

Renewable and Exhaustible Energies as Factors of Growth and Economic Development from the Perspective of Neoclassical Theory

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Abstract

Energy is considered a fundamental factor of production, as the production process becomes impossible without it. It has been first addressed by neoclassical economists, and it is divided into renewable and exhaustible energy sources. Its impact differs in both cases, as its former type has a positive effect on economic growth and development, while the latter type has a negative impact on them.

- ✓ Renewable energies; Exhaustible energies; Factors of production; Economic growth; Economic development.

1. INTRODUCTION

Economic growth and economic development are among the important terms in human history, as they are associated with the emergence of capitalism and the development of its industry, accompanied by technical changes and capitals accumulation, which led to radical transformations in human societies. They have occupied a significant place in economic studies, starting with the classical school, then the neoclassical and contemporary schools. Economic thought has always attempted to explain their sources and determinants in order to achieve the optimal targeted rate set by governments using various economic policies.

Energy is considered one of the key components of civilized societies, needed by all sectors of society, in addition to its essential role in managing daily life. It is a fundamental factor in achieving economic and social development, as it is used in operating factories, moving various means of transportation, and other purposes that contribute to human material production. It is important to note that the consumed energy on the global level does not come from a single source but from multiple sources. There are exhaustible energy sources such as oil and coal, as well as renewable energy sources such as solar energy and hydroelectric energy. Each source represents a percentage of the total international energy consumption, and this percentage is an indicator of the importance of that source. Therefore, the problem of this study can be summarized in the following question:

- What is the contribution of renewable and exhaustible energies to achieving economic growth and development?

This problem encompasses a set of sub-questions, including the following:

- What are renewable and exhaustible energies?
- What is the role of renewable and exhaustible energies in achieving economic growth and development?

1.1. Research Objectives:

This study aims to identify a set of objectives, including the following:

- Revealing the nature of renewable and exhaustible energies.
- Identifying the factors influencing economic growth and development.
- Understanding the effects of using renewable and exhaustible energies on economic growth and development.

1.2. Research Methodology:

This study will rely on a combination of descriptive and analytical methodologies, utilizing data from books, specialized research papers, and available journals. The study has been divided into two main axes, namely: the concept of energy according to economic theory and the role of renewable and exhaustible energies in achieving economic growth and development

2. Section One: The Concept of Energy According to Economic Theory:

In a closed economic system, goods and services are produced using inputs of capital and labor, which are then exchanged between producers and final consumers. Economic growth is achieved through an increase in the quantity and quality of these inputs, as well as through improvements in the quality of the technology used in the production process. The role of natural capital in economic growth has been addressed by neoclassical economists, as natural capital consists of renewable and non-renewable natural resources such as water and fossil fuels (Ockwell, 2008, p. 4600).

Energy is considered a factor of production and one of the intermediate inputs in the production process, along with primary resources and others. While capital and labor were the main elements in classical thought, but the neoclassical thought added technology and energy to the other factors of production. The economist Robert M. Solow was the first to consider energy as a factor of production in his paper "Intergenerational Equity and Exhaustible Resources" in 1974. His study focused on non-renewable natural resources, and Solow introduced the production function after incorporating non-renewable natural resources as follows (Solow, 1974, p. 34):

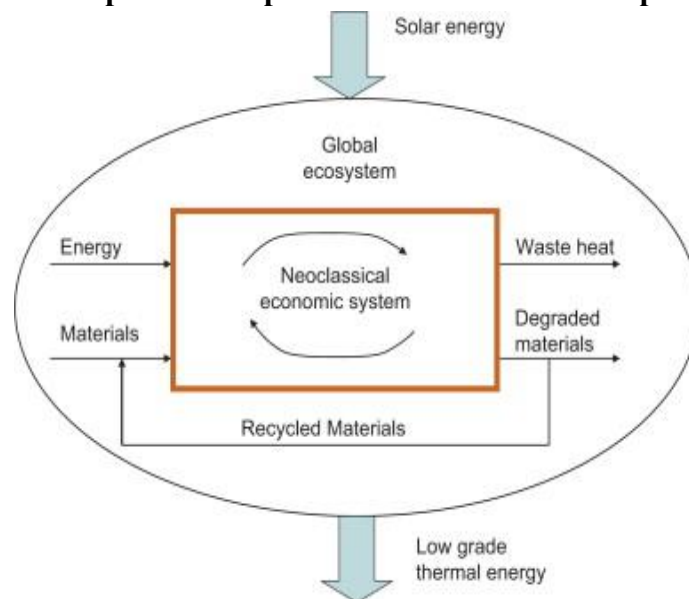
$$Q = F(K, L, R);$$

Where R represents the rate of flow of the extracted and pre-existing natural resources in the Earth's crust, it was recognized as necessary to incorporate these resources into the production process while excluding the possibility of their occurrence in the absence of availability. It was also considered that the production process is limited, bounded by the quantity of resources existing in nature. If all natural resources are consumed ($R = 0$), this will be reflected in the outputs of the production process, making it $Q = 0$ (Solow, 1974, p. 34).

The most popular Neoclassical growth model uses economic growth to recognize mostly the development of the contemporary world. In the neoclassical economic model, goods are produced by capital and labour input as a closed economic system. However, energy together with capital and labour are regarded a critical input in the growing infrastructure process (Afroz, 2022, p. 04).

Subsequent studies have extended to include renewable natural resources and even some waste materials. These expanded models have been applied within the framework of the ongoing debate on achieving environmental sustainability, as illustrated in Figure 1 (Stern, 2004, p. 38).

Figure 1: The production process from a neoclassical perspective.



Source: David G. Ockwell, «Energy and Economic Growth: Grounding our understanding in Physical Reality», **Energy Policy**, 36 (2008), p. 4601.

Figure 1 illustrates the production process from a neoclassical perspective. They considered energy as a raw material or an intermediate commodity analytically equivalent to glass, wood, or raw cotton, while ignoring its fundamental role as a driving force that converts raw materials into finished products by providing the energy for the transformation of raw materials into usable products (Alam, 2006, p. 06).

3. Section Two: The Role of Renewable and Exhaustible Energies in Achieving Economic Growth and Development:

The neoclassical thought focuses on the factors that achieve the sustainability of economic growth, while the technical and institutional conditions in the economy determine whether this sustainability is possible or not. Technical conditions refer to the ease of substitution between capital inputs and natural resources, as well as the possibility of blending renewable and non-renewable natural resources. The institutional framework includes multiple elements such as market structure (competition versus central planning), property rights system (private ownership versus common ownership), and the value system related to the well-being of future generations (Stern, 2004, p. 40).

According to neoclassical economists, the production function includes the following elements (Ruhul A. Salim, 2014, p. 352):

$$Y_t = AK_t^\alpha L_t^\beta E_t^\gamma$$

- Y_t : Gross Domestic Product during period t .
- K_t : Capital.
- L_t : Labor.
- E_t : Total energy used in the production process.
- A : Measures the impact of technological progress.
- γ, β, α : Coefficients that measure the elasticity of Gross Domestic Product with respect to capital, labor, and energy.

Energy can be divided into clean or renewable energy and non-clean or non-renewable energy. Thus, we have the following equation (Ruhul A. Salim, 2014, p. 352):

$$Y_t = AK_t^a L_t^\beta R_t^{\gamma_1} N_t^{\gamma_2}$$

- R_t : Renewable energy sources;
- N_t : Represents non-renewable energy sources;
- γ_1, γ_2 : Represent the production elasticity for both renewable and non-renewable energy sources.

Non-renewable energy sources constitute for economic growth an obstacle which may eliminate the positive impact of technological progress on individual incomes. On the other hand, renewable energy sources contribute positively to supporting the economic growth process, despite all the environmental constraints they may face. The use of energy affects economic growth based on the composition of the economy, the intensity of its use of energy, and the stage of growth it is going through (Marcelo Arbex, 2010, p. 43).

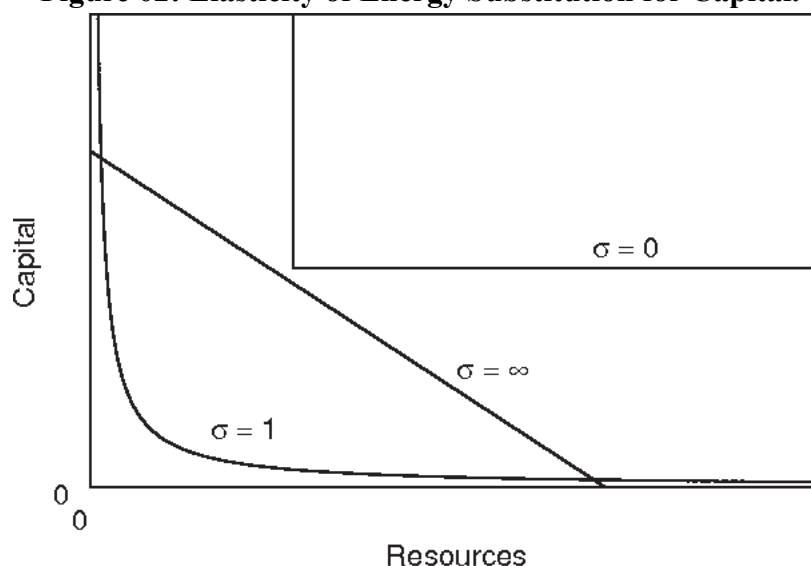
There can be a substitution between labor and energy, where mechanical energy can replace human labor through electric-powered engines, for example. Therefore, substituting labor with energy requires the substitution of capital with labor. Energy and capital are also substitutable, and a choice will be made between the energy-efficient machines which practically lead to the substitution of capital with energy. In contrast, when energy prices (energy inputs) rise, it is observed that the substitution between capital and labor privileges more energy-intensive production paths, as the use of equipment is accompanied by additional energy purchases.

The elasticity of energy substitution for capital (σ) is defined as the relationship between the logarithmic derivative of E/K and the logarithmic derivative of P_e/P_k , as follows:

$$\sigma = \frac{d\left(\frac{E}{K}\right) / \frac{E}{K}}{d\left(\frac{P_e}{P_k}\right) / \frac{P_e}{P_k}}$$

When the value of this elasticity (σ) is high, it means that the substitution process is easy, while the opposite occurs when this elasticity is low (Stern, 2004, p. 40).

Figure 02: Elasticity of Energy Substitution for Capital.



Source: David I. Stern, «Economic Growth and Energy», **Encyclopedia of Energy**, Volume2 (2004), p. 41

The figure 02 illustrates the impact of energy substitution with capital in the production process. The unit elasticity of substitution ($\sigma = 1$) represents perfect substitutability, indicating that any change in two inputs produces the same level of production. This is depicted by the isoquant curves, which are parallel to both axes and converge towards zero resource usage. It is impossible to increase production infinitely by increasing the use of capital.

Additionally, the total production cost remains constant along the isoquant curve. Perfect substitution does not imply that the ratio between resources and capital is always successful; this case is known as "infinite substitution" ($\sigma = \infty$), where producers do not differentiate between inputs and choose the cheapest option. The elasticity of substitution in this case is greater than 1. The figure also illustrates the case of "No Substitution" ($\sigma = 0$), where inputs must be used in fixed proportions. Perfect substitution is an unrealistic assumption from a biophysical perspective as it assumes the application of all possible ratios between capital and resources, as well as the elasticity of substitution between energy and other inputs, including different forms of energy itself, which is usually constrained between 0 and 1 (Stern, 2004, pp. 40-41).

Many experimental studies have examined the relationship between energy consumption and economic growth in various countries over different periods of time using different models. Although certain points of agreement have been reached, there is no consensus on the causal relationship between energy and economic growth (Omri, 2014, pp. 951-952).

The first researcher to study the causal relationship between energy consumption and economic growth was Kraft and Kraft, who used the data of Panel of US between 1947 and 1974. They concluded that an increase in gross national product leads to an increase in the consumed energy (Chirai și Caraiani, 2015, p. 199). Subsequent studies have explored the causal relationship between different energy inputs and economic growth. The general conclusion of these studies regarding the causal relationship between energy and economic growth can be divided into four hypotheses: growth, conservation, neutrality, and feedback hypotheses, which have the following meanings (Sebri, 2015, pp. 657–658):

- ✓ The feedback hypothesis: Confirms the bidirectional causality between energy consumption and economic growth, indicating that both variables influence each other;
- ✓ The conservation hypothesis: Affirms the unidirectional causality between energy consumption and economic growth, where economic growth leads to increased energy consumption without any reverse feedback. In this case, economic policies can reduce energy consumption without affecting future economic growth.
- ✓ The growth hypothesis: Considers energy as a determinant and essential factor for economic growth. In this case, economic policies aim to limit energy consumption due to the negative impact of high energy prices on economic growth.
- ✓ The neutrality hypothesis: Indicates the absence of causality between energy consumption and economic growth, meaning that these two variables are not linked. This table can be summarized as ratios.

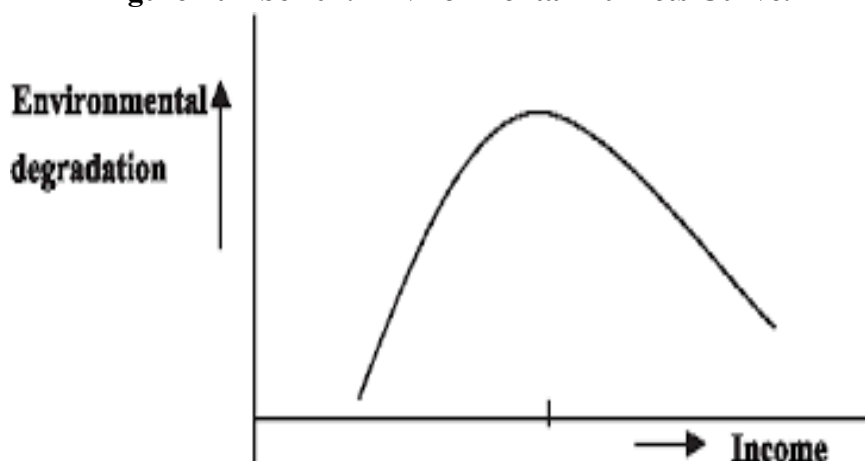
All four hypotheses have been confirmed by empirical literature using different samples. Inglesi found renewable energy consumption positively impacts economic growth. Encouraging renewable energy benefits the environment and the economic development of individual countries.

(Wang, 2022, p. 02)

As a result of the ongoing debate about the relationship between energy consumption and economic growth, questions have arisen about the environmental impact of this consumption. Because with increasing rates of economic growth and energy consumption, the environmental pollution rate is expected to rise. Hence, there is a need to strive for economic efficiency in the use of intermediate inputs in the production process, including energy sources, aiming to maximize the benefits derived from their consumption. This also aims to preserve those resources for as long as possible and reduce environmental pollution.

In 1971, economist Simon S. Kuznets conducted his Nobel awarded research on economic growth in advanced and developing countries, to explore the relationship between energy consumption and economic growth. Through his research, he introduced the concept of the "Kuznets curve," as shown in figure 03, which linked the stages of economic growth to energy efficiency. He found that in the early stages of economic growth, the rate of energy consumption is high, indicating inefficiency in energy consumption and leading to higher environmental pollution rates. However, in advanced stages of growth, energy efficiency is achieved through pollution reduction measures. This curve was used to explain the reasons for the high energy consumption in developing countries and its decrease in industrially advanced countries to achieve similar growth rates.

Figure number 04: Environmental Kuznets Curve.



Source : Soumyananda Dinda, «Environmental Kuznets Curve Hypothesis: A Survey », **Ecological Economics** 49 (2004), P. 434.

The figure number 04 represents the relationship between the income and the environment, known as the Environmental Kuznets Curve (EKC). It takes the inverse U-shaped form and is named after Kuznets, who hypothesized a positive relationship between pollution and economic growth in the early stages of industrialization. In this stage, pollution grows at a faster rate because priority was given to increasing material output at the expense of the environment. People were more concerned with jobs and income rather than clean air and water, leading to rapid economic growth and increased use of natural resources, putting more pressure on the environment.

In the subsequent stage of industrialization, this relationship became negative due to income growth, which pushed people to pay greater attention to the environment. They established environmental regulations and institutions, resulting in a decrease in environmental pollution levels (Dinda, 2004, p. 432).

As a consequence, numerous nations are pivoting their policies towards sustainable

development. This transformation can be accomplished by embracing sustainable energy practices. Hence, it is advisable to increase the proportion of green and renewable energy sources within their energy portfolios. Additionally, the adoption of eco-friendly technologies can further bolster sustainable energy utilization (Ojekemi, 2023, p. 03). A renewable energy policy serves as a pivotal instrument for stimulating the widespread adoption of renewable energy. These renewable energy sources, including solar, wind, hydro, geothermal, and biomass, derive from natural resources that can be continually replenished in a sustainable manner (Maria, 2013, p. 84).

4. CONCLUSION

The process of economic growth requires a real and cumulative increase in the quantity of goods and services produced in the long term, aiming to raise real individual income and improve the living standards of individuals. This is achieved through improvements in the production process and the productivity of production factors. Energy is considered a fundamental factor in this process as it is the driving force that transforms raw materials into finished products. The importance of energy was first recognized by neoclassical economists, and it is divided into renewable and non-renewable energy sources. Its impact differs in both cases, as its former type has a positive effect on economic growth and development, while the latter type has a negative impact on them.

5. Bibliography List :

1. Journal article :

- Afroz, Rafia, and Md Muhibbullah. « Dynamic linkages between non-renewable energy, renewable energy and economic growth through nonlinear ARDL approach: evidence from Malaysia. », *Environmental Science and Pollution Research* 29.32 (2022).
- Anis Omri, «An international literature survey on energy-economic growth nexus: Evidence from country-specific studies», *Renewable and Sustainable Energy Reviews* 38 (2014).
- Chirăţ a Caraiani, Camelia I. Lungu, Cornelia Dascălu, «Energy consumption and GDP causality: A three-step analysis for emerging European countries», *Renewable and Sustainable Energy Reviews* 44 (2015).
- David G. Ockwell, «Energy and economic growth: Grounding our understanding in physical reality», *Energy Policy*, 36 (2008).
- David I. Stern, «Economic Growth and Energy», *Encyclopedia of Energy*, Volume 2, (2004).
- M. Shahid Alam, «Economic Growth with Energy», MPRA Paper No. 1260, (December 2006).
- Marcelo Arbex , Fernando S. Perobelli, « Solow meets Leontief: Economic growth and energy consumption», *Energy Economics* 32 (2010).
- Maria, Maria Magdalena Bate'E., and Khaira Amalia Fachruddin. « Investment decision analysis on sustainable renewable energy policy: Literature review. » *MBR (Management and Business Review)* 7.1 (2023).
- Ojekemi, Opeoluwa Seun, Mehmet Ağa, and Cosimo Magazzino. « owards Achieving Sustainability in the BRICS Economies: The Role of Renewable Energy Consumption and Economic Risk. » *Energies* 16.14 (2023)

- R. M. Solow, «Intergenerational Equity and Exhaustible Resources», *The Review of Economic Studies*, Vol. 41, Symposium on the Economics of Exhaustible Resources (1974).
- Ruhul A. Salim, Kamrul Hassan, Sahar Shafiei, «Renewable and non-renewable energy consumption and economic activities: Further evidence from OECD countries», *Energy Economics* 44 (2014).
- Soumyananda Dinda, «Environmental Kuznets Curve Hypothesis: A Survey », *Ecological Economics* 49 (2004).
- Wang, Qiang, et al. « Renewable energy and economic growth: New insight from country risks. », *Energy* 238 (2022).