Economics and the Finite Planet: Evolving Paradigms of Resources and Sustainability

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Abstract. Traditional business concepts based on unlimited natural resources are being replaced by ecological analysis of fixed biophysical foundations, as demonstrated by ongoing shifts in resource and sustainable development paradigms. This paper examines significant paradigm shifts in economic theory regarding the relationship between the economy and the environment. Historically, mainstream economics excluded nature from its central models, operating under the implicit assumption of infinite resource availability and unlimited waste absorption capacity. In response to escalating ecological crises and conceptual advances, a "finite foundation" paradigm has emerged, which recognises biophysical limits as the primary boundary condition for economic activity. The present study utilises descriptive-analytical methodology based on the historical development of economic theory and conceptual analysis. The analysis contrasts the core principles of ecological economics and neoclassical environmental economics using a comparative paradigm framework. The study also integrates concepts from thermodynamics, ecology, and Earth system science, synthesising insights from interdisciplinary literature. Although the Neoclassical tradition offers essential tools for efficient allocation, it demonstrates a significant limitation in addressing the overall scale of the economy and its reliance on irreplaceable natural capital. In contrast, Ecological Economics reintegrates the economy within the ecosphere by emphasising sustainable scale and equitable distribution, grounded in thermodynamic principles. The findings indicate that contemporary frameworks, such as Planetary Boundaries, provide the scientific foundation for the "finite foundation" paradigm. This shift requires a move from incremental policy adjustments to comprehensive economic transformation, with a focus on qualitative development within established ecological limits. The central theoretical and practical challenge for modern economics remains the incomplete realisation of this paradigm shift.

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1. Introduction

The interwoven relationship between human society/civilizations with nature helps to sustain civilization and the continuation of civilization through time. All economic activity, from farming crops to creating cell phones, can be viewed as biophysical processes that extract low-entropy modifying organic materials and energy from the surrounding ecosystem with the eventual disposal of high-entropy waste back into the ecosystem. Economic theory's view of this relationship dramatically influences policy, perceptions of economic progress, and long-term viability of the chosen development path.

In the vast majority of the history of economics as an academic discipline, mainstream economics has operated on an implicit, and often explicit, assumption of unlimited resource supply and unlimited waste absorption capability. The natural world became a static backdrop, characterized as a factor of production known as "land," a repository of "free gifts" (Jevons, 1865), and an infinite sink for industrial by-products. Karl Polanyi (1944) might call this view of the economy "disembodied." It was an intellectual model that could be studied without considering its biophysical foundations. The primary inquiries of economics focused on the effective distribution of limited capital and labour, whereas the scarcity of the environmental system itself was excluded from the fundamental model.

This paper says that there has been a big, controversial, and still-unfolding change in economic thought over the last hundred years. It is a definite, but also an imperfect, move from a view of resources as infinite inputs to a view of a finite ecological base as the dominant boundary condition for economic movement. This shift is more than the mere addition of something new to what was already known, but also an ontological conflict between two perspective that are basically different. One world view is trying to incorporate environmental concerns into the current neoclassical growth model ("weak sustainability"), and another is trying to move our understanding of economics from a traditional development field to something more similar to an empirical life science ("strong sustainability").

The inferences of this rational shift go far beyond the realm of academia, as it will affect the way in which the world responds to the three major crises that face humanity, which are climate change, biodiversity loss, and pollution. In addition, this conceptual shift will call into question the way in which the success of a nation is measured, moving away from the use of GDP (Gross Domestic Product) and towards a more accurate measure of a nation's progress. This rational shift also has suggestions in terms of our understanding of development in the context of the Anthropocene.

This paper describes how economic thinking is being enforced to react to the non-negotiable constraints that come with living on a finite planet. There are four levels of this relationship: (1) A legacy of classical and neoclassical economics that defined the concern for limits and the tools to define those limits; (2) A mid-20th century awakening that saw the reintroduction of thermodynamic principles and systems theory; (3) The realm of weak vs. strong sustainability; and (4) The integration of Earth system science in the 21st century that defined the "finite foundation" through measurable parameters.

2. Objectives and Significance

2.1 Research Objectives

The objectives of this study are to:

1.To outline the historical development of paradigms of resource and sustainability in economic thought.

2.To evaluate the historical and current development of conceptual advancements in economic theory due to ecological crises.

3.To propose a framework for the integration of economic policy instruments in a hierarchical governance structure.

4.To develop policy recommendations and innovations that facilitate a transition from quantitative growth to qualitative development.

2.2 Significance

The consequences of this research outspreads far beyond just one or two disciplines. The classic literature on sustainability economics has provided an intellectual history and summary of differing school of thought regarding sustainability; thus, making all the various philosophical differences that exist between schools of thought more

evident and therefore contributing to the overall historical literature regarding the history of economics. This literature is very useful to policymakers as it provides a diagnostic framework that can be used to assess the effectiveness and shortcomings of present-day policies. In addition, this research highlights that market-based instruments alone are insufficient to attain sustainability; therefore, it has developed a theoretical basis for the development of more transformative approaches, such as the development of biophysical quota systems and redistribution of wealth. Finally, this research provides the tools necessary for the population in the Anthropocene Epoch to advocate for systemic change by demonstrating the relationship between the way economic theory impacts the sustainability of this planet and the well-being of humanity.

3. Research Methodology

The research involved a qualitative interdisciplinary approach, which is to say that the researcher was using a number of different perspectives to view an issue or topic. A conceptual analysis of the important terms used by different authors in their economic models (capital, scarcity, sustainability, etc.) was the starting point of the research. Next, a historical analysis of the authors' writing was done in chronological order by using historical information about the events in history (such as population growth) in the context in which the author was writing. Thirdly, the researcher used a method known as comparative paradigm analysis to compare and contrast the “infinite input” of the neoclassical paradigm against the “finite foundation” of the ecological paradigm in terms of various characteristics. The last component of the research was to combine different ideas from three distinct fields (economics, physics, & ecology/earth system’s science) and use this information to develop a coherent framework for understanding human economic activity within the “limits of nature”.

4. The Classical School: Land as the Limiting Factor

Economists of the classical school, writing during the Agricultural Revolution and early stages of the Industrial Revolution, considered land as the most valuable resource found in nature, assuming it to be permanently limited in its supply.

4.1. Malthus: Malthus (1798, An Essay on the Principle of Population) established that the limits of our natural resources had significant and strict biophysical limits. He thought that the population would grow geometrically and eventually outstrip

agricultural production, which could only grow arithmetically because of land constraints. This "Malthusian trap" argued that famine, disease, and poverty would always be potential to check progress. Malthus had the key insight that nature imposes a tough, systematic limit on human economic activity, although he was wrong about the timing because he did not foresee the technological developments.

4.2. Ricardo: Differential Rent and Diminishing Returns David Ricardo gave a better definition of scarcity in his book “On the Principles of Political Economy and Taxation” in 1817. His concept of differential rent was that as the population increases, society must cultivate less fertile land, and this implies that every unit of labour and capital gets a lower return. The owners of better and more fertile land earned profits by charging economic rent on the marginal land as the cost of production increased. He argued that scarcity differs from person to person and leads to distributional conflict. But he also argued that it is a constraint on economic growth because of the quality and quantity of land.

4.3. Mill: The Stationary State and Qualitative Development John Stuart Mill presented a more intricate perspective in his book “Principles of Political Economy” (1848). He agreed with Ricardian declining returns, but he came up with the idea of a "stationary state," which is when the population and capital stocks stop expanding. Mill saw this not as a disaster, but as a good thing. He saw a change from collecting more things to making things better: more free time, moral and artistic growth, and a natural world that was maintained for its beauty and healing power. Mill, therefore, sowed the initial seeds for sustainability, stewardship, and the critique of expansion as a final objective.

5. The Neoclassical Ascendancy: Externalization, Substitution, and Hope

The Marginalist Revolution of the 1870s (Jevons, Menger, Walras) shifted the emphasis of economics from production and class to price, exchange, and individual maximization. This radically and irreversibly altered our thinking about nature.

5.1. The Marginalist Revolution: From Physical to Relative Scarcity: The concept shifted from a physical limit (such as Malthusian land) to a relative condition indicated by prices. The value of a resource was determined by its marginal utility, which is the

satisfaction derived from the last unit of expenditure, and its opportunity cost, which is the cost of not using it for something else.

5.2. Nature as Capital and Externalities Framework: Natural resources were given a new definition in terms of capital stock that provides services. The issue of managing natural resources became one of how to utilize them. The idea of externalities was introduced by Arthur Pigou in 1920. Externalities are costs or gains that are incurred by third parties and are not considered in the price of goods traded in the market. The idea of environmental degradation as a "market failure" implies that it is an error in the otherwise efficient Economic Model that can be remedied by using Pigouvian taxes or subsidies. Nature is therefore an externality when viewed from this basic economic perspective.

5.3. The Substitution Paradigm: The Hartwick-Solow rule is regarded as the core neoclassical answer to the problem of resource reduction. Robert Solow (1974) posited that sustained consumption (an indicator of welfare) could be preserved throughout generations if the rents derived from depleting finite natural resources were reinvested into other kinds of capital (made, human, knowledge). This concept is based on the important idea that natural and man-made capital can almost always be used in place of each other. People believe that technology, which is seen as outside of and always improving, can get around any physical limits, making the depletion of some resources unimportant for overall well-being.

5.4. Disregarding Systemic Limits: This hopeful attitude led most people to ignore the 1972 Limits to Growth report. William Nordhaus and Robert Solow, two economists, said that its systems modelling was bad since it did not have pricing mechanisms or trust in human creativity. The neoclassical paradigm thus coalesced around a perspective that externalized nature philosophically, constraining sustainability to a limited issue of efficient pricing and investment within a framework of continuous growth.

6. The Awakening of the Mid-20th Century: Putting the Economy Back in Its Place The industrial growth that happened after World War II led to radical criticisms that tried to put the economy back into its biophysical framework.

6.1. Boulding's "Spaceship Earth": From Cowboy to Spaceman In his important 1966 essay, Kenneth Boulding compared the "cowboy economy" of the past, which had no limits on resources, heroic exploitation, and a linear "throughput," with the "spaceman economy" of the future, which must work like a closed, finite spaceship, where survival depends on keeping and recycling limited resources. The focus was changed by Boulding from the Gross National Product to the health of capital holdings, particularly natural capital.

6.2. Bioeconomic Revolution: Nicholas Georgescu-Roegen presented a deep theoretical challenge to neoclassical economics in his 1971 book “The Entropy Law and the Economic Process”. He argued that the field was fundamentally distorted, based on 19th-century mechanics modelled economic processes as reversible, without regard to the second law of thermodynamics, or entropy. He described the economy as an entropic process: it starts with low-entropy, valuable natural resources like concentrated ores and fossil fuels, and end with high-entropy waste material such as heat and pollution. Recycling, he said, is never complete, because mankind is always extracting low-entropy resources from the Earth. The work provides an irrefutable, qualitative, and permanent biophysical basis for economics (Georgescu-Roegen, 1971).

6.3. The Limits to Growth: Systems Dynamics and Global Overshoot. The Limits to Growth report published by the Club of Rome in 1972 employed system dynamics to model the interconnections between population growth, industrialization, pollution, food production, and resource depletion on a global scale. The base-case scenario assumed that exponential growth would lead to economic and environmental disaster in the 21st century. The paradigm-shifting aspect of this report was its representation of the global economy as a unitary complex system with feedback time lags and nonlinear thresholds, contrary to the neoclassical approach, which emphasized reductionism and equilibrium (Meadows, et. al.,1972).

7. The Disputed Ground: Weak vs. Strong Sustainability

The "limits" conversation solidified into a principal contention between two sustainability frameworks.

7.1. Weak sustainability is the neoclassical view. It characterizes sustainability as the maintenance of a stable total capital (comprising natural, human, and manufactured

components). It is OK to deplete natural capital if it is offset by growth in other forms of capital, if they can be replaced (Solow, 1974; Hartwick, 1977). Ecological economics supports the development of policies using tools such as Pigouvian taxes, tradable permits (cap-and-trade), and cost-benefit analysis to address market deficiencies and the internalization of externalities. This goal is to produce environmentally efficient levels, and to reach “green growth” or “ecological modernization”: the use of emerging technologies that can enable sustainable economic growth without environmentally degrading the natural system.

7.2. Strong Sustainability and Ecological Economics Strong sustainability, whose principal advocate is Herman Daly, refers to the position adopted by many ecological economists that there is no substitute for natural capital and manufactured capital; therefore, they are complementary assets. Critical natural capital (like climate regulation, the ozone layer, and biodiversity) supports life in ways that nothing else can. This model sets two rules that cannot be changed:

Sustainable Scale: The economy's physical throughput (its metabolism) must not be more than the ecosystem's ability to regenerate and absorb.

Fair Distribution: Resources and sink rights must be shared fairly among people in the current generation and between generations. From this point of view, continued GDP growth becomes bad for the environment on a large scale, and the goal changes to "qualitative development" in a steady-state or post-growth economy.

7.3. Daly’s logical hierarchy for economic policy:

Herman Daly proposed a logical hierarchy for economic policy, ordering three key goals: first consider Scale, then Distribution, and finally Allocation. Scale ensures that the economy is of a size that is ecologically sustainable. Distribution is concerned with just allocation. Allocation, finally, uses the market mechanism for efficient allocation, but only within the framework set by Scale and Distribution. This inverts the neoclassical priority, which treats allocation (efficiency) as the primary, and often sole, concern.

8. The 21st-Century Synthesis: Putting the Finite Foundation into Action Recent progress in Earth system research has given the strong sustainability critique

scientific precision, transforming it from a theoretical concept into a quantifiable phenomenon.

8.1. The Planetary Boundaries Framework: A Scientific Basis for Scale. Rockström et al. (2009) and Steffen et al. (2015) updated this framework, which lists nine planetary systems that are important for keeping the Holocene-like stability that made human civilization possible. For each (like climate change, biosphere integrity, and nitrogen/phosphorus cycles), it suggests a number that marks the point at which the risk of causing sudden, permanent changes to the global environment rises. Human behaviour has breached many crucial thresholds (e.g. Climate change, biosphere integrity; biogeochemical flows). This gives us the most precise scientific definition of the "finite foundation" and the "safe operating space" within which humankind can thrive.

8.2. Kate Raworth (2017) combined these two concepts into a simple, visual representation, known as Doughnut Economics. The Doughnut has a social foundation (representing people and their needs - for example food, water and fairness), and an ecological ceiling (conformity with planetary boundaries). Together these create the 'Doughnut' shape of a safe and just area for humanity to operate within (or thrive within). The purpose of 21st Century Economics is to create economies that are designed to help all humans thrive in this safe and just area. In contrast to traditional economic systems that have grown indefinitely in terms of GDP, new economic systems will be focused on regenerative (closed-loop, no-waste) and distributive (fair) systems of production and consumption.

8.3. Implications for Measurement Beyond GDP: The New Progress Paradigm Requires New Metrics to Measure Our Advancement by Looking at Other Dimensions - GDP Measures Only Economic Flow and Does Not Account for the Loss of Natural Resources, Unpaid Care Work, or Human Health). Suggested Alternatives Include - GPI: Genuine Progress Indicator-GPI Measures GDP By Including Environmental And Societal Costs Associated With Producing Goods And Services) I Would Support These Measurements By Suggesting That Alternative Indicators Include - The IWI: An Inclusive Wealth Index That Includes Natural Capital, Human Capital, And Manufactured Capital) Other Measurements Could Be: A Biophysical (Ecological Footprint) Or The Material Flow Analysis) Policy Must Transition From A Marginal

Internalisation Of External Costs (e.g., A Tax On Emission) To A Systemic Transformation Including: Implementing Absolute Caps On Extraction And On Emissions (The Scale Of The Transition), Progressive Taxation And Universal Basic Services (The Distribution Of The Transition), And A Tax Shift From Labour To Resources And Pollution(An Ecological Tax Shift)

9.The Paradigm Clash in Today's World: Its Relevance Today

The rational development described in this paper is more than just a concept in academia; it is the ideological ground in which many of the most persistent issues of our time are being determined.

9.1. Climate Policy: Carbon Pricing vs. Systemic Transition – The debate about whether to implement a carbon price (using a Pigouvian tax, which is a weak sustainability tool) or require a just and rapid phase-out of fossil fuel use (a strong sustainability goal that uses scale to define the phase-out) clearly illustrates this paradigm clash. The former operates within a market framework; the latter sets biophysical limits on consumption and production.

9.2. Biodiversity and the Post-2020 Global Framework – The climate agreement to protect 30% of terrestrial and marine ecosystems, known as the Kunming-Montreal Global Biodiversity Framework, is another example of a critical application of the concept of critical natural capital in acknowledging the irreplaceable nature of biodiversity to maintain both global ecosystems as well as human life.

9.3. The Beyond GDP Movement – The OECD, EU, and various national governments (e.g., New Zealand, Bhutan) have all begun to develop metrics other than GDP to assess the health and wealth of their citizens; this demonstrates that people are beginning to reject the "fetishization" of GDP, a prediction made by Mill more than 150 years ago, and theorised by Daly more than three decades ago.

9.4. Thermodynamic Reality versus the Circular Economy: The Circular Economy's goal is to close the flow of materials, but 'Complete circularity' is impossible due to the entropy law proposed by Georgescu-Roegen. There is an energy loss from the thermodynamic process and all materials will be degraded over time. The first step is to reduce total throughputs and not just try to control the flow of the throughput.

9.5. Inequality, Degrowth and Green Growth: The argument about sustainability is now about those supporting green growth (the belief that it is possible to separate GDP from resource consumption) and those supporting degrowth/post-growth (the belief that rich countries will have to consume less energy and materials in order for their country to be ecologically sustainable and fair). The current sustainability debate can be seen as a continuation of the weak vs. strong sustainability debate.

9.6. ESG & Corporate Social Responsibility: This paper provides a perspective on Environmental, Social and Governance (ESG) claims, and distinguishes between small efficiencies improvements under an unsustainable model, referred to as "greenwashing", and significant changes to corporate strategy bringing operations within the safe and just operating space in line with the Doughnut.

10. Conclusion: The Unfinished Paradigm Shift

The evolution of economic theory surrounding resources and sustainability can be described as a dialectical progression or cycle, beginning with Classical economics' view of limits resulting from biophysical definitions of the environment, followed by Neoclassical economics' faith in capital substitution and technology to overcome these limits, and concluding with an updated perspective from a very contemporary position based on much more rigorous science, a planetary focus, and strong moral consideration for the environment all affirming that there are indeed limits today on a macro level. In addition to providing essential instruments for microeconomic analysis of pricing and optimal allocation of resources (neoclassical economics), neoclassicism does not recognize that the economy ultimately relies upon, and is totally proportionate to, the ecosphere. As an additional framework or body of knowledge (macroeconomic), ecological economics integrates both thermodynamic law and systems theory to create potentially the most important solution to this deficiency at a macro level. Planetary Boundaries, in conjunction with other frameworks, now create a "finite foundation" for measuring ecological and economic/socioeconomic interactions.

- To solve the issues of the Anthropocene, more than minor alterations will be required. We will need an entire new economic system in order to accomplish this.
- To accept the limits of the planet as the main macroeconomic limit.

- Differentiates between growth (quantitative augmentation of throughput) and development (qualitative enhancement of human welfare).
- Puts the protection of important natural capital first.
- It accepts both intergenerational and intragenerational justice as necessary for sustainability.

An economic system that can help create safe and equitable conditions in which to grow economies, through the development of institutional frameworks and measures of performance. If economics is to continue to play a role in determining the direction of our futures, then it must be capable of enacting a dramatic change in the manner in which we view and interact with nature. The essence of 21st century economic theory is not about controlling nature, but rather understanding the limits of nature and designing beautiful, equitable, and sustainable systems that enable individuals to thrive using shared, finite resources.

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