pandemic statistics being widely reported. The real issue isn't the number of cases we know about, it's about getting a reasonable estimate *of the number of cases we don't know about,* because those are the people who are continuing to spread the infection.

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As countries increase the measures against spreading of the virus, the *true but unobservable growth rate* of the infection can't logically be going up. This means that if the reported growth rates are going up it has to be because we're discovering a larger portion of the existing pool of previously unknown cases. The faster countries discover the previously unknown infections, the faster that the spread will eventually subside. This leads to the somewhat *counterintuitive result that rapid growth in the number of reported infections may be a positive development* in that the number of existent but unknown infections is apt to be declining.

Within the model, you can think of three key input variables: the mortality rate of those infected (M), *the rate of spread of the infection per day (E)*, and the discovery of infected persons through testing which impacts the number of patients actively in treatment (A). A fourth parameter, the capacity of the health systems is presented as a condition of the extreme upper boundary on mortality. For any selected values of the parameters the potential for the virus to spread from infected to uninfected persons can be estimated along with a forecast for cumulative mortality.

I'll present a set of stylized facts to start which should motivate the design of the model. It is now believed that the first Covid-19 case was in Wuhan on November 17th and went unnoticed in a large industrial city. By January 22nd, 845 cases had been identified and there was an unknown number of people infected but who did not know. Over those first 66 days this is an exponential growth rate of about *10.7% per day (noted as E in the model).* Given that many infections probably went undetected at the time, the true rate of spread might have been much higher in those early days (maybe 15-20% per day). There was also a spike in reported cases between January 22nd and January 31st when widespread testing went into effect, with a daily growth rate of about 35% as previously undetected infections became known. Chinese health authorities also changed the criteria for *presuming* someone was infected in mid-February which also caused a one-time spike in the apparent growth of cases. It should be noted that Wuhan is a city of eleven million people with an area of 3820 square miles. This works out to a population density of about 3,000 persons per square mile. By contrast, the population density of the world is about 317 persons per square mile of habitable land.

Please note that the current daily exponential growth rate ("E") is not the same mathematical quantity as the exponential growth rate of an infection across patients, which is widely referred to as "R" in medical studies. The two concepts are similar and are a frequent source of confusion. The R parameter refers to how many new infections might be caused by interaction of an infected person and uninfected persons. For example, if R is 2, then one infected person is expected to infect two others. Those two infected persons would be expected to infect two each, or four. So in two transmissions from a single infected person the count has grown to seven (1 + 2 + 4). While the R value for the corona virus has not been well established, early indications are that it is closer to R for common flu (R = 1.2) than for some other illnesses. For Ebola, R has been estimated in the range of 2 to 2.5, and for measles in excess of 15.

To get a useful estimate of the likely extent of the pandemic, *what we really care about is how many people are continuing to spread the virus.* This consists of two groups, those that don't know they are infected and those that do know but continue to interact with others. The mathematical model presented in the appendix is designed to infer the number of "infected but unaware" persons. We define a particular time interval of interest (e.g. two weeks) and then estimate the number of deaths expected in that period based on the information available at the start of the interval (number of known infections) and the *assumed* mortality rate. If the number of deaths during the interval is larger than was expected, the additional mortality is presumed to be the result of infections that had *not been identified by the interval start date.* To date, the incubation period of the corona virus (from infection to the onset of symptoms) has averaged around five days, while the average period between infection and resolution (recovery or death) has averaged around fourteen days. There is some evidence of longer spans but these analyses are clouded by the potential for a recovered individual to have been separately infected again.

The second quantity is the number of people who are infected and *knowingly* continue to interact with uninfected persons, essentially “breaking quarantine.” Several published medical studies on quarantine compliance indicate that the effectiveness of isolation ceases to materially improve once compliance is at 90% or above. A just released study of corona virus done by Imperial College assumed a United Kingdom compliance rate of only 75% which unsurprisingly leads to very high estimates of infection and related mortality.

So far the World Health Organization published assumption of mortality rates is 3.4% of known cases of infection. As noted above, this is probably a much too high estimate for the entire world. The rate of mortality has seen wide cross-sectional variation across countries. This is likely to be the result of different prevalence of underlying medical conditions (heart disease, diabetes) particularly among the elder population and smoking, as well as the availability of high-quality medical treatment. It should also be remembered that not everyone who is exposed to the virus actually becomes infected. While reliable data on this point is scarce, certainly some significant portion of the population (maybe half) does not become infected even with exposure. The most recent published “worst case” estimate for the United States from the Center for Disease Control is for 1.7 million deaths, about .5% of the population.

A particularly interesting example of the variation in mortality rates is the situation of the Diamond Princess cruise ship which was held at sea for about two weeks with an unknown number of infections already existent. After disembarkation, 712 passengers and crew were diagnosed as positive for corona virus, a rate of about 20% of the 3500 persons onboard. Of those 712 infected persons, only seven deaths have resulted. This is a somewhat surprising result given the typical age distribution aboard cruise ships which are heavily weighted toward older passengers.

One factor that is often cited as having the potential to greatly increase the mortality rate (i.e. 7% to 14%) is that if the infections become sufficient widespread, hospitals will run out of the capacity to care for infected patients. As of today, the percentage of infected patients in “serious” or “critical” condition is around 6% of active (known) cases globally but only 1% in the USA. While the “breaking point” of hospital capacity would vary widely from country to country, the worst-case scenario is that patients that are seriously ill from corona virus would not receive medical care and the mortality rate would rise materially. More likely due to the infectious nature of the illness, corona patients might receive preferential treatment over patients with non-communicable conditions (e.g. cancer or diabetes). As such, there could be an indirect increase in mortality that would not be immediately attributable to corona virus infection.

Implications for Long Horizon Investment Institutions

The impact of the variation in mortality rates from conflict casualties on financial markets is summarized in this essay from 2015, https://www.northinfo.com/Documents/646.pdf. Even if the implausible worst case of 60 million deaths were to come about, this would represent about a 9% increase in global mortality over a ten-year time horizon (much smaller than multiple years of sustained large-scale war). When we did the war study cited above, the correlation of decade long returns with the variations in mortality rates was on the order of -.35 (mortality rates up, equity market returns down).

As a concept, *risk is always in the future.* Volatility of asset values has occurred in the past, and volatility of asset values will occur in the future, but there is no risk in the past. What is done is done. The problem is that most organizations equate past volatility and future risk in wholly unsound ways. The potential for *rare* extreme events of any kind (think Pompeii in 79 AD) is routinely ignored by financial institutions. Northfield has persistently pointed this out to clients in work like this newsletter article on proper risk assessment, https://www.northinfo.com/Documents/802.pdf. Our systems can routinely incorporate the potential for rare extreme events as described in https://www.northinfo.com/documents/901.pdf.

Let's walk through the financial algebra for a moment for a typical institutional investor. Initial assumptions are:

a. Future equity returns would be 6% in an average year with a volatility of 15% (this is a geometric mean return of 4.875%) or a cumulative return of 59% over a decade
b. Future fixed interest returns would be 2% with a volatility of 7% (this a geometric mean return of 1.755% annually)
c. The correlation of equities and fixed interest returns is .3
d. The investor is 60% equities and 40% fixed interest by asset value
e. The total portfolio expected arithmetic return works out to 4.4% with a volatility of 10.67.
    a. This equates to a geometric mean return of 3.83% annually or a cumulative return of 45.6% over a decade

So, if an investor had a 10-year time horizon and the pandemic effects are similar to war, the expectation of the cumulative return of their portfolio would decline by -1.44%. This arises from the expected return of 45.6% over ten years times the 9% total increase in mortality over the decade times the correlation coefficient of -.35 from the 2015 study. So the expectation of cumulative return over a decade declines from 45.6% to 44.16% which is a net geometric mean return of 3.72%. As you can see, the expectation of the geometric mean annual return on the investor's portfolio *has declined only by a very modest one-tenth of 1% per annum,* conditional on an extremely grim scenario for mortality.

There are also other considerations at play which suggest this is a pessimistic assessment in other ways as well. War destroys physical capital (factories, roads, trucks) and war is expensive to wage, heavily impacting bond markets. In one year of World War II the US military budget reached 35% of GDP. Nothing like that is plausible in this situation. Even the massive financial steps just proposed by the US government represent a one-time event of about 4% of GDP. War casualties are also skewed toward younger persons who would otherwise be the most productive members of an industrial society. The corona virus mortality is skewed toward the elderly. Total per capita income in the US tends to almost equal the overall median for persons between 60 and 80, but most of this income is *unearned* income (private pension payments, government payments, and investment income). As such, the economic impact of each death is smaller.

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As physicist Niels Bohr said, "it is always hard to forecast, especially about the future", so I usually decline to prognosticate. However, it seems that the current crashing of markets around the world cannot be explained by rational actions of long-term investors conditioned on the only available data on large variations of mortality rates. We must therefore fall back onto a couple possible explanations.

1. Investors are very short sighted so that nobody is thinking logically about 10-year horizons right now. Obviously, if you think about a worst-case scenario of 60 million dead over a span of a few months it is *very, very, scary,* as are the likely economic impacts of virus mitigation efforts.

2. Investors switching from risky assets to riskless assets (e.g. cash, sovereign debt) have a relatively simple decision as they don't have to decide what the risk-free asset is. However, investors choosing to move from riskless assets to risky assets have to make decisions about what risky assets they believe are appropriate. This means that selling is always faster than buying which leads to crashes which are eventually made up by long growth periods (e.g. the GFC was followed up by an eleven-year bull market in global equities). A similar pattern of a long expansion was experienced in the "roaring 20's" after the Spanish flu pandemic in 1918 was roughly coincident with the end of World War I.

3. Investors are relatively indifferent to small changes in their wealth level but extremely sensitive to larger changes in wealth so the current a large amount of selling by investors may be partly logical but mostly not. You can think of this as various processes defined by Wilcox (Journal of Portfolio Management, 2003), Barro (National Bureau of Economic Research, 2005) and Gabaix (NYU, 2009, http://people.stern.nyu.edu/xgabaix/papers/tenPuzzlesAERPP.pdf. You can also make a "behavioral" argument in the form of "Cumulative Prospect Theory."

Investor Risks in the Short Run

As described in the section above, one explanation for the large recent decline in equity markets is that investors are not thinking long term, but rather are thinking about their portfolio assets in a "one day at a time" fashion. While Northfield takes no position on the likely success or failure of measures taken by various governments to stimulate economic activity and calm investors, we can certainly shed light on daily variations in investor confidence.

To assess very short-term risk, Northfield has maintained our US Short Term risk model since 1997. In this approach, a statistical factor model is adjusted daily for changes in the implied volatility of options traded on equities in the US. A mathematical process then maps the day to day changes in security level volatility across the factors of covariance so that changes in market conditions are applied to all securities, not just equities in which options are traded. Security coverage includes all non-US equities traded on US exchanges in ADR form, so the model does the majority of most large publicly traded firms globally. Mathematical details of the model are presented in https://www.northinfo.com/Documents/534.pdf which was subsequently published in 2005. Although volatility levels are presented in the usual annualized units, the intended time horizon for the risk forecast is the next trading day.

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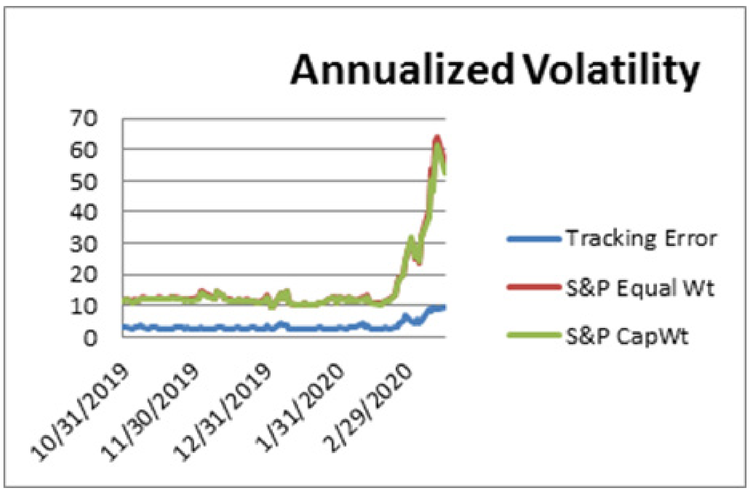
The chart below shows the expected volatility of the S&P 500 on an equal weighted basis, the S&P 500 on the conventional capitalization weighted basis, and the tracking error of the two portfolios. The time period is from the end of October 2019 through to March 16th, 2020, at a daily frequency.

The chart shows that the volatility values for both series increased roughly five-fold over the sample period. Peak annualized volatility values of over 60% were observed on March 13th but decreased to 52% for cap weighted index and 55% on the equal weighted index by March 16th. As is common in crisis periods, correlations have increased with the *expected* correlation of the two portfolios going from .968 at the start to .984 at the end.



Inference on the Length of the Pandemic

We can use the above information to make a useful inference about US equity investors *expectations* of the persistence of heightened risk from the pandemic. Let's assume that at the start of the period, investors believed the expected total return of the S&P 500 was 6% with a known dividend yield of 2%, implying a growth rate of 4%. We will also assume that the market was fairly valued implying that expected returns and required returns were equal.

Over the period of the sample, the expected volatility of the S&P 500 increased by roughly 40 percentage points. We assert that rational investors would respond by increasing their required rate of return by 6.7% per annum (40/6) for the period of heightened risk. The denominator scalar of about six is derived from the implied risk boundary of an investor's original risk level. A detailed explanation of this analysis will be presented in the Northfield online webinar on March 26th, 2020 (see "Events" at www.northinfo.com).

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In a Gordon dividend discount model, we obtain:

P(start) = 1 / (.06 -.04) or $50 per $1 of dividends (2% yield)

If we now add an increment to the required return for the heightened expected risk, we get:

P (now) = 1 / (.127 - .04) = $11.49

So, if investors believed that the massively heighted risks would be permanent, the S&P 500 should have fallen by 78%, not the observed roughly 20%. To get the 20% drop to make sense, the *long term* required rate of annual return must increase from 6% to 6.5%. Using our "rule of six," this means that investors are pricing the market as if the long term expected volatility increased by 3% (e.g. from 12% to 15%). If we assume that the median survival time for a publicly traded firm in the USA is 20 years (consistent with diBartolomeo, *Journal of Investing*, 2010) we can infer how long investors expected the heightened risks to last.

The underlying model in this paper is based on the contingent claims concept from Merton (JOF, 1974). Essentially it argues that stockholders have two options that lenders don't have. One is a call option on the assets of the firm which can be exercised by paying off the firm's debt. The other option is a put option associated with the limited legal liability of shareholders. If the assets of a firm fall sufficiently, the shareholders can walk away transferring the assets to lenders. The "underlying" of these options is the assets of the firm, and the strike price is approximately the value of the firm's debt. Using option pricing models, we can solve the relationships for the expected expiration date of the options which is the median of the expected distribution of firm survival time.

Using the mathematical property that variances are additive, we obtain an ***implied* length for the pandemic of approximately seven months.** Please note that this analysis ignores the increase in the S&P dividend yield over the sample period from 2% to about 2.4%, and the potential loss of a modest amount of total return (-.11) over long horizons as previously discussed.

Conclusions

It should be clear that the corona virus pandemic is a very serious matter. Allowed to spread entirely without limit the death toll would be massive in number and comparable to the peak year of World War I or World War II as percentage of the population. However, it is also obvious that steps have already been taken to slow the spread of the infection, even if those efforts have seemed laggard in some countries. We have presented a simple algebraic model with which any investor can track the progress of the pandemic.

While we do not take a position on the matters of morality, ethics, or public policy associated with the pandemic, it is clear that even worst case scenarios for related mortality and health care expenditures, the economic impact for financial market investors should be minimal when observed over long horizons of ten years or more. For investors, the corona virus pandemic itself is not the end of the world. Assuming global trends hold our maximum likelihood estimate from the model is for less than 40,000 deaths which is not sufficient to represent material threat to global financial stability. By comparison, the Asian tsunami of 2005 killed over 300,000.

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Much greater risk to investors and the world economy at large comes from clumsy handling of mitigation measures than from the virus itself. Of greatest concern is that many organizations, companies, and governments have been engaged in an undesirable game of managing the "optics" of the situation. Whether out of concern for liability in litigation, the ability to enforce business interruption insurance, political expediency, or reputational issues of being *thought* less prudent than their cohorts, *the actions of many entities are being driven by a desire to be perceived as managing risk as opposed to actually managing risk in response to factual information and analysis.*

Appendix 1: A Model for Tracking the Pandemic

Let's first write down our equations and define our variables

S(t) = U(t) + C * A(t)

A(t) = T(t) – L(t) – D(t)

S(t) = the count of people currently spreading the virus as of day t

U(t) = the count of people who are infected but don't know it as of day t

D(t) = the cumulative number of deaths up to day t

T(t) = the total number of cases diagnosed up to day t

L(t) = the total number of infected persons who have recovered by day t

A(t) = the active number of cases (i.e. persons infected but alive, presumably in treatment) on day t

E = the decimal rate of exponential growth of the number of infected persons who continued to spread the corona virus as of 14 days ago

M = the mortality rate

C = the rate of "cheating of quarantine"

Values for T(t), L(t), D(t) and A(t) are being published in "near real time" on websites like Wikipedia and Worldometer. Now we need an expression for a key variable, the number of people spreading the virus because they don't know they are infected.

Our first step is to consider that they must have been a certain number of "infected but unaware people" fourteen days ago who went on spreading the virus.

U(t) = U(t-14) * (1 + E)^14 - (T(t) – T(t-14))

This expression simply says that the number of people "infected but unaware" as of day T is equal to the number of unaware persons to whom we think the infection was spread, minus the number of people who were diagnosed with the infection during the 14 day interim (i.e. people who were infected and became aware of it). So now we just need an estimate of how many people were infected but unaware as of two weeks ago.

U(t-14) = (D(t) – D(t-14)) / M - A(t-14)

The logic of this expression is that the number of people dying over the past two weeks should reflect both the people who were infected and knew it A(t), and the number of people who died who had been "infected but unaware." We therefore infer the total number of infected persons as of two weeks ago from the deaths over the interval. We then subtract the known active cases as of two weeks ago to get the number of "infected but unaware" cases as of two weeks ago.

Example

Let me now do a fully worked example as of *March 16th based on **global** figures from Worldometer as of 1:25 PM US Eastern time.* For the purposes of illustration only, we will use a 3.4% (.034) mortality rate and a "cheating" rate of 3% (.03). In the subsequent three days, the cross-sectional variation among countries increased, with China reporting their first two days of zero new domestic infections, and a significant slowing in South Korea. The US, Iran, Italy and Spain continue to report an acceleration of growth *in the number of known infections* much of which is hopefully attributable to increased testing.

A(t) = 98,371

T(t-14) = 90,443

D(t-14) = 3,117

A(t-14) = 39,218

The daily exponential initial period was in China was "greater than" 10.7% but with all the various mitigation steps being taken around the world (lockdowns, travel bans, increased testing) the current rate is probably materially below 8% per day. Let's do the arithmetic 8%, 6%, and 4%. As a matter of public policy, there are three "levers" available. You can try to bring down the rate of spread (E) by lockdowns, closed borders, and social distancing (most countries). You can decrease the mortality rate (M) by keeping most likely to die (elderly, pre-existing medical conditions) isolated from the infection, which seems to be the game plan in the UK and Switzerland. You can also increase testing so cases go from "infected but unaware" (U) to "active" category (A) as South Korea has aggressively pursued.

A key to understanding these practical implications of these examples is whether our chosen values for the exponential growth rate of infections are reasonable in ranging from 4% to 8% per day. The first thing to recall is what we care about is how fast the virus will spread in the future, *not how fast it spread in the past.* We also need to be cognizant that the *actual* rate of spread of the infection logically *must be below the rate of reported spread* once testing is *widespread.* This boundary condition exists because testing will capture at least some number of infected persons who would otherwise have gone unnoticed because they were not showing symptoms. From January 31 to March 17th (10:24 AM Eastern time), the number of global reported cases rose from 11,950 to 188,423 which is a daily growth rate of 6.2% per day. Again, the differences in testing rates are extreme. According to a March 20th report from Reuters, the highest rates of testing are in Norway and South Korea with both at over 6000 tests per million of population. By contrast the US and numerous other countries are below 150 tests per million of population.

We can also consider the decline in the rate in terms of a simple "change in the change" or the second derivative of the case count. The exponential growth rate in reported cases averaged 10.7% between November 17th and January 31st with the midpoint day being December 20th. In the subsequent period from February 1 to March 17th, the reported growth rate is 6.2% with the midpoint day being February 23rd. The interval between December 20th and February 23rd is 65 days during which the daily growth rate dropped by 4.5%, for an average of .07% per day or roughly 2% per month. If that rate of decline continues, the global rate should be close to zero in about three months after February 23rd. This is consistent with the recent experience in China in that new infections being reported had slowed to a trickle by late February (see graph below). *As of March 17th, this leads to an estimated global growth rate of 4.4% per day currently at the global level and an exponential daily growth rate of about 5.3% as of fourteen days ago which is what is required in our calculation.*

One could reasonably argue that our example is downward biased in one important respect. The spread of the virus has virtually stopped in China which now accounts for only about 31% of total worldwide cases, with 69% of worldwide cases occurring outside the country. This would imply that the exponential growth rates of 8 to 14%. But these higher growth rates would now apply to the "ex-China" case counts. The aforementioned cross-sectional variation in mortality rates to date (8% in Italy, 1.5% in the USA) would make the choice of a mortality rate more uncertain as we reduce sample size.

It should be noted that it is possible that the second derivative may be closer to zero for a while, as China has effectively reduced new cases to the lower boundary, while the total case count in some countries continues to grow rapidly. W*e expect to see downward trend in the growth rate stop or reverse to an upward trend for a while as more countries ramp up testing.*

Japan is an anomaly, where relatively few restrictions on movement of the population have been put in place. The reported case count remains low as does the number of deaths. One possible explanation is that the Japanese public health effort was successful in tracking down cases early, so the pool of persons "infected but unaware" remained small.

U(t-14) = (7067 – 3117) / .034 – 39,218 = 76,959

<u>For 8% per day growth</u>
U(t) = 76959 * (1 + .08)^14 = 226, 042
S(t) = 226,042 + .03 * A(t) = 226042 + 2951 = 228,993

<u>For 6% per day growth</u>
U(t) = 76959 * (1 + .06)^14 = 173,996
S(t) = 173996 + .03 * A(t) = + 2951 = 176,945

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<u>For 4% per day growth</u>

$U(t) = 76959 * (1 + .04)^{14} = 133{,}267$

$S(t) = 226{,}042 + .03 * A(t) = 133267 + 2951 = 136{,}216$

So as of now, the number of people who are infected and still likely to spread the infection to others is roughly comparable to all the cases identified so far. The growth rate of deaths (log scale) indicates that there may still be a very large number of undiagnosed cases. The sharp rise in active (under treatment) cases is likely to be a positive development. It means that the number of identified cases is increasing rapidly implying that the number of known cases may be starting to catch up with the number of undiagnosed infections.

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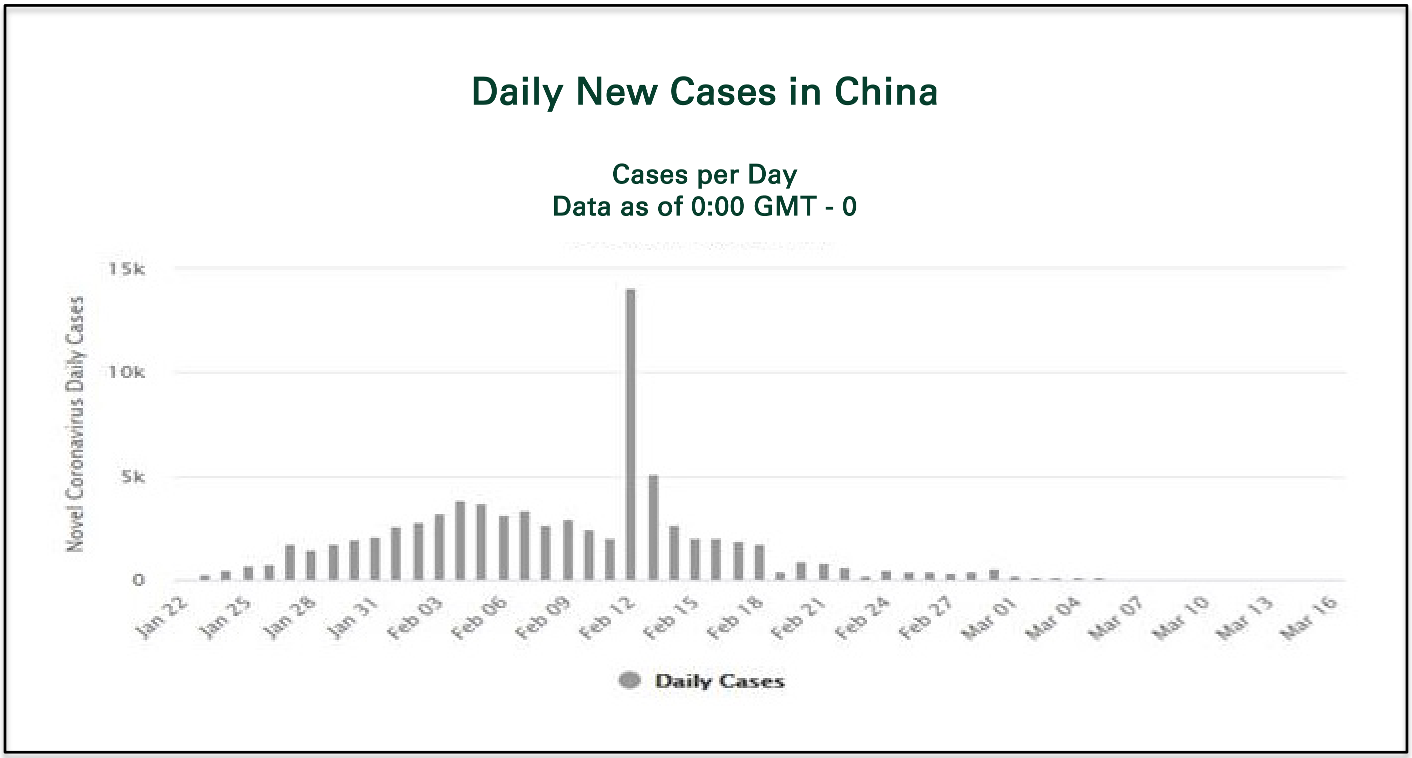

The key question is whether the rate of spread of the corona virus will decline in other countries on roughly the same timeline as it did in China and is doing in South Korea. The worst scenario of global exposure leading to mass death remains. While there is no guarantee that current trends will hold bringing the pandemic to a close, it is easy to project the total impact if trends do hold, bringing this horrific episode to a close in a few months. Under that relatively optimistic assumption, the total number of new cases will reach roughly 4.2 times the current level of persons infected who are continuing to spread the corona virus. If we choose something like 160,000 out of our range above, this would be an increase in cases of about 800,000 with a likely total of new mortality of around 30,000 (on top of the roughly 10,000 deaths to date) for a total of 40,000. If countries now struggling to slow the spread of the infection are unsuccessful, the loss of life will be horrific on a human scale, irrespective of materiality or long-term impact on financial markets.