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Solar impacts on the sustainability of economic growth

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ABSTRACT

Mainstream economists have used various growth models to predict the interaction between sustainable economic growth and the endless accumulation of capital while environmental concerns and their negative externalities are left out, in most cases. In this paper, I present a structural economic model that explicitly allows for the interaction between an economy and an ecosystem. The proposed model indicates that—given a wide range of development and socio-economic infrastructure—while population growth might be a reason for the constant growth trajectory, it has an adverse effect due to the constraints of resources and the environment. This is because economic activities and population growth increase ecological disordering as they downgrade the environment, while the later element has a negative impact on living standards. The collected data focusing on different economic components show that the growth rate of GDP per capita may fall below zero as the population grows with the rate of capital accumulation and environmental depletion. Finally, considering different scenarios of utilizing solar energy for economic growth, a feasible endurance factor for sustainable development might promote the methods of using the substituted energy, focusing on solar energy. This, however, cannot be accomplished given the current speed and direction of technological progress and energy utilization.

1. Introduction

Climate models predict that an increase in the amount of carbon dioxide will lead to an increase in global surface temperature, causing a higher rate of evaporation and precipitation and more extreme phenomena such as rising sea levels and hurricanes [58]. But still, anticipating environmental change and its impacts on the ecosystem at any scale remains a major challenge for scientists. This is mainly because Earth is an open and complex dynamic system and its nonlinear interactions are intrinsically unpredictable [21]. The mainstream view of economic growth ignores much of what science has discovered about the reaction of nature to the augmentation of the distribution of resources. This may cause an overestimation of what is reported as the result of these economic forces.

National and international economic policies have frequently ignored the environment, instead promoting gross national product growth [6]. Fischer and Heutel [29] indicate that ignoring the interaction between macroeconomic indicators and environmental policies risks omitting some essential reactions in the economy. While the Industrial Revolution allowed for the development of new schemes of utilizing fossil fuel resources that led to economic growth [78], there is solid evidence that devastating effects of climate change will take place unless major actions are taken immediately to change our fossil fuel-based energy system into a solar-based system [71]. With this in mind, specific policy initiatives must be taken to diminish the extent of environmental capital depreciation [80], such as the development of low greenhouse emission technologies [61,74] and improvements in innovative production systems that reuse emissions and wastes [84], instead of the discovery of new fossil fuel reserves.

In this paper, I present a comprehensive structural model that explicitly allows for the interaction between an economy and an ecosystem. Given the endogenous population growth framework, I am linking the population not only to living standards and government policies but also to renewable natural resources, while solar energy and nonrenewable natural resources are the exogenous factors of this model. Solar energy outsourced from the production cycle could maintain a possible inefficiency within the system by providing relatively infinite and clean energy for human activities.

In the current work, renewable (e.g., solar) and nonrenewable natural resources cannot be replaced by other elements such as technological progress or labor forces, which is also the case in models such as KLEC, DICE, and others [42,46,47,62,79]. However, nonrenewable energy itself can be substituted by renewable sources of energy such as solar. Furthermore, there is a binding constraints for the resources – implemented in studies such as Acemoglu et al. [3] – which limit growth. The other distinction is that the effect of population growth on economic activities is not clear based on different models and approaches. Accordingly, the main issue is the methods scholars use to incorporate population into their models. Treating population endogenously at the macro level, as in Malthusian models, might lead to different results when comparing exogenous population growth. In this study, not only does the author believe in the urgency of population endogeneity as well as technology [31,37,43,63] within the model, but we also must consider environmental concerns apart from household income level.

The proposed model indicates that—given a wide range of development and socio-economic infrastructure—while population growth might be a reason for the constant growth trajectory, it has an adverse effect due to resource and environmental constraints. This is because economic activities and population growth can be detrimental to the environment, and population overgrowth has a negative impact on living standards.

Endogenizing the population growth, while including environmental concerns, the results show that the GDP per capita growth rate will fall

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below zero with the current rate of capital accumulation, existing production technologies, and energy utilization. One of the reasons for such a different conclusion compared to the existing literature is that in the current study, the negative externalities of capital accumulation have been considered while these are usually ignored in economic growth estimation. Population growth leads to economic growth through knowledge accumulation, while at the same time it adjusts itself by diminishing the resources through living standards and degrading environmental quality. Considering different scenarios of solar energy use – as the exogenous factors to this model – for economic growth, a feasible endurance factor for sustainable development and capital accumulation is to promote the methods of utilizing solar energy.

The paper is structured as follows: The first section below introduces the major elements of the current model based on the previous literature. Then, Section 2 presents a theoretical model that can be used to verify the validity of the discussed questions in this research, followed by a short section on data description and the parameters' evaluation. In Section 4, the results of the analysis will be discussed, including affordances and constraints of the proposed framework. In the end, I briefly conclude the findings.

2. Background

In frameworks that include economic sustainability and global environmental changes, most models consider energy to be a primary factor of production. In this perspective, all value is evolved from the action of energy that is directed by labor and capital. The flow of energy in the economy is the service of the sources of fossil fuels and, lately, the sun. When energy is limited, it imposes an extreme constraint on economic growth; conversely, when energy is sufficiently accessible, its effect on the growth of the economy is trimmed. Energy is also required in the production of other inputs, and it is available in limited quantities on the Earth and is non-recyclable [78], excluding solar energy. In this matter, various studies reveal the causality linkage between energy and economic growth [60,7,77,86].

Daly [20] claims environment, natural resources, and pollution are not noteworthy in the leading textbooks in macroeconomics. In this notion, the Macroeconomy is seen as an isolated system in which exchange value circulates between households and firms in a closed loop. The necessary change in this framework is to picture the Macroeconomy as an open subsystem of the finite natural ecosystem and not as a sequestered circular flow of conceptual exchange value, unconstrained by entropy, mass balance, and finitude. Like the micro unit of the economy operates as part of a larger system, so the aggregate economy is similarly part of a larger system, the natural ecosystem or environment.

The issue here is that the production of goods generates negative externalities such as pollution, loss of resources, and environmental degradation. All of these can cause increased entropy in the system. Gowdy and Erickson [36] show that the production of capital is a biophysical process in which waste is simultaneously produced. Analyzing the environment-economy interaction, in every stage of the production process, waste will be produced [32,12]. Accordingly, entropy will arise from the emission of the energy that is wasted through economic activities [30]. While recycling helps to slow down the exhaustion of the earth's resources, it only partly impacts the entropy production process. Therefore, whenever economic processes have been fully developed, one should also take into account the associated rate of entropy production that is affected [22]. With this in mind, specific policy initiatives must be taken to diminish the extent of environmental capital depreciation [80], such as the development of low greenhouse emission technologies [61,74] and improvements in innovative production systems that reuse emissions and wastes [84], instead of the discovery of new fossil fuel reserves.

Stiglitz [79] examines the implications of introducing exhaustible natural resources, which can make a system unstable, as an essential factor of production with a constant rate of population growth. However, Cigno [19] argues that the assumption of a constant rate of population growth is implausible in an economy constrained by exhaustible resources, and examines the implications of making the population growth rate a function of consumption and capital per capita. Considering the mentioned environmental concerns, Kummel et al. [46] presents a more advanced model, called KLEC, in which the combination of capital, labor, energy, and creativity produces a final good. In such models, energy and other factors can be substituted by each other. Later on, he extends his model by including the influence of entropy production and emission mitigation on output and growth [47].

In another attempt, Nordhaus [58] introduces a model called DICE, in which he illustrates the economics of climate change from the perspective of neoclassical growth theory by including the natural resources of the climate system as an additional capital stock. The DICE aggregates different countries into a single level of output, technology, capital stock, and emissions. A parallel research effort, jointly with Zili Yang [57], has been devoted to an integrated, multi-region version of the DICE model called RICE. In that model, population growth and technological change are region specific and exogenous.

The effect of population growth on economic activities is not clear based on different models and approaches. Hardin [41] argued that, to have a sustainable economy, population growth must be zero in order to keep our limited resources from being overutilized. Club of Rome [53] reported that the Earth's industrial capacity and population will catastrophically decline if we continue the level of capital accumulation that Turner [81] and Hall and Day [39] showed.

Ehrlich and Ehrlich [24] claim that the issue with overpopulation is not population density itself but the number of inhabitants in an area relative to its resources and the capacity of the environment to preserve their activities; that is, to the area's carrying capacity. Carrying capacities differ according to alterations in value judgments and objectives. In any society, institutional arrangements are possible to adjust the carrying capacities and desired levels of populations, and carrying capacities in the shorter term may differ from those in the longer term [68].

One of the main issues of the aforementioned conflict is the methods scholars use to incorporate population into their models. Treating population endogenously—as proposed by Becker [14], Eckstein and Wolpin [24], Becker et al. [15], and Ehrlich and Lui [26] at the micro level—might lead to different results when comparing exogenous growth in population. Endogenous population growth on the Macro level can be traced to Malthus' study [52], and after that [70]. Nerlove and Raut [55] modify the Solow-Swan [75] model by introducing a simple form of an endogenous population, assuming that the rate of growth of the population depends on the real wage or per capita consumption; this was also suggested in the variation model by Niehans [56]. The Nerlove and Raut [55] model shows that as income grows, fertility rate might not change because both birth and death rates fall, and physical and human capital per capita increase over time.

At the same time, works by the new generation of growth economists such as Sandberg [67], Romer [65], and Jones [44], explain that technological progress, on the other hand, is the engine of long-run economic growth. An increase in population will accelerate that progress by increasing the number of researchers (for instance, consider the required investments in higher education) that can develop new ideas, leading to more innovation and eventually offsetting the environmental costs of population growth. Models of endogenous technological change, such as Aghion and Howitt [4] and Grossman and Helpman [37], typically imply that high population spurs technological change. As Kuznets [48] and Simon [73] argue, a higher population means more potential inventors. Following Lee [51], Kremer [45] constructs an integrated model of