Asian Journal of Geological Research

4(2): 33-44, 2021; Article no.AJOGER.68684

Biophysical Limits to Economic Growth and Sustainable Development: Perspectives and Approaches

Surendra Singh Jatav[1*], Sanatan Nayak[1] and Sonali Narang[2]

[1]Department of Economics, BBA University, Lucknow, Uttar Pradesh, India.
[2]Department of Political Science, Parul University, Vadodara, Gujarat, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author SSJ collected literature and reviewed. Author SN written first draft of this paper and author SN revised the paper and incorporated relevant information in the paper. All authors read and approved the final manuscript.

Article Information

Editor(s):
(1) Dr. Ahmed Abdelraheem Frghaly, Sohag University, Egypt.
Reviewers:
(1) Somayeh Rezaei Kalvani, UPM, Malaysia.
(2) Manuel Emilio Milla Pino, National University of Jaen, Peru.
(3) G. Saravanan Gengan, Kl Deemed To Be University, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/68684

Review Article

Received 10 March 2021
Accepted 17 May 2021
Published 21 May 2021

ABSTRACT

The debate on sustainable use of natural resources, population growth, the role of technology in economic growth, and individual preferences have a long history, starting from Malthus's noble argument on biophysical limits to growth to ecological economist's sustainable development perspective. After more than two centuries of Malthus's argument, still we are in progress to understand the relationship between human beings and nature. It is prerequisite to track the economic growth and development pattern of north and south. Hence, By reviewing the growth pattern of the global south and north, the present paper systematically reviewed the different perspectives of biophysical limits to economic growth. Further, the paper comes up with a new estimation of economic growth trajectory by incorporating negative and positive externalities occurs during the production process.

**Corresponding author: Email: surendra.singh735@gmail.com;*

Keywords: Population and development; resource scarcity; technological transformation; green economy.

1. INTRODUCTION

There has been a subject of controversy for more than two centuries that can we expect unlimited economic growth in a world endowed with finite resources, if biophysical limits are important factors in determining future trends of economic growth [1]. With scare natural resources and exponential growth in population, can we achieve economic growth indefinitely? Does technology should be perceived as the "ultimate" escape from the problem of resource scarcity or technology contribute further environmental deterioration? Does human- made capital equally substitutable with the natural capital? These are some policy questions raised by the (i) Malthusian, (ii) Neoclassical, and (iii) Ecological economists in the context of biophysical limits to growth. Malthusian economists argued that economic activity cannot be expected to grow indefinitely unless the rates of population growth and/or the rate of resource utilization are effectively controlled [2]. Limits to economic growth could come through either the depletion of key resources and/or large-scale degradation of the natural environment. Malthusian economists have provided a simple functional relationship between population, growth and resource scarcity. They have postulates that the total amount of land available for agriculture is immutably fixed, while the growth of population is limited by amount of food available for subsistence, and human population will invariably increase where the means of subsistence increase. They then stated that if no prevented by some checks, the tendency is for the population to grow geometrically (2, 4, 8, 16, etc.) while the means of subsistence grows arithmetically (1, 2, 3, 4, etc). Unless this tendency of ever-increasing imbalance between the growth rates in population and the means of subsistence is resolved by moral restraints, on the long-run vice and misery will ultimately repress the superior power of a population to a level consistent with the means of subsistence. In other words, population growth, if left unchecked, would lead to the eventual downfall of living standards to a point sufficient for survival. This has been called Malthus's iron low of wages.

Fig. 1 graphically explained the Malthus law. If we assume that quantity of labour L, can be used as a proxy for population size and real output, Q/L, as a measure of per capita income, Fig. 1 can be viewed as depicting the relationship between population size and per capital income. This relationship is constructed assuming fixed amounts of resources (i.e., land & technology). Since the intent here is to offer an alternative explanation to the simple Malthusian model, let output, Q, represent agricultural or food products in general.

In Fig. 1, per capita food output, Q/L, was initially rising with an increase in population. This positive association between population and per capita food production continued until the population size (labour force) reached L_1. Beyond this point, however, farm labour productivity (measured in terms of output per unit labour service) started to decline with each successive addition of labour service in accordance with the law of diminishing marginal product. Since fertile land is assumed to be fixed is supply, more labour applied to a given plot of a homogeneous quality of land or to a successively less fertile plot of land yields a proportionately smaller return. Hence, as the population increases and, accordingly, so does the demand for food and fiber, the production of any additional units of farm output requires progressively larger quantities of labour.

The thick horizontal line in Fig. 1- represents the output per unit of labour (or real wage rates) barely sufficient for survival, i.e., the subsistence level of food. Thus, when the labour force (i.e., the population) has increased to a level L_2, the Malthusian margin is attained. This will be a stable long-run equilibrium, because for a population below L_2, unless enforceable public policy measures are taken to limit population growth, according to Malthus the natural tendency of the human population is to continue growing as long as the per capita food exceeds the minimum food required for a subsistence like-Q^*/L^*. On the other hand, any increase of population beyond L_2 would be prevented, or, to use Malthus's terms, by "vice and misery". Thus, in the long-run, disease, malnutrition and famine will bring growth to a halt at L_2. Finally, one interesting feature of the simple model above is its suggestion of an optimum population size (labour force). In Fig. 1, the optimum population size is attained at L_1, where the per capita food level is at its maximum.

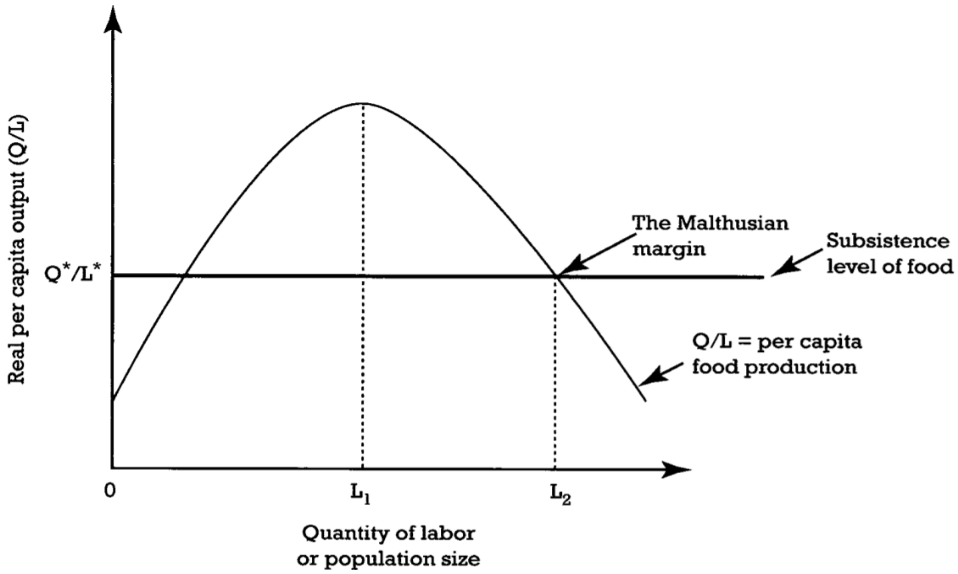

Fig. 1. Malthusian growth model

Even though, Malthusian economists have been provided a simple function relationship between population, growth and resource scarcity, but it ignores (i) the institutional factors that affect population growth, (ii) underestimate the role of technology in the growth process and, (iii) fails to explain the effect of economic growth on the natural ecosystem and its inhabitants as a whole [3]. In totality, the simple Malthusian theory of population and resources is viewed as incomplete from economic, technological, and ecological perspectives [4].

Neoclassical economists argued that natural resource scarcity can be continually augmented by technological means. Human-made capital such as machines, building, roads, etc., and natural capital such as forests, coal deposits, wetland preserves, wilderness, etc. are substitutable indefinitely [5]. They believed that technology- by finding substitutes, through discovery of new resources, and by increasing the efficiency of resource utilisation has almost no bounds in ameliorating natural resource scarcity.

They also argue that significant improvements in environmental quality are fully compatible with economic growth for the following reasons: First, one of the benefits of economic growth is an increase in per capital income. Higher per capital income will increase the demand for improved environmental quality. This means increased expenditures on environmental clean-up operations. Second, continued improvement in pollution abatement technology will not allow the cost of environmental clean-up to grow without bound. That is, in a healthy and growing economy, growth in pollution abatement expenditures will be continually moderated by technological advance, furthermore, even if this is not the case, increase in pollution clean-up expenditure need not be a major concern unless it is a large proportion of the Gross National Product (GNP). In general, expenditures on pollution abatement are a very small portion of GNP.

Although, neoclassical economists have provided a better understanding about the relationship between technology, resource scarcity and economic growth, yet ecological economist criticized that human- made capital and natural capital are not substitutable indefinitely. They are complementary in nature. They argued by the use of the second law of thermodynamics. The law place limits on the substitution of human-made capital for natural capital (law of entropy matter and energy) and, therefore, the ability of technological change to compensate for the depletion or degradation of natural capital. In fact, in the long run, natural and human-made capital is complements because the later requires material and energy for its production and maintenance. This is indeed a rejection of one of the important core principle of the neoclassical growth paradigm, i.e., the notion of infinite substitution between human-made and natural capital. Third, ecological economists suggested that economic growth is a subsystem of natural ecosystems. They suggested that balance between human economy and natural ecosystem should be maintained through sustainability approach. In the economic growth estimation, loss of natural resources should be accounted[1].

With the above evidences, this paper systematically reviewed the different perspectives of limits to growth starting from Malthusian to ecological economists. Paper also comes up with sustainable solutions (i.e, green economy) which rejects Malthusian hypothesis on limits to growth.

This paper divided into three sections. Discussion on limits to growth in brief is made in Section- 1, while different perspectives and approaches of limits to growth are systematically and critically reviewed in Section-2, and concluding remarks are made in the Section-3.

2. BIOPHYSICAL LIMITS TO ECONOMIC GROWTH

2.1 Malthusian Perspective

Malthus started debate on biophysical limits to economic growth by using of his first official known work on the relationship between resource use, population, and unlimited economic growth. Malthus argued that the development of mankind was severely limited by the pressure of population growth exerted on the availability of resources. Malthus had given three assumptions in his population and resource use theory, i.e., (i) natural resources are fixed in absolute term, (ii) the world's population tends to increase at a faster rate than the resource regenerate, and (iii) population grows at a geometric rate, the production capacity of resources only grows arithmetically. By using these three assumptions, Malthus predicted that in a short period of time, limits to economic growth would be in reliability. To avoid limits to economic growth, Malthus was suggested two possible solutions, viz., preventive check and positive check. The preventive check consists of voluntary limitations of population growth and On the other hand; the positive check to population is a direct consequence of the lack of a preventive check[2]. When society, does not limit population growth voluntarily, diseases, famines, and wars reduce population size and establish the necessary balance with resources[3]. Hence, preventive and positive checks, by controlling population growth, eventually close the mismatch between the size of population and availability of resources. The preventive and positive checks are temporary measures and in the long-run, cost of creating misery and wickedness, such as climate change and loss of biodiversity cannot be avoided and are beyond the control of mankind.

Malthus also discussed about the role of technology in the economic growth paradigm. He argued that technological improvement that contribute to the increase in agricultural yields would not only produce a temporary increase in living standards, but also offset in the long-run by a corresponding increase in population size. Malthus has opposed to resources substitution such as monetary transfer from rich to poor individuals[4]. He argued that increasing welfare of the poor by giving them more money would eventually worsen their living conditions, as they would mistakenly be lead to think that they can support a bigger family, which would in turn depress the preventive check and generate higher population growth. At the end of this process, the same amount of resources has to be divided into a larger population, triggering the work of the positive populations check. More specifically, an immediately after such a transfer, people can afford buying more food, bidding its price up and decreasing real wages which hurt poor individuals whose main income comes from their labour.

After nearly two centuries of Malthus argument on limits to economic growth, Ehrlich- Commoner (EC) [7] has developed a model by using the population, affluence, and technology. The EC

[1] Stern [6] suggested that without accounting of natural resources depletion, we cannot estimate real growth rate. Defensive expenditure in terms of health expenditure has also to be accounted. Further, the rate of renewable and non-renewable resources depletion should be account in the gross national product, which is best acceptable indicator for economic growth.

[2] The positive check suggested that individuals, before getting married and building a family, make rational decisions based on the income they expect to earn and the quality of life anticipate for maintaining in the future for themselves and their families.

[3] Malthus argued that, the positive checks acts more intensively in lower classes, where infant mortality rates are higher and unhealthy conditions are more common.

[4] Later on neoclassical adopted this assumption that natural resources and human-made resources are equally substitutable and we can achieve indefinitely economic growth.

model starts with the postulate that all human activities modify the natural environment to some extent. In its simplest form, this model can be mathematically expressed as follows:

$$I = P * F \ldots\ldots\ldots\ldots(1)$$

Where the variable I represents the total environmental effect or damage measured in some standard unit, P is a variable representing population size in terms of head count, and F is an index that measures the per capital impact (or damage) to the environment. Equ. 1 formally states that, at any given point in time, the total environmental impact of human activities is a product of the underlying population size, P, and the per capita damage to the environmental, F. in other words, total environmental impact equals total population multiplied by the average impact that each individual person has on the environment. However, this function dos not tell us what factors determines the per capita impact, F, or whether or not population size and per capita impact are interrelated. In other words, a good deal of complexity is masked in the above model. Thus, to make this simple model more revealing and of some practical value, we need to further examine the per capital impact as a separate function that is affected by several key variables as expressed below:

$$F = f\big(P, c, t, g(t)\big) \ldots\ldots\ldots(2)$$

Where c indicates per capita consumption or production, t represent technology and g refers to the composition or the mix of material inputs or output used in an economy.

Thus, when we take equations 1 & 2 together, we see that the total environmental impact, I, of human activities depends on total population, P, and a host of other interrelated variables affecting the per capita damage function.

In this model, population was in the centre, as Malthus was taken, however EC have taken an unwavering position that human population growth is the primary culprit in a period of continued resource depletion and environmental degradation. By using the law of diminishing marginal returns, he argued that the total impact on the environment is equalled total population multiplied by the average impact that each person has on the environment. The argument is that most of developed nations' economies are already operating at a high level of production capacity. These nations are, therefore, on the diminishing returns of their production activities. Under these circumstances, if other factors are held constant, successive additions of population would require the increased use of natural resources [8]. Thus, as population continues to grow, per capita impact, in terms of resource depletion and environmental deterioration will increase successively [9]. Further, the decision to change the composition of economic inputs and outputs is made purely for profit motives. Therefore, input and output decisions are made on the basis of technical efficiency (increased per capita production, which increases profit), rather than the impacts these decisions may on the environment [10].

The EC have criticized to Malthus on the role of population. He argued that population is not solely responsible for the natural resource depletion. His argument was that the population growth plays a minor role in explaining the environmental and resource conditions of the modern era, especially in economically advanced regions of the world. Instead, EC believes that a major part of environmental results from the inappropriate application of modern technology in the economy. This is because technological choices are often made purely on the basis of profitability rather than environmental sustainability[5].

2.2 Neoclassical Perspective

Neoclassical economists in majority believed that there is no such kind of resources depletion as pointed by the Malthusian and neo-Malthusian economists. Instead, the real issue of significance is to understand the circumstances under which technological progress would continue to ameliorate resource scarcity as pointed by the Malthusian economists. In other words, the fundamental issue addressed in this context was not much in existence for biophysical limits, but rather important, through technological progress and appropriate institutional arrangements. The neoclassical economic prospective of natural resource scarcity, allocation and measurement is based on the following assumptions: (i) nothing rivals

[5] Ehrlich-Commoner [7] belongs to neo-Malthusian club of economists. He believed that use of technology can be harmful in the resource full closed agro-based economy. Later on ecological economists partially agreed with commoner that technology can be increased the rate of natural resources depletion especially of non-renewable resources. In many parts of the world, the rate of mining for coal and fossil fuels has increased many fold observed in the recent decades.

the market as a medium for resource allocation, (ii) resources valuation depends only on individual preferences and initial endowments as determinants of prices, (iii) for privately owned resources, market prices are "true" measures of resource scarcity, (iv) price distortions arising from externalities can be effectively remedied through appropriate institutional adjustments (v) resource scarcity can be continually augmented by technological means, and (vi) human-made capital (such as machines, buildings, roads etc.) and natural capital (such as forests, coal deposits, wetlands preserves, wilderness, etc.) are perfectly substitutes.

On the basis of these assumptions, neoclassical economists rejected Malthusian theory of population and resource scarcity. They criticized about the role of technology in the economic growth process. They believed that, under the right circumstances, technology will continue not only spare resources, but also to expand our role [11,12]. Kuznets's [12] by used of inverse relationship between pollution and economic growth, and Grossman and Krueger (1996) argued that continued improvement in pollution abatement technology will not allow the cost of environmental cleanup to grow without bound. That is, in a healthy and growing economy, growth in pollution abatement expenditures will be continually moderated by technological advancement ([8]. Further, even if this is not the case, increase in pollution cleanup expenditure need not be a major concern unless it is a large proportion of the Gross National Product (GNP). In general, expenditures on pollution abatement are a very small portion of GNP.

Neoclassical economists also rejected Malthusian assumption that natural resources are fixed in absolute term. They argued that biophysical limits to economic growth can be overcome by substituting natural resources by the human-made resources. By using of the advance and efficient technological development, resources can be substituted from more plentiful to less plentiful, such as wood replaced by coal, coal replaced by natural gas, and natural gas replaced by solar energy.

Lastly, neoclassical economists criticized the Malthusian economists on the issue of population. They believed that economic growth is not only good for the environment, but also a cure for a nation's population problem. This contention is supported by what is commonly known as the theory of demographic transition. This theory is based on the empirical generalization and it claims that as nations develop, they eventually reach a point where birth rate falls. In other words, in the long-run, the process of industrialization is accompanied by a sustained reduction in population growth. This is because the increase in income of the average family in the course of industrialization reduces the desire for more children. However, they ignored the heterogeneity in the growth placed by the regional disparities. They failed to explain individual preference(s) and change in consumption pattern in the developed countries with reducing population size maintain the level of resource use. Further, current pattern of resource use, technological advancement, population size, and economic growth in the so called developed countries, rejected the core principle of neoclassical [12] that technology would be ultimate solution of all environmental evils.

2.3 Ecological Perspective

The resource use, growth in population size, improvement in technology, the role of institutional sector, depletion of natural resources and human wisdom presented complex relationship between natural and human-made economy as discussed by Malthus, Malthusian and neoclassical economists. In contrast to neoclassical economists, ecological economist believed that human economy is a subsystem of the ecosystems. Limits to economic growth could no longer be argued solely on the basis of the possibility of running out of conventional resources as Malthusian believed nor could technology be viewed as the ultimate means of circumventing ecological limits as neoclassical economists advocated. Ecological economists argued that technology can be abused or misused and it could be blessed. For example, a technological advance that decreases the need for throughput, while maintaining a material standard of living at some desired level, is indeed to be sought after. On the other hand, if technological advance is directed towards producing more goods and services with no limit in sight, such a strategy is highly questionable from the viewpoint of long-term sustainability. Further, the use of technology in the production process is purely based on cost-benefit analysis. For example, a producer or entrepreneur only used technology when the cost of technology adoption is cheaper than the substitutes, i.e., labour and natural resources. On the other hand, if cost of technology is higher than the labour and natural resources, the entrepreneur preference would be labour and natural resources rather than technology.

Ecological economists argued by using the steady- state economy model, any technological change that results in the maintenance of a given stock (labour, capital and natural resources) with a lessened throughput is clearly to be encouraged [13]. Ecological economists criticized the Neo- classical economists on resource substitution through the use of the law of thermodynamics. It placed limits on the substitution of technological change to compensate for the depletion or degradation of natural capital [14]. It is valid in the short-run, because regeneration rate of natural resources quite slow as compared with its use in the economic growth process we observed over the last century. In fact, in the long-run, natural and human-made capital is complements because the later requires material and energy for its production and maintenance. Furthermore, neither capital not labour physically creates natural resources, depletion of natural resources cannot be resolved through endless substitutions of labour and capital for natural resources. This is indeed a rejection of one of the core principle of the neoclassical growth paradigm, i.e., the notion of infinite substitution between human-made and natural capital.

Ecological economists such as Daly (1993) argued that neoclassical economic growth paradigm is untenable, because it is not based on sustainable biophysical and moral consideration. He explained this argument by using a simple scheme of a mean and end spectrum. He argued that standard economic growth model ignore the ultimate means by which the growth of material standards of living are attainable The fact is that the ultimate means are scarce in absolute or that these basic resources constrained by natural laws is considered irrelevant by mainstream economists [15]. Instead, because of their blind faith in technology, neoclassical economists exclusively focused on the availability of intermediate means such as labour, capital, and conventional natural resources (such as raw material). In the process, the fact is that the availability of intermediate means ultimately depend on the availability of ultimate means seems to have escaped standard economic thinking. For this reason, focusing on intermediate means, ecological economists discussed relative scarcity and process, on the basis of which resources are allocated to alternative societal uses.

By criticising the two core assumptions, ecological economists suggested that the loss of ecosystem resilience has key limiting factors in humanity's pursuit for a material pleasure [15,16,11]. The loss of ecosystem resilience is potentially important for at least three reasons. First, the discontinuous change in ecosystem flips from one equilibrium to another could be associated with a sudden loss of biological productivity and so to a reduced capacity to support human life. Second, it may imply an irreversible change in the set of option open to both present and future generations such as loss of biodiversity, soil erosion, and desertification. Lastly, discontinuous, and irreversible changes from familiar to unfamiliar states increase the uncertainties associated with the environmental effects of economic activities (Arrow K. et al., 1995). If economic growth is to be sustainable, we need to ensure that the ecological systems on which our economy depends are resilient.

Given this biophysical reality, it is no wonder that neoclassical economists are so captivated with continual growth in intermediate ends such as market- valued goods and services. But, how the total quality of goods and services produced in a given period of time is distributed among the people of the current generation (intra-generational), and how current economic growth may affect the well-being of the future generation (intergenerational), are simply not considered by the neoclassical economists. Here, argument is not that neoclassical and ecological economists are in denial of the existence of misdistribution of income among the current generation, or that they are insensitive to the possible adverse effects of current production (such as climate change) on the wellbeing of the future generation. Rather, the main position of ecological economists has been for sustaining a moderate to high economic growth rate is the single most effective solution for the current and future economic and ecological problems.

Now question arises that if above growth paradigm is to be rejected on the basis of its incomplete material and ethical consideration, what alternative model could be proposed. On this point, ecological economists suggested a new growth model called steady-state economy (SSE). Model consists of biophysical, economic, and ethical dimensions. SSE in the purely biophysical state Daly [16] suggested that the total inventory of all intermediate means and ends, including human population, is frozen at some “desirable” constant. In other words, in quantitative terms, the material requirements to run an economy are held constant at all times. Thus the primary focus is on stock maintenance: maintaining a constant inventory of intermediate means and ends. How it is possible because the economic world is defined not only by material flow or transformation of matter-energy, but by “an immaterial flux: the enjoyment of life”.

How does the SSE address this important dimension of the economic world? Daly [16] suggested that this objective can be achieved through what he called service efficiency, which is identified as the ratio of service to the constant stock. Maximization of this ratio amounts to finding ways of making the numerator larger while keeping the denominator constant. Now again question arise, how to constant stock? For this Daly [16] provided two specific solutions, viz., allocative and distributive Efficiencies.

Fulfilment of allocative efficiency requires two specific conditions. First, the production of goods and services should use the least amount of intermediate means (labour, capital and natural resources). Second, the good and services that are produced should be the once that provide the most satisfaction to people. On the other hand, distributive efficiencies require that the distribution of the constant stock should be done in such a way that the “unimportant” wants of some people do not take precedence over the basic needs of others.20 It is important to ensure that current generations are not enriching themselves at the expense of future generations There are, conceptually, three general principles which govern the operation of the SSE. First, the SSE requires the use of throughput (low-entropy matter-energy) to be minimized at times. This suggests that in the SSE, as much as feasible, all possible technological avenues must be pursued to produce goods and services that are long-lasting and easily recyclable. Second, in the SSE, service (utility) is to be maximized. This should be done through a combination of both production efficiency and distributive efficiency. Finally, the SSE requires that stock should be held constant because in a world endowed with finite resources, equity considerations in both time and space make the requirement of constant stock as an essential prerequisite of the SSE.

First two preconditions of SSE cannot achieve without violating third condition. If the natural resources are finite in absolute term, then how stock remains constant, whereas natural resources are key determinants of economic growth. Daly [16] replied on this question that (i) while physical stocks are held constant, the stress should be on measuring economic improvements in terms of non-physical goods, i.e., services and leisure, (ii) emphasis should be placed on technological progress that increases leisure activities (such as a growing appreciation of environmental amenities, friendships and meditation), which are far less material-intensive that the production of physical outputs. With these adjustments, economic growth, measured in terms of increasing level of satisfaction from a given level of resource stocks, it is quite possible.

Ecological economists emphasized more on sustainable use of natural resources by use of efficient technological improvements. SSE model somehow successful (at least theoretically) that indefinite economic growth can be achieved if all suggested precautionary measures would be taken. But they are more or less silent about irreversible changes in the extremely uncertain circumstances, such as global warming and climate change. Since first intergovernmental panel on climate change [17] report came in public domain that it has a hard task to predict that which types of changes occur in the near future. The predictions about global warming and climate change are yet not valid predicted in the first IPCC report.

Uncertainty is a vital consideration among the researchers associated with sustainability, because it is expected that changes will occur in technology, income, and people’s preference over time. Technology may change enormously in response to change in relative scarcities and knowledge. Income will not be constant and preference will differ across generations. The problem is not that changes will occur, but rather that we do not know for sure how and when these changes will occur and we do not know what the implications of these changes will be on future resource availability. Therefore, a special branch of economics called the economics of sustainability has given attention to the uncertain effects of the current level and pattern of human enterprise on the integrity of the natural ecosystem [18,19,12].

It deals with the issue of irreversibility. That is, beyond a certain threshold level, continued human exploitation of nature or economic growth may cause irreversible damage to certain vital components of a natural ecosystem such as forestland. Therefore, sustainable development cannot be achieved without addressing following four key issues. (i) physical limits of natural system, (ii) intergenerational equity and economic efficiency, (iii) technological options and social values, and (iv) inter-temporal management of natural resources under in conditions of uncertainty and irreversibility. These four broad issues are examined by assuming that the overriding social goal, which are in progress toward sustainable economic development.

The term "sustainability" was coined in the Brundtland commission report [20] "our common future". It was already discussed by the Malthusian and neoclassical economists called week sustainability. Malthusian economists were against monetary transfer from rich to poor (weak sustainability). They believed that due to this, the rate of resource use would be increased. On the other hand, neoclassical were in favour of and they believed that natural resources are equally substitutes towards the human-made resources. Hartwick [21] and Solow [22] defined "weak sustainability" in terms of maintaining a constant real consumption of goods and services over an indefinite period of time while recognizing the constraints imposed by a given set of resource endowments. They suggested that maintaining a constant real consumption of goods and services, or real income (in the Hicksian sense), are possible even in the presence of exhaustible resources, and provided that the rent (income) derived from an inter-temporally efficient use of these resources is re-invested in renewable capital assets. Thus, the focus of concern is on the prudent use of the returns on, or a savings of exhaustible resources, rather than the depletion of these resources. Basically, to maintain sustainability (weak) needs of a situation in which a nation could maintain a non-declining of consumption income over several generations, provided the productive capacity (capital stock) of the nation in held intact. This can be achieved provided that allowances for capital consumption have kept proportionate to the level of investment necessary for the country to maintain its productive capacity.

In contrast, the concept of "strong sustainability" implies a physical principle which is founded upon the laws of thermodynamics and processes of biological growth. As a basic principle of resource management, it has a long tradition in forestry, and has logically been extended to other domains of natural resource management. For instance, minimum criteria of "strong" sustainability" is generally in physical terms, saying that certain properties of the physical environment must be sustained. It is argued that ecological sustainability needs to be beyond human interest. At least in principle, the ecological economists approach to sustainability involves concerns extending beyond the human species, i.e., the well-being of ecological systems in their entirety. For this reason, the ecological approach to sustainability is broadly defined and has both economic and ecological dimensions. Thus, the level at which the non-declining natural capital stock is set is expected to be consistent not only with economic sustainability, but also with the ability of the ecosystem to withstand shocks, i.e., ecological resilience. The ultimate effect of all this will be to provide greater allowance for natural resource preservation for the purpose of safe-guarding future generations against large-scale, irreversible ecological damage such as biodiversity loss and climate change. To maintain strong sustainability, following goal should be achievable: (i) the rate of exploitation of renewable resources should not exceed that regeneration rate; (ii) waste emission (pollution) should be kept at or below the waste-absorptive capacity of the environment. For flow or degradable wastes the rate of discharge should be less than the rate at which the ecosystem can absorb those wastes, and (iii) the extraction of non-renewable resources such as oil should be consistent with the development of renewable substitutes.

Sustainability approaches of neoclassical and ecological economists partially cleared the importance of natural resources in the production process, but still, there is a possibility that natural resources stock is not available in the future or remains constant. Therefore, [23,24,18,25] emphasized the collective actions of the society for the preservation of natural resources. They argued that the collective actions of all class population groups deal with irreversible environmental changes such as climate change. They have suggested a new approach called safe minimum standard (SMS). SMS has provided a more realistic solution for the environmental negative externalities. It started as a practical guide to natural resource management under the conditions of extreme uncertainty, for example, the preservation of individual species such as Asiatic lions. For problem of this nature, it is argued that irreversibility becomes a key issue to consider.

That is beyond a certain threshold or critical zone; the exploitation of natural resources may lead to irreversible damage. For example, the Asiatic lions would be declared extinct if managing natural resources of this certain minimum; and this maximum is greater than zero. Therefore, in managing natural resources of this nature, it is highly important to pay serious attention to not extending resource use beyond a certain safe minimum standard (SMS). Otherwise, the social opportunity cost of reversing direction might become "unacceptably large". However, it is important to note that considerable uncertainty exists regarding both the cost and the irreversibility of particular human impacts on the natural environment. Therefore, in this sense, uncertainty is central to the concept of safe minimum standard.

The SMS approach to sustainability does not totally invalidate the standard economists approach to resource assessment and management (neoclassical "weak" and ecological "strong"). It simply narrows the scope and the applicability of the standard economics conception of sustainability by restricting its relevance to human impact on the natural environment, where the potential consequences are regarded as being small and reversible. In some degree, the SMS and the ecological approaches to sustainability share common features. Both approaches adhere to the notion of limits in the substitution possibilities between human and natural capital. However, these two approaches provide different explanations for limits in factor substitution. The SMS uses irreversibility, while the ecological economics approach relies on all encompassing physical laws (of which ecological irreversibility in only a part). The SMS approach to sustainability can be perceived as a hybrid between the weak and strong approaches to sustainability [12].

The idea of sustainability has very much fascinating. But in practical, it is requires lots of efforts to imply in the current economic growth estimation [28]. It requires a modification of the conventional national accounting concepts of income, in particular the gross national product (GNP). The key issue has been that a nation's income as measures traditionally by the GNP does not account for all the resources, costs that are attributable to the production of goods and services and cannot reflect a level of income that is sustainable indefinitely [16,12]. Therefore, to the measurement of real economic growth, Daly [16] and Pearce [27] suggested that the cost of natural resources depletion should be deducted from the national income accounting. Thus, the relevant income measurement is the net national income (NNP) not gross national income (GNP). Hence, modified national income accounting terms as follow.

$$NNP = GNP - DHC \ldots\ldots\ldots\ldots.(3)$$

Where, NNP is net national product (income), GNP is gross national product and DHC is the depreciation allowance of human capital.24 Apart from the cost of natural resources depletion, Daly [16] and Pearce [26] suggested the cost of defensive expenditure due to depletion of natural resource quantity as well as quality to be included.

$$NNP = DNC - EDE \ldots\ldots\ldots\ldots..(4)$$

Where, NNP is net national product (income), DNC is the depreciation of natural capital and EDE represents the environmentally defensive expenditures. Although, Daly [16]; Pearce [27] and Hussain [12] presented a modified version of national income accounting, but they did not included the cost incurs due to uncertainty and irreversibility. It is important where the intensity of natural calamities is increasing with highly uncertain consequences. Therefore, net national product (NNP) could be sustainable national income (SNI) if following condition is accepted.

$$SNI = NNP - DNC - EDE - UC - EIC \ldots\ldots\ldots..(5)$$

Where, SNI is sustainable national income, NNP, net national income, DNC depreciation of natural cost, EDE, environmental defensive expenditures, EC uncertainty cost and EIC represents environment irreversibility cost. It is important to recognize that conceptually, assuming no change in technology, SNI represents the maximum amount of income that can be expended for current consumption without impairing the future productive capacity of a nation keeping natural capital stock intact.

3. CONCLUSION

The debate on sustainable use of natural resources, population growth, the role of technology in economic growth and individual preferences has a long history, starting from the Malthus's noble argument on biophysical limits to growth to ecological sustainable development perspective. This paper critically reviewed the different perspectives and approaches of limits to growth and highlighted the weak and strong points of Malthusian to ecological economists. Each approach has evolved after failure of previous one. Ecological perspective is a hybrid approach which covers Malthusian and Neoclassical approaches and gives direction for sustainable development and infinite economic growth with finite resources. Though, presently none of the country in the world has in situation to achieve all the sustainable development goals as majority of their energy production is relies on the cheap non-renewable resources and continuously increasing population further making situation worsen. Further, war, genocides, social and religious discrimination, poverty, large-scale unemployment, mass migration, and rapid deforestation are some of critical barriers in the path of sustainable development as ecological economists dreamed.

Further, though this paper critically reviewed different perspectives of limits to growth and come up with unique solutions as suggested by ecological economist, but authors believed that none of a single study able to cover all the issues of limits to growth. Hence, this paper also has some limitations. First, authors do not critically review ecological perspective as physics laws of thermodynamics are totally disagree with ecological economists. Second, authors believed that meta- analysis will be provides clear picture of weakness of different perspectives. Lastly, empirical study is also needed for evidence based findings to validate the hypothesis made by different school of economists

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Singh S, Sanatan N. Climate variability and agricultural productivity in Uttar Pradesh, India: Evidence from Panel Study. Journal of Regional Development and Planning. 2017;7(2):23-43.
2. Singh S, Sanatan N. Planned adaptation strategies and climate variability: Evidences from NSSO Households Level Data. Research Review International Journal of Multidisciplinary. 2018;3(10):423-430.
3. Singh S. Soil health security in India: Insights from soil health card data. Research Review International Journal of Multidisciplinary. 2019;4(3):322-325.
4. Singh S, Alka S. Farmers' Perception of Climate Change and Livelihood Vulnerability in Rainfed Regions of India: A Gender-environment Perspective. International Journal of Environment and Climate Change. 2019;9(12) 878-889.
5. Singh S, Md Awais, Alka S. Irrigation development and equity implications in India: Revisiting sustainable development agenda. Environment and Ecology. 2019; 37(4A):1537-1545.
6. Stern D. The rise and fall of EKC. World Development. 2004;8(32):23-30.
7. Ehrlich PR. The population bomb, Ballantine Books, New York, USA; 1968.
8. Singh S, Santan N. Development of sustainable livelihood security index for different agro-climatic zones of Uttar Pradesh. Journal of Rural Development. 2020;39(1):110-129.
9. Singh S. Bridging the gap between biophysical and social vulnerability in rural India: A community livelihood vulnerability approach. Area Development and Policy. 2020a;5(2):1- 22.
10. Singh S. Farmers' perception of climate change and adaptation decisions: A micro-level analysis of farmers in the Bundelkhand region, India. Ecological Indicators. 2020b;115:1-13.
11. Ausubel JH. Can technology spare the Earth. American Scientist. 1996;84:166-178.
12. *Hussain, H.M. Principals of Environmental Economics: Economics, Ecology and Public Policy*, Routledge, London, New York.
13. Kuznets S. Economic Growth and Income Inequality, American Economic Review. 1955;45:1-28.
14. Singh S. MGNREGA: 100 days employment Guarantee in Bundelkhand (M.P.)?. International Journal of Management and Development Studies. 2013;2(4):1-10.
15. Ayres RU. application of physical principles to economics, in R. U. Ayres, (ed.) Resources, Environment, and Economics: Applications of the Materials/Energy Balance Principle, John Wiley, New York, U.S.A; 1978.
16. Boulding KE. The economics of coming spaceship Earth, in Daly HE, Townsend KN, (eds.) Valuing the Earth: Economics, Ecological,

Ethics, The MIT Press, Cambridge, MA; 1966.

17. Daly HE. Introduction, in H.E. Daly, (ed.) Towards a Steady State Economy, W.H. Freeman, San Francisco; 1973.
18. IPCC. Scientific assessment of climate change, contribution of Working Group I to the First Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, Switzerland; 1990a.
19. Krutilla JV. Conservation Reconsidered, American Economic Review. 1967;57(4):777-786.
20. Perrings C. Reserved rationality and the precautionary principles: Technological change, time, and uncertainty in environmental decision making, in R. Costanza, (ed.) Ecological Economics: The Science and Management of Sustainability, Columbia University Press, New York; 1991.
21. UNEP. Our common future, brundtland report No. 307, United Nations Environmental Programme, Nairobi, Kenya; 1987.
22. Hartwick JM. Intergenerational equity and the investing of rents from exhaustible resources, American Economic Review. 1977;67:972-974.
23. Solow RM. On the Inter-temporal allocation of natural resources, Scandinavian Journal of Economics. 1986;88:141-149.
24. Ciriacy-Wantrup S. Resource conservation: Economics and Policy, University of California Press, Berkeley, USA; 1952.
25. Hardin G. The Tragedy of the Commons, Science. 1968;162:1243-1248.
26. Bishop RC. Endangered species and uncertainty: The Economics of a Safe Minimum Standard. American Journal of Agricultural Economics. 1978;60:10-18.
27. Pearce D, Cline W, Achanta A, Frankhauser S, Pachuri R, Tol R, Vellinga P. The social cost of climate change: Greenhouse Damage and the Benefits of Control, in Bruce, H. Lee and E. Haites, (eds.) Climate Change 1995: Economic and Social Dimensions of Climate Change, Cambridge University Press, Cambridge, U.K; 1996.
28. Singh, S, Sanatan, N. Assessment of Climate Change impact on Wheat Yield in Western Dry Region: A District- Level Analysis. Climatic Change. 2021; 7(23): 25-33.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/68684