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Defining the Optimal Global Population A Framework Balancing Resource Constraints and Human Flourishing

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Abstract:
The rapid growth of the global population intensifies the fundamental economic tension of infinite human wants amidst finite resources. This article investigates the concept of an optimal global population, defined not merely as Earth's maximum carrying capacity, but as a size wherein every individual has the potential to achieve a high living standard. The analysis critiques the famous Simon-Ehrlich wager by arguing that apparent short-term resource abundance is an illusion fueled by technological efficiency gains, as explained by the Jevons Paradox and the IPAT equation. Frameworks such as the Solow-Swan model and the Human Development Index (HDI) illustrate how capital dilution and resource strain resulting from overpopulation can erode per capita well-being. Furthermore, an intertemporal social welfare function model indicates that optimal population policy must balance size with individual living standards. Ultimately, while a population size maximizing well-being at a micro-level is theoretically identifiable, an optimal global population is only reached when individual well-being and output per head are maximized.

Keywords: Optimal Population, Resource Scarcity, Carrying Capacity, Human Development Index (HDI), Solow-Swan Model

The global population has shot up to 8.0 billion in mid-November 2022, representing 7% of the total number of people who have ever lived.[1] Projections indicate that by 2050, this number will reach 9.7 billion, reaching a peak of a staggering 10.4 billion in the mid-2080s.[2] Increasing rapidly, this progressive trend is underpinned by the mechanism that, with more people, consumption increases, and the basic economic problem escalates. Given the infinite wants and needs of human beings and finite resources, does a statistically optimal global population where every individual can live an adequate living standard with opulence, utility, and the ability to flourish[3] exist?

The maximum carrying capacity of Earth, an estimation of the number of people that Earth's resources can sustain without the guarantee of adequate living standards, can be calculated. However, the optimal global population, an approximation of the number of people that Earth's resources can support where every individual is given the resources to pursue adequate living standards, is given not through statistical calculations, but through conceptual delineation.[4] While many scholars used mathematical models and predictions to find the optimal global population, results are largely dependent on their subjective interpretations of what adequate living standards are, and therefore on the term "optimal".

Keeping "minimal physical ingredients of a decent life" such as food access, education, healthcare, and sanitary conditions in mind, Daily et al. give an estimation of 2 billion as the optimal global population size whilst Pimentel et al., considering food supply and soil conservation, asserts the maximum global population to be of the same number, both in the same year of 1994.[5] This article will argue that an optimal global population is reached when personal well-being and output per head are maximized on a micro level.[6] This metric is much more essential and relativity to assessing optimal global population as it focuses not just on the essential aspects of survival, but also pursues for thriving of individuals in a holistic sense.

Before we discuss the desired capacity of Earth, it is imperative to acknowledge its maximum capacity. Study shows that the optimal population lies within two boundaries, with the lower bound (P3) being the minimum viable population size[7] and the upper bound being the maximum carrying capacity (Fig. 1). Since, given the current progression, the lower bound will never be crossed, it becomes more essential to clarify the upper bound. Being calculated using the ecological footprint[8], P1 serves as a more objective measure than the theoretical and subjective P2. The area between these two boundaries is the population size's range to fulfill decent living standards.

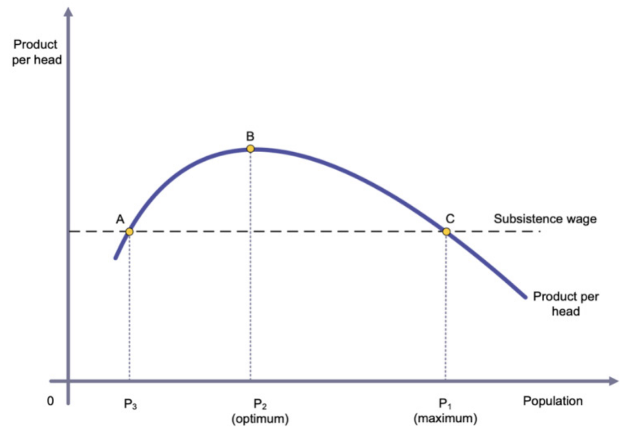

FIGURE 1. Population-product per head relationship[9]

In 1980, two American professors, Julian Simon and Paul Ehrlich, bet $1000 on the question of whether the earth would run out of resources to sustain a growing human population.[10] Ehrlich believed that physical limits of both renewable and nonrenewable natural resources would be unable to supplement the increasing population, while Simon argued that substitutes and increased efficiency would combat these scarcities and lead to an abundance of resources. Since the price of chosen metals of chromium, copper, nickel, tin, and tungsten decreased 10 years later in the 1990s despite the increased population, a victory was signaled for Simon. [11]

On the contrary, a study from the College of the Holy Cross found that from the year 1900 to the next consecutive 180 years, Ehrlich, not Simon, would have won the majority of the bets, and on a large scale (Fig. 2),[12] indicating Simon's asserted victory to be merely of luck due to short term market fluctuations and not driven by a fundamental outward shift in resources scarcity.

	10-year intervals	25-year intervals
Number of intervals in data	98	83
Percentage of bets won by Ehrlich	61.2%	59.0%
Average return on bet for Ehrlich	10.5%	13.8%

FIGURE 2. Ehrlich-Simon Bet Extended Results (1900-2007)[13]

Furthermore, the Jevons paradox exemplifies the existence of an illusion of abundance, when the rebound effect exceeds 100%, resulting in efficiency gains leading to increased resource consumption.[14] This is due to lower production costs that result in increased production outputs, which in turn proves Simon's abundance index and the decreased price of the 5 metals to not be because of actual abundance, but rather faster extraction of scarce resources. The paradox leads to a population beyond the optimal, where limited resources are only being used at an increased rate, leading to resource depletion that would eventually be insufficient to supply the global population size. This is similarly implied by the IPAT equation that Ehrlich and Holdren created in the early 1970s, which states $I = PAT$, where impact (I) is the product of population product (P), affluence (A), and technology (T), im-

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plying that increased technological advancements lead to more efficient and cost-effective extraction of resources[15], thereby accelerating resource depletion. The encouraged resource overuse suggests that the price of commodities in the Ehrlich-Simon debate is not caused by an increase in scarce resource availability, but rather due to an increase in supply resulting from technological advancements and thus an “illusion” of resource abundance.

Moreover, the Solow-Swan Model depicts a situation where the economy will eventually return to a steady state. This model is built on the basis that income per capita (y) is the sum of consumption per capita (c) and investment per capita (i) in a closed economy. As the population growth rate (n) increases, the original line i_1 will shift to i_2 as depreciation occurs, due to capital stock either falling from equilibrium, resulting in the economy converging to a steady state. The amount of capital needed to maintain a constant level of capital per capita increases, and assuming no change in investment, the level of capital stock declines to a lower steady state. This is a result of capital dilution, caused by an increased strain on limited resources.[16] This dilutes capital per person and thus income/capital because k is essentially a scarce resource, ultimately leading to a reduction in y, which is GDP/capita, decreasing living standards, and failing to meet the previously outlined requirements.

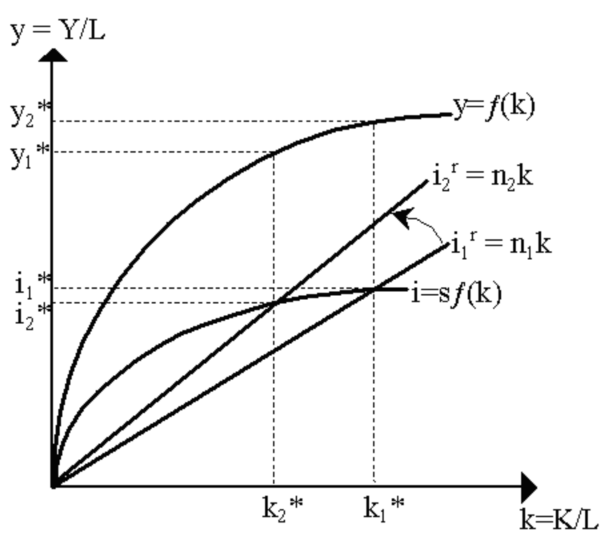

FIGURE 3. Solow Swan Model with endogenous population growth[17]

Water resources mirror the capital dilution in the Solow Swan Model as both surface and groundwater are over-drafted to meet the demand of the rapidly growing human population that is projected to reach 8.4 billion by 2025. Vletrop (1991) estimates that for every 20% increase in the global population, the demand for water will double. Current slow renewal rates are as low as 1% per year for underground water. In regions like India, groundwater levels declined 25-30 meters due to over-irrigation; in the United States, overdraft averages a quarter more than replacement.[18]

These scarce resources further result in decreased living standards as by measurement of the Human Development Index (HDI) (1) the difference between expected and mean years of schooling increases due to fewer educational resources, (2) life expectancy at birth shortens as a result of decreased healthcare resources, (3) GDP per capita lessens because of increased global population for GDP to be distributed.[19]

Additionally, the discrete-time intertemporal social welfare function evaluates the utility of the society by weighing on population size and the type of social planner. It implies that β is the weight of future value to present welfare, u(ct) is the utility of every person from consumption within the time period of t, n is the population size at time t, and α is the parameter that determines how much weight to place on the population size (Fig. 3). α is particularly important as the subjective measure of optimal global population differs based on the social planner; specifically, this written research places a higher welfare weight on population size and living standards, justifying the existence of an optimal global population. In the context of the optimal global population, u(ct) could decrease as nt increases due to diminishing returns, thus exacerbating the difference between the current population size and both average and total utilitarianism. The study concludes with the statement that exhaustible resources can impact the optimal population and that policies could be undertaken to reduce the population size where living standards for individuals are maximized.

$$W = \sum_{t=0}^{\infty} \beta^t n_t^{\alpha} u(c_t)$$

FIGURE 4. Discrete-time intertemporal social welfare function[20]

Amartya Sen set clear distinctions on the term “living standard” in her published essay in 1984, where living standards revolved around the terms opulence, utility, and capabilities for flourishing. Sharing a common ground with Aristotle’s theory, the first, opulence, refers to material satisfaction that would increase the quality of life for individuals if commodities increase. The second, utility, stresses the difference between quantity and quality and focuses more on the “psychic satisfaction” that commodities can provide. Only after an income level of $15000/capita does the life-satisfaction score respond to a large increase in GDP[21], further iterating the importance of a limited global population size to achieve high living standards, which can be measured by GDP/capita. The third, the capabilities for flourishing, indicates that living standards are based on the individual's ability to function to any given extent. However, the freedom that this third criterion asserts should be considered with limits so that the freedom for people, though in a liberal society, should not be taken too far to hoard material goods in the minority, so that personal well-being per capita is fully utilized for each individual.

Scholars such as Simon with his Abundance Index[22] and Ester Bserup with her Agricultural Intensification[23] may assert that an increase in global population leads to more efficiency and innovation, increasing national and global output levels, and thus enhancing the living standards of individuals through rising incomes and purchasing powers. However, in reality, wealth is often kept in the hands of the few, with GDP/capita being inequitable due to income inequality. In 2014, the richest 10 percent of the OECD earned 9.5 times the income of the poorest 10%[24], failing to meet the micro-level criteria of the optimal global population previously established in this article.

Conversely, countries might converge to a long-term population rate by themselves due to an increase in couples' ability to prevent pregnancies, postponed childbearing[25], higher education rates, and increased economic costs. Since the late 1970s, total fertility rates for all selected countries have shown a progressively decreasing trend, with most European and North American countries having experienced persistent low levels of fertility rates (Fig.6).

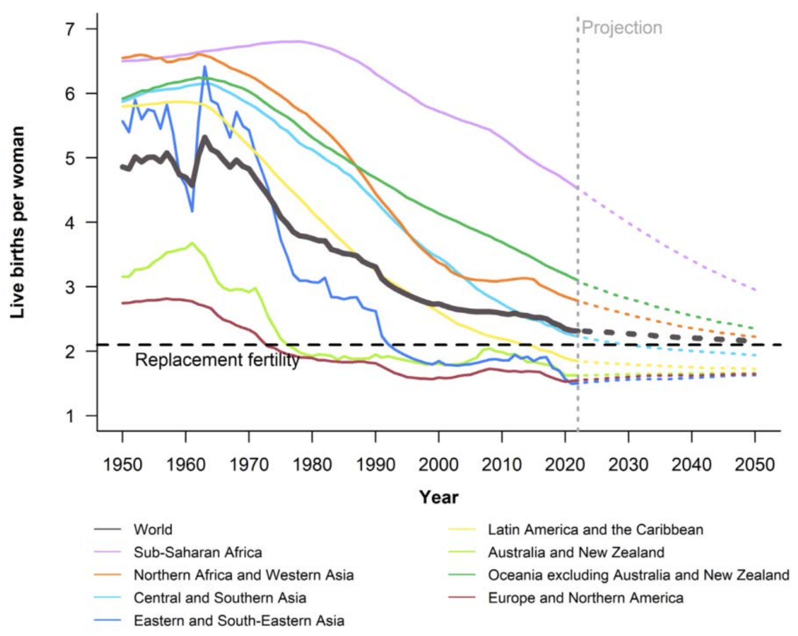

FIGURE 5. Total estimated fertility rate (1950-2021) and medium scenario (2022-2050)[26]

If this regressive trend continues, there may be a time when the global population converges to a point between P1 and P2. Until then, given birth to be a fundamental human right outlined in the Declaration on the Elimination of Discrimination against Women, Article 6 (e)[27], would it be ethically and politically feasible to allow international organizations to align each nation with a set population to achieve the optimal global population?

Even if birth rates decline, negative trade-offs are presented due to higher dependency ratios (Fig. 8), burdening pension systems, and stripping workers of taxes, which pressures the labor supply and decreases the possibility for new innovative technologies to be created due to less human capital. Nations could increase retirement ages, but that would decrease individual utility levels and thus living standards or increase public spending, which would simultaneously result in a budget deficit.

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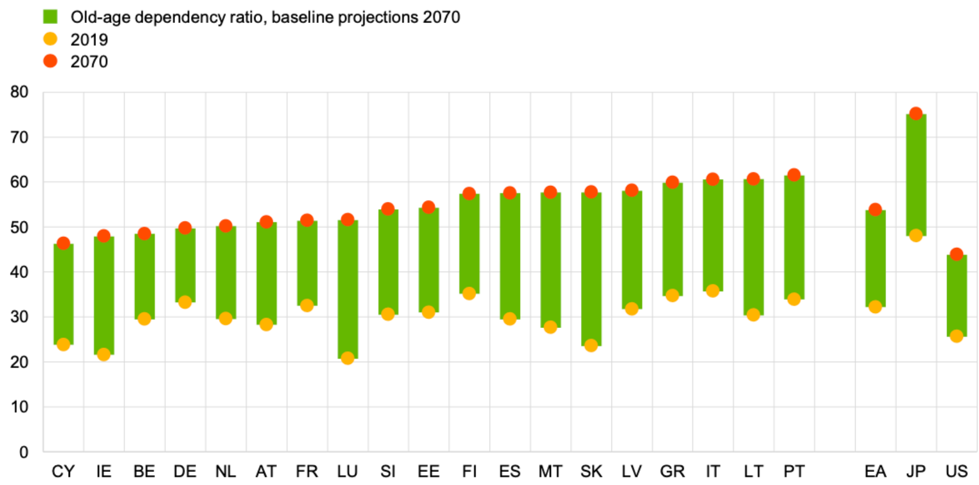

FIGURE 6. Projected old-age dependency ratio (2019-2070) with the ratio accounting for the dependent population/working population[28]

To conclude, even though Simon seemingly won the debate, the IPAT equation and Jevons paradox show it was simply due to short-term market fluctuations and not an increase in resource availability. Under the premise that optimal population size is when individuals fulfill the three factors of living standards, as stated by Amartya Sen, whilst output per head is maximized, resources will still become more limited even though prices decrease, as exemplified by the Solow Swan model and HDI measures, meaning inadequate satisfaction of every individual's desires. However, the means to achieve the optimal global population is more complicated in terms of global corporations for birth rate planning. Perhaps someday in the future, nations will stand as a unity to achieve the ultimate sustainable goal— an optimal global population.

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