The Mathematics of Human Population Growth and CO_2 Emissions

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In a paper published in the Science magazine in 1960, von Foerster et al. argued that human population growth follows a hyperbolic pattern with a singularity in the year 2026. Using current empirical data from 10,000 BCE to 2023 CE, we re-examine this claim. We find that human population initially grew exponentially as N(t)~exp(t/T) with T~3000 years. This growth then gradually evolved to be super-exponential with a form similar to the Bose function in statistical physics. Population growth further accelerated around 1700, entering the hyperbolic regime N(t)=C/(ts-t) with the extrapolated singularity year ts=2030, which is close to the prediction by von Foerster et al. We attribute the switch from the super-exponential 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 population and the increase in the atmospheric level of CO_2 from 1700 to 2000. But in the 21st century, we observe that the inverse population curve 1/N(t) deviates from a straight line and follows a pattern of "avoided crossing" described by the square root of the Lorentzian function. As a result, the singularity transforms into a peak in human population at ts=2030 of the time width \tau=32 years. We also find that the increase in the atmospheric CO_2 level since 1700 is well fitted by arccot[(ts-t)/\tau_F] with \tau_F=40 years, which implies a peak in the annual CO_2 emissions at the same year ts=2030.

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