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Technological Innovation and Economic Growth – Focus on Environmental Pressures

Summary

The article presents the relationship between economic growth and environmental pressures, highlighting the role and importance of innovation. Following a comprehensive literature review, it is demonstrated through international practice that an environmentally responsive innovation ecosystem can effectively support both economic growth and sustainable development.

Keywords: sustainability, sustainable development, innovation, Kuznets curve, GDP

Jel-code: Q56, Q01, Q5, G10, F43

Introduction

The relationship between environmental pressures and economic growth is one of the most important links at the heart of research. Interest in the subject has increased particularly since the 1990s when concerns about climate change became a growing preoccupation of the scientific community. Today, it is clear that one of the causes of global warming is the increase in carbon dioxide emissions, with economic growth being accompanied by increasing environmental pressures. The links between economic growth, energy consumption, and carbon emissions have also given rise to new research.

The increase in global energy consumption will exacerbate the problem of energy scarcity and pollution, leading to increased carbon emissions (Sharif et al., 2019). High carbon emissions will have irreversible impacts on global climate conditions (Zoundi, 2017). Climate change will also impact the decline in economic performance, with the increasing frequency of extreme weather events making it difficult to control risks (Burke et al., 2016).

The complexity of the issue is indicated by the large differences in economic development between economies and the different resource endowments (Zhang et al., 2023) Europe is facing energy shortages, and its dependence on external energy supplies has reached 60%, despite the EU's early focus on energy security and clean energy (Brodny and Tutak, 2022). While the EU has a high and growing share of clean energy sources, this is not yet sufficient (Puertas and Marti, 2022). The emergence of global epidemics and geopolitical conflicts is a further challenge for nations.

Economy and Climate Change

Despite recent increases in the share of renewable energy, fossil fuels continue to dominate globally. The extraction and use of fossil energy keep carbon emissions high (Avotra and Nawaz, 2023), and inappropriate allocation of resources also increases emissions (Xie et al., 2023). Extreme climate conditions interact with energy consumption and carbon emissions. Extremely hot summers and cold winters result in increased electricity and heating demand, and consequently raise energy consumption and lead to increased carbon emissions (Shang et al., 2022).

Growing dependence of industries on fossil fuels exacerbates the occurrence of extreme weather events that threaten sustainable economic growth (Zhao et al., 2018). Reduced production due to climate change leads to reduced investment, which hinders future production. Extreme weather events–temperature swings, heavy rains, droughts, and hurricanes – directly affect agriculture, energy, and construction. For these industries, investment, labor productivity, and output are reduced, resulting in economic losses (Acevedo et al., 2020).

The Role of Innovation in Economic Growth

According to the Kuznets theorem, in the early stages of economic development, the pressure on the environment is high and the environment deteriorates as a result. However, as the economy grows, the pressure on the environment is reduced and the quality of the environment begins to improve. This is of particular importance to policymakers when considering the relationship between economic growth and environmental protection (Kuznets, 1955).

According to Todaro, economic growth is supported by three important factors: capital accumulation, including new investment in land, physical plant, and human resources; population and hence labor force growth; and technological progress (Todaro, 1997).

New growth theories emphasize the importance of technological change as a source of growth. According to these theories, innovation is the main driver of economic growth (Bayarcelik, Tasel, 2012).

The question is to what extent innovation contributes to competitiveness, and to the growth of companies, industries, and entire national economies.

The literature describes two major growth models, exogenous and endogenous.

In the exogenous model, technological progress has been treated as a process driven only by time (Bayarcelik, Tasel, 2012), where growth is the increase in GDP per hour of work per unit of time (Griffith et al., 2004).

In endogenous growth models, growth depends on technological change resulting from deliberate investment decisions (Romer, 1990).

Schumpeter's early work (1911) established the concept of the "entrepreneur as innovator" as the key to economic development. The innovative activity of entrepreneurs fuels the process of 'creative destruction' (Schumpeter, 1942) by causing continuous disruption to the equilibrium economic system and creating new opportunities. In the process of adaptation, new entrepreneurs launch different other innovations and enter the economic system therewith contributing to achieve a new equilibrium. This development leads to an increase in the number of entrepreneurs and thus to further growth of the economy (Wong et at., 2005).

The contribution of technological innovation to economic growth is well established in the economic literature, both theoretically (Solow, 1956; Romer, 1986) and empirically (Mansfield, 1972; Nadiri, 1993).

As a determinant of growth, innovation is well-measured in empirical research (Wong et al, 2005). Researchers use input-oriented measures such as R&D expenditure (Mansfield, 1972) or output-side measures that show innovation outcomes such as patents (Griliches, 1990). Empirical research suggests that technological innovation contributes significantly to economic performance, especially at the firm and industry level (Wong et al, 2005).

Studies of the impact of technological innovation on economic growth are predominantly based on the neoclassical tradition established by Solow (1956) (Wong et al., 2005), where growth is driven by improvements in the quantity, quality, and productivity of capital and labor inputs.

Solow (1956) and Nadiri (1993) summarized studies consistent with this, showing that sustained long-run growth depends on the growth rate of inventions, which is exogenously determined.

There is no consensus among researchers on the link between technological innovation and economic growth. Many researchers believe that the relationship between technological innovation and economic growth is linear and positive, which is consistent with the theory of endogenous economic growth (Adak, 2015; Thompson 2018; Yan et al., 2023) According to this school, innovation can be an important driver of economic growth and even a source and driver of social development (Zhang et al., 2018; Assi et al., 2021). Critics, however, note the lack of pattern matching to prove the theory's validity (Zhang et al., 2023)

Innovation, nevertheless, has an impact on several economic indicators, including the Sustainable Development Goals (SDGs). Innovation affects the achievement of the SDGs and the competitiveness of countries (Arcentales et al., (2023).

Digitalization can reduce environmental pressures by reducing the intensity of industrial pollution. At the same time, it promotes environmental investment and green innovation. Companies can both increase their operational efficiency and reduce their ecological footprint by proactively integrating green initiatives into their digitalization strategies. The synergy between digitalization and environmental sustainability is tangible (Yang et al., 2024)

Lorente et al. (2021) came to a similar conclusion when looking at air transport. They argue that energy innovation mitigates the negative impacts of international tourism. Green innovation cannot only impact one sector but can also lead to major technological changes in other sectors (Zhang et al., 2023).

Research shows that technological innovation can be an effective tool for reducing pollution in the long run (Peng et al., 2021; Cai et al., 2020; Liu et al., 2022; Li and Ye, 2021).

Relationship Between Gross Domestic Product and Carbon Dioxide Emissions

Rich and developed countries have a higher gross domestic product (GDP) per capita, but all this comes with huge energy consumption. Globally, energy-intensive industries account for 46% of carbon emissions (Bokde et al., 2021).

In the Paris Agreement, all Organisation for Economic Co-operation and Development (OECD) member countries committed to decarbonizing the power sector to keep atmospheric carbon dioxide concentrations below 450 ppm and keeping the global average temperature rise below 2 degrees Celsius. All this requires the provision of clean energy (Bilgili et al., 2016).

Growth in gross domestic product measures the success of the rational and efficient use of available resources but does not take into account the negative impact of resource use on the environment. Therefore, it cannot be ignored that existing resources are to be used as efficiently as possible, including both environmental and quality-of-life aspects. In many countries around the world, the fundamental objective of economic growth is not only to maximize gross domestic product but also to achieve this within the constraints imposed by environmental protection. Another important question is whether environmental stewardship and the increasing use of renewable energy sources constrain and slow economic growth (Pejovic et al., 2021).

Although developing countries are placing less emphasis on clean energy due to technological and financial constraints, developed countries are gradually relying more on renewable energy sources than ever before. Energy is the most fundamental driver of economic growth, regardless of the level of development of a given region. Most energy is produced using conventional energy sources, including oil, coal, and gas. Developed countries have been focusing on the exploitation of clean energy for years, but the lower price and easy availability of conventional fuels pose a serious dilemma (forcing countries not to completely abandon environmentally polluting resources either) (Cai et al., 2018).

However, it should also be borne in mind – in sub-Saharan Africa – that regions with potential for renewable energy development are not fully exploiting their potential, even when clean energy sources are available (da Silva et al., 2018).

Kuznets-Curve Analysis – Research Results

Research in the United States concluded that there is a two-way causal relationship between carbon emissions and economic performance, energy consumption, and urbanization, but no causal relationship between carbon emissions and trade openness and financial development (Pejovic et al., 2021). In the context of the United States, Dogan and Turkekul (2016) also addressed the Kuznets curve, but they could not confirm the existence of the curve.

Solarin et al. (2017), looking at India and China separately, confirmed the existence of a curve for carbon emissions, gross domestic product, urbanization, and hydropower consumption. In Malaysia, a long-run relationship between car-

bon emissions and GDP has been shown (Saboori et al., 2012), and for the countries that make up the Association of Southeast Asian Nations (ASEAN), the hypothesis that an increase in energy consumption can stimulate economic growth has been confirmed (Magazzino, 2014). Data for the countries that make up ASEAN have also been analyzed by Borhan et al. (2012), and data from 1965-2010 indicate that there is a mutual dependence between carbon emissions and income.

For the emerging economies of BRICS (Brazil, Russia, India, China, and the Republic of South Africa), Bildirici and Bakirtas (2016) also considered oil and coal consumption. The analysis shows that there is a unidirectional relationship between coal consumption, oil consumption, and carbon emissions and that there is a bidirectional relationship between GDP and coal consumption. For the OIC (Organization of the Islamic Cooperation) countries, it can also be concluded that long-term GDP growth contributes to environmental degradation. However, in the short term, there is no significant impact on carbon emissions (Shaari et al., 2020).

In Turkey, Ozturk and Acaravci (2010) show that neither per capita carbon emissions nor per capita energy consumption cause per capita GDP growth, so attempts to reduce carbon emissions and rationalize energy consumption will have no impact on GDP growth. Based on an analysis of ten Middle Eastern countries, Magazzino (2016) concludes that for the GCC (Gulf Cooperation Council) member countries, there is a unidirectional relationship between energy consumption and economic growth, i.e., an increase in energy consumption can cause economic growth, but for non-GCC countries, there is no causal relationship between energy consumption and GDP.

An analysis of MENA (Middle East and North Africa) countries concluded that there is a positive relationship between GDP growth and carbon emissions (Farhani et al., 2013). Al-Mulali and Sab (2012) analyzed sub-Saharan and African countries for the period 1980-2008 and found that energy consumption plays an important role in the growth of economic and financial development of countries. However, as a consequence of increased energy use, pollution is also increasing. Similar results have also been obtained by researchers who studied the economies of 22 African countries – for the period 1990-2011 – and found that there is a unidirectional and irreversible relationship between energy consumption and gross domestic product (Attiaoui et al., 2017). However, we also find results that assume a bidirectional relationship (Mensah et al., 2019).

Research by Huang et al. (2008) concludes that in low-income countries there is no relationship between energy consumption and GDP, in middle-income countries this relationship exists and is positive, while in high-income countries an increase in GDP leads to a decrease in energy consumption.

Kim (2019), using data from 57 developing countries between 1980 and 2013, concludes that there is no relationship between FDI and carbon emissions in the short run, but a cointegrating relationship between emissions, GDP, and FDI in the long run. The results confirm the existence of the Kuznets ecological curve.

EU Member States' Carbon-Dioxide Emissions and GDP Trends

Kasperowicz (2015) analyses data from 18 EU Member States for the period 1995-2012 and finds that there is a long-term negative relationship between carbon emissions and GDP growth, due to the development of low-emission technologies. These technologies with lower emissions allow for higher GDP in the long run.

Pejovic et al., (2021) looked at data for the 27 EU Member States and the Western Balkan countries from 2008-2018. They found that the growth rate of carbon dioxide emissions is strongly determined by GDP and renewable energy growth. In addition, the high growth rate of the economy contributes to a reduction in the growth rate of carbon dioxide emissions as a result of more energy-efficient technologies and renewable energy sources.

Dogan and Seker (2016) reach a similar conclusion by analyzing data from 1980-2012. They found evidence of the existence of an environmental Kuznets curve in the EU. In their opinion, the EU should increase the share of renewable energy sources, as reducing non-renewable energy does not reduce the real income of the EU, these policies can be implemented without reducing GDP.

The results of Madaleno and Moutinho (2018) show that economic growth outpaced output growth in most of the EU-15 between 1995 and 2014. However, it is not proven whether economic growth is independent of environmental pressures, but it can be argued that the economies of the countries studied were able to grow while carbon emissions growth became slower.

The relationship between energy consumption and GDP was also examined for the 27 EU Member States (2010-2019). Török (2023) found that a decoupling of GDP and energy consumption occurred in this period: while the GDP of EU Member States increased by 27.6%, consumption of EU Member States decreased by 6.5%. This decoupling occurs when energy consumption (and thus environmental pressure) does not increase, but only economic output increases. In those countries where energy consumption fell by more than 8% above average (Slovenia, Finland, Slovakia, Denmark, the Netherlands, Germany, France), GDP increased significantly in purchasing power parity terms over the period. Another important finding of the study is that countries where the service sector is dominant (Ireland, Greece, Malta, Cyprus) have not been able to reduce energy consumption significantly, compared to more industrialised countries.

Papiez et al., (2021) conclude from their analysis that the decoupling of greenhouse gas emissions from economic growth in almost all EU countries is a result of EU energy policy and not just that of outsourcing.

Bianco et al. (2024) examined economic growth in the 27 EU Member States (1995-2019) and found that technical factors (energy consumption patterns, energy intensity) also supported the decoupling of carbon emissions and GDP. Although increases in economic output and spending capacity continue to increase carbon emissions, technological innovation can reduce this effect.

In the EU, there is a direct link between energy consumption and emissions growth, with investment being inversely proportional, with higher investment rates being associated with lower emissions. These investments can increase GDP while helping to reduce energy consumption (Loures and Ferreira, 2019)

The existence of an environmental Kuznets curve has been confirmed by several researchers (Lorente et al., (2021). How-

ever, there may be differences between countries. The environmental Kuznets curve can be confirmed for the countries of the fifth wave of EU enlargement, but not for the former accession countries (Mert et al., 2019). Economic growth has been the main contributor to energy consumption and FDI inflows. Papiez et al., (2021) find that old EU countries are better at reducing GHG emissions, replacing fossil fuels largely with renewable energy.

Conclusions

The relationship between economic growth and environmental pressures is a leading research topic today. The review of major publications on the subject has highlighted the need for further research to better understand the relationship between economic growth and environmental pressures, with a focus on the diffusion of innovation.

The results have shown that economic growth is associated with increased environmental pressures, especially in energy-intensive industries and emerging economies, and that further innovative technological solutions are needed for a sustainable future.

While international examples have confirmed the Kuznets curve, it is also highly dependent on the drivers of economic development.

The link between innovation and sustainability is a new area of research. The results achieved are encouraging, but the efficient use of allocated resources is necessary to ensure that an environmentally friendly innovation ecosystem can effectively support economic growth and sustainable development.

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