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A study of the Dynamic Relationship Between Optimal Global Population and Technological Progress

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Abstract:

It is the quantity that depends on the interconnection between population and technology, the latter being capable of advancing to support the growth of the population. Taking into consideration the findings of Malthus, Harding, and other authors, this paper elaborates on the multifaceted and developmental connection between population growth and technological advancement within the context of the optimal population. It critiques the fallacy that population growth will always result in the depletion of resources. This paper seeks to establish the fact that a large enough optimal population can foster the generation of a positive feedback loop of technological advancement and population expansion but, at the same time, results in vices such as pollution of the environment and depletion of resources. In contrast, the population can increase the market needs, encourage the advancement of renewable energy sources, and decrease the energy depletion rate. Technological advancements, boosted by population pressure, have let human beings overcome perceived environmental and resource barriers. Thus, the optimal population is not the specific number but the goal that is set to change depending on the level of technology development. Lastly, this paper stresses the importance of technological equity on the international level.

Keywords: Optimal Population; Technological Progress; Sustainable Development.

1. Introduction

The idea that 'A finite world can support only a finite population; therefore, population growth must eventually equal zero' proposed by Garrett Hardin (1968) in his essay The Tragedy of Commons, points to the problem of population and its expansion about the earth's resources. But history has shown time and again that technology has always surpassed the anticipated population growth through such things as agriculture to the current renewable energy sources that help in optimizing resource use and thus increasing the world's carrying capacity.

The most important thing in defining the optimal population is to understand that it is not about finding a specific number. However, this paper holds that the ideal population is always a moving target that should guarantee that the technologies being developed can support the growing population and do not negatively impact the environment through resource depletion.

2. What Does the Historical Evidence Show?

The claim that the optimal population should be sufficiently large to encourage technological advancement can be strongly supported by historical evidence showing that technological progress, spurred by the challenges of a growing population frequently, has effectively addressed issues related to population growth.

Historical predictions of global overpopulation and consequent disasters have repeatedly surfaced over the centuries. Beginning in 1798, Thomas Robert Malthus proposed in his book An Essay on the Principle of Population that population will enlarge until the environment can no longer support the individuals, surpassing the capacity of the finite food resources, leading to disease, famine, and disastrous events (Malthus, 1798). Similarly, the book The Limits to Growth, which was supported by the World 3 computer model, incorporating factors such as production, industry growth, and the environment, suggested that there is a maximum number of people given the finite resourced world (Meadows et al., 1975). While both perspectives are influential, time has shown that these authors severely underestimated the potential and impact of technological advancements.

Instead, historical evidence has indicated that technological innovation, actuated by the pressures and demands of increasing populations, has significantly expanded the Earth's carrying capacity by increasing productivity and creating new resources. Whenever the population was about to reach the carrying capacity, humans always found

ways to increase food production through innovation to push the frontier of the carrying capacity (Boserup, 1965). Boserup (1965) argued that technological innovation is stimulated by population pressure and, in turn, increases food production, which Malthus failed to anticipate(seen in Figure 1)

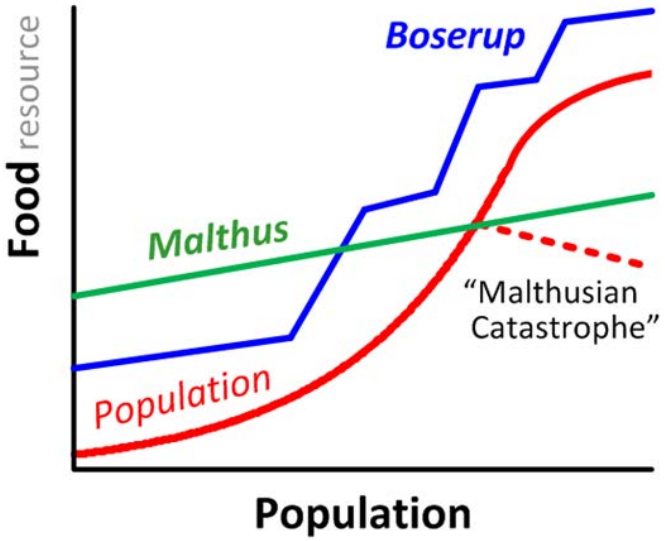

Fig. 1 The Malthusian vs. Boserup/Simon Prediction

3. Positive Loop Between the Population and Technology

Population growth has undeniably been a critical driver of technological innovation due to several factors: larger populations create greater demand for resources, spurring innovation to increase efficiency and production to meet this growing need (Collins et al., 2013). Population growth creates a broader market for technological progress, stimulates investment and innovation, and ultimately helps to improve people's living standards, which in turn encourages investment and innovation. It can be seen that the more extensive market proves and drives the economic viability of scaling up new technologies. (Collins et al., 2013). Hence, the increased population from around 2.5 billion in 1951 to 3 billion in 1960 (Worldmeter, n.d.) prompted farmers and scientists to develop new technologies to raise the food supply to meet the growing population, which commenced the Green Revolution (Ritchie, 2017). During the Green Revolution, advancements in high-yielding varieties (HYVs) increased agricultural productivity and yield from the shortened maturity time of 180 days to 100 days (Nelson et al., 2019). Specifically, between 1960 and 1985, the world saw "the doubling of yield per hectare, total productivity, and total food production in developing countries" (Nelson et al., 2019); hence, driven by the growing population, advancements in HYVs were made to supply the larger population with sufficient food supply, which further pushed the frontier of the population capacity to sustain more people.

The effect of technological advancement from population growth during the Green Revolution is apparent in India. Between the 1950s and 1960s, India used traditional farming methods, primarily relying on animal and human labor (Nelson et al., 2019). However, when new HYVs and new agricultural machinery were introduced, the growth rate of food-grain output increased from 2.4% per annum before 1965 to 3.5% after 1965 (Nelson et al., 2019). The steady rise in food supply production can partially be attributed to India's growing population from 500 million in 1965 to 697 million in 1980 (Worldometer, 2024), as the increased food supply expands the carrying capacity. Therefore, the agricultural transformation during the Green Revolution proves the validity of Boserup's theory and contrasts with the pessimistic and near-complete dismissal of the technological advancement proposal from Malthus and Meadows, where human carrying capacity is limited. Overall, historical evidence suggests that the optimal population should be large enough to encourage technological advancement while maintaining sustainable growth, creating a loop of increasing population and technological progress.

4. Challenges Faced by Growing Population

While population growth can drive technological advancement, it also introduces complex sustainability challenges that must be addressed to maintain an optimal balance between a population size that not only fosters economic and technological advancement but does so in a manner

that is sustainable for both current and future generations (Nations, 2023). These progressives not only address immediate challenges posed by population increases but also contribute to long-term economic and social development. Consequently, to address these issues, governments must strategically integrate sustainability into their development goals through modern technology and innovative approaches.

As shown in Figure 2, humans have historically relied on non-renewable resources like petroleum, coal, and natural gas to meet their energy demands. These non-renewable resources release harmful particles polluting the air, increasing the carbon dioxide and exacerbating the greenhouse effect (Morse, 2022). Since 1960, carbon dioxide levels have risen from 316.42 ppm to 242.62 ppm, severely affecting the environment (NASA, 2023). Furthermore, the continuous extraction of crude oil strains global resources. For instance, the world is estimated to reach peak production and spiral downward by 2050 (National Geographic, 2023). Nevertheless, as technology advances from population growth, emerging renewable technologies, such as wind turbines, hydroelectric, and solar panels, were developed to provide for the ever-growing energy demand while being highly sustainable (Ritchie et al., 2024). In 1965, renewable sources merely contributed 941.18 TWh of energy; in 2022, they generated 8538.5 TWh, around one-third of the world's electricity usage (Ritchie et al., 2024). In the sustainable energy sector, solar energy is utilized efficiently. As proof, early solar panel versions only had an efficiency of 1%, but now, it has increased to 25% (Matasci, 2022). Thus, the innovation of renewable energy due to the increased demand from the larger market suggests that a larger population propels innovation, creating a positive loop of a larger population and increased innovation.

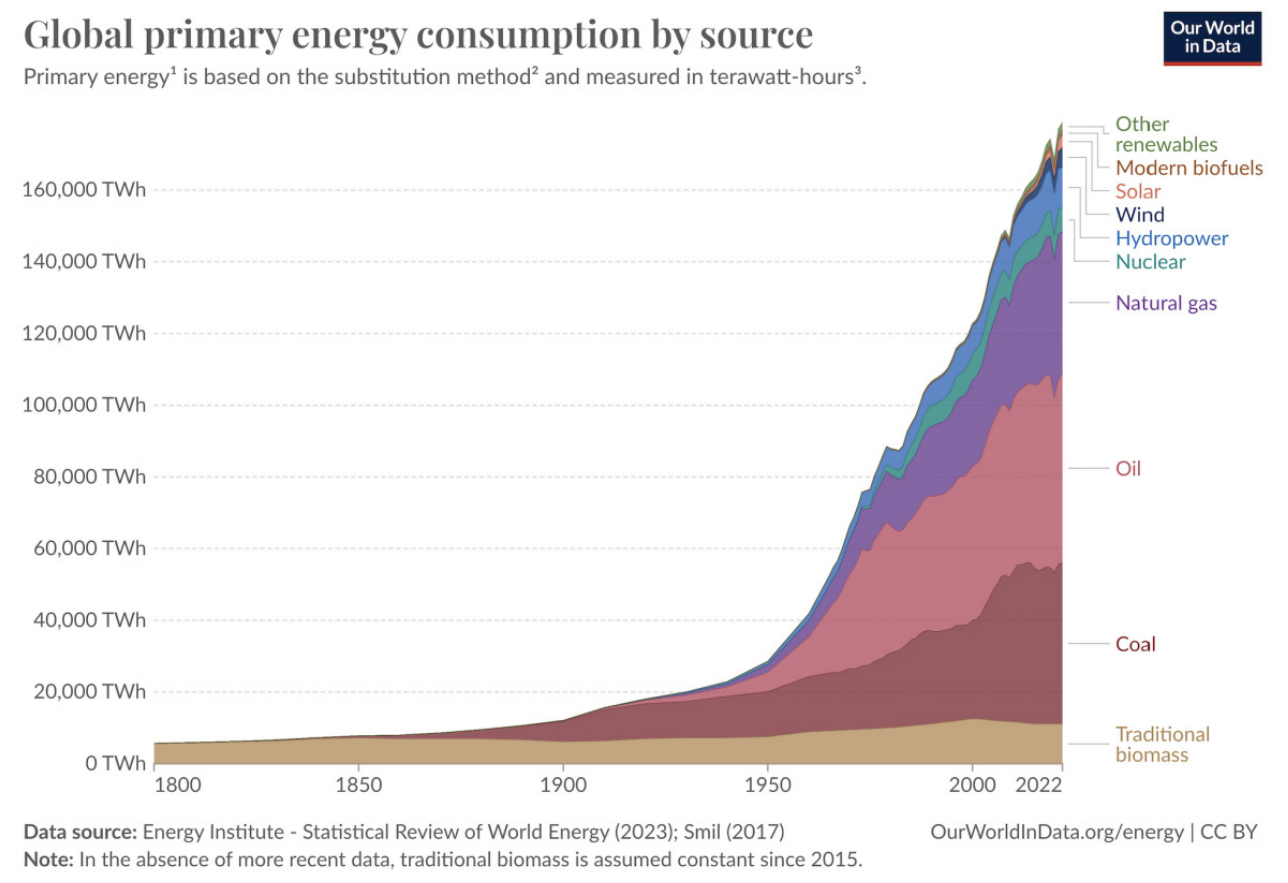

Fig. 2 Global Energy Consumption Sources

5. What is the Sustainable State?

The optimal population can be a dynamic number based on the relationship between population growth and technological advancement. Technological advancement can be measured by the Global Innovation Index, which encapsulates values such as Science and innovation investment, computing power, connectivity, and workforce (World Intellectual Property Organization, n.d.). As technological capabilities expand, the optimal population could also in-

crease, reflecting improved efficiencies, innovations, and better management of resources. Conversely, if technological advancement slows or stagnates while the population continues to grow, the optimal population could decrease, indicating that fewer people can be sustainably supported.

As shown in Figure 3, the Technological Surplus Period occurs when the technology curve is above the population curve, indicating a time when technological advancements exceed the needs of the population, leading to an abundance of resources, enhanced living standards, and sustainable growth. In contrast, the Technological Deficit Period occurs when technological advancement lags behind population growth, indicating times when technology cannot meet the population's demands, potentially leading to resource strain and sustainability challenges. Thus, the "optimal" point or range is where the curve of technological advancement intersects, or love crosses the curve of population growth, which means that the balance between the population size and technology is attainable and constantly changing, giving a certain population size an optimal one. This approach needs active strategies that promote innovation and guarantee the implementation of these innovations at the scale and speed that can help reduce the negative effects of population on the environment and society.

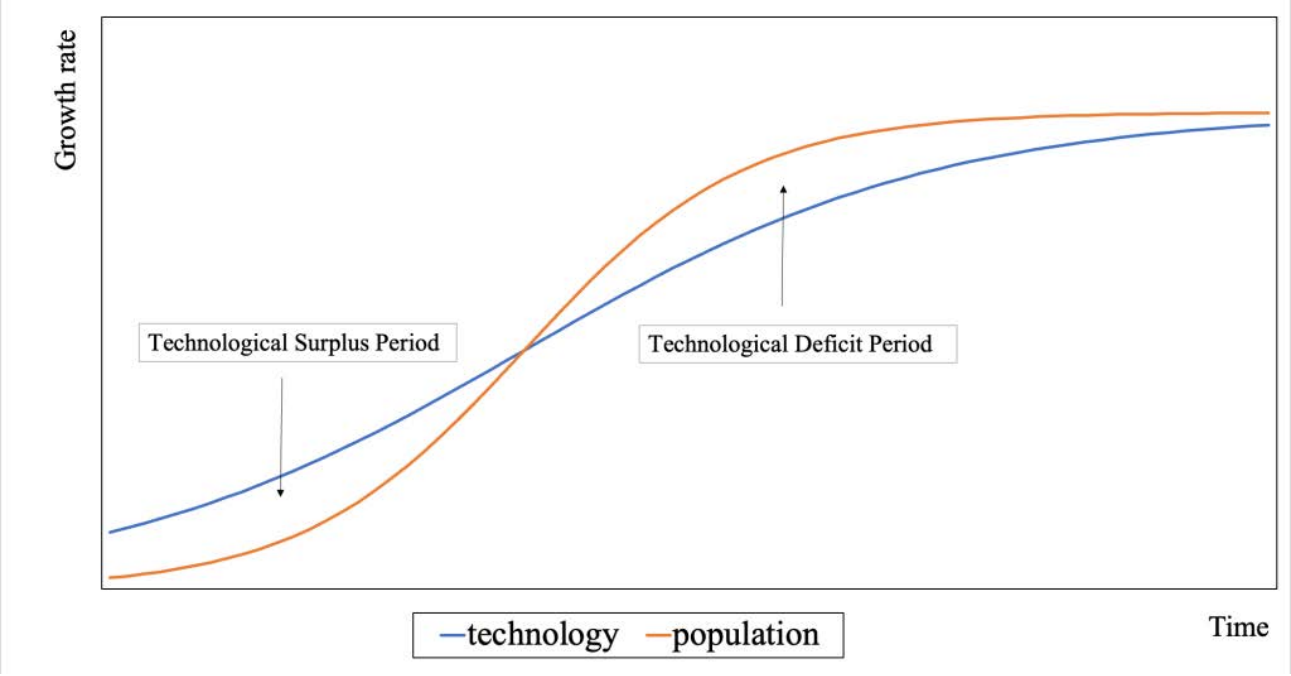

Fig. 3 Population Growth and Technological Advancement Curve Compared

6. Is There Equal Access to Technology in All Countries?

Inequality in access to technology affects countries' population management, which results in a gap between the developed nations that progress quickly. On the contrary, developing countries constantly fight to fulfill their people's basic needs and cope with environmental issues. This is because the developed countries may have low population growth rates while they are capable of supporting larger populations because they have a higher technological intensity, more efficient use of resources, and better health delivery systems. On the other hand, countries with limited technology have problems with maintaining the minimal growth of population without worsening the standard of living and environmental conditions.

This divergence implies that such population size cannot be easily identified but has to be understood in relation to certain circumstances due to differences in technology, economic development, and social relations in various countries. Emphasis on technology and population increase in the developed world may worsen the disparities across the globe or can be perceived as neo-imperialist measures from the developing world's viewpoint. Also, these nations may not accept a definition of 'optimum population' that does not include the development and cultural factors of these nations. Hence, an approach that is more sociopolitical and gives due recognition to the place of every population of the world is needed in order to come up with a fair and equitable definition of what makes a good population size. Thus, the management of technological advancement per capita in each nation to be faster than the population growth rate guarantees that all

the nations sustain their increasing population sustainably, leading to the sustenance of the optimal population.

7. Conclusion

In conclusion, the analysis of the best global population in this essay focuses on the relationship between technology and population, stressing the role of technology in increasing the carrying capacity of the earth and offering practical solutions to the world's problems. The facts from the historical and recent past show that the advancement in technology due to overcrowding of the world has always helped humanity overcome what was considered the final environmental and resource barrier. The above, therefore, implies that an ideal population is not a set figure but a moving target influenced by the level of technology and may differ with the various regions depending on the level of technology advancement.

Hence, it is crucial to pay attention to technological equality across the globe since the technological gap greatly influences the sustainable development of population growth and the attainment of the optimal population size. From an ethical standpoint, this work aligns with the principle that all populations should be considered equal, thus calling for the equal distribution of technologies worldwide. If these ethical concerns are not taken into account and if the main emphasis is placed on increasing the population and technology in developed countries, it may lead to the intensification of global inequalities with all the consequences for the socio-economic and environmental spheres.

References

[1]. Boserup, E. (1965). Conditions of agricultural growth, the. the econ. of agrarian change under population pressure. London.

[2]. Collins, J., Baer, B., & Weber, E. J. (2013). Population, Technological Progress and the Evolution of Innovative Potential. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2284456

[3]. Garrett James Hardin. (1968). The Tragedy of the Commons. University Of California. Intel. (n.d.). Intel in Vietnam. In Intel. Intel. Retrieved June 27, 2024, from https://www.intel.com/content/dam/www/public/apac/xa/en/asset/world-economic-forum/pdf/Investing%20in%20asean%20region/article%204/Intel%20Vietnam%20backgrounder%20Final.pdf

[4]. Malthus, T. R. (1798). An Essay on the Principle of Population. Cambridge University Press. (Original work published 1798)

https://www.energysage.com/solar/solar-panel-efficiency-cost-over-time/

[5]. Matasci, S. (2022, February 8). How Solar Panel Cost & Efficiency Change Over Time. EnergySage. https://www.energysage.com/solar/solar-panel-efficiency-cost-over-time/

[6]. Meadows, D. H., Meadows, D. L., Randers, J., & Behrens III, W. W. (1972). The Limits to Growth: A report for the Club of Rome's project on the predicament of mankind. Universe Books.

[7]. Morse, E. (2022, July 29). Non-Renewable Energy. National Geographic. https://education.nationalgeographic.org/resource/non-renewable-energy/

[8]. NASA. (2024, February). Carbon Dioxide Concentration | NASA Global Climate Change. Climate Change: Vital Signs of the Planet. https://climate.nasa.gov/vital-signs/carbon-dioxide/?intent=121

[9]. National Geographic. (2023, October 19). Petroleum | National Geographic Society. Education.nationalgeographic.org; National Geographic. https://education.nationalgeographic.org/resource/petroleum/

[10]. Nations, U. (2023). As the World's Population Surpasses 8 Billion, What Are the Implications for Planetary Health and Sustainability? United Nations. https://www.un.org/en/un-chronicle/world-population-surpasses-8-billion-what-are-implications-planetary-health-and

[11]. Nelson, A. R. L. E., Ravichandran, K., & Antony, U. (2019). The impact of the Green Revolution on indigenous crops of India. Journal of Ethnic Foods, 6(1). https://doi.org/10.1186/s42779-019-0011-9

[12]. Ritchie, H. (2017, August 22). Yields vs. Land Use: How the Green Revolution Enabled Us to Feed a Growing Population. Our World in Data.

https://ourworldindata.org/yields-vs-land-use-how-has-the-world-produced-enough-food-for-a-growing-population

[13]. Ritchie, H., Roser, M., & Rosado, P. (2024a, January). Energy Production and Consumption. Our World in Data. https://ourworldindata.org/energy-production-consumption

[14]. Ritchie, H., Roser, M., & Rosado, P. (2024b, January). Renewable Energy. Our World in Data; Our World in Data. https://ourworldindata.org/renewable-energy Saved! by Ester Boserup. (n.d.). Anthroecology Lab.

[15]. World Intellectual Property Organization. (n.d.). The Global Innovation Index 2023 captures the innovation ecosystem performance of 132 economies and tracks the most recent global innovation trends. In World Intellectual Property Organization. World Intellectual Property Organization. https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2023-section1-en-gii-2023-at-a-glance-global-innovation-index-2023.pdf

[16]. Worldmeter. (n.d.). World Population by Year - Worldometer. Www.worldometers.info. https://www.worldometers.info/world-population/world-population-by-year/#google_vignette

[17]. Worldometer. (2024). India Population (2024) - Worldometers. Worldometers.info; Worldometers.info. https://www.worldometers.info/world-population/india-population/