Renewable and Non-Renewable Energy Consumption for Economics

Subjects: Economics

Contributor: Miloš Žarković, Slobodan Lakić, Jasmina Ćetković, Bojan Pejović, Srdjan Redzepagic, Irena Vodenska, Radoje Vujadinović

Balancing of different dimensions of development—economic, environmental, social, is an imperative of policies and strategies of sustainable growth, which are practiced today in the EU and globally. A 1% increase in the share of renewable (REC) and information and communication technology (ICT) in total exports leads to GDP p.c. growth in the long run by 0.151% and 0.168% in old EU countries, i.e., 0.067% and 0.039% in new EU countries, respectively. Contrary, an increase of non-renewable energy consumption (NREC) by 1% has a significant and negative impact on GDP p.c. in the long run, in both groups, leading to a decrease of economic growth by 0.512% in the old and 1.306% in the new EU group.

Keywords: sustainable economic growth ; renewable energy consumption ; non-renewable energy consumption

1. Introduction

In the 1950s, macroeconomics and economic growth received significant scientific attention. Starting from the understanding of the availability of natural capital in abundance, the economic theory has long been focused on produced and human capital. However, with exponential population growth and accelerated economic development, attention is focused on natural capital, which is a necessary condition for achieving sustainable growth and development. EU affirmed the concept of sustainable development, which presents a global political agreement that is made up of a balance between the social, economic and environmental aspects of development at all levels, from local to global.

Energy is key to the process of economic growth in many countries. Therefore, the main issue is the contribution of all energy sources to economic growth. Energy consumption is one of the basic indicators of economic growth and development. On the other hand, more efficient use of energy requires a higher level of economic development. In the past two decades, EU members have been working intensively on creating an internal energy market and an energy union. It is emphasized that it is crucial for the EU to decouple energy consumption from economic growth. After the financial sector, energy is probably the largest global industry, i.e., the industry with the widest impact on other sectors of the economy, on which the entire economic activity depends. Changes in the structure of GDP that have occurred in the past decades lead to significantly lower energy consumption per unit of GDP, i.e., to a decrease in energy intensity.

Non-renewable energy sources, as potential carriers of some form of energy that have been created but cannot be renewed, represent the most important source of total world energy. The use of non-renewable energy sources is primarily associated with significant environmental pollution and climate disturbances. The key disadvantage of non-renewable energy sources is the combustion of fossil fuels (coal, oil, gas) into the atmosphere, creating a large amount of carbon dioxide (CO_2). The problem of non-renewable resources escalated in the 1970s when many industries around the world were suddenly faced with shortages of the materials from which their products are manufactured. According to Motesharrei et al. [1], uncontrolled exploitation of non-renewable natural resources, unequal distribution of wealth and excessive consumption of these resources could lead to the collapse of industrial society over several decades. Higher energy consumption is a consequence of the world's population growth, while the reduction of reserves of non-renewable energy sources (oil, gas and coal) represents a threat to the survival of the current living conditions. The EU directive on energy efficiency [2], which was adopted in 2012, establishes a common framework of measures to improve energy efficiency within the EU, which would ensure the achievement of the goal of reducing energy consumption by 20% by 2020. In 2014, EU countries agreed on a new goal regarding the energy efficiency, of at least 27% or more of reduction by 2030. Furthermore, the European Commission has proposed a binding goal of increasing energy efficiency by 30% in all countries by 2030. The increase in economic efficiency has led to the fact that the EU today consumes less energy than ten years ago.

Renewable energy has strategic importance for overall social development. The "100% renewable energy" approach implies a situation in which all energy needs are met exclusively from renewable energy sources. Numerous scientific studies qualify sources of renewable energy, i.e., permanent energy sources, as one of the key components of the concept of sustainable growth and development. At the same time, these sources contribute to the reduction of ecological vulnerability and the stimulation of economic and social development. Within the Europe 2020 strategy for smart, sustainable and inclusive growth [3], the share of renewable energy in gross final energy consumption is determined as a key indicator for measuring progress. The European Commission [4] emphasized that a more coordinated European

approach to establishing and reforming support programs should be determined, as well as noting that renewable energy trading among EU member states should be strengthened. In 2014, the European Commission proposed a set of energy and climate targets for 2030 [5] that seek to encourage private investment in infrastructure and low-carbon technologies. However, the key obstacles to the widespread implementation of renewable energy strategies are not technological, but mainly political in nature.

Primarily due to the use of fossil fuels (coal, oil, natural gas) in energy and industrial plants and modern traffic, as well as due to intensive agriculture, deforestation and other activities, the GHG emissions have increased significantly since the beginning of the industrialization period. Achieving zero net emissions implies reducing GHG in such a way that they are equal to the amount of CO_2 that can be absorbed from the atmosphere. Countries will have to stop the practice of relying on the growth of their economies on carbon, through increasing energy efficiency and the share of renewable energy sources (solar, wind energy and biomass, hydro and geothermal energy) in total consumption. EU and its member countries are obliged to report on their GHG emissions annually, in accordance with the United Nations Framework Convention on Climate Change (UNFCCC). The annual report on the GHG inventory at the EU level is prepared by the European Environment Agency, whereby countries should also report annually on policies and measures in the field of climate change through national communications. The EU inventory is based on the monitoring of GHG emissions by member states. The goal of the new Monitoring Mechanism Regulation (MMR) from 2013 [6] was to improve the quality of reporting data, help member states monitor progress in achieving emission reduction goals in the period 2013–2020, and facilitate the further development of EU policies in the field of climate change. EU is recognized as a leader in the field of climate policies, both because of its commitment to undertaking further efforts at the international level, and because of its own ambitious goals and concrete instruments, such as the EU Emissions Trading System (ETS).

One of the key prerequisites for economic and social development is the rapid growth of information and communication technology (ICT), which is considered a generic technology of exceptional importance for every country. As early as 2000, the OECD [7] proved the contribution of information and communication technology to GDP growth. As the bearer of development processes, ICT emphasized changes in business relations, contributed to the establishment of new forms of business and communication, improved the growth of innovation and productivity and affirmed the improvement of global efficiency. The consequences of these changes are: high level of economic efficiency, new competitive conditions, development and growth of sectors that use new technologies, market liberalization, different marketing structure, reduction of obstacles in trade and easier access to information, globalization of business. In this context, the significant economic impact of ICT in the EU is particularly emphasized at the beginning of this century. According to some estimates, the ICT sector is responsible for about half of the achieved productivity, considering return on investment in this sector. At the same time, the progress of digital technology represents a potential that must be exploited. The European Commission adopted the Digital Agenda for Europe [8] among the seven leading initiatives of the Europe 2020 development strategy, which should enable Europe to benefit from new jobs, promote economic prosperity and improve business and the everyday life of EU citizens. ICT is a catalyst for economic development, often in a short period of time, that optimizes the rising costs of human inputs. Information technologies continue to represent the main drivers of change in the global world, at all macroeconomic and microeconomic levels, and ICT specifically is even an imperative of the economy, regardless of the development level.

2. Renewable and Non-Renewable Energy

Researchers focus on the key results of previous empirical research that relate to the effect estimates of determinants included in the model on economic growth in EU countries. Researchers present the results of research covering not only EU, but also other countries, in order to compare obtained results.

Currently, in the world, there are dirty and clean sources of energy. Dirty sources are fossil fuels (coal, natural gas, oil and nuclear energy) related to environmental pollution and are being depleted. In contrast, clean energy comes from natural renewable sources that do not pollute the environment and have a minor negative effect on it. Moreover, clean energy comprises the energy of sun, wind, water (wave, hydropower and tidal energy), geothermal energy and biomass (waste, wood and crops) [9]. Renewable energy can help countries to develop green economy, to reduce carbon emissions and to achieve the United Nations Sustainable Development Goals [10]. This reveals the significance of new technologies and policy initiatives targeted on renewable energy. The results of a recent empirical study demonstrate that the renewable energy consumption has a positive impact on economic growth in the EU countries, both in the short and long run, encouraging further development of renewable energy sources [11]. Armeanu et al. [12] conclude that renewable energy sources are eco-friendly sources of energy or green energy. Additionally, they consider that renewable energy sources drive sustainable growth through energy and financial savings accomplished by substituting non-renewable energy sources and expensive energy with low-priced renewable energy sources, resulting in slower exhaustion of natural resources. Kahia et al. [13] warn that most renewable energy technologies can be less competitive than non-renewable energies due to their high level of initial cost of capital and therefore, high electricity costs. This indicates the competitive disadvantage of renewable energy due to the long payback period required to recover the high initial cost of capital.

EU Directive on the promotion of the use of energy from renewable sources [14], signed in 2009, estimated that in all EU countries by 2020, the use of energy from the renewable sources will be 20%. Across the EU countries, this target varies

from 10% to 49%. Pursuant the new Directive signed in 2018, all EU countries should decrease GHG emissions by 2030, for at least 40% compared to 1990 level on one hand, and to increase the share of renewable energy sources up to 32% and increase energy efficiency by at least 32.5%, on another [15].

Based on the literature, it can be concluded that the nexus between renewable energy consumption and economic growth is controversial: it ranges from positive, through neutral, to negative [16]. Some research also examined the presence of a long-term relationship between renewable and non-renewable energy and economic growth [17]. In addition, certain studies investigated the existence of short run causality where the results confirmed the relationship that occurs, also, in the long run [18][19] where the impact of renewable energy on economic growth was positive. A large number of studies have confirmed the contribution of renewable energy to economic growth. Soava et al. [20] revealed a positive impact of renewable energy consumption on economic growth, on a sample of EU-28 member states from 1995 until 2015. The Granger causality test indicated both one-way and two-way causal relations between renewable energy consumption and economic growth for different countries. Additionally, Rafindadi and Ozturk [21] note two-way causal relations between renewable energy consumption and economic growth in Germany in the 1971–2013 period. Therefore, they estimate that a 1% increase in renewable energy consumption contributes to economic growth by 0.2194%. Furthermore, Alper and Oguz [22] examined the causal relations between economic growth, renewable energy consumption, capital and labor in the new member states of the EU from 1990 until 2009 by applying ARDL approach. They indicated a significant and positive impact for Bulgaria, Estonia, Poland and Slovenia, but insignificant for other new EU countries. On a sample of 20 OECD countries, out of which 12 belong to the old EU group, in the period 1990–2008, Ohler and Fetters [23] confirmed that renewable energy sources (wind, biomass, waste and hydroelectric power) are positively related with GDP in the long run. In addition, they proved a short-run bidirectional relation only between hydroelectric power and waste and GDP growth. Additionally, in the 1995–2015 period, Saint Akadiri et al. [24], applying the ARDL approach, found the existence of positive and significant long-term relationship between environmental sustainability, renewable energy consumption and economic growth in EU-28 countries. Inglesi-Lotz [25] concluded that the renewable energy consumption growth increases GDP and GDP p.c. in the OECD countries (of which 23 countries are EU members) in the 1990–2010 period.

Contrary to the above-presented results, Silva et al. [26] have warned that renewable energy can initially decrease the growth of the economy in a certain number of EU countries. Chen et al. [27] proved significant and positive impact of renewable energy consumption on economic growth only when developing countries and non-OECD countries overcome a certain threshold of renewable energy consumption. Otherwise, this impact is negative. Additionally, they confirm no significant impact of renewable energy consumption on economic growth in developed countries and positive and significant impact in OECD members.

A certain number of studies have examined the impact of non-renewable energy sources on economic growth. Coal, oil and natural gas, which are the traditional energy sources, contribute significantly to the economic growth [28]. However, considering the issues of global warming and GHG emissions, all essential measures need to be taken to avoid environmental disasters. Therefore, the global warming impact on the economy is assessed to decrease the global GDP by 25% [29]. Therefore, transition from non-renewable to a renewable source of energy is urgently needed. Regarding non-renewable energy, Asiedu et al. [30] found that an increase of non-renewable energy on the sample of 26 European countries decreases economic growth. So far, non-renewable energy leads to economic growth, but environmental decline. Le et al. [31] on a sample of 102 countries, which includes all EU countries in the period from 1996 to 2012, found that both renewable and non-renewable energy consumption significantly contribute to income. Their results confirm that renewable energy sources to a significant extent contribute to environmental protection in developed countries. On the contrary, developing countries still have difficulties in utilizing renewable energy sources in order to decrease GHG emissions, which entails substantial scope for policy improvements in this area. Interestingly, Gozgor et al. [32], using ARDL and panel quantile regression methods on the EU sample during 1990–2013, fount that both economic complexity and consumption of energy from non-renewable and renewable sources are accompanied with increase in economic growth. According to Saqib [33], non-renewable energy consumption leads to carbon footprint, while green energy sources are more environmentally friendly.

In addition to methane (CH_2), carbon dioxide (CO_2) is the main contributor in the GHG emission inventory leading to planetary heating. Earlier research has found that almost 59% of total GHG emissions are CO_2 emissions, which are dominantly generated by energy consumption and economic growth [34]. Some studies have found bidirectional causality between carbon emissions and economic growth [35]. In other studies, only unidirectional causality is found between growth and CO_2 emissions [36]. Therefore, the relationship between CO_2 emissions and economic growth is of great importance for sustainable economic growth. Numerous empirical findings related to the nexus between CO_2 and economic growth should serve to policy makers to define pollution control policies, which should help strengthen sustainable economic growth and development. Not a small number of studies have indicated that the consumption of primary energy sources has led to GDP growth, but also to high pollution [37].

A certain number of studies on CO_2 emissions and economic growth relationship cover European countries, including EU member states. Acaravci and Ozturk [38], on a sample of a certain number of EU countries, found positive long-run elasticity estimates of carbon emissions with respect to real GDP and negative long-run elasticity estimates of carbon emissions with respect to the square of per capita real GDP (at a significance level of 1% in Denmark and 5% in Italy,

while statistically insignificant in Germany, Greece, Iceland and Portugal). At the same time, a one-way causal relationship has been noted in Denmark, Germany, Greece, Iceland, Italy, Portugal and Switzerland between energy consumption, real GDP and the square of per capita real GDP on the one hand and carbon emissions per capita on the other. A short-run unidirectional causal relationship is observed in Denmark and Italy between real GDP per capita and the square of per capita real GDP, on the one hand, and carbon emissions per capita, on the other. In general, the results showed that the practices of rationalization of energy consumption and controlled CO_2 emissions in most of the considered countries will not have a negative impact on real output growth. Lee and Brahmasrene [39] explored the nexus between CO_2 emissions, tourism, FDI and economic growth between 1988 and 2009 for the EU countries. Their results confirmed that CO_2 emissions, FDI and tourism have a positive effect on economic growth, but also that economic growth has had a positive effect on CO_2 emissions. Kasman and Duman [40], on the sample of new EU members and countries aspiring to become EU members, suggest that in these countries, a decrease of CO_2 emissions should not be expected in the near future if their economic outputs continue to increase. In OECD countries, including EU member states, Sun et al. [41] concluded that the volume of CO_2 emissions will continue to grow in the long run if economic productivity continues to grow, while policies should focus on increasing the participation of green technology and clean energy, in order to decarbonize the energy industry. Furthermore, Saboori et al. [42] in 27 OECD countries, including 15 EU countries, confirmed a long-run bidirectional relationship between economic growth, CO_2 emissions and energy consumption in the road sector. Saidi and Hammami [43] confirmed the negative impact of CO_2 emissions on the economic growth in 60 countries (including a certain number of European countries), finding that a 1% increase in CO_2 emissions reduces economic growth by 0.0067%. In this regard, they recommended investment in clean and alternative energy sources for sustainable economic growth. In three regional sub-panels, including Europe, for the period 1990–2011, Omri et al. [44] confirmed that CO_2 emissions affected significantly and negatively economic growth in all the panels, including the panel of European countries. Only for the Middle Eastern, North African and sub-Saharan panel, it has been confirmed that CO_2 emissions are positively linked to economic growth. Dogan and Aslan [45], using a sample of EU countries, pointed to the existence of two-way causality between real income and CO_2 emissions. However, Gardiner and Hajek [46] determined that CO_2 emissions affect GDP in both the old and new EU member countries, while a negative bidirectional relationship was only confirmed for the 15 old EU countries. Therefore, it is recommended to increase the share of renewable energy sources in the energy mix and increase energy efficiency. A recent d, covering certain number of EU countries, confirmed that there has been no separation of economic growth from CO_2 emissions in France and Spain, which indicates an insufficient reduction in energy consumption from non-renewable sources. However, Sweden has managed to decouple economic growth from CO_2 emissions, making CO_2 emissions less sensitive to variations in GDP, which confirms that environmental policies have not hampered economic growth [47]. Additionally, Wang et al. [48] showed that Sweden and other European countries, such as Germany, France, Finland and Denmark, grew with reduced CO_2 emissions, with decarbonization of the energy system being crucial. They also emphasize that decarbonization must be further accelerated if the Paris climate target is to be achieved. Moreover, the researchers warn that the challenges of reconciling the economic growth goals and climate change mitigation are complicated by further support of fossil fuel production and emission-intensive industries, without using the influence of public policy as climate-relevant for changing economic structure. A study covering Germany in the period 1975–2014 determined the long-run relationship between CO_2, energy consumption and economic growth, and recommended the introduction of energy tax and regulatory mechanisms to limit the use of fossil fuels and encourage the use of hydropower and biomass as green energy sources [49].

Numerous studies that investigated the nexus between CO_2 emissions and economic growth were conducted on the sample of developing and countries that are significant emitters of GHG emissions. Analyzing the relationship between CO_2 and economic growth in selected higher CO_2 emissions economies, Azam et al. [50] concluded that uncontrolled CO_2 emissions have a destructive effect on economic growth if the use of green economies and good environmental practices are lacking. This confirmed that in some countries, e.g., the USA, China and Japan, the results for the individual analysis across countries, over the period from 1971 to 2013, showed that CO_2 emissions have a significant and positive relationship with economic growth. On the contrary, in India, as one of the largest emitters of CO_2, a negative impact of CO_2 emissions on economic growth is found, which can serve as a good basis for further policy implications, and to force economic development on a sustainable basis. However, Wang et al. [51] confirmed separation of economic growth from CO_2 emissions in the USA, in the period 2007–2016, when energy-related CO_2 emissions fell by 12% (with a total of 738.14 million metric tons), while GDP increased by 19%. Bozkurt and Akan [52] found a positive relationship between CO_2 emissions and economic growth and warned that achieving long-term growth and development with high carbon emissions may damage the quality of the environment. They suggest that solution in these countries should be sought in the mechanisms of CO_2 emission control and the implementation of regulatory policies to reduce emissions. Additionally, the results of another study show that total primary energy and CO_2 consumption have a long-run and positive causal relationship with GDP growth in developing countries, which leads to high levels of pollution [53]. Ahmad and Du [54] confirm the existence of a long-run and positive relationship between CO_2 emission and economic growth. Therefore, they suggest a greater focus on sectors that require less energy consumption, as well as reducing non-renewable energy consumption. Adebayo [55] noted that CO_2 emissions, energy use, urbanization and globalization were driving economic growth in Japan for the period 1970–2015. Borhan et al. [56] in ASEAN-8 countries determined a negative relationship between CO_2 emissions and GDP p.c., which confirms the long-term destructive effect of environmental pollution on economic prosperity. Interestingly, some studies have confirmed that economic growth does not have to be accompanied by growth of CO_2 emissions, i.e., it can be achieved without endangering the quality of the environment [57][58]. Therefore,

the development of low-carbon economies and the adaptation of industrial structures are the basic levers for achieving the climate change mitigation goal. Additionally, the experience of some countries has shown a different relationship between CO_2 and economic growth, depending on the country's stage of development [53]. In the first phase, when the country's development is based on less energy-intensive activities (agriculture, fisheries, forestry), there is a negative path between CO_2 and economic growth (emissions fall, GDP grows). In the industrialization phase, it shows the positive path (emissions grow, GDP grows), while in the third phase, when the country focuses on green energy policy, it again shows the negative path between CO_2 emissions and GDP growth. Therefore, the recommendation is to constantly balance economic and environmental conditions, where renewable energy has a significant role in the balancing process and the realization of the interests of sustainable development.

ICT has been recognized as one of the key factors of economic growth for two decades. According to the World Bank [59] (p. 20) definition, ICT includes "hardware, software, networks, and media collection, storage, processing, transmission, and presentation of information (voice, data, text, images)". Intensive and rapid expansion of ICT, especially in the last two decades, has encouraged research on the impact of this technology on economic growth in EU countries. Both developed and underdeveloped economies have turned to ICT, which is used as a modern tool to increase competitiveness, employment and economic growth. Therefore, some research has recognized this technology as a driver of economic growth in both developed and developing countries [60]. It is noticeable that the development of ICT is not homogeneous, but in both groups of countries, there are pronounced differences between regions. In addition, countries need to be as interested as possible in investing in ICT because the greater the investment in this technology, the greater the return on these investments.

The benefits of using ICT are multiple: promoting and developing entrepreneurship and sustainable development [61][62], faster and cheaper access to new markets [63][64], reduced production costs and increased productivity [65][66], fast and efficient access to new information and knowledge [67][68]. The dominant number of empirical studies has confirmed that this technology has significant economic implications, and that it is an important driver of economic growth. Empirical evidence relates to productivity growth, poverty reduction, and increasing economic growth. Relevant international institutions recognize ICT as a key factor of economic growth. Accordingly, the World Economic Forum [69] in its 2013 report confirmed that an increase in digitalization by 10% leads to a decrease in unemployment by 1.02% and an increase in GDP p.c. to 0.75%. With the generation of new jobs and sources of income, and the reduction of costs of health and education services, this technology has long been recognized as one of the key actors in poverty reduction [70].

Previous studies have focused on the impact of telecommunications, as an important aspect of ICT, on economic growth. Thus, research conducted on the sample of CEE countries confirmed the nexus between telecommunication investment, as part of ICT investment, and economic growth. Moreover, further increase in these investments can improve the impact of aggregate investment on economic growth [71]. Similarly, Roller and Waverman [72] in OECD countries, including old EU members, found that a 10% increase in telecommunications investment increases GDP by 2.8%, while Datta and Agarwal [73], for the same group of countries, confirmed a statistically significant and positive correlation between these two variables. In addition, a study on the impact of ICT on economic growth conducted for OECD countries, dominantly including European countries, found that the broadband penetration rate of 10% leads to an increase in GDP p.c. by 0.9–1.5% [74]. Another study offered similar results, for EU countries belonging to the OECD, proving that ICT positively impacts GDP growth [75]. Furthermore, Shiu and Lam [76] found in over 100 countries a two-way relationship between telecommunications and economic growth in European and high-income countries, while in other countries in the sample, the impact of GDP on telecommunications investment was identified. Additionally, Pradhan et al. [77][78] detected a bidirectional causal relationship between telecommunications development and economic growth (long-term and short-term), in both developed and developing countries. Similarly, another study that was regionally conceived confirmed the impact of telecommunications on income at the regional level [79]. Moreover, Hanclova et al. [80] confirmed the influence of ICT capital on economic growth in old and new EU countries and demonstrated that the elasticity in new EU was higher compared to the old EU group.

Subsequent research focused more on the impact of internet on economic growth. Thus, research including a large number of countries and using cross-country data assessed that internet access is statistically significant and positively correlated with economic growth, which contributes to the effect of knowledge and information spillovers across countries [81]. Another study did not establish a direct relationship between internet use and economic growth, but an indirect one, through trade openness [66], finding that internet use contributes more to trade in countries lower-income than in high-income countries. Salahuddin and Gow [82] obtained similar results. Namely, their findings from ARDL cointegration tests confirmed the positive and long-term effects of internet use on economic growth, while the short-term relationship between these variables is found to be statistically insignificant. Therefore, the policy implication was a further increase in investment in internet infrastructure development. Chen et al. [62] examined the impact of the internet on better access to external financing, which overcomes the financial difficulties of small and micro businesses in particular. Overcoming the information asymmetry and reducing agency costs improves the credit availability of companies, which contributes to their sustainable development. Najarzadeh et al. [83] confirmed the positive and statistically significant impact of internet use on productivity growth. Their research showed that increasing the number of internet users by 1% increases GDP per employee by USD 8.16–14.6. Based on the findings, policy implications of this were related to subsidizing the bringing of

the internet to remote locations, taking initiatives to reduce internet membership fees, expanding internet bands and strengthen internet security.

Numerous studies have identified statistically significant and positive effects of ICT investment on economic growth [84][85], which implies that it is necessary to implement special policies that facilitate ICT investment, in order to improve economic growth. Another study found that a 10% increase in fixed broadband penetration increases GDP p.c. growth by more than 1%, both in developed and developing countries [86]. Crandall and Singer [87] offer similar results which showed that increasing broadband investments affects job creation and employment and intensifies economic growth, while Thompson and Garbacz [88] proved that mobile broadband has a positive and significant impact on GDP per household, with a greater impact in underdeveloped countries. A positive impact of broadband adoption on economic growth was confirmed in a study covering EU countries for the period 2005–2011 [89], where in the defined scenario, the total benefits outweigh the costs by over 30% at EU level. This implies the recommendation for public support for the generalized build out of broadband infrastructure. The research on the sample of CEE countries [90] pointed out the significant and positive impact of investment in ICT on GDP p.c., which is why incentives for technological development and investment in this technology should be provided. Interestingly, Yousefi [91] did not confirm the contribution of ICT investment on GDP in developing countries, and concluded that impact of ICT is stronger in high-income countries, compared to low-income countries. Additionally, one study showed that investments in ICT are important for increasing the cost efficiency of banking sector [92], while another assessed the impact of internet banking on improving the efficiency of banks [93][94]. Similarly, recent studies have confirmed a significant and positive impact of ICT investment on economic growth [95][96][97][98].

References

1. Motesharrei, S.; Rivas, J.; Kalnay, E. Human and nature dynamics (HANDY): Modeling inequality and use of resources in the collapse or sustainability of societies. Ecol. Econ. 2014, 101, 90–102.
2. European Commission. Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. Off. J. Eur. Union 2022, L 315/1, 1–56. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&from=EN (accessed on 18 July 2022).
3. European Commission. Europe 2020. A European Strategy for Smart, Sustainable and Inclusive Growth. Working Paper. 2010. Available online: https://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf (accessed on 15 June 2022).
4. European Commission. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Renewable Energy: A Major Player in the European Energy Market. Renewable Energy: An Important Factor In the European Energy Market. Available online: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0271:FIN:EN:PDF (accessed on 20 July 2022).
5. European Commission. 2030 Targets. EU Policy, Strategy and Legislation for 2030 Environmental, Energy and Climate Targets. Available online: https://ec.europa.eu/info/energy-climate-change-environment/overall-targets-and-reporting/2030-targets_en (accessed on 20 July 2022).
6. European Environmental Agency. Monitoring Mechanism Regulation 525/2013. Available online: https//www.eea.europa.eu/policy-documents/monitoring-mechanism-regulation-525-2013 (accessed on 19 July 2022).
7. OECD. Information Technology Outlook 2000. ICTs, E-Commerce and the Information Economy. Available online: https://www.oecd-ilibrary.org/science-and-technology/information-technology-outlook-2000_it_outlook-2000-en (accessed on 17 July 2022).
8. European Commission. The Digital Agenda for Europe: Key Initiative, Why Digital Agenda for Europe? Brussels, 2010, 3–15. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52010DC0245&from=en (accessed on 19 July 2022).
9. Nelson, V.C.; Starcher, K.L. Introduction to Renewable Energy, 2nd ed.; CRC Press: Boca Raton, FL, USA, 2015.
10. United Nations. The 17 Goals: Sustainable development. United Nations, Department of Economic and Social Affairs. 2015. Available online: https://www.un.org/sustainabledevelopment/wp-content/uploads/2019/01/SDG_Guidelines_AUG_2019_Final.pdf (accessed on 9 June 2022).
11. Davidson, N.; Maksimova, E.; Mariev, O. How does renewable energy consumption affect economic growth? Evidence from the European Union countries. In Proceedings of the 21st International Scientific Conference Globalization and its Socio-Economic Consequences, Zilina, Slovakia, 13 October 2021.
12. Armeanu, D.Ş.; Vintilă, G.; Gherghina, Ş.C. Does renewable energy drive sustainable economic growth? Multivariate panel data evidence for EU-28 countries. Energies 2017, 10, 381.
13. Kahia, M.; Aïssa, M.S.B.; Charfeddine, L. Impact of renewable and non-renewable energy consumption on economic growth: New evidence from the MENA Net Oil Exporting Countries (NOECs). Energy 2016, 116, 102–115.

14. European Commission. Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Off. J. Eur. Union 2009, 140/116, 1–47. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=en (accessed on 5 June 2022).
15. European Commission. Directive 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Off. J. Eur. Union 2018, 5, 82–168. Available online: https://eurlex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=fr (accessed on 5 June 2022).
16. Adewuyi, A.O.; Awodumi, O.B. Renewable and non-renewable energy-growth-emissions linkages: Review of emerging trends with policy implications. Renew. Sust. Energ. Rev. 2017, 69, 275–291.
17. Chang, T.; Gupta, R.; Inglesi-Lotz, R.; Simo-Kengne, B.; Smithers, D.; Trembling, A. Renewable energy and growth: Evidence from heterogeneous panel of G7 countries using Granger causality. Renew. Sust. Energ. Rev. 2015, 52, 1405–1412.
18. Sadorsky, P. Renewable energy consumption and income in emerging economies. Energ. Policy 2009, 37, 4021–4028.
19. Gyamfi, B.A.; Bein, M.A.; Bekun, F.V. Investigating the nexus between hydroelectricity energy, renewable energy, nonrenewable energy consumption on output: Evidence from E7 countries. Environ. Sci. Pollut. R. 2020, 27, 25327–25339.
20. Soava, G.; Mehedintu, A.; Sterpu, M.; Raduteanu, M. Impact of renewable energy consumption on economic growth: Evidence from European Union countries. Technol. Econ. Dev. Eco. 2018, 24, 914–932.
21. Rafindadi, A.A.; Ozturk, I. Impacts of renewable energy consumption on the German economic growth: Evidence from combined cointegration test. Renew. Sust. Energ. Rev. 2017, 75, 1130–1141.
22. Alper, A.; Oguz, O. The role of renewable energy consumption in economic growth: Evidence from asymmetric causality. Renew. Sust. Energ. Rev. 2016, 60, 953–959.
23. Ohler, A.; Fetters, I. The causal relationship between renewable electricity generation and GDP growth: A study of energy sources. Energ. Econ. 2014, 43, 125–139.
24. Saint Akadiri, S.; Alola, A.A.; Akadiri, A.C.; Alola, U.V. Renewable energy consumption in EU-28 countries: Policy toward pollution mitigation and economic sustainability. Energ. Policy 2019, 132, 803–810.
25. Inglesi-Lotz, R. The impact of renewable energy consumption to economic growth: A panel data application. Energ. Econ. 2016, 53, 58–63.
26. Silva, S.; Soares, I.; Pinho, C. The impact of renewable energy sources on economic growth and CO2 emissions: A SVAR approach. Eur. Res. Stud. J. 2012, 15, 133–144.
27. Chen, C.; Pinar, M.; Stengos, T. Renewable energy consumption and economic growth nexus: Evidence from a threshold model. Energ. Policy 2020, 139, 111295.
28. Ellabban, O.; Abu-Rub, H.; Blaabjerg, F. Renewable energy resources: Current status, future prospects and their enabling technology. Renew. Sust. Energ. Rev. 2014, 39, 748–764.
29. DeCanio, S.J. The political economy of global carbon emissions reductions. Ecol. Econ. 2009, 68, 915–924.
30. Asiedu, B.A.; Hassan, A.A.; Bein, M.A. Renewable energy, non-renewable energy, and economic growth: Evidence from 26 European countries. Environ. Sci. Pollut. R. 2021, 28, 11119–11128.
31. Le, T.H.; Chang, Y.; Park, D. Renewable and nonrenewable energy consumption, economic growth, and emissions: International evidence. Energ. J. 2020, 41, 73–92.
32. Gozgor, G.; Lau, C.K.M.; Lu, Z. Energy consumption and economic growth: New evidence from the OECD countries. Energy 2018, 153, 27–34.
33. Saqib, N. Green energy, non-renewable energy, financial development and economic growth with carbon footprint: Heterogeneous panel evidence from cross-country. Econ. Res. Ekon. Istraz. 2022, 1–20.
34. Bacon, R.W.; Bhattacharya, S. Growth and CO2 emissions: How do different countries fare? Environ. Work. Pap. Ser. 2007, 113, 1–50.
35. Yang, Z.; Zhao, Y. Energy consumption, carbon emissions, and economic growth in India: Evidence from directed acyclic graphs. Econ. Model. 2014, 38, 533–540.
36. Bhattacharya, M.; Lean, H.H.; Bhattacharya, S. Economic Growth, Coal Demand, Carbon Dioxide Emissions: Empirical Findings from India with Policy Implications; Monash University, Department of Economics: Melbourne, VIC, Australia, 2014; Available online: https://www.monash.edu/__data/assets/pdf_file/0003/925707/economic_growth,_coal_demand,_carbon_dioxide_emissions_empirical_find (accessed on 19 May 2022).
37. Al-Mulali, U.; Sab, C.N.B.C. The impact of energy consumption and CO2 emission on the economic growth and financial development in the Sub Saharan African countries. Energy 2012, 39, 180–186.
38. Acaravci, A.; Ozturk, I. On the relationship between energy consumption, CO2 emissions and economic growth in Europe. Energy 2010, 35, 5412–5420.

39. Lee, J.W.; Brahmasrene, T. Investigating the influence of tourism on economic growth and carbon emissions: Evidence from panel analysis of the European Union. Tour. Manag. 2013, 38, 69–76.
40. Kasman, A.; Duman, Y.S. CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: A panel data analysis. Econ. Model. 2015, 44, 97–103.
41. Sun, H.; Samuel, C.A.; Amissah, J.C.K.; Taghizadeh-Hesary, F.; Mensah, I.A. Non-linear nexus between CO2 emissions and economic growth: A comparison of OECD and B&R countries. Energy 2020, 212, 118637.
42. Saboori, B.; Sapri, M.; bin Baba, M. Economic growth, energy consumption and CO2 emissions in OECD (Organization for Economic Co-operation and Development)'s transport sector: A fully modified bi-directional relationship approach. Energy 2014, 66, 150–161.
43. Saidi, K.; Hammami, S. The impact of energy consumption and CO2 emissions on economic growth: Fresh evidence from dynamic simultaneous-equations models. Sustain. Cities Soc. 2015, 14, 178–186.
44. Omri, A.; Nguyen, D.K.; Rault, C. Causal interactions between CO2 emissions, FDI, and economic growth: Evidence from dynamic simultaneous-equation models. Econ. Model. 2014, 42, 382–389.
45. Dogan, E.; Aslan, A. Exploring the relationship among CO2 emissions, real GDP, energy consumption and tourism in the EU and candidate countries: Evidence from panel models robust to heterogeneity and cross-sectional dependence. Renew. Sust. Energ. Rev. 2017, 77, 239–245.
46. Gardiner, R.; Hajek, P. Interactions among energy consumption, CO2, and economic development in European Union countries. Sustain. Dev. 2020, 28, 723–740.
47. Piłatowska, M.; Geise, A. Impact of clean energy on CO2 emissions and economic growth within the phases of renewables diffusion in selected European countries. Energies 2021, 14, 812.
48. Wang, R.; Assenova, V.A.; Hertwich, E.G. Energy system decarbonization and productivity gains reduced the coupling of CO2 emissions and economic growth in 73 countries between 1970 and 2016. One Earth 2021, 4, 1614–1624.
49. Khoshnevis Yazdi, S.; Shakouri, B. The renewable energy, CO2 emissions, and economic growth: VAR model. Energ. Source Part B. 2018, 13, 53–59.
50. Azam, M.; Khan, A.Q.; Abdullah, H.B.; Qureshi, M.E. The impact of CO2 emissions on economic growth: Evidence from selected higher CO2 emissions economies. Environ. Sci. Pollut. R. 2016, 23, 6376–6389.
51. Wang, Q.; Jiang, X.T.; Ge, S.; Jiang, R. Is economic growth compatible with a reduction in CO2 emissions? Empirical analysis of the United States. Resour. Conserv. Recycl. 2019, 151, 104443.
52. Bozkurt, C.; Akan, Y. Economic growth, CO2 emissions and energy consumption: The Turkish case. Int. J. Energy Econ. Policy 2014, 4, 484–494.
53. Bekhet, H.A.; Othman, N.S. The role of renewable energy to validate dynamic interaction between CO2 emissions and GDP toward sustainable development in Malaysia. Energ. Econ. 2018, 72, 47–61.
54. Ahmad, N.; Du, L. Effects of energy production and CO2 emissions on economic growth in Iran: ARDL approach. Energy 2017, 123, 521–537.
55. Adebayo, T.S. Do CO2 emissions, energy consumption and globalization promote economic growth? Empirical evidence from Japan. Enviro. Sci. Pollut. R. 2021, 28, 34714–34729.
56. Borhan, H.; Ahmed, E.M.; Hitam, M. The impact of CO2 on economic growth in ASEAN-8. Procedia Soc. Behav. Sci. 2012, 35, 389–397.
57. Ghosh, B.C.; Alam, K.J.; Osmani, M.A.G. Economic growth, CO2 emissions and energy consumption: The case of Bangladesh. Int. J. Bus. Econ. Res. 2014, 3, 220–227.
58. Lim, K.M.; Lim, S.Y.; Yoo, S.H. Oil consumption, CO2 emission, and economic growth: Evidence from the Philippines. Sustainability 2014, 6, 967–979.
59. World Bank Group. Information and Communication Technologies: A World Bank Group Strategy; World Bank: Washington, DC, USA, 2002; Available online: https://documents1.worldbank.org/curated/en/421471468325303463/pdf/800880PUB0Info00Box379796B00PUBLIC0.pdf (accessed on 20 May 2022).
60. Lovrić, L. Information-communication technology impact on labor productivity growth of EU developing countries. Zb. Rad. Ekon. Fak. Rije. 2012, 30, 223–245.
61. Henry, B.C. ICT for sustainable development. Sci. Technol. 2012, 2, 142–145.
62. Chen, Y.; Gong, X.; Chu, C.C.; Cao, Y. Access to the internet and access to finance: Theory and evidence. Sustainability 2018, 10, 2534.
63. Alfaro Cortés, E.; Alfaro Navarro, J.L. Do ICT influence economic growth and human development in European Union countries? Int. Adv. Econ. Res. 2011, 17, 17–28.
64. Pradhan, R.P.; Mallik, G.; Bagchi, T.P. Information communication technology (ICT) infrastructure and economic growth: A causality evinced by cross-country panel data. IIMB Manag. Rev. 2018, 30, 91–103.
65. García-Muñiz, A.S.; Vicente, M.R. ICT technologies in Europe: A study of technological diffusion and economic growth under network theory. Telecommun. Policy 2014, 38, 360–370.

66. Meijers, H. Does the Internet generate economic growth, international trade, or both? Int. Econ. Econ. Policy 2014, 11, 137–163.

67. Pradhan, R.P.; Arvin, M.B.; Nair, M.; Bennett, S.E. Sustainable economic growth in the European Union: The role of ICT, venture capital, and innovation. Rev. Financ. Econ. 2020, 38, 34–62.

68. Sepehrdoust, H.; Ghorbanseresht, M. Impact of information and communication technology and financial development on economic growth of OPEC developing economies. Kasetsart J. Soc. Sci. 2018, 40, 546–551.

69. World Economic Forum. The Global Information Technology Report 2013, Digitization for Economic Growth and Jobs in a Interconnected World. 2013. Available online: https://www3.weforum.org/docs/WEF_GITR_Report_2013.pdf (accessed on 16 May 2022).

70. OECD. ICTs for Development: Improving Policy Coherence; OECD: Paris, France, 2010; Available online: https://read.oecd-ilibrary.org/development/icts-for-development_9789264077409-en#page1 (accessed on 25 May 2022).

71. Madden, G.; Savage, S.J. CEE telecommunications investment and economic growth. Inf. Econ. Policy 1998, 10, 173–195.

72. Roller, L.H.; Waverman, L. Telecommunications infrastructure and economic development: A simultaneous approach. Am. Econ. Rev. 2001, 91, 909–923.

73. Datta, A.; Agarwal, S. Telecommunications and economic growth: A panel data approach. Appl. Econ. 2004, 36, 1649–1654.

74. Czernich, N.; Falck, O.; Kretschmer, T.; Woessmann, L. Broadband Infrastructure and Economic Growth. Econ. J. 2011, 121, 505–532.

75. Fernández-Portillo, A.; Almodóvar-González, M.; Hernández-Mogollón, R. Impact of ICT development on economic growth. A study of OECD European Union countries. Technol. Soc. 2020, 63, 101420.

76. Shiu, A.; Lam, P.L. Causal relationship between telecommunications and economic growth: A study of 105 countries. In Proceedings of the 17th Biennial Conference of the International Telecommunications Society, Montreal, QC, Canada, 24 June 2008.

77. Pradhan, R.P.; Arvin, M.B.; Norman, N.R.; Bele, S.K. Economic growth and the development of telecommunications infrastructure in the G-20 countries: A panel-VAR approach. Telecommun. Policy 2014, 38, 634–649.

78. Pradhan, R.P.; Arvin, M.B.; Hall, J.H. Economic growth, development of telecommunications infrastructure, and financial development in Asia, 1991–2012. Q. Rev. Econ. Finance 2016, 59, 25–38.

79. Cieślik, A.; Kaniewska, M. Telecommunications infrastructure and regional economic development: The case of Poland. Reg. Studies 2004, 38, 713–725.

80. Hanclova, J.; Doucek, P.; Fischer, J.; Vltavska, K. Does ICT capital affect economic growth in the EU-15 and EU-12 countries? J. Bus. Econ. Manag. 2015, 16, 387–406.

81. Choi, C.; Yi, M.H. The effect of the Internet on economic growth: Evidence from cross-country. Econ. Lett. 2009, 105, 39–41.

82. Salahuddin, M.; Gow, J. The effects of Internet usage, financial development and trade openness on economic growth in South Africa: A time series analysis. Telemat. Inform. 2016, 33, 1141–1154.

83. Najarzadeh, R.; Rahimzadeh, F.; Reed, M. Does the Internet increase labor productivity? Evidence from a cross-country dynamic panel. J. Policy Model. 2014, 36, 986–993.

84. Nasab, E.H.; Aghaei, M. The effect of ICT on economic growth: Further evidence. Int. Bull. Bus. Adm. 2009, 5, 46–56.

85. Dimelis, S.P.; Papaioannou, S.K. FDI and ICT effects on productivity growth: A comparative analysis of developing and developed countries. Eur. J. Dev. Res. 2010, 22, 79–96.

86. Qiang, C.Z.W.; Rossotto, C.M.; Kimura, K. Information and Communications for Development 2009: Extending Reach and Increasing Impact; World Bank: Washington, DC, USA, 2009; Available online: https://documents1.worldbank.org/curated/en/645821468337815208/pdf/487910PUB0EPI1101Official0Use0Only1.pdf (accessed on 17 May 2022).

87. Crandall, R.W.; Singer, H.J. The Economic Impact of Broadband Investment. Study for Broadband America. 2010. Available online: https://www.researchgate.net/profile/Charles-Jackson-6/publication/265631048_C_The_Effect_of_Ubiquitous_Broadband_Adoption_on_Investment_Jobs_and_the_US_Economy/links/587cdbdThe-Effect-of-Ubiquitous-Broadband-Adoption-on-Investment-Jobs-and-the-US-Economy.pdf (accessed on 17 June 2022).

88. Thompson, H.G., Jr.; Garbacz, C. Economic impacts of mobile versus fixed broadband. Telecommun. Policy 2011, 35, 999–1009.

89. Gruber, H.; Hatonen, J.; Koutroumpis, P. Broadband access in the EU: An assessment of future economic benefits. Telecommun. Policy 2014, 18, 1046–1058.

90. Zagorchev, A.; Vasconcellos, G.; Bae, Y. Financial development, technology, growth and performance: Evidence from the accession to the EU. J. Int. Financ. Mark. Inst. Money 2011, 21, 743–759.

91. Yousefi, A. The Impact of Information and Communication Technology on Economic Growth: Evidence from Developed and Developing Countries. Econ. Innov. New Technol. 2011, 20, 581–596.
92. Lin, H.J.; Lin, W. International E-Banking: ICT Investments and the Basel Accord. J. Comp. Int. Manag. 2007, 10, 23–39.
93. Stoica, O.; Mehdian, S.; Sargu, A. The impact of Internet banking on the performance of Romanian banks: DEA and PCA approach. Procedia Econ. Financ. 2015, 20, 610–622.
94. Ghita-Mitrescu, S.; Duhnea, C. Internet Banking in Romania at a Glance. Ovidius Univ. Ann. Econ. Sci. Ser. 2016, 16, 508–514.
95. Niebel, T. ICT and economic growth–Comparing developing, emerging and developed countries. World Dev. 2018, 104, 197–211.
96. Majeed, M.T.; Ayub, T. Information and Communication Technology (ICT) and Economic Growth Nexus: A Comparative Global Analysis. Pak. J. Commer. Soc. Sci. 2018, 12, 443–476.
97. Haftu, G.G. Information communications technology and economic growth in Sub-Saharan Africa: A panel data approach. Telecommun. Policy 2018, 43, 88–99.
98. Latif, Z.; Latif, S.; Ximei, L.; Pathan, Z.H.; Salam, S.; Jianqiu, Z. The dynamics of ICT, foreign direct investment, globalization and economic growth: Panel estimation robust to heterogeneity and cross-sectional dependence. Telemat. Inform. 2018, 35, 318–328.

Retrieved from https://encyclopedia.pub/entry/history/show/70623