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Sustainable development goals, emissions and sector's performance.

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The present dissertation entitled "Sustainable development goals, emissions and sector's performance." was submitted by Avgeros Fotios, SID 1046279, in partial fulfilment of the requirements for the degree of Master of Science in "Applied Economics & Data Analysis" at the University of Patras, Department of Economics and was approved by the Dissertation Committee Members.

I would like to dedicate my dissertation to my grandfathers Christos and Vasilis and to my dog Gorbi, whom we lost in 2022.

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SUMMARY

This study examines the energy and environmental efficiency of various industry sectors using Data Envelopment Analysis model (DEA), to identify the extent to which industry sectors address the Sustainable Development Goals. It also investigates the direct relationship between energy environmental efficiency and CO₂ emissions, which consequently has an effect on the goals. The findings indicate that there are considerable differences in efficiency scores and production technology between and within different industry sectors, which causes the majority of the sample to produce at levels that are much below ideal. Additionally, a regression model that was created showed a direct negative impact of efficiency on CO₂ emissions. We have suggested that inefficient industries require cooperation within the Sectors, investment in production technology, and properly targeted tax regulations and penalties in order to maximize their contribution to the SDGs.

Keywords: Sustainable Development Goals (SDGs), Data Envelopment Analysis (DEA), Constant Returns to Scale (CRS), Variable Returns to Scale (VRS), CO₂, Energy, Efficiency, Sector's Performance.

Π Ε Ρ Ι Λ Η Ψ Η

Αυτή η μελέτη εξετάζει την ενεργειακή και περιβαλλοντική αποτελεσματικότητα των διαφόρων βιομηχανικών τομέων χρησιμοποιώντας το οικονομικό μοντέλο ανάλυσης (DEA) , για να προσδιορίσει τον βαθμό στον οποίο οι κλάδοι ανταποκρίνονται στους Στόχους Βιώσιμης Ανάπτυξης (SDGs) . Διερευνά επίσης την άμεση σχέση μεταξύ της ενεργειακής περιβαλλοντικής αποτελεσματικότητας και των εκπομπών διοξειδίου του άνθρακα, η οποία κατά συνέπεια έχει επίδραση στους στόχους. Τα ευρήματα δείχνουν ότι υπάρχουν σημαντικές διαφορές στους βαθμούς αποτελεσματικότητας και στην τεχνολογία παραγωγής μεταξύ και εντός των διαφορετικών βιομηχανικών τομέων, γεγονός που προκαλεί την πλειοψηφία του δείγματος να παράγει σε επίπεδα πολύ χαμηλότερα από το ιδανικό. Επιπλέον, ένα μοντέλο παλινδρόμησης που δημιουργήθηκε έδειξε άμεσο αρνητικό αντίκτυπο της αποτελεσματικότητας στις εκπομπές διοξειδίου του άνθρακα. Προτείνουμε ότι οι αναποτελεσματικές βιομηχανίες απαιτούν συνεργασία εντός των Τομέων, επενδύσεις στην τεχνολογία παραγωγής και σωστά στοχευμένους φορολογικούς κανονισμούς και κυρώσεις, προκειμένου να μεγιστοποιήσουν τη συμβολή τους στους Στόχους Βιώσιμης Ανάπτυξης (SDGs) .

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1 | CHAPTER 1

1.1 INTRODUCTION

On 15 September 2015, a plan was adopted by the United Nations (UN) which calls for worldwide action among governments, businesses, and civil society organizations to achieve shared and sustainable prosperity. This plan is named “Transforming Our World: The 2030 Agenda for Sustainable Development” and it is incorporating 17 Sustainable Development Goals (SDGs) and 169 related targets addressing global challenges of climate change, social inequality, and environmental degradation, and it has been described as “the closest thing the Earth has to a strategy”. However, it is widely known that the 2030 agenda cannot be achieved only from the contribution of the public sector and that the private sector must contribute as well. Sustainable development is known as the ability to meet existing needs without compromising the capacity of future generations to meet their own needs [Brundtland et al., 1987]. From this point of view, the worldwide production of all sectors should minimize the consumption of natural resources while maintaining the production level in order to meet human needs with the principle of environmentally friendly operation through technological progress. This study’s main objective is to create a comprehensive model that uses energy and environmental efficiency as

important indicators to examine how the performance of the industry sectors is influencing the advancement of the SDGs. More precisely, CO₂ emissions of business sectors are faced as an indicator of progress on the following goals, life above and below the water SDG 14, life on land SDG 15, clean water and sanitation SDG 6, and improved climate action SDG 13. Additionally, economic efficiency is faced as an indicator of progress on SDG8 economic development and due to the inclusion of total energy consumption as input for SDG7 clean and affordable energy.

The main argument against the accepted goals is that there can be trade-offs if they are viewed as separate, disconnected components of a larger system. Various SDGs may contradict one another, be inconsistent, or be out of sync, according to research [Allen et al. 2016, Spaiser et al. 2016]. The pursuit of one objective may prevent the fulfillment of another. For instance, the SDG1 goal of ending extreme poverty is typically associated with rapid health benefits (SDG3). However, SDG13, which includes addressing climate change, may be impacted by the usage of fossil fuels. A cheap and expedient strategy to advance the two aforementioned objectives would be to invest in fossil fuel power facilities [Spaiser et al., 2016]. The main force behind economic and social progress as well as a key factor in the rising standard of living is energy. However, it is a major contributor to CO₂ emissions, which worsens the environment [Wang et al., 2021]. The International Energy Agency (IEA) estimates that the power sector is responsible for almost two-thirds of the increase in global emissions, with over 40% of energy-related CO₂ emissions coming from burning fossil fuels to produce electricity. Global energy use and production account for a size-

able portion of non-sustainable activity. Global issues like climate change and environmental degradation have negative effects on the economy, society, and the environment [Ibrahim & Alola, 2020]. However, due to its role in eradicating poverty, advancing healthcare and education, industrialization, and improving water supplies, energy is a crucial prerequisite for achieving practically all SDGs. In order to facilitate important development processes, energy efficiency, renewable energy, energy access, and other energy-related challenges are essential. For the development to be sustainable, social, ecological, and economic concerns must be considered. In this context, this study investigates a development strategy for the various industry sectors that satisfies both human needs and Sustainable Development Goals, through an effective system of input utilization.

2 | CHAPTER 2

2.1 LITERATURE REVIEW

The literature review in this thesis is organized as follows: first, in section 2.1.1, the relationship between energy environmental efficiency and the Sustainable Development Goals in the existing economic literature is researched and analyzed, and then, in section 2.1.2, the ten SDGs, their targets, and the most recent reports of global progress are analyzed [United Nations, Sustainable development Goals, n.d.].

2.1.1 Energy-Environmental Efficiency

Sustainable development goals and energy-environmental efficiency are linked and widely documented in the economic literature. Energy efficiency is linked in several studies to both SDG 8 Economic Development and SDG 7 Clean and Affordable Energy. Additionally, research has shown that economic development enhances gender equality SDG 5, reduces inequality SDG10, reduces poverty SDG1, ends hunger SDG2, and enhances the overall quality of life SDG10 [Department for International Development (2018)]. Environmental efficiency also

has a direct impact on life above and below the water SDG 14, life on land SDG 15, clean water and sanitation SDG 6, and improved climate action SDG 13.

According to studies on the progress of the Sustainable Development Goals (SDGs) based on the energy-environmental performance of Latin American and Caribbean (LAC) countries, there has been a slow advancement towards the SDGs, primarily due to technological advancement as opposed to catch-up efficiency, which seems to be a barrier to SDG achievement. A slow but steady route toward the SDGs is created by the significant importance of environmental performance and renewable energy. Data Envelopment Analysis (DEA), a mathematical technique, was employed to measure the effectiveness of systems generally or decision-making units (DMUs), presuming that a system employs a vector X to produce a vector Y [Ferreira, 2022]. Another study suggests that inefficiencies are responsible for 85 percent of energy use and 89 percent of CO₂ emissions. In more detail, the 19 major economies used 71.27 percent of the total 13361.32Mto of energy consumption, out of which only 15 percent was required to maintain the level of production at the time, 44 percent was lost to economic inefficiency, and 41 percent was lost to inefficient distribution. In contrast, the total CO₂ emissions worldwide were 32363.85 MMtons, of which the 19 main economies contributed 73.82 percent, despite the objective being just 11 percent of the overall emissions. Of this CO₂, 54 percent was caused by economic inefficiencies, and 35 percent was caused by distributive inefficiencies [Iftikhar et al., 2018].

Another study that used DEA analysis within the regulatory framework [Thanassoulis, 2002] in order to compare the efficiency of the Italian water firms and contribute to the ongoing discussion on the organizational and strategic decisions made by both policymakers and utility managers. The key findings show that, when compared to mixed- or privately-owned firms, public-owned firms have the highest efficiency scores, indicating that they purchase and use inputs far more effectively, which confirms the already existing literature. The inherent monopoly nature of the water service and the necessity for an upgraded regulatory framework that takes sustainability concerns into account and implements a tariff mechanism based on a national standard are both confirmed by the public businesses' higher efficiency scores. In actuality, there has been no improvement in sector efficiency throughout the first application period of the new tariff mechanism. Efficiency ratings are on the decline, which has detrimental effects on both the economy and the environment. In order to protect the public interest and address the water sector's lack of effective competition regulation, this calls for the implementation of certain adjustments. It also calls for reducing/avoiding potential monopoly power abuse that could harm natural monopolies like water services [Lombardi et al., 2019]. Evaluation of the energy and CO₂ emissions efficiency of Central-Eastern European countries, through a non-radial meta-frontier directional distance function by applying DEA analysis, revealed a tendency toward decreasing efficiency for nations in Central and Eastern Europe from 2010 to 2015 (0.832 to 0.792), as well as a large average technology gap ratio of 0.904. Concluding that the Central-Eastern European countries should benefit from the management expertise of the North-Western European countries after comparing the potential for

improvement in energy and CO₂ emissions for various countries. Limiting the transfer of companies with high carbon emissions and promoting the long-term sustainable development of renewable energy, is an efficient strategy to enhance the energy and CO₂ emission performances of EU countries [Teng et al., 2020].

It is anticipated that nations with high levels of productivity and maximal energy reserves will be able to maintain government performance by keeping input levels constant while also making an effort to raise output in order to maintain or perhaps improve the level of community welfare indicated in the SDGs indicators the following year. Countries that have not yet attained a high level of productivity and efficiency ought to be able to enhance the performance of their governments by selecting the best method for greater SDG achievement [Rusydiana, 2021]. Energy innovation can have a variety of effects, including equitable and positive impact, negative impact, and inequitable influence on income distribution. Government should encourage corporate cooperation to facilitate technology transfer and the establishment of new companies and make innovations more accessible in order to improve living conditions as an objective of SDG 8 and reduce income inequalities objective of SDG 10 [Sinha et al., 2020]. Research and innovation in the fashion sector are closely related to SDG 14 Life below Water and SDG 15 Life on Land. For the preservation of biodiversity and subsequently improved soil, sustainable resource management practices such as decreasing the use of fertilizers and pesticides are also crucial, preventing soil deterioration. Additionally, the use of technologies for the protection of animals and biodiversity through the use of substitute animal-like materials is necessary to achieve SDG target 15.6: promoting proper access to such resources

as agreed upon internationally and the fair and equitable sharing of benefits resulting from the use of genetic resources. Similar to the previous goal, SDG 15.3's rehabilitation of degraded land and soil can be accomplished by employing eco-friendly practices and encouraging effective recycling procedures and technology [Arana et al., 2020]. Taxes on water and sanitation services, private management of these services, population density, local government budget revenues, household income in the municipality, and the fragmentation of local governments are all factors that may assist the improvement of Spanish local governments' efficiency to achieve the SDG 6 Clean Water and Sanitation [Martínez-Córdoba et al., 2020].

Another study examined the relationships between energy efficiency, financial development, and sustainable economic development, focusing on the countries with the highest renewable energy use and considering a specific type of innovation where government policies are relevant, using data from 20 countries in Asia and the Pacific between 2000 and 2018. They introduced green innovation, which is measured as the number of patents in environmental-related technologies and is sourced from OECD Statistics (2021), to ascertain the effort of these countries in maintaining a green environment. They discovered that one way to improve energy efficiency is through investment in sustainable economic development. Every person and organization will do better in a well-developed economic system, according to this analogy, resulting in the energy market becoming competitive, allowing people and businesses to purchase energy at extremely low prices and promoting energy efficiency. Similarly, they discovered that energy efficiency is promoted by sustainable financial

development; this conclusion is predicated on the idea that financial institutions like banks may finance enterprises given sustainable financial growth, resulting in energy sector participants buying and selling energy at a lower price, which promotes energy efficiency. Additionally, they examined the relationship between energy efficiency and the green innovation perspective idea, that green innovation could exert pressure on businesses and the government to abandon the use of fossil fuels, concluding that green innovation is sensitive to energy efficiency since they show a favorable relationship between the two [Zakari et al., 2022]. One different research examined how GHG emissions as a negative output in a multiproduct analysis affect productive efficiency using data on an Alberta dairy producer sample from 1996 to 2016. Their findings suggest that because technical efficiency and environmental efficiency are highly correlated the reduction of emissions aligns with the pursuit of maximum technical efficiency, meaning that strict government interventions like emission limitation may not be necessary. Instead, strategies like education and outreach can be used to address issues like increasing agricultural profitability. Additionally, they discovered that Alberta dairy farms have very high mean efficiency levels, with many of them already being in close proximity to the frontier. As a result, additional GHG emission reductions would result in a decrease in overall milk production, imposing a large private cost on the producers in exchange for a social benefit. Given these findings, it may be necessary to take into account policy instruments that involve cost-sharing between the government and dairy farmers in order to accomplish additional emissions reductions [Le et al., 2020].

2.1.2 Sustainable Development Goals

The first goal, which has been broken down into the following seven targets, is to "End poverty in all its forms worldwide". Eliminate severe poverty, which is currently defined as a person making less than \$1.25 a day, for all people worldwide. Reduce the percentage of men, women, and children of all ages who, in accordance with national definitions, live in poverty in all of its manifestations by at least 50%. Implement social protection systems and policies for all, including floors, and ensure that the poor and vulnerable are adequately covered. Assure that all men and women, especially the weak and impoverished, have equitable access to economic resources, basic services, ownership of and control over real estate and other types of property, inheritance, natural resources, suitable new technologies, and financial services, including microfinance. Increase the resilience of the underprivileged and those who are already vulnerable and lessen their exposure to and susceptibility to extreme weather events connected to climate change as well as other shocks and disasters in the economic, social, and environmental spheres. Make sure that significant resources are mobilized from a variety of sources, including through improved development cooperation, to give developing countries, particularly least developed countries, adequate and predictable means to implement programs and policies to end poverty in all of its forms. To encourage increased investment in initiatives aimed at eradicating poverty, build effective policy frameworks at the national, regional, and international levels that are based on pro-poor and gender-sensitive development policies. Although governments and international organizations tried to address these effects, the covid-19 pandemic was a

major setback that erased more than 4 years of progress made against poverty. Additionally, the working poverty rate increased for the first time in 20 years, pushing an additional 8 million workers into poverty. Despite these negative effects, cash benefits for people in high-income countries were significantly larger than those in low-income countries, where they were almost nonexistent. Additionally, the outbreak of the war in Ukraine made things worse by pushing up the projected number of people living in extreme poverty from 581 million before the pandemic to 657–676 million now.

The second goal, "End hunger, achieve food security and improved nutrition, and promote sustainable agriculture," has been broken down into the next eight targets. End hunger and ensure that everyone has access to enough food throughout the year, with a focus on the underprivileged and those in vulnerable situations, such as infants. End all types of malnutrition, including reaching the goals for stunting and wasting in children under the age of five by 2025, and address the nutritional needs of adolescent girls, pregnant and lactating women, and elderly people. Double the agricultural productivity and incomes of small-scale food producers, especially women, indigenous peoples, family farmers, pastoralists, and fishermen, by providing them with secure and equal access to land, other productive resources, and inputs, as well as education, financial services, markets, and opportunities for value-adding and non-farm employment. Ensure sustainable food production systems and put in place resilient agricultural practices that boost output and productivity, support ecosystem preservation, boost the ability to adapt to climate change, extreme weather, drought, flooding, and other disasters, and gradually improve land

and soil quality. Maintain the genetic diversity of seeds, cultivated plants, domesticated animals, and their related wild species, including through well-managed and diversified seed and plant banks at the national, regional, and international levels, and encourage access to and fair and equitable sharing of benefits resulting from the utilization of genetic resources and related traditional knowledge, as internationally agreed. To increase agricultural productivity in developing nations, especially the least developed nations, more money should be invested in rural infrastructure, agricultural research and extension services, technology development, and plant and livestock gene banks, among other things. In accordance with the Doha Development Round's objective, trade restrictions and distortions in the global agricultural markets must be corrected and prevented, including by simultaneously eliminating all forms of agricultural export subsidies and any export measures with a comparable impact. To help reduce excessive food price volatility, take steps to ensure the smooth operation of the markets for food commodities and their derivatives as well as to promote prompt access to market information, including on food reserves. However, conflict, COVID-19, and climate change are working together to erode food security globally; over 1 in 10 people experience hunger globally, and roughly 1 in 3 does not regularly have access to enough food. Additionally, 149.2 million children under the age of 5 are stunted, and the rate of reduction must double from 2.1 to 3.9 percent annually by 2030 in order to reduce stunting in children by 50%. Finally, as a result of the Ukraine crisis, there are now food shortages and higher food costs for the world's poorest people. Ukraine and Russia export 30% of wheat, 20% of maize, and 80% of sunflower seed products globally.

The fifth goal, which comprises the following nine targets, aims to "Achieve gender equality and empower all women and girls". End all forms of prejudice against girls and women worldwide. Eliminate trafficking, sexual exploitation, and all other forms of violence against women and girls in both the public and private domains. Eliminate all harmful practices, such as female genital mutilation and child, early, and forced marriage. Recognize and value unpaid care and household work by offering governmental services, infrastructure, and social protection measures, as well as by encouraging shared responsibility within the home and family as is culturally and legally acceptable. Make ensuring that women have equal chances for leadership at all levels of political, economic, and public decision-making, as well as full and effective involvement. As outlined in the Beijing Platform for Action, the Programme of Action of the International Conference on Population and Development, and the conclusion texts of their review conferences, ensure that everyone has access to sexual and reproductive health care and reproductive rights. Implement reforms in accordance with national legislation to grant women equal access to economic resources, as well as ownership and control over land and other types of property, financial services, inheritance, and natural resources. Enhance the promotion of women's empowerment through the use of enabling technology, particularly information and communications technology. Adopt and reinforce sensible laws and policies that will advance gender equality and the full and equal empowerment of women and girls. This goal was not significantly impacted by either pandemic or war, and while some progress has been made, it has been done so slowly that it will take another 40 years before women and men are equally represented in national political leadership, given that

women's representation in national parliaments increased from 22.4 to 26.2 percent between 2015 and 2022. Women made up 39 percent of the workforce in 2019 but 45 percent of all job losses worldwide in 2020, which is another disadvantage. Additionally, it is believed that more than 1 in 4 women will experience intimate partner abuse at least once in their lives. Finally, just 57% of women make their own educated decisions on their sex and reproductive health.

The sixth goal, which has been deducted from the eight targets, is to "Ensure availability and sustainable management of water and sanitation for all." Achieve equal and universal access to clean, cheap drinking water for all. End open defecation and provide all people with access to adequate and equitable sanitation and hygiene, paying particular attention to the needs of women, girls, and those who are vulnerable. Reduce dumping of hazardous chemicals and materials, cut in half the amount of untreated wastewater, significantly increase recycling and safe reuse internationally, and reduce pollution to improve water quality. To solve water shortage and significantly reduce the number of people affected by it, significantly improve water usage efficiency across all sectors and ensure sustainable withdrawals and supplies of freshwater. At all levels, implement integrated water resources management, including, where necessary, transboundary collaboration. Including mountains, forests, wetlands, rivers, aquifers, lakes, and ecosystems that are related to water, protect, and restore them. Increase international collaboration and capacity-building assistance for developing nations' activities and programs relating to water and sanitation, including technology for water harvesting, desalination, water efficiency, wastewater treatment, recycling, and reuse. Support and increase local com-

munity involvement in bettering water and sanitation management. Over the past 300 years, more than 85% of the world's wetlands have been lost, and more than 733 million people live in nations with high and critical levels of water stress. As a result, the world's water-related ecosystems are deteriorating at an alarming rate. At the current rate, by 2030, 1.6 billion people will lack access to safely managed drinking water, 2.8 billion people will lack access to safely managed sanitation, and 1.9 billion people will lack basic hand hygiene facilities. In order to meet drinking water, sanitation, and hygiene targets by 2030 requires a quadrupling increase in the pace of progress. Only 25% of the reporting nations have operational agreements covering more than 90% of their transboundary waters.

"Ensure access to affordable, reliable, sustainable, and modern energy for all" is the seventh goal, and it is followed by the five targets and indicators listed below. Ensure that everyone has access to modern, dependable, and cheap energy services. Significantly increase the proportion of renewable energy in the world's energy mix. Double the rate of increase in energy efficiency on a worldwide scale. Promote investment in energy infrastructure and clean energy technology while enhancing international cooperation to make clean energy research and technology, such as renewable energy, energy efficiency, and advanced and cleaner fossil fuel technologies, more accessible. In accordance with their separate support programs, create infrastructure and modernize technologies to deliver modern and sustainable energy services to all developing nations, particularly least developed nations, small island developing states, and landlocked developing nations. Due to the difficulty in reaching individuals who are

difficult to reach, electrification has slowed down in recent years. In 2010, 1.2 billion people lacked access to electricity; in 2020, 733 million people did; and, based on current trends, 679 million people will be without electricity in 2030. Although the total amount of renewable energy consumed has increased by a quarter since 2010, the share of renewables in total final energy consumption is only 17.7 percent. International financial flows to developing countries for renewable electricity sources have decreased for the second year in a row, from 24.7 billion dollars in 2017 to 14.3 billion dollars in 2018 to only 10.9 billion dollars in 2019. Last but not least, the rate of improvement in energy efficiency must increase from 1.9 percent annual energy intensity improvement to 3.2 percent in order to meet the global climate targets by 2030.

The eighth goal, which has been broken down into the following twelve targets, aims to "Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all." Maintain per capita economic growth in accordance with regional circumstances, with the GDP growth rate for the least developed countries required to be at least 7% annually. Increase economic productivity through innovation, technical advancement, and sector-specific attention to high-value-added and labor-intensive industries. Encourage the implementation of development-oriented policies that encourage productive endeavors, the creation of respectable jobs, entrepreneurship, creativity, and innovation, as well as the formalization and growth of small, medium, and enterprise firms, including by gaining access to financial services. According to the 10-Year Framework of Programmes on Sustainable Consumption and Production, developed countries should take the lead in progressively increas-

ing global resource efficiency in consumption and production through 2030 and attempting to decouple economic growth from environmental degradation. Achieve full and productive employment, respectable jobs for women and men of all ages, including those with impairments, and equitable remuneration for a labor of comparable value. Reduce the percentage of young people who are not in work, school, or training significantly. Ensure that the worst types of child labor, including the recruitment and employment of child soldiers, are prohibited and eliminated by 2025. Take quick and effective action to eradicate forced labor, modern slavery, and human trafficking. All workers, especially those who are migrant workers, particularly women migrants, and those in insecure employment, should have their labor rights protected, and safe and secure working conditions should be encouraged. Create and put into place regulations that will encourage sustainable tourism that supports local economies, supports local culture, and promotes local goods. Boost domestic financial institutions' ability to promote and widen access to banking, insurance, and financial services for everyone. Increase aid for trade support for developing nations, especially the least developed nations, through the Enhanced Integrated Framework for Trade-Related Technical Assistance to Least Developed Countries, among other means. Create and implement an international strategy for young employment, and put the ILO's Global Jobs Pact into effect. Today, several factors, including the spread of the COVID-19 pandemic in fresh waves, rising inflation, interruptions in the supply chain, policy uncertainty, and labor market difficulties, are impeding global economic recovery. Additionally, the Ukraine issue has further slowed down the global economic recovery; after reaching a full recovery in 2021 (4.4 percent), it began to decline once more in

2022, falling to 2.1 percent. From a different angle, the global unemployment rate will remain above the pre-pandemic crisis level in 2021, at 6.2 percent. Additionally, 160 million children will be working as children globally in 2020, and worker productivity will have stagnated from 1.6 percent growth in output per worker between 2015 and 2019 to 3.2 percent in 2021.

The tenth goal, "Reduce inequality within and between countries," has been broken down into the subsequent ten targets. Gradually increase and maintain the bottom 40% of the population's income growth at a rate faster than the national average. Regardless of age, sex, disability, color, ethnicity, origin, religion, economic status, or another status, encourage and support the social, economic, and political inclusion of everyone. Eliminate discriminatory laws, policies, and practices, as well as encourage proper legislation, policies, and action in this area to provide equal opportunity and eliminate outcome inequities. Adopt measures, particularly those about the economy, wages, and social protection, and gradually advance toward more equality. Boost the regulation and oversight of the world's financial markets and institutions, as well as the enforcement of such regulations. To create more efficient, trustworthy, accountable, and legitimate institutions, ensure that developing nations have a stronger voice and representation in global economic and financial decision-making. Promote responsible, regular, safe, and orderly migration of people, especially through putting in place well-thought-out migration regulations. In accordance with World Trade Organization accords, apply the notion of special and differential treatment for developing countries, particularly least developed countries. Encourage the flow of foreign direct investment and official development assis-

tance to nations where the need is greatest, particularly in the least developed nations, African nations, small island developing states, and landlocked developing nations, in accordance with their national plans and program. Eliminate remittance corridors with costs greater than 5% and lower the transaction costs of migrant remittances to less than 3%. The epidemic has, however, resulted in the first increase in country-to-country income inequality in a generation. In addition, 2021 was the bloodiest year for migrants since 2017 with 5895 fatalities. Additionally, between 2015 and 2021, the number of refugees living outside of their nation of origin rose by 44%, pushing the total number of refugees worldwide to an all-time high. The conflict in Ukraine only makes this situation worse.

The thirteenth goal, which has been broken down into the following five targets, is to "Take urgent action to combat climate change and its impacts". Boost global resilience and capability for natural disasters and hazards related to the climate. Include climate change mitigation measures in national planning, policies, and strategies. Enhance human and institutional capacity for mitigation, adaptation, impact reduction, and early warning of climate change. Implement the pledge made by developed-country parties to the UNFCCC to a target of mobilizing \$100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation, and as soon as possible fully operationalize the Green Climate Fund through its capitalization. Encourage systems to increase the ability for efficient planning and control of climate change in the least developed countries and small island developing states, with an emphasis on women, youth, local communities, and marginalized groups.

Importantly, the window of opportunity to avert a global climatic catastrophe is rapidly closing. It is predicted that by 2100, the sea level will have risen by 30 to 60 cm, 700 million people will have been forced to leave their homes due to drought, and the number of medium- to large-scale disasters, including fires, floods, storms, and droughts, will have increased by 40%. While the rise in global temperatures continues unabatedly, causing more extreme weather, and energy-related CO₂ emissions rose by 6% in 2021 to reach their greatest level. Despite this, rich countries only provided 79.6 billion dollars in climate money in 2019, falling short of the 100-billion-dollar target.

The following ten targets are listed after the fourteenth goal, which is to "Conserve and sustainably use the oceans, seas, and marine resources for sustainable development". Prevent and drastically minimize all forms of marine pollution, especially that caused by land-based activities, such as pollution from nutrients and marine debris. In order to attain healthy and productive seas, it is necessary to sustainably manage and maintain marine and coastal ecosystems. This includes enhancing their resilience and adopting steps to aid in their restoration. Reduce and mitigate the effects of ocean acidification, notably through improved cross-cutting scientific collaboration. Implement science-based management plans to efficiently control fishing, put an end to overfishing, illegal, unreported, and unregulated fishing, as well as destructive fishing methods, and restore fish stocks as quickly as is practical, if not to levels that can produce the maximum sustainable yield as determined by their biological characteristics. Conserve at least 10 percent of coastal and marine areas, consistent with national and international law and based on the best available

scientific information. Eliminate subsidies that support illegal, unreported, and unregulated fishing, prohibit certain types of fisheries subsidies that contribute to overcapacity and overfishing and refrain from introducing new forms of these subsidies while acknowledging that developing and least developed countries should receive appropriate and effective special and differential treatment as part of the World Trade Organization fisheries subsidies negotiation. Increase the economic gains from the sustainable use of marine resources for Small Island Developing States and Least Developed Countries, especially through the management of fisheries, aquaculture, and tourism. In order to improve ocean health and increase the contribution of marine biodiversity to the development of developing countries, particularly small island developing States and least developed countries, it is important to increase scientific knowledge, develop research capacity, and transfer marine technology while taking into consideration the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology. Access marine resources and markets for small-scale artisanal fishers. Implement international law as it is reflected in the United Nations Convention on the Law of the Sea, which offers the legal framework for the conservation and sustainable use of oceans and their resources, as mentioned in paragraph 158 of "The future we want," will help to improve the conservation and use of oceans and their resources. In a nutshell, overfishing, eutrophication, acidification, ocean warming, and plastic waste are all threats to the ocean, which is the planet's biggest ecosystem. Additionally, 17 million metric tons of plastic were introduced into the ocean in 2021, and it is predicted that this number will double or triple by 2040. Moreover, the oceans are absorbing roughly a quarter of the world's annual CO₂ emissions, which is

endangering marine life and reducing their ability to mitigate climate change.

The following twelve targets have been assigned to the fifteenth goal, "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.". In accordance with duties under international agreements, ensure the conservation, restoration, and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains, and drylands. Stop deforestation, restore damaged forests, and significantly boost afforestation and reforestation globally. Promote the application of sustainable management of all types of forests. In order to attain a world free of land degradation, it is necessary to fight desertification and rehabilitate damaged land and soil, particularly that which has been impacted by drought, floods, and desertification. Ensure that mountain habitats are preserved, especially their biodiversity, to increase their ability to offer advantages that are crucial for sustainable development. Take immediate and meaningful action to stop biodiversity loss, stop the deterioration of natural ecosystems, and, by 2020, protect and stop the extinction of vulnerable species. Promote proper access to these resources, as per international agreements, and fair and equitable sharing of the benefits resulting from their use. End poaching and trafficking of protected flora and animals immediately, and deal with the demand for and supply of illegal wildlife products. Introduce methods to manage or eradicate the priority species as well as to prevent the introduction of and greatly minimize the impact of invasive alien species on land and aquatic ecosystems. Include environmental and biodiversity values in planning, development,

and strategies and accounts for reducing poverty at the national and local levels. Increase financial support from all sources and mobilize it to protect and sustainably use ecosystems and biodiversity. Provide developing nations with sufficient incentives to enhance sustainable forest management, including for conservation and reforestation, by mobilizing large resources from all sources and at all levels. Boost international support for initiatives to stop the poaching and trade of protected species, among other things by giving local communities more options to pursue sustainable means of subsistence. In total, 10 million hectares of forest are lost each year, with agricultural growth accounting for about 90% of deforestation worldwide, followed by cropland expansion by 49.5 percent and animal grazing by 38.5 percent. Unfortunately, biodiversity is generally ignored in spending on the recovery from the COVID-19 pandemic, despite the fact that 40000 species are known to be at risk of extinction in the upcoming decades. On the other hand, protections have been made for about half of the important freshwater, terrestrial, and mountain biodiversity.

3 | CHAPTER 3

3.1 DATA & VARIABLES

The data set used for the analysis resulted from the publicly available source of Groningen Growth and Development Centre, Part of the University of Groningen. The World Input-Output Database (WIOD) was released in November 2016, it includes 28 EU countries and 13 other important nations, and 42 industrial sectors for the years 2000 to 2014 and is made up of several databases. The database contains Gross output in 2000 constant prices (million \$) which in our analysis is considered as an output, while the inputs are Capital (million \$), Energy Usage (Ktoe), Labor force (total), and Intermediate Inputs (million \$), also CO₂ emissions which are considered as a negative output. Table one is showcasing the descriptive statistics, while figures 1-6 are showcasing the yearly average of all six variables of the data set that was used. Important to note is that in 2009 during the economic crisis all six variables decreased, although Energy usage and CO₂ emissions were dramatically reduced, which suggests that the most environmentally damaging input is Energy Usage.

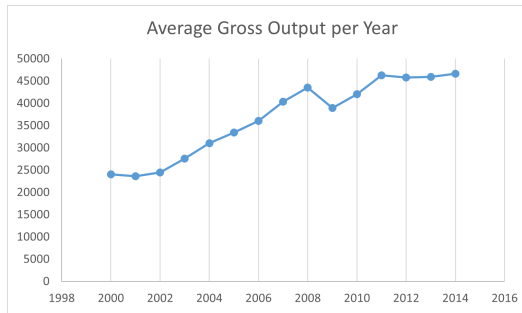


Figure 1: Average Sectoral Gross Output per Year.

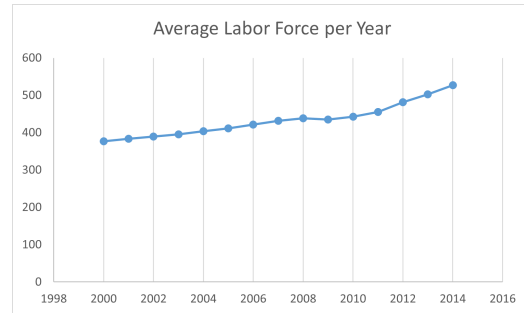


Figure 2: Average Sectoral Labor Force per Year.

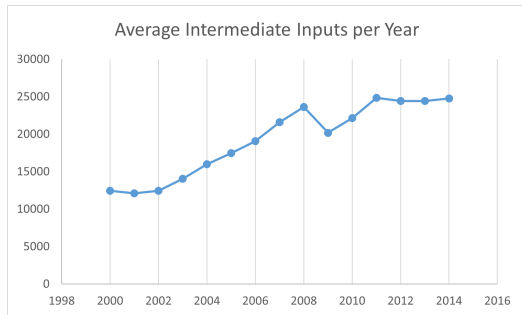


Figure 3: Average Sectoral Intermediate Inputs per Year.

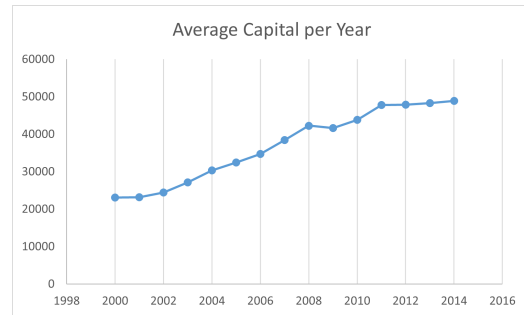


Figure 4: Average Sectoral Capital per Year.

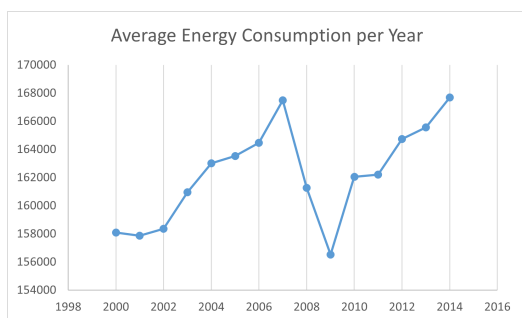


Figure 5: Average Sectoral Energy Usage per Year.

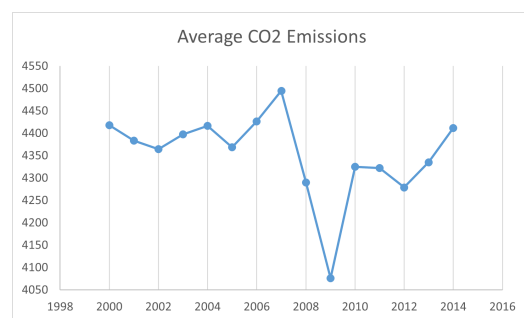


Figure 6: Average Sectoral CO2 Emissions per Year.

Table 1: Descriptive Statistics of the World Input-Output Database.

Variables	Observations	Mean	Standard Dev.	Min	Max
Gross Output	24,859	36642.46	116064.8	0.4477677	3438163
Labor Force	24,859	432.9821	1665.573	0.03	58948.11
Energy Usage	24,859	162254.1	1200550	0.0683905	4.46e+07
Intermediate Inputs	24,859	19306.26	53060.22	0.2275426	1202349
Capital	24,859	36976.79	265951.8	0.1581421	1.32e+07
CO2 Emissions	24,859	4353.942	17178.21	0	320387.8

3.2 METHODOLOGY

3.2.1 Efficiency score estimation.

Data envelopment analysis, a non-parametric research method based on a series of simple linear programs, is used to assess the technical efficiency of "Decision Making Units" (DMU). DEA models can be input-oriented or output-oriented, having the purpose of minimizing inputs while maintaining the same level of outputs or increasing outputs while maintaining the same amount of inputs accordingly [Malana and Malano, 2006]. An input-oriented approach is more suitable due to the nature of this research from the viewpoint that firms should minimize their input consumption like energy in order to achieve the Sustainable Development goals while maintaining the level of production in order to meet human needs. Therefore, our main goal was to assess efficiency under the assumption that a DMU might generate the same amount of output with fewer inputs. Each DMU uses a varied number of inputs to produce varying

quantities of output, therefore the process compares with the most efficient. According to the assumption of constant returns to scale (CRS), the CCR model was developed in 1978 for this type of study, which estimates the gross efficiency of a DMU [Ramanathan, 2003]. Then in 1984, the BCC model was developed with the assumption of variable returns to scale (VRS) measuring purely the technical efficiency [Banker, 1984]. A doubling of all inputs will result in a doubling of output according to the CRS, however the VRS takes into account the possibility of increasing, constant, and falling returns to scale depending on the production technology. The following notations are used by the models: n the number of DMUs that need to be assessed, each DMU generates s outputs from m inputs, a DMU j uses x_{ij} inputs and generates y_{rj} outputs, λ_j are the ascribed weights by the linear programming, θ is the efficiency measurement, s_i and s_r are the input and output slacks, ε is a non-Archimedean element that has the property of being smaller than any positive real number. [Markovits-Somogyi, 2011].

Constant returns to scale (CRS):

$$\begin{aligned}
 & \text{Min } \theta + \varepsilon \left[\sum_{i=1}^m S_i^- + \sum_{r=1}^s S_r^+ \right] \\
 & \sum_{j=1}^n x_{ij} \lambda_j + S_i^- = \theta x_{i0}, i = 1, 2, \dots, m \\
 & \sum_{j=1}^n y_{rj} \lambda_j - S_r^+ = \theta y_{r0}, r = 1, 2, \dots, s \\
 & \lambda_j, S_i^-, S_r^+ \geq 0, \quad j = 1, 2, \dots, n
 \end{aligned}$$

Variable returns to scale (VRS):

$$\begin{aligned}
 & \text{Min } \theta + \varepsilon \left[\sum_{i=1}^m S_i^- + \sum_{r=1}^s S_r^+ \right] \\
 & \sum_{j=1}^n x_{ij} \lambda_j + S_i^- = \theta x_{i0}, i = 1, 2, \dots, m \\
 & \sum_{j=1}^n y_{rj} \lambda_j - S_r^+ = \theta y_{r0}, r = 1, 2, \dots, s \\
 & \sum_{j=1}^n \lambda_j = 1 \\
 & \lambda_j, S_i^-, S_r^+ \geq 0, \quad j = 1, 2, \dots, n
 \end{aligned}$$

DEA analysis has several advantages, it does not need a specific relationship between inputs and outputs to be identified [Hajiagha et al., 2016], no statistical distributions are required for the data of input and output variables, it can present information on how to make an inefficient entity to operate effectively [He J et al., 2016].

3.2.2 Regression model.

To assess the impact of sectors in achieving the SDGs, that were discussed previously we utilize the CO₂ emissions as a proxy for the extent to which the sectors contribute to the SDGs. Prior research has shown evidence to support the use of CO₂ emissions as a measure of sustainability performance and the impact of the SDGs [Iftikhar et al., 2018] and [Teng et al., 2020]. We estimate the following models in order to determine how the input-oriented efficiency of the sectors, which maintains output levels, is affecting the CO₂

emissions, we estimate the following models while keeping in mind that energy efficiency should have a negative influence on CO₂ emissions. In other words, we examine what occurs to CO₂ when industries pursue efficiency, not as a means of reducing their carbon footprint but rather as a means of reducing their inputs and achieving economic prosperity and profitability.

$$\log(\text{CO}_2)_{it} = \beta_0 + \beta_1 \text{CRS}_{it} + \gamma_1 S_1 + \dots + \gamma_n S_n + u_{it} \quad (1)$$

$$\log(\text{CO}_2)_{it} = \beta_0 + \beta_1 \text{VRS}_{it} + \gamma_1 S_1 + \dots + \gamma_n S_n + u_{it} \quad (2)$$

- $\log(\text{CO}_2)_{it}$: is the logarith of the dependent variable CO₂ emissions,
- CRS_{it} : represents the independent variable CRS efficiency,
- VRS_{it} : represents the independent variable VRS efficiency,
- β_1 : is the coefficient for independent variables,
- u_{it} : is the error term,
- S_n : Dummies for each sector, $n=1\dots 42$,
- γ_n : Is the coefficient for the Dummies, $n=1\dots 42$,

To capture the variation within the cross-sectional data and time effects in the panel data, this study is employing a panel regression. We also employ dummy variables, to analyze the impact of efficiency scores on CO₂ within the sectors, since it would be misleading to compare the efficiencies from different sectors. Hausman's specification test is employed to determine whether a ran-

dom or fixed-effects panel regression best fits our examined sample. The result reports a p-values < 0.000 , thus, the null hypothesis is rejected, recommending the use of fixed effects (see Appendix A).

4 | CHAPTER 4

4.1 RESULTS

4.1.1 CRS & VRS Efficiency scores analysis.

We utilized a separation model in the first stage to measure the energy and CO₂ emissions efficiency of 42 major industry sectors, with the models of constant returns to scale (CRS) and variable returns to scale (VRS), benchmarking for each sector in each year separately in order to grade the efficiency scores taking into consideration the technological advancement, assuming that the available technology remains the same during each year, and creating efficiency scores from 2000 to 2014.

The findings are shown in Table 2 and table 3 the sectoral efficiency scores were averaged to provide the overall efficiency scores. The sectors of Manufacture of wood and of products of wood and cork, Manufacture of paper and paper products, and Manufacture of electrical equipment are the three most efficient based on the CRS efficiency score. From the other hand, based on VRS, Manufacture of textiles, wearing apparel and leather products, Manufacture of paper and paper products, and Manufacture of wood and of products of wood

and cork are the three most efficient, with the Manufacture of textiles, wearing apparel and leather products having a score very close to 1, following Iftikhar et al. [2]'s classification, we can refer to these sectors as "Star". Additionally, the sectors of Manufacture of chemicals and chemical products, Other professional scientific technical and veterinary activities, Education, Administrative and support service activities are the four less efficient sectors based on both CRS and VRS efficiency scores.

Table 4 and 5, are displaying the sectoral efficiency scores per Country. United States, despite having nearly perfect VRS efficiency scores, which makes them extremely efficient, the United States only ranks sixth in the CRS level, behind Canada. Furthermore, based on an average of the two efficiency scores, Russia, the Slovak Republic, Hungary, Bulgaria, and the Czech Republic are the least efficient nations.

Overall, the results indicate that there is a significant disparity in technology and productivity within industry sectors and nations, demonstrating that many resources are squandered during production when they could be employed more effectively, resulting in lower CO₂ emissions for the same amount of outputs. Moreover, the findings demonstrate that the SDGs can be achieved and that effective production is a method for accelerating the achievement of the goals.

Table 2: Efficiency (CRS) statistics per Industry Sector.

Sector Description	mean	sd	N
Manufacture of wood and of products of wood and cork	0.932	0.074	615
Manufacture of paper and paper products	0.920	0.078	615
Manufacture of electrical equipment	0.915	0.085	600
Manufacture of machinery and equipment n.e.c.	0.905	0.092	615
Manufacture of rubber and plastic products	0.895	0.088	615
Manufacture of motor vehicles, trailers and semi-trailers	0.894	0.102	615
Manufacture of textiles, wearing apparel and leather products	0.893	0.099	615
Construction	0.893	0.105	615
Air transport	0.888	0.099	615
Manufacture of basic metals	0.887	0.123	615
Manufacture of food products, beverages and tobacco products	0.885	0.082	615
Manufacture of other non-metallic mineral products	0.885	0.088	615
Manufacture of computer, electronic and optical products	0.882	0.113	615
Manufacture of coke and refined petroleum products	0.882	0.112	582
Computer programming, consultancy and related activities; information service activities	0.877	0.118	600
Manufacture of furniture; other manufacturing	0.875	0.116	615
Other service activities	0.875	0.130	600
Insurance, reinsurance and pension funding, except compulsory social security	0.874	0.132	585
Motion picture, video and television programme production, sound recording	0.872	0.114	543
Manufacture of fabricated metal products, except machinery and equipment	0.869	0.090	600
Warehousing and support activities for transportation	0.866	0.121	615
Public administration and defence; compulsory social security	0.865	0.139	600
Water transport	0.858	0.126	615
Advertising and market research	0.857	0.130	495
Land transport and transport via pipelines	0.845	0.133	615
Accommodation and food service activities	0.840	0.127	615
Manufacture of other transport equipment	0.839	0.145	599
Postal and courier activities	0.839	0.149	540
Publishing activities	0.837	0.129	565
Architectural and engineering activities; technical testing and analysis	0.828	0.158	525
Activities auxiliary to financial services and insurance activities	0.826	0.153	506
Telecommunications	0.817	0.153	615
Scientific research and development	0.810	0.166	540
Human health and social work activities	0.805	0.181	615
Financial service activities, except insurance	0.796	0.168	615
Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.787	0.142	584
Sewerage; waste collection, treatment and disposal activities; materials recovery	0.772	0.228	540
Legal and accounting activities; activities of head offices; management consultancy activities	0.770	0.180	570
Manufacture of chemicals and chemical products	0.768	0.162	615
Other professional, scientific, technical and veterinary activities	0.757	0.181	540
Education	0.752	0.230	615
Administrative and support service activities	0.743	0.202	615
Total	0.850	0.145	24859

Table 3: Efficiency (VRS) statistics per Industry Sector.

Sector Description	mean	sd	N
Manufacture of textiles, wearing apparel and leather products	0.951	0.070	615
Manufacture of paper and paper products	0.949	0.067	615
Manufacture of wood and of products of wood and cork	0.945	0.074	615
Manufacture of machinery and equipment n.e.c.	0.936	0.076	615
Manufacture of electrical equipment	0.936	0.083	600
Manufacture of motor vehicles, trailers and semi-trailers	0.930	0.079	615
Air transport	0.930	0.087	615
Manufacture of basic metals	0.925	0.099	615
Manufacture of rubber and plastic products	0.924	0.086	615
Manufacture of computer, electronic and optical products	0.922	0.097	615
Warehousing and support activities for transportation	0.921	0.107	615
Manufacture of other non-metallic mineral products	0.916	0.084	615
Insurance, reinsurance and pension funding, except compulsory social security	0.911	0.122	585
Computer programming, consultancy and related activities; information activities	0.911	0.108	600
Construction	0.911	0.105	615
Water transport	0.906	0.117	615
Manufacture of food products, beverages and tobacco products	0.905	0.086	615
Manufacture of furniture; other manufacturing	0.904	0.109	615
Other service activities	0.903	0.121	600
Public administration and defence; compulsory social security	0.901	0.129	600
Manufacture of fabricated metal products, except machinery and equipment	0.901	0.095	600
Manufacture of coke and refined petroleum products	0.899	0.107	582
Manufacture of other transport equipment	0.896	0.117	599
Advertising and market research	0.896	0.112	495
Motion picture, video and television programme production, sound recording	0.895	0.113	543
Architectural and engineering activities; technical testing and analysis	0.887	0.131	525
Telecommunications	0.887	0.125	615
Accommodation and food service activities	0.884	0.121	615
Activities auxiliary to financial services and insurance activities	0.882	0.138	506
Scientific research and development	0.881	0.143	540
Postal and courier activities	0.878	0.131	540
Manufacture of chemicals and chemical products	0.876	0.142	615
Land transport and transport via pipelines	0.875	0.133	615
Legal and accounting activities; activities of head offices; management activities	0.870	0.158	570
Financial service activities, except insurance	0.870	0.148	615
Publishing activities	0.864	0.122	565
Human health and social work activities	0.852	0.176	615
Sewerage; waste collection, treatment and disposal activities; materials recovery	0.850	0.208	540
Other professional, scientific, technical and veterinary activities	0.841	0.166	540
Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.831	0.144	584
Administrative and support service activities	0.824	0.195	615
Education	0.808	0.228	615
Total	0.895	0.130	24859

Table 4: Efficiency (CRS) statistics per Country.

Country	mean	sd	N
Switzerland	0.961	0.080	555
Ireland	0.957	0.076	630
Luxembourg	0.957	0.088	615
Norway	0.956	0.087	620
Canada	0.943	0.089	615
United States	0.934	0.083	630
France	0.930	0.088	630
Mexico	0.923	0.123	600
Sweden	0.919	0.086	615
United Kingdom	0.916	0.104	630
Australia	0.915	0.109	570
Netherlands	0.915	0.091	630
Greece	0.910	0.108	630
Denmark	0.910	0.091	630
Finland	0.910	0.087	630
Germany	0.907	0.116	625
Japan	0.892	0.117	585
Austria	0.890	0.109	630
Belgium	0.888	0.116	630
Italy	0.887	0.092	630
Malta	0.874	0.139	611
Cyprus	0.862	0.142	620
Spain	0.846	0.108	630
Turkey	0.819	0.152	525
Lithuania	0.815	0.168	630
Brazil	0.812	0.115	540
Portugal	0.800	0.122	630
Croatia	0.796	0.127	628
Korea	0.787	0.139	630
Indonesia	0.783	0.209	540
Poland	0.782	0.129	630
Slovenia	0.769	0.114	630
Estonia	0.768	0.143	628
Taiwan	0.767	0.146	630
Latvia	0.750	0.144	622
India	0.747	0.163	495
Russia	0.739	0.144	390
Hungary	0.734	0.127	630
Slovak Republic	0.722	0.162	630
Bulgaria	0.717	0.126	630
Czech Republic	0.702	0.127	630
Total	0.850	0.145	24859

The results in Tables 4 and 5 lines up with the energy sources of the various nations. Nuclear energy and expanding renewable energy innovation have ranked them in first place, and in Western Europe, the production of wind and solar energy has grown quickly in the United Kingdom, Spain, and Germany. In France, nuclear energy is the primary energy source. With adequate hydropower resources, Northern Europe's primary source of hydroelectricity, which is augmented by wind and solar energy, makes up more than 50% of the whole power system. While they lag considerably behind the nations of North-Western Europe in the usage of new energy, the Central-Eastern European nations continue to generate the majority of their electricity using conventional fossil-fuel thermal power generation. Russia, which ranks as the seventh least energy-efficient country, relies primarily on gas-fired power facilities. Asian nations have low energy efficiency because coal is their primary energy source.

We observe that the countries with the lowest efficiency values, under or close to 0.8, are all from Central-Eastern Europe and Russia, including the Czech Republic (0.731), Hungary (0.756), Slovak Republic (0.757), Bulgaria (0.788), Slovenia (0.806), Poland(0.809), and Russia(0.809). These countries have significantly higher energy intensities and carbon emission intensities than other nations and reducing them would be an effective way to improve their energy efficiency.

Table 5: Efficiency (VRS) statistics per Country.

Country	mean	sd	N
United States	0.998	0.024	630
Malta	0.995	0.031	611
Luxembourg	0.989	0.044	615
France	0.976	0.046	630
Cyprus	0.975	0.059	620
Germany	0.973	0.071	625
Japan	0.973	0.071	585
Switzerland	0.972	0.071	555
Ireland	0.966	0.068	630
Norway	0.965	0.076	620
Canada	0.965	0.066	615
United Kingdom	0.960	0.073	630
Italy	0.954	0.072	630
Mexico	0.951	0.102	600
Australia	0.938	0.095	570
Netherlands	0.937	0.084	630
Sweden	0.930	0.080	615
Greece	0.924	0.099	630
Finland	0.921	0.080	630
Denmark	0.920	0.089	630
Austria	0.909	0.106	630
Belgium	0.908	0.109	630
Estonia	0.908	0.110	628
Lithuania	0.897	0.124	630
Spain	0.883	0.107	630
Brazil	0.881	0.103	540
Turkey	0.864	0.136	525
Latvia	0.850	0.121	622
Croatia	0.839	0.116	628
India	0.829	0.143	495
Korea	0.829	0.143	630
Indonesia	0.820	0.204	540
Taiwan	0.813	0.142	630
Portugal	0.813	0.119	630
Russia	0.809	0.153	390
Poland	0.809	0.126	630
Slovenia	0.806	0.106	630
Bulgaria	0.788	0.131	630
Slovak Republic	0.757	0.155	630
Hungary	0.756	0.129	630
Czech Republic	0.731	0.132	630
Total	0.895	0.130	24859

4.1.2 Regression analysis.

Table 6 presents the results of our estimations to test the two hypotheses of the effect of efficiency scores on CO₂ emissions. Model (1) includes CRS efficiency scores (Constant Returns to Scale) and Model (2) includes VRS efficiency scores (Variable Returns to Scale). Because the Hausman's test suggested fixed effects estimation, we are primarily considering those results. The only statistically significant variable of the two is the VRS at a level of significance 0.1%. The VRS has a negative coefficient of -0.296, suggesting that as the VRS efficiency scores of the sectors are increasing their CO₂ emissions are declining.

Table 6: Fixed and Random effects logarithm of CO₂ and efficiency.

Variables	Fixed effects	Random effects
CRS	-0.0178725 (0.0699853)	.0119183 (0.0693686)
VRS	-0.2961247*** (0.0811421)	-0.2728443 ** (0.0803572)

Robust standard errors in parentheses

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, . $p < 0.1$

The statistically insignificant coefficient of CRS on CO₂ emissions is logical when one considers that output varies proportionally to input changes (e.g., doubling all inputs will result in a doubling of output). However, VRS reflects the fact that production technology may exhibit increasing, constant, and decreasing returns to scale. Its statistically significant negative impact on CO₂ suggests that sectors are facing increasing returns to scale because of the

production technology, meaning that they can produce the same amount of output with less input consumption (because of our input-oriented approach), especially energy usage. In this manner, their CO₂ emissions are rapidly decreasing while the sectors are becoming more efficient at the VRS scale. Our findings are consistent with earlier research that contends that technologically efficient nations have lowered CO₂ emissions from less developed nations [Teng et al., 2020]. Additionally, the findings imply that, even though from this perspective sectors only pursue energy efficiency as a means of achieving economic development and profitability through input minimization, they also contribute to the environment and the achievement of the SDGs through their reduced emissions.

5 | CHAPTER 5

5.1 CONCLUSIONS

This study performs a sectoral input-output analysis of 28 European countries and 13 other important nations using Data envelopment analysis model (DEA) taking a sector as a complete system carrying out the production of economic and environmental outputs, using four major imports. The aim of this analysis is to create proxy measurements, through CO₂ emissions, Energy usage and efficiency score, to assess ten of the seventeen Sustainable Development Goals at the Sectoral level. After creating those proxies, they were evaluated to determine their effectiveness in accelerating the SDGs' accomplishment. The energy environmental efficiency that was developed demonstrates that there is a significant difference in production technology across and within the various industries. The majority of the sample produces at a level that is considerably below optimal, wasting resources and producing CO₂ pointlessly, while impeding the achievement of the SDGs. In order to further evaluate the impact of energy environmental efficiency on the sectors' CO₂ emissions, a regression model was developed. Once more, the findings pointed to the fact that efficiency is reducing CO₂ emissions, and as a result, production technology can be crucial to reaching the SDGs.

According to our research, there is an urgent need to invest in production technologies, particularly in low-efficiency industries like the Manufacture of chemicals and chemical products, Other professional scientific-technical and veterinary activities, Education, and Administrative and support service activities. We are able to offer some insightful recommendations for policymakers as a result of the analysis done in this paper, which will aid them in developing better policies for the advancement of economies and the achievement of the SDGs. First, we advocate for a focus on energy and CO₂ emissions-efficient production across all sectors. The efficiency gap between the different industries will be closed by investing in advanced equipment, which will also decrease on energy use and CO₂ emissions. In this sense, the sectors will attribute more to the SDGs, but they will also benefit in the long run from the cost reduction. Second, cooperation amongst sectors is necessary to aid the less efficient in evolving, as the 17th goal, "Partnerships for the Goals," urges. Finally, we recommend the use of sanctions at the governmental and regulatory levels as well as newer tax policies, to discourage the excessive use of energy resources and to reduce CO₂ emissions related to energy usage.

6 | APPENDIX A

Table 7: Hausman's Specification Test.

	CRS	VRS
Chi-square test value	10.33	4.28
P-value	0.0013	0.0387
P-value < 0.05, null hypothesis rejected		

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