ORIGINAL SCIENTIFIC PAPER

DECOUPLING OF NATURAL CAPITAL USAGE FROM PRODUCTION GROWTH IN THE MANAGEMENT OF MODERN DEVELOPMENT

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ABSTRACT

The rise of ecological economics and the verification of the sustainable development concept in the last decade of the previous century led to the recognition of the important role of natural capital in economic growth. With the ever-growing depletion of natural resources and increasing environmental expenditures caused mostly by human activities, it is necessary to disconnect natural capital usage from economic growth, especially bearing in mind current and future economic and societal development. The paper first presents an overview of natural capital as a driver of production growth in economic theory. Then, the phenomenon of decoupling is explained, with particular emphasis on resource decoupling and impact decoupling. In light of the imperative to decouple production growth from the consumption of natural capital, the importance of the circular economy model as a tool through which the goals of decoupling can be achieved to a significant degree is discussed. Due to the possibility of multiple resource use in the production process and the reduction of environmental pollution, the circular production model is particularly applicable in the fields of agriculture and the food industry.

***Keywords**: natural capital, economic growth, decoupling, circular economy model, agricultural production*

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INTRODUCTION

Schumacher, a British economist, was the first author to introduce the concept of natural capital into economic theory [1]. He classified natural capital into two types. The first referred to fossil fuels, which are intensively used, while the second referred to the regenerative capacity of ecological systems, which is threatened by new chemical substances against which nature cannot effectively respond. He pointed out that stocks of irreplaceable natural capital constitute a major part of total capital, and that economists mistakenly treat its consumption as income [1]. According to Harris, natural capital represents “available land and resources, including water, air, soil, forests, fisheries, minerals, and ecological systems that support life” [2]. This comprehensive definition of natural capital can be considered satisfactory within the framework of development economics [3].

In development economics, over the last three decades, the concept of natural capital has been frequently analysed, particularly by economists focused on ecological issues. They emphasize that economic growth should be limited, as natural capital is scarce, the environment is increasingly polluted, and large amounts of physical waste are generated during production and consumption processes.

Natural resources represent an indispensable input in the process of material production, while the total stock of non-renewable natural resources is permanently reduced through use. Even renewable natural resources may be depleted if exploited at an intensity exceeding their natural rate of renewal. In short, the extraction of renewable resources contributes to human well-being; however, their excessive long-term use limits global economic growth [4]. Environmental services, as a component of natural capital, are also essential for production growth. As the depletion of natural capital represents a contemporary global issue, and natural capital is a limited production factor, it raises numerous questions regarding the management of its fundamental components [5].

The current state of global economic growth is being questioned for at least two reasons: pronounced imbalances between economic processes and the excessive use of natural resources, which leads to environmental degradation and disturbances of natural balance [6]. Data show that nearly 92 percent of the world’s resources—including metals, plastics, wood, concrete, chemicals, and other materials in circulation—are used only once, in a single product, before becoming waste. These materials could be reused and would generate significantly lower environmental impacts [7]. The circular economy model has recently been promoted as a methodological approach for decoupling economic growth from the overuse of natural resources and negative environmental impacts. The circular economy represents a regenerative economic system in which the use of production resources, waste generation, emissions, and energy outflows are significantly reduced by slowing, closing, and extending energy and material cycles within the production process. This is achieved primarily through product design aimed at extending product lifespans, as well as through maintenance, servicing, and recycling.

NATURAL CAPITAL IN ECONOMIC GROWTH THEORY

In the last three decades, the concept of natural capital has been frequently discussed in economic science. It has been particularly emphasized by economists analysing ecological issues. The theoretical framework states that economic growth should be sustainable and should restrain itself from the overuse of natural capital, thus avoiding global environmental imbalances. According to ecological economists, the extraction of renewable resources must not exceed their rate of regeneration, while waste disposal must remain within the absorptive capacity of ecosystems [8][9]. In economic growth modelling, natural capital was not considered a factor of production until relatively recently [10]. Even when it appeared as a variable in certain types of production functions, it was generally assumed that it could be substituted with anthropogenic capital. The dominant position of neoclassical economic theory was that, if natural and anthropogenic capital could be substituted in the production process, natural capital could not affect global production growth, despite its continuous depletion.

Natural resources are substances found in nature that are considered valuable in their relatively unchanged natural form. They are sometimes defined as natural assets consisting of air, water, soil, forests, geological resources, flora, and fauna. These resources have multiple uses in the economy, ranging from the production of goods essential for everyday life, such as electricity generation and agricultural production, to numerous other activities. Although they are widely distributed in nature, due to increasing human needs, they are being rapidly consumed[11].

The environment represents a set of natural and created values whose complex interrelationships constitute the conditions and space necessary for life. Its basic components include air, water, soil, flora, and fauna. The environment consists of three interrelated spheres: the natural environment, population, and the modified (built) environment. These three spheres must be harmonized in order to establish a balanced relationship between economic development, society, and the environment. Ecosystem services form the foundation of human activities and include food, water, energy, climate regulation, and other essential services.

When the environment is observed as a component of natural capital, it is, in principle, possible to analyse it as a factor of economic growth, similar to other forms of capital. However, within the context of this research, it is more appropriate to treat the environment as a prerequisite for performing a wide range of economic activities. This primarily refers to services dependent on a healthy environment, such as tourism, organic agricultural production, and specific health services. The success of these industries is closely dependent on environmental conditions, ecological stability, and the impacts imposed by other economic activities. Therefore, a healthy environment represents a key factor in the development of production activities that can be considered environmentally acceptable or whose outputs are intended to mitigate existing environmental damage.

In the eighteenth century, economists identified capital, labour, and land as the fundamental factors of economic growth [12]. Classical economists of the nineteenth century regarded land as a factor of production encompassing all natural resources, according to their characteristics. Land was treated as a fundamentally different production factor in comparison to physical capital and labour. Malthus based his theory of growth limitation on the assumption that population grows geometrically, while food production increases only arithmetically, pointing to the inevitability of population growth control[13]. Ricardo identified growth constraints in the limited productivity of agricultural land and food production, formulating his theory of rent [14]. He argued that population growth would lead to the cultivation of increasingly lower-quality land with diminishing marginal productivity. Such expansion requires higher investment, resulting in rising rents. At the same time, higher food prices increase rents, keeping labour costs close to subsistence levels. Since average production costs are given, the increased costs associated with cultivating inferior land (differential rent) reduce profits, thereby discouraging entrepreneurial activity.

Neoclassical economic growth models operate with three key determinants of growth: physical capital, labour, and technological change [15][16]. The category of technological change broadly includes factors other than physical capital and employment, such as improvements in production techniques, educational advancement, and organizational change. As a result, neoclassical theory largely ignores the role of natural capital in driving economic growth. Furthermore, Nobel laureate Robert Solow concluded that the global economy could continue to grow even in the absence of natural resources [17]. Later versions of neoclassical growth models incorporated natural resources as a production input, but only under the assumption of their substitutability with other factors of production, an assumption that is largely inconsistent with economic reality [18]. The limitations of this approach are reflected in the fact that certain neoclassical assumptions support the view that natural resources are not essential for economic growth [19].

The slowdown of global economic growth during the final decades of the twentieth century led development economics to incorporate the concepts of positive and negative externalities, as well as endogenous explanations of growth. Although various strands of endogenous growth theory exist, they share a common objective of identifying the fundamental mechanisms behind technological innovation. Methodologically, most endogenous growth models are based on the analytical framework of standard neoclassical growth theory. Even those endogenous growth models influenced by Joseph Schumpeter's evolutionary approach—which view technological change and economic growth as outcomes of internal economic and social dynamics and institutional structures—do not challenge the necessity of decoupling economic growth from the consumption of natural capital.

THE IMPERATIVE OF DECOUPLING ECONOMIC GROWTH FROM NATURAL CAPITAL USAGE

For a long period of time, human society has not behaved in accordance with the basic laws of ecology and has continuously endangered the biophysical capacity of geographical space, initially at the local and regional levels, and subsequently at the global level. Consequently, over time, the issue of human existence has shifted from the scarcity of resources to the limits of the ecological capacity of planet Earth. There are indications that the biophysical capacity of the planet was exceeded almost three decades ago, which is illustrated in a specific way by the data presented in Table 1. However, it is an undeniable fact that collective awareness regarding ecological responsibility for the future is still far from being clearly articulated. On the contrary, dilemmas concerning development perspectives between ecologists and economists remain unresolved and are commonly positioned along a wide spectrum: unlimited growth and development – sustainable development – zero growth – sustainable withdrawal. Economists tend to express more optimistic views regarding the consequences of economic and population growth than ecologists, who analyse the state of the global ecosystem. A significant epistemological and methodological tension exists between ecology and economics in the perception of sustainability [20].

Table 1. Indicators of the Growth of Anthropogenic Pressure on Planetary Geographical Space Over Time

Size	Growth	
	1890 -1990	1900-2000
World population	× 4	× 3,8
City population	× 13	×12,8
Industrial production	× 40	× 35
Energy consumption	× 16	× 12,5
Oil production	-	× 300
Coal production	× 7	-
Water consumption	-	× 9
Irrigated areas	× 5	× 6,8
Number of cars	-	× 7.750

Source: [20]

In 2009, Rockström et al. [21] quantified planetary boundaries within which civilization can develop and ensure a healthy future for future generations (Table 2). Exceeding these limits increases the risk of irreversible environmental consequences for the planet.

Table 2. Planetary Boundaries of Sustainability

Planetary limit			Unit measures	Proposed limit	Current state
1	Climate change		CO_2 (ppm)	350	387
2	Biodiversity loss		E/MSY[1]	≤ 10	>100
3	Anthropogenic contribution to the biogeochemical cycle	nitrogen	Mt N/god	≤ 35	121 Mt
		phosphorus	Mt P/god	11	8,5-9,5
4	Ozone layer		DU[2]	276	283
5	Ocean acidification		pH[3]	2,75	2,90
6	Global use of fresh water		km^3/per year	≤ 4.000	2.600
7	Changes in land use		% od ∑ land	≤ 15	11,7
8	Chemical pollution		qualitative		
9	Atmospheric changes		qualitative		

Source: [21]

[1]Number of extinct species per million per year (approximately 0.1% of total species per century).
[2]DU (Dobson unit) is the most common measure used to quantify the amount of ozone in the atmosphere. It is equal to 0.01 mm of the ozone layer under normal conditions of pressure and temperature in the vertical profile of the atmosphere.
[3]Carbon dioxide from the atmosphere is absorbed and dissolved in the world's seas, primarily the oceans, where it forms carbonic acid. Its dissociation into H^+ and HCO_3^-, that is, the accumulation of positive hydrogen ions, leads to an increase in ocean acidity, resulting in a mean pH decrease of approximately 0.1.

Quantified planetary boundaries include climate change, ozone depletion, ocean acidification, biogeochemical flows, freshwater use, land-use change, and biosphere integrity. Planetary boundaries have not yet been fully quantified for new entities, such as chemical and toxic substances, and atmospheric aerosol accumulation.

Climate change and land-use change are currently considered to be within a zone of increased risk. Biogeochemical cycles of nitrogen and phosphorus have been significantly altered by human activities in industry and agriculture. Due to excessive or inappropriate use of these elements, they often enter aquatic ecosystems, threatening their normal functioning. As a result, this planetary boundary has been exceeded to a considerable extent. In addition, the boundary related to biosphere integrity has also been significantly surpassed.

In other words, humanity has altered ecosystems more during the last half-century than during any other period in history. The primary drivers of these changes are the growing demand for food, water, and natural resources. This represents further evidence of the imperative to conserve resources in the coming years. In this context, the question of the appropriate level of economic growth necessary to keep key planetary processes within safe limits naturally arises.

Natural resources have become increasingly scarce and costly to extract. Price volatility of natural and energy resources, as well as their environmental impacts, ultimately threatens economic development even in countries rich in natural resources. The conventional linear production model based on the "take–make–dispose" approach has persisted for decades due to the mistaken perception of unlimited natural resources and the almost infinite carrying capacity of the environment to absorb production-related pressures [22]. Environmental impacts such as water, air, and soil pollution, species extinction, and climate change are consequences of excessive and unsustainable resource use [23]. A country's economic success is increasingly determined by its ability to use natural resources efficiently, particularly materials required for the production of large volumes of goods and services[24].

Economists studying natural capital emphasize that it represents a necessary factor of production, while other analysts argue that natural capital should be treated in the same way as other production inputs in achieving economic growth. These perspectives differ in their interpretation of how society should treat the components of natural capital. Nevertheless, there is consensus that effective management of natural capital is of crucial importance for the future development of both the economy and society as a whole, since the paradigm of unlimited economic growth combined with unlimited natural capital use is clearly no longer realistic [25].

The neoclassical views of a broad group of ecological economists became increasingly critical of the key drivers of economic growth at the beginning of the eighth decade of the twentieth century [26]. These critiques are rooted in the work of Georgescu-Roegen [27], who argued that the economy represents an open system subject to the laws of thermodynamics—an aspect largely neglected by neoclassical and endogenous growth theories [28]. From the perspective of ecological economics, understanding the economy as an open system highlights the impossibility of infinite production growth. This stems from the irreversible nature of processes in open systems, which necessitates adherence to the first and, in particular, the second law of thermodynamics when modelling natural systems.

In the early 1990s, a group of economists supported the idea that economic growth could be decoupled from environmental impacts without significant threats to human well-being or the environmental conditions that support life on Earth. The separation of economic growth from the use of natural materials, as well as from air pollution, has been proposed by some authors as a response to environmental degradation and natural capital depletion[29]. To assess impacts on the quality of life, it is necessary to analyse indicators beyond GDP, such as wealth and income distribution, ecosystem health at global and regional levels (including climate), multi-level social interactions, and the value of unpaid activities such as parenting, household work, and volunteer work [30][31]. However, while decoupling implies a shift from debt-financed consumption towards sustainability-oriented investments and eco-innovation, consumption patterns in developed countries may create an illusion of decoupling. In reality, environmental impacts often occur elsewhere, particularly in developing and emerging economies where resource extraction and production take place [30]. Resource-intensive production is frequently relocated away from points of consumption. According to UNEP [30], economic growth may also be driven by financial activities, such as currency trading and complex financial instruments, rather than by resource extraction, contributing to the appearance of decoupling (Figure 1).

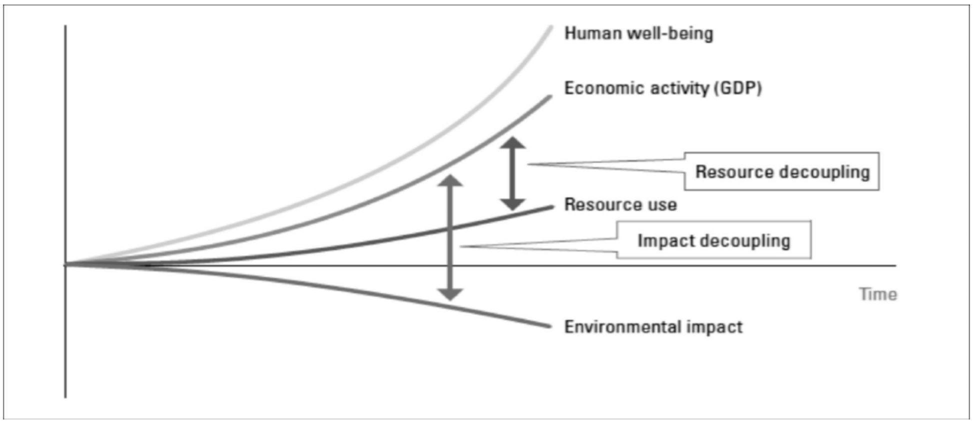

Figure 1. Decoupling Concept
Source:[29].

Decoupling occurs when resource use grows more slowly than the economic activities that drive it (resource decoupling), and when economic growth is accompanied by a reduction in environmental pollution (impact decoupling). This distinction is crucial, as the pursuit of intensified economic growth and improved well-being implies extensive use of natural resources, whose extraction and processing generate serious environmental and health consequences. Decoupling can reduce both resource use and environmental pollution, thereby mitigating negative effects on human health [32].

A distinction must be made between absolute (strong) and relative (weak) decoupling. Relative decoupling occurs when production growth outpaces the increase in resource use and environmental degradation. Absolute decoupling, by contrast, occurs when economic growth is accompanied by an absolute reduction in resource use and/or environmental impact. Relative decoupling does not necessarily lead to absolute decoupling, as improvements in efficiency may persist over long periods without resulting in an overall decline in resource use.

Time also represents an important dimension in decoupling analysis. Achieving permanent decoupling is more challenging than attaining decoupling over a limited period. Permanent decoupling requires long-term structural changes in production, which represent a particularly demanding process.

Decoupling can be analysed within individual sectors or across the entire economy. A widely discussed issue related to sectoral decoupling is the rebound effect, also known as the Jevons paradox. For example, improvements in energy efficiency in one sector may lead to increased energy consumption in other sectors [33][34]. Consequently, empirical evidence of sectoral decoupling must be assessed in relation to developments in other sectors of the economy.

In empirical research, decoupling is examined across different geographical scales, ranging from local and national to global levels. Decoupling is easier to identify at the local level than at national or global scales. Importantly, local decoupling does not necessarily imply global decoupling [35].

Table 3. Dimensions of Decoupling

	Easier	Harder
Type of decoupling	Relative	Absolute
Economic scale	Sector	National economy, global
Duration	Limited	Long-term
Geographical scope	Local	Global

Source: [36]

The extraction, processing, and use of materials and fossil fuels are responsible for numerous environmental problems, ranging from greenhouse gas emissions to water, air, and soil pollution, as well as biodiversity loss [37]. Total material extraction increased eightfold between 1970 and 2005 and threefold between 1990 and 2005 [38]. OECD projections indicate that global material use will more than double between 2011 and 2060 [39].

Since the 1990s, a large body of research has examined the possibility of decoupling GDP per capita from pollutant emissions and additional resource consumption across individual countries, using specific indicators of final consumption or the use of particular materials (metals, biomass, fossil fuels, and minerals). For example, in a recent study, Charlier and Fizaine [40] investigated the relationship between economic growth and the use of three types of natural resources—ranging from extraction to final consumption—across 163 countries over the period from 1990 to 2015, using various econometric models. Their findings indicate the existence of a strong and persistent relationship between economic growth and natural resource exploitation. Specifically, they found that the elasticity of GDP per capita with respect to natural resource use per capita ranged from 0.41 to 1.061, depending on the model employed. In this context, the authors conclude that it is not possible to speak of spontaneous decoupling between environmental impact and economic growth, despite the evident necessity of reducing natural and energy resource use per unit of newly created value. They further emphasize that the decoupling imperative is relatively more pronounced in less developed countries.

The necessity of achieving both resource and impact decoupling has recently been discussed primarily within the frameworks of sustainable development and the green economy. Most researchers support the view that economic growth should be sustainable, meaning that it should not involve excessive use of natural capital or compromise the absorptive and regenerative capacities of ecological systems per unit of value created. Some scholars see the realization of resource and impact decoupling embodied in the concept of green growth, defined as a resource-efficient and low-carbon mode of production [41]. Other theorists argue that, in realistic terms, the idea of decoupling is fundamentally unattainable and advocate alternative visions of future economic activity based on the principle of social and economic development without economic growth. Among the most prominent of these approaches are degrowth [42][43][44], post-growth [45], and doughnut economics [46]. These perspectives stand in sharp contrast to mainstream economic views on the possibility of unlimited future economic expansion, largely because natural capital—one of the key drivers of economic growth—is limited and cannot always be substituted by other factors of production.

CIRCULAR ECONOMY CONCEPT IN AGRICULTURE AS A MODEL OF DECOUPLING PRODUCTION AND NATURAL CAPITAL USAGE

By applying the concept of the circular economy, natural materials can be recycled and used multiple times in the production process, thereby prolonging their exploitation period and reducing the amount of resources required per unit of output. This leads to the decoupling of natural capital usage from production growth. Such an approach increases resource productivity and reduces demand for natural resources, thereby contributing to a more sustainable economy and society, not only for current but also for future generations [47].

The concept of the circular economy is particularly applicable in the fields of industry, construction, and agricultural production. The decoupling effect of the circular economy will be further discussed in the context of agricultural production in the following section.

Over the last century, the Earth has experienced significant population growth. Rapid demographic expansion has posed increasing challenges to global food production. According to data from the United Nations Economic and Social Council, by 2050 the world population is expected to increase by more than half compared to the year 2000, reaching approximately 9.8 billion people [48]. This represents an additional reason for the urgent establishment of new methods for producing safe and high-quality food for all, without causing environmental degradation.

In order to achieve growth in food production while simultaneously complying with ecological standards and preserving ecosystems and biodiversity, the concept of the circular economy should be applied. This involves the adoption of production, processing, transportation, and business practices in the food sector that do not harm the environment and that support economic and social development. The controlled and rational use of chemical inputs, including artificial fertilizers, must be a priority for all producers—not only with regard to short-term yields, but also in long-term production planning and, ultimately, in preserving natural resources and environmental quality.

Agricultural production is among the major sources of environmental pollution worldwide. Conventional agricultural practices—characterized by intensive use of chemical fertilizers, genetically modified seeds, and deforestation for land conversion—represent some of the key drivers of ecological degradation and biodiversity loss, as well as sources of adverse effects such as the emission of toxic gases into the atmosphere. The linear production model in agriculture significantly contributes to climate change and land degradation. According to data from the European Environment Agency (EEA), conventional agriculture is the main source of nitrogen pollution in water bodies, accounting for 50–80% of the total nitrogen load [49]. At the global level, agriculture contributes approximately twice as much to greenhouse gas emissions as the transport sector. Agricultural activities and technologies—from the application of chemical agents in crop production to methane emissions from livestock farming—represent major sources of water, soil, and air pollution. Agriculture has a particularly negative environmental impact due to the circulation of pollutants throughout the entire production system, from soil as the initial source, through the food chain, and ultimately to humans. Because agricultural production systems are highly interconnected across sectors, it is difficult to eliminate environmental risks even within regulated frameworks, as irresponsible practices by individual producers may affect the entire surrounding environment. For this reason, it is essential to establish effective systems for monitoring input use and to ensure strict adherence to the principles of the circular economy.

Moreover, the implementation of standardized production cycles contributes to reduced risks and lower costs, which represent significant challenges to the sustainability of conventional agricultural production.

In addition to addressing environmental issues, the circular economy also promotes innovation in agriculture by encouraging new business practices and creating employment opportunities through the use of agricultural waste as by-products. However, despite its global importance, the agricultural sector is traditionally slow in adopting new technologies and innovative production methods.

CONCLUSION

Over the past decade of the twentieth century, natural capital has increasingly been recognized for its contribution to economic growth. It is now regarded both as a driver of growth and as a potentially limiting production factor in the future. The assumption that natural resources are inexhaustible and capable of supporting infinite production without affecting ecosystem regeneration has proven to be unrealistic. On the contrary, it has become evident that the overuse of natural resources leads to significant environmental consequences, which in turn negatively affect both economic performance and human well-being.

Decoupling represents an innovative economic concept that enables economic growth without a corresponding increase in natural capital usage, while also reducing environmental pressures. This separation is crucial, as the pursuit of higher levels of human well-being and intensified economic growth inevitably increases reliance on natural resources for the provision of goods and services. The extraction, processing, and use of these resources generate serious environmental and health impacts. Achieving decoupling can slow resource depletion and, more importantly, reduce environmental degradation and negative effects on human health.

An increasingly important instrument for realizing the concept of decoupling is the circular economy model. This model primarily refers to changes in business processes that address global environmental challenges—such as the depletion of natural and energy resources—while simultaneously enhancing the carrying capacity of the environment in the context of continuous population growth.

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