The Mathematics of Population Growth

Victor M. Yakovenko*

Department of Physics and JQI, University of Maryland, College Park

(Dated: 10 July 2024)

Arguably, an important part of science is information compression. Kepler succeeded, purely empirically, in reducing reams of data for planet positions to a few parameters of elliptic orbits, thus achieving great compression of information. Subsequently, this compression enabled Newton to propose the law of gravity as an explanation for the elliptic orbits, found empirically by Kepler. This talk presents information compression for the growth of human population $N(t)$ in time t using empirical data from 10,000 BCE to 2022 CE. We find that human population initially grew exponentially in time: $N(t) \propto e^{t/T}$ with $T \approx 3050$ years. This growth then gradually evolved to be super-exponential with a form similar to the Bose function in statistical physics. Between 1600 and 1700, population growth further accelerated, entering the hyperbolic regime as $N(t) = C/(t_s - t)$ with the singularity year $t_s = 2026$, identified by von Foerster *et al.* in 1960. We attribute the switch to the hyperbolic regime to the onset of the Industrial Revolution and the transition to massive use of fossil fuels. This claim is supported by a linear relation that we find between the increase in CO_2 level and population from 1700 to 2000. By the end of the 20th century, the inverse population curve $1/N(t)$ begins to deviate from a straight line and to follow a pattern of "avoided crossing," where $N(t)$ is described by the square root of the Lorentzian function. From this fit, we predict that human population will attain a maximum $N_{\max}$ of slightly more than 8 billion people at $t = t_s$. The width in time of the population peak is $2\tau \approx 55$ years, indicating a decrease in population to $N_{\max}/\sqrt{2}$ at $t = t_s \pm \tau$. We compare this prediction with current demographic forecasts.

*URL: `https://physics.umd.edu/~yakovenk/econophysics/`