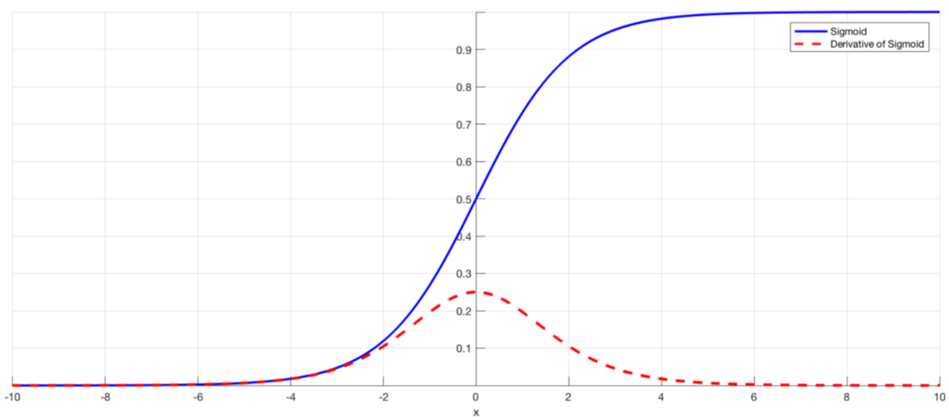
The Corona pandemic – some thoughts and graphs

Joop Varekamp, E&ES, Wesleyan University

Prelude

I was scheduled to teach in Italy during March, but already in January I decided that I should not be abroad at the beginning of an incoming pandemic. Since early March I have plotted every day the corona data for the US and Italy to see how their growth curves compare. Infectious diseases follow initially exponential growth patterns until measures are taken to limit transmission or a vaccine becomes available. I wanted to know how disease propagation compares to population growth, which I teach in some detail in my classes. In ecology, populations grow exponentially until resources become limiting, and the growth rate decreases over time until a stable number arises (known as the carrying capacity). Could it be that the total number of corona cases similarly follows such a logistic trend as the population growth curve, with a bell-shaped curve for the 'per day' increases (the first derivative of the logistic equation, Fig 1).



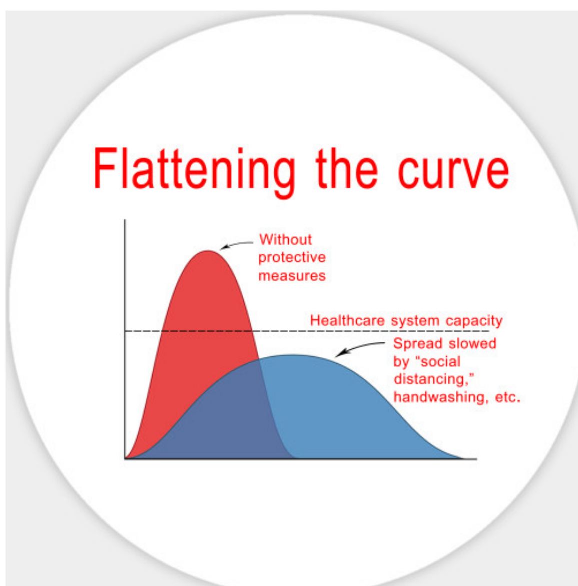


Figure 1. Top. Graph with no "real" units along the axes of a logistic curve (sigmoid) typical for population growth with individuals along the y axis versus time along the x axis. The red stippled bell curve shows the "growth per day".
Bottom. Mid March 2020 Tee shirt design. Note the symmetrical bell shape form.

In the early days of the disease, diagrams such as Fig 1 were shown on a daily basis in the press, and we were told that we had to ‘flatten the bell curve’ so we would not overwhelm our hospital ICU’s. If I had asked Fred Cohan early on, I would have known that past experience and mathematical models (e.g., Chowell et al., 2016) tell us that epidemics behave differently from the logistic population growth curves, and that the decrease in the transmission factor Ro is a determining factor (See Fred’s write up in ‘The Conversation’). Anyway, I decided to follow this pandemic ‘day by day’ to compare the disease evolution in the two countries. **Disclaimer.** I am a geochemist fascinated by numbers but not an epidemiologist, so take this for what it is worth.

The facts.

We cannot use the # of cases because we have no idea how many people are infected. The testing rates simply have been too low and the increase in documented cases is as much a reflection of increases in testing as due to true changes in disease transmission rates. So sadly enough, the only somewhat reliable numbers are the deaths related to corona infections. Since March 3, every day I plotted the total cumulative death data for Italy and the US, and fitted them with exponential functions (Figure 2). In Italy, the data started to deviate from exponential growth around March 13 at a total death count of ~ 1000. The Italian government had imposed a stepwise lockdown of the country in late February, and the data deviated consistently from the exponential J-shaped curve after March 13. I plotted the same data on a semi-log plot, where the exponential curve is a straight line, and the deviation is easier to see (Fig 3). While Italy was already on a path of reduced growth of corona casualties, the US kept evolving along its original exponential function (see blue J curve and straight line in the semi-log plot in Figs 2 and 3).

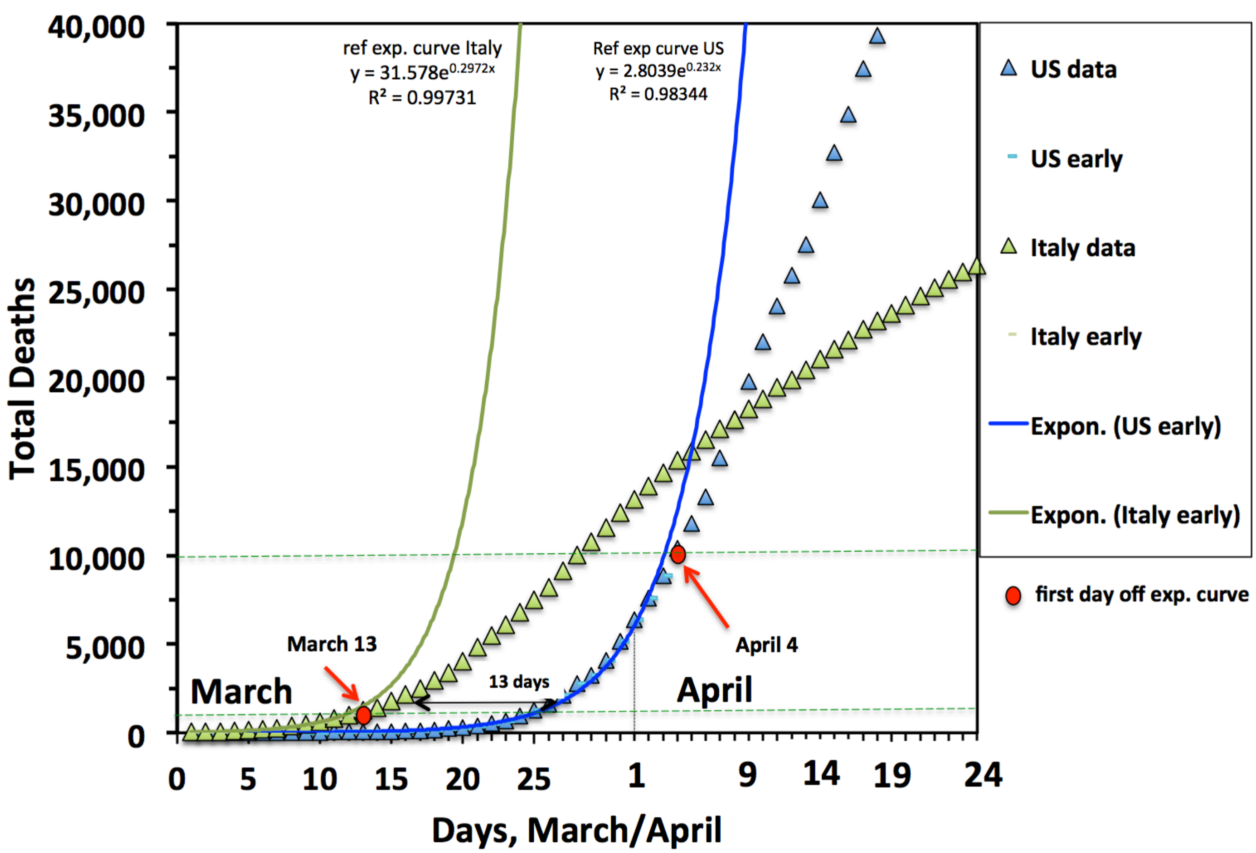


Figure 2. Linear – linear plot of corona deaths in Italy and the US.

It was only on April 4, 22 days after Italy, that the US trend started to deviate from exponential growth, at a cumulative death total of ~10,000. From then on, the US has stayed on that slower growth trend, and a polynomial fit suggests that we will end up with >90,000 deaths in the US by mid May, while Italy will have about 30,000 casualties (assuming that social distancing etc. remains in place). I also plotted the daily death rates and compared them to a Gaussian bell curve (Fig 4). The notion that the course of the disease on a daily basis would follow a bell curve is simply wrong. Italy appeared to be following such a trend until April 9th, but since then the data have formed a steady tail that only slowly descends over time (Figure 4). In the US we followed the up-going trend of a bell curve until April 7, but then it started tailing as well with a very choppy trend, and a very slow decrease in death numbers. The theory of epidemic modelling (Chowell et al., 2016) indeed suggests that the case rate of fatalities may tail off according to a polynomial function, when Ro goes from its "free transmission value" to values below 1.

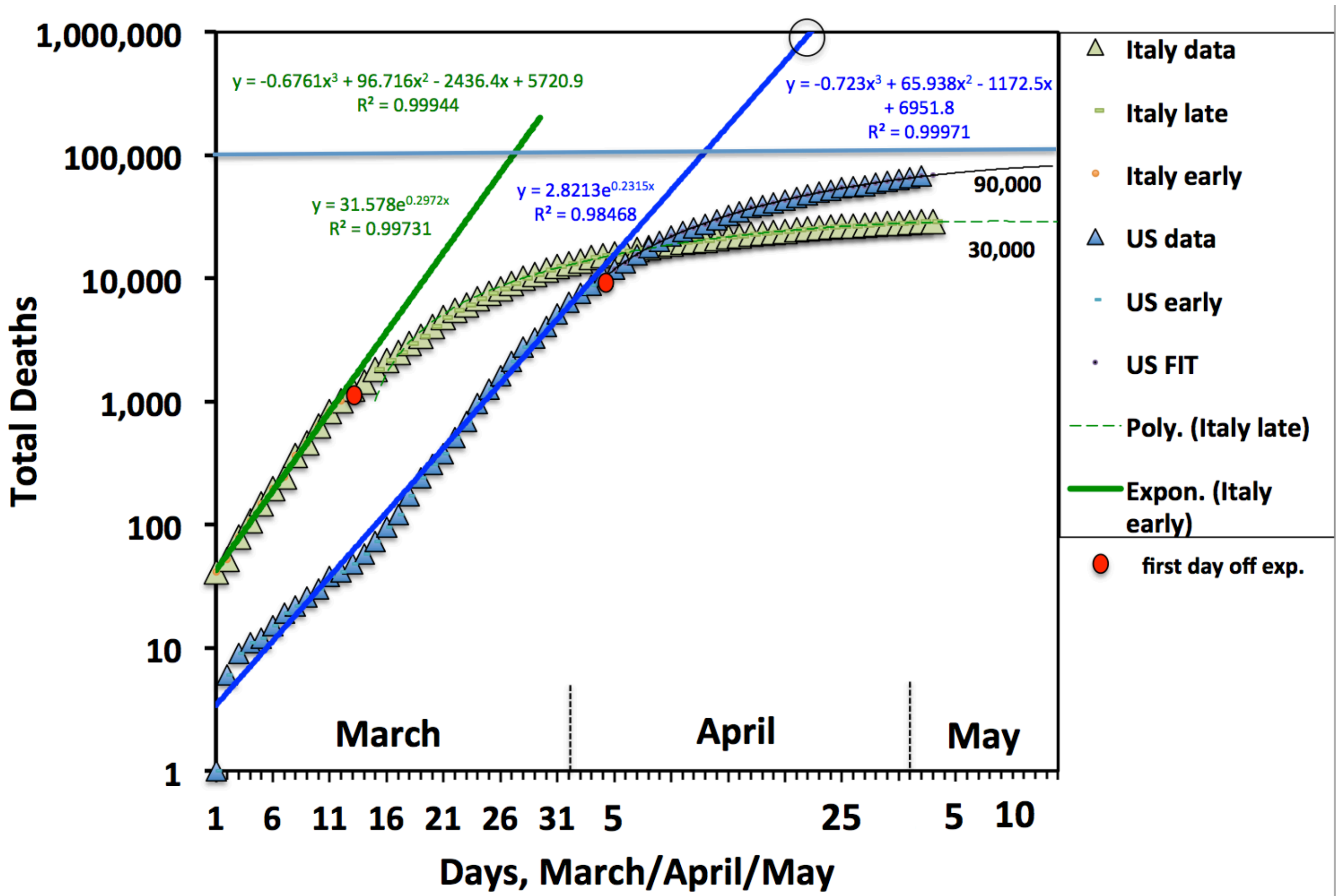


Figure 3. Linear – Log plot of time versus death data in Italy (green) and the US (blue). Straight line segments represent exponential growth, and the curved arrays occur after lock down and social distancing rules have been imposed. Extrapolation of the straight line for the US (deep blue line) would have reached the 1 million casualties (black circle) around April 21.

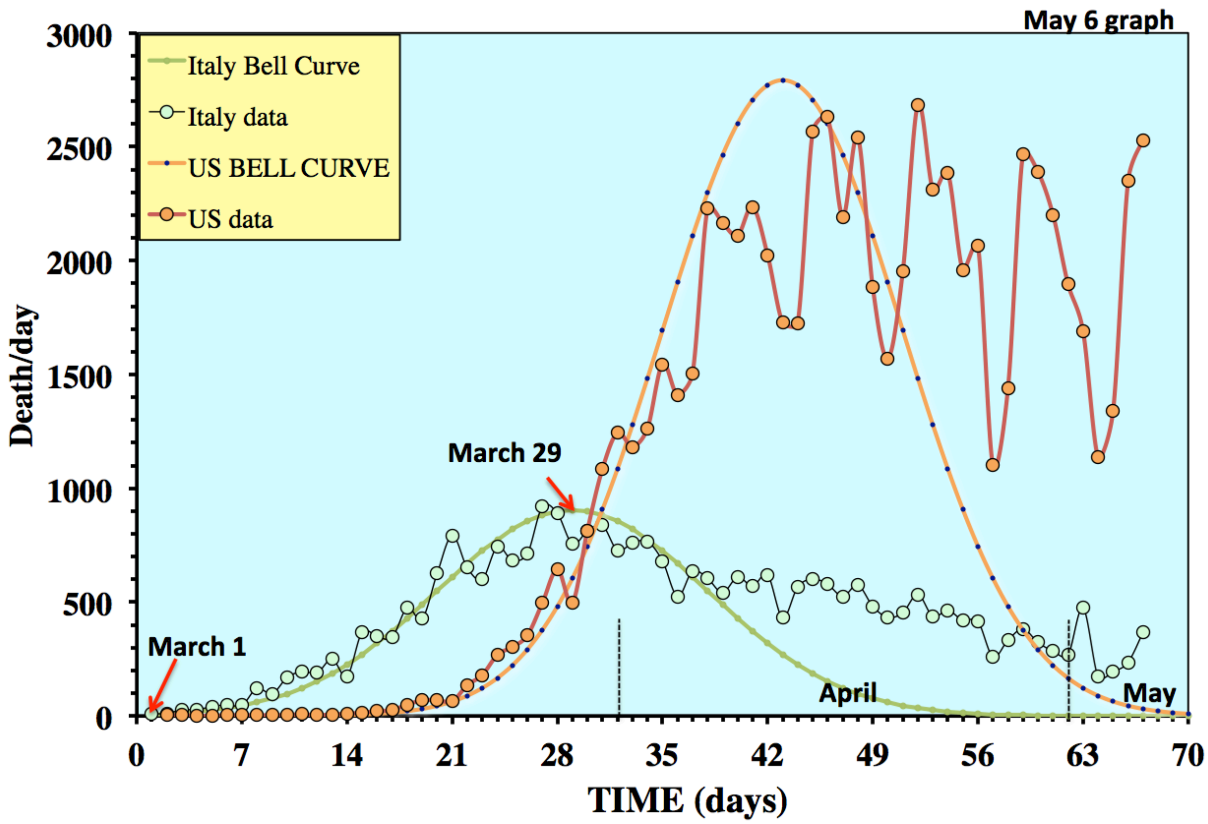


Figure 4. The real data as circles and dots (green Italy, orange US), with two bell curves that fit the data more or less on the left side of each bell curve. It shows the slow tailing off in the more advanced stages of the disease progression on the right side of the bell curves. The choppiness in the later record of the US may stem from death reporting issues and/or from the heterogeneity of the US on a state by state basis.

What can we learn from this empirical approach?

1. The Italian government stepped in with a lock down when several 100 deaths had occurred. The result was a deviation from exponential growth by March 13, with the first isolation / lock down imposed in late February. In the US, warnings to avoid large meetings started ~March 15 and shelter in place in N-California started on March 17. True lock downs came later, and some states never imposed them. We came off exponential growth at 10,000 deaths on April 4, and as a result the infection count was then already so high that we will end up with at least close to 100,000 casualties if all social distancing rules remain in place. If the US had imposed a formal lock down nation-wide before we reached ~ 1000 deaths, as done in Italy, the curves for the two countries might have evolved similarly, and many US lives could have been saved (this is an hypothesis!).
2. If no social distancing had been ordered in the US in late March, the US would have stuck to its exponential growth pattern, and close to 1 million people would have died by the end of April. The comparisons presented on TV talk shows (e.g., Dr. Phil) that we do not shut the country down because of casualties related to traffic accidents or the flu, which have similar death counts as corona, is totally fallacious. Comparing the current casualty numbers while we are in lock down mode with flu-related deaths is wrong, because without the lock down we would have been looking at very large numbers of casualties by late April.
3. The bell curves that were so common in the early press coverage with the consideration that ‘once we were over the hump we would go quickly down to zero new cases’ turn out to be untrue. Once off

the exponential curve, the tailing end is a very slow descent that follows approximately a polynomial trend for the total number of casualties. Such fits allow us, however, to make cautious estimates of the total number of corona deaths to be expected when the trends level out (Fig 3).

A review of the 1918 Spanish flue evolution in a short article in the Washington Post is very illustrative with respect to the success of social distancing and lock downs.

https://www.washingtonpost.com/outlook/2020/03/25/president-trumps-desire-reopen-businesses-quickly-is-dangerous/

Postscript

Despite the greater disaster in the US, it was the right decision for me not to go teach in Italy, because non-US citizens (like me) were no longer allowed to re-enter the US starting late March.

If the social distancing rules are weakened too early, the disease will pick up where it left off at the exponential end, and this will all be repeated until about 60-70% of the population has been infected with the disease. Only then the virus burns itself out, to some degree as a result of lack of non-immune individuals, and transmission rates will decrease to values below one.

My plots result from a 'backward looking' method, which is very common in the geological sciences. We analyse a series of rocks that were erupted from a volcano over time and try to tease out the underlying process. In this case, we do not know what exactly drives the numerical evolution of the disease pattern. Once a good data fit is obtained, only very cautiously can this be used for any predictive applications. The predictive models of e.g., the Univ. of Washington (IHME) work the other way around: they have an existing mathematical model based on decades of earlier development work, and they tune the various knobs in their algorithms to make their model fit the available data and then make (and regularly adjust) their predictions (see the 'epidemic calculator' below).

References

G. Chowell, L. Sattenspiel, S. Bansal, and C. Viboud, Mathematical models to characterize early epidemic growth: A Review. Phys Life Rev. 2016 September; 18: 66–97. doi:10.1016/j.plrev.2016.07.005.

The epidemic calculator: https://gabgoh.github.io/COVID/index.html