PROCEEDING BOOK

VI INTERNATIONAL CONGRESS ON THE VI INTERNATIONAL CONGRESS ON SUSTAINABLE DEVELOPMENT (SD2024):

Banking, Energy Transition, and Green Economics

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Congress Schedule

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Klemens KATTERBAUER

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Laurent CLEENEWERCK

Abstract

The deep sea is a challenging habitat for life but also encounters mountain ranges, plateaus, volcanic peaks, gorges, and enormous abyssal plains that represent a significant challenge for the exploration of minerals. The minerals specific to the deep ocean include most of the minerals encountered on land and are typically enriched. Deep seabed mining has attracted significant attention to satisfy the growing demand for minerals across the globe and the ever more challenging environments encountered to exploit these resources. Deep seabed mining represents a different domain, given that most of the resources are experienced in international waters that, according to international law, may not belong to a specific nation. This represents a considerable challenge for international financing of deep seabed mining, requiring funding providers to navigate the challenging environments from a regulatory and risk perspective. Generative AI may provide some considerable opportunities related to supporting the financing of deep-seabed mining companies, improving risk assessment, and navigating the challenging regulatory environment. Furthermore, generative AI may significantly support companies in enhancing operational efficiency and improving profitability from their activities.

Keywords: Generative AI, Deep seabed mining, Project financing, Mineral exploitation

JEL Codes: F30, F65

1. Introduction

The deep sea, which is more than 200 meters below the surface, is a challenging habitat for life but also encounters mountain ranges, plateaus, volcanic peaks, gorges, and enormous abyssal plains. In addition to minerals specific to the deep ocean, including ferromanganese crusts and polymetallic nodules, it contains most of the minerals found on land, frequently in enriched forms. Ever since the 1800s, there has been considerable recognition that mineral deposits exist in the ocean's deepest regions. While the 1800s led to the first discovery of resource wealth in the deep sea, there was considerable underestimation of the ease at which these resources may be exploited (Levin, Amon, & Lily, 2020).

American geologist John L. Mero, in the 1960s, argued that the seafloor may become a significant source of supply for supplying the world's mineral demands, attracting increasing attention from the scientific community. This prompted the Maltese ambassador Arvid Pardo to address the UN General Assembly's First Committee, advocating for the designation of the deep seabed's resources as the "common heritage of mankind" and for the establishment of an international regulatory framework to stop technologically developed nations from colonizing the seafloor and monopolizing these resources at the expense of developing nations. The 1960s led to a significant transformation, with the United Nations attempting to develop a comprehensive framework for ocean governance between 1967 and 1982 (Thompson, Miller, Currie, Johnston, & Santillo, 2018).

The seabed was declared a common heritage and exploited for the benefit of all humans on Earth. Following the early excitement of the 1970s, interest in seabed mining was tempered by a decline in global metal prices and relatively easy access to minerals in emerging nations.

Due to the General Assembly's machinery proposal, the International Seabed Authority, an independent body operating within the UN standard system with its main office in Kingston, Jamaica, would take an additional twenty-four years to materialize. The authority comprises 168 countries, including the European Union, all states that are party to the 1982 United Nations Convention on the Law of the Sea (UNCLOS). The Commission on the Limits of the Continental Shelf and the International Tribunal for the Law of the Sea are the other two international organizations created by UNCLOS, of which the authority is one. The principal role of the authority is to govern the search and extraction of deep seabed minerals within the area, which the Convention delineates as the seafloor and subsurface situated outside national jurisdiction boundaries, i.e., beyond the outer limits of the continental shelf. The area makes up more than half of the Earth's seafloor (Glasby, 2002).

Enterprises and governments have shown a renewed interest in using deep sea minerals to deal with access to mineral resources. The main forces behind this renewed interest are technological developments in marine mining and processing and a rise in the long-term demand for minerals due to globalization and developing-nation industrialization. Because of the need to feed a world population that is only getting bigger, an expanding middle class that is fueling urbanization, and the demand for low-carbon, renewable infrastructure, terrestrial mineral reserves are under increasing strain. High-grade mineral resources that are easily extractable are also depleting at rapid rates (Guo, et al., 2023).

Deep underground or isolated areas will likely contain new resources, but extracting these terrestrial reserves will need a lot of energy and significantly impact the environment and society. Although recycling will contribute to satisfying the demand, more is required to meet the demand's predicted long-term rise. Therefore, it is increasingly conceivable that deep seabed minerals will play a significant role in sustainable development, especially for those nations lacking reliable land-based supplies and small island developing states with limited prospects for economic growth.

Various marine mineral resources are of great interest. Polymetallic nodules are found on the sea floor, frequently partially buried in fine-grained sediments. Numerous metals, including manganese, iron, copper, nickel, cobalt, lead, and zinc, are in nodules in significant yet trace amounts, along with molybdenum, lithium, titanium, and niobium. At water depths of 3,500 to 5,500 meters, the eastern Pacific's Clarion-Clipperton Zone (CCZ) is the most researched area of commercial interest. More nickel, manganese, and cobalt can be found in this one deposit than in all terrestrial resources combined. The Cook Islands', Kiribati's, and French Polynesia’s exclusive economic zones, as well as the Central Indian Ocean basin, are further areas of possible interest for these minerals that may be extracted (Lodge, 2017).

Seafloor massive sulfides, or SMS, are polymetallic sulfides rich in copper, iron, zinc, silver, and gold. Deposits are encountered near tectonic plate boundaries along active volcanic arcs, back-arc ridges, and mid-ocean ridges. Mid-ocean ridges are commonly found at water depths of about 2,000 meters, and hydrothermal activity created deposits thousands of years ago. In this case, metals precipitated from water heated to 400 degrees Celsius and released from the Earth's crust through hot springs.

Cobalt crusts build up on the tops and flanks of the seabed and are located at water depths ranging from 400 to 7,000 meters. They are made of iron, manganese, nickel, cobalt, copper, and various rare metals precipitating from saltwater, including rare earth elements. While there is an abundance of cobalt crust-related minerals, challenges in extracting these minerals may be limited to only certain areas, such as the East of Japan and the Mariana Islands.

UNCLOS stipulates that the contracts with the International Seabed Authority and adherence to its policies, guidelines, and procedures can be used to explore and extract seabed resources. This implies that both public and private mining companies are eligible for contracts as long as they are supported by a UNCLOS-signatory state and satisfy specific requirements regarding their financial and technological capabilities. There has been significant discussion arising from the exclusive economic zones and the extent to which the ISA can control the exploration of such resources within these areas, given that they are within the jurisdiction of the assigned nation (Bräger, Rodriguez, & Mulsow, 2020).

In order to control exploration, the authority has created regulations that include sections about environmental preservation. More than 1.3 million square kilometers of ocean floor have been covered by the 28 exploration contracts it has already approved for the Pacific, Indian, and Atlantic Oceans. Poland applied for the twenty-ninth exploration contract in January 2017. The state parties to UNCLOS and businesses supported by those parties hold these types of contracts for exploration. The authority's priority is creating a regulatory framework for utilizing natural resources. Analyzing the contracts entails considering various financial, technological, and environmental factors.

The fundamental idea and recovery process are the same, even though the mining equipment needed for each type of mineral deposit would differ technologically. In each scenario, a collector vehicle will touch the sea floor to gather the mineral deposits. This will require chopping or breaking the mineral deposits from the substrate in the SMS and cobalt crusts cases. One can extract nodules straight from the ocean floor. Under all circumstances, a riser system will raise the mined materials to the surface and transfer them to a surface support vessel and seawater. After being extracted from the salt water, the ore will be shipped to land-based processing facilities (Jaeckel, 2016).

There is a significant tradeoff between protecting the environment and benefits arising from deep seabed mining. The authority's main regulatory concern may be balancing the need to protect the marine environment and the societal benefits of deep seabed mining, such as access to essential minerals and the avoidance of community displacement, extensive deep-sea research, and technological advancement. Naturally, the prohibition on using any portion of the area for commercial purposes without Authority approval guarantees that an international organization will oversee and regulate the environmental effects of deep seabed mining. This illustrates a cautious approach to seafloor development on its own. However, mining will have some impact on the marine ecosystem, particularly in the immediate area of mining operations (Wedding, et al., 2015).

Various challenges may arise. The elimination of the habitat and destruction of living organisms are some issues. Additionally, silt plumes may arise. Additional environmental harm could result from hydraulic leaks, noise and light pollution, and problems with the riser and transportation system. The authority's work so far has consisted chiefly of mandating that exploration contractors gather baseline data, particularly about the distribution and composition of deep-sea organisms, and carry out scientific studies to better understand the possible long-term effects of deep-sea mining. Deep sea mining has the potential to help achieve Sustainable Development Goal 14 if it is managed well and in compliance with the rules of law outlined in the Convention. This is especially true for small island developing states, landlocked and geographically disadvantaged States, and developing states that heavily rely on the ocean and its resources for economic development.

2. Literature review

The provisions in UNCLOS primarily regulate the deep sea mining environment. UNCLOS specifies the creation of ISA, also commonly called the authority to control the DSM. The ISA plays a significant role in this context. According to the 1994 Implementing Agreement, the ISA

is entitled to create and manage the financial terms of agreements with sponsored entities. This is outlined in the UNCLOS annex in section 8 of the implementing agreement. According to the UNCLOS, any fiscal regime should be designed with the guiding principles, goals of policy, and, in this case, the legal duties it is expected to achieve in mind. The 1994 Implementing Agreement (UN, 1994) and UNCLOS stipulate three primary DSM prerequisites (Miller, Thompson, Johnston, & Santillo, 2018).

According to UNCLOS Article 140, DSM has to be carried out for the benefit of society, and the resources shall be considered to support the societies. As stated differently, any DSM payment scheme needs to make up for the loss of human resources appropriately, namely the CHM. To achieve this, ISA is required to strike a balance between two goals. The first goal is to guarantee the authority receives the maximum amount of money from the sales of commercial production. The second goal is to draw technology and investments to explore and exploit the deep-sea mining environment. In other words, any payment scheme should maximize profits for the ISA, contingent on the requirement to draw in capital. This implies that the rate of payments under the system shall be within the range of those prevailing regarding land-based mining of the same or similar minerals to prevent giving deep-seabed miners an artificial competitive advantage or imposing a competitive disadvantage on them. This is based on Section 8(1)(b) of the Annex to the Implementation Agreement and can be interpreted as the fact that no DSM payment scheme may provide DSM with a competitive economic advantage over land-based mining by lowering its tax burden. According to UNCLOS Article 151(10), the Assembly must create a system of compensation or take other steps to assist with economic adjustment (Krutilla, Good, Toman, & Arin, 2021). This includes working with specialized agencies and other international organizations in order to support developing nations whose economies or export earnings are seriously harmed by a decline in the value of a mineral or in the volume of that mineral's exports to the extent that the decline is a result of activities in the area. Therefore, any DSM payment policy must not only disadvantage land-based mining but also lead to sufficient revenues to make up for any economic losses to poor nations' land-based mining industries caused by DSM. The government revenues include the total amount of money that the host government (the country where the resource is situated) receives through a land-based mining enterprise. Its policy objectives will determine the level at which the host government sets the government rate (for example, 50% or 60% of net project cashflows). It is likely to involve various taxes and levies, such as customs charges, export taxes, and so forth, in addition to the corporate income tax (CIT) and royalties often connected with land-based mining. The government's portion of a nation's economy is its entire financial contribution. This may also be considered as the average effective tax rate (AETR). Governments often develop fiscal regimes for land-based mining based on the intended AETR or range of AETRs. The AETR should be determined by considering several factors, including a government's administrative capabilities and policy objectives. DSM is the only one that requires comparability with land-based mining regarding the AETR (Feichtner, 2019).

To prevent giving deep-seabed miners an unfair competitive advantage or placing them at a disadvantage, the rates of payments under the system must be within the range of those that apply to land-based mining of the same or similar minerals. This implies that the DSM AETR should be within a reasonable range of the land-based mining AETR. The AETR typically ranges from 40% to 50% for land-based mining. Several studies have reduced this to between 46% and 49%.

In 21 governments across Africa, the AETRs for land-based mining in 2018 ranged from 27% to 52.2%. The median AETR climbed from 41.5% to 46.2%, and the average AETR increased from 42.7% to 43.8% between 2016 and 2018. The AETR may be more significant, and consequently, these ranges should not be viewed as the DSM ceiling (Hauser, 1978).

Setting a higher goal AETR for DSM may make sense. While land-based mining nations are required to make up for the loss of their non-renewable resources to their citizens, DSM must

produce enough income to cover the costs for the entire human race in addition to making up for the detrimental effects on land-based mining nations' economies and budgets, particularly those with higher tax rates.

For instance, Tanzania's and Chad's mining AETRs are 51.7% and 52.2%, respectively. DSM might have a detrimental effect on these nations if the rates were any lower. Lastly, a sizeable portion of the economic benefits are derived from other taxes that land-based mining nations collect but are generally not included in the AETR for mining. Government payments are mostly made up of payroll and indirect taxes from the mine's surrounding economy. Significant financial gains could also result from indirect upstream and downstream operations. This incomparability should be considered while setting any goal AETR for DSM. With a particular set of economic assumptions, any payment regime alternative may be created to attain the same AETR during a DSM project. However, profitability levels fluctuate over different projects and time frames. Profitability varies with time, by company, by region, and so forth. Due to the industry's current state of restricted development, all of the MIT and IGF models' underlying assumptions are highly tentative. Earnings may vary significantly from the current projections. As a result, the chosen payment schedule needs to be adaptable enough to consider DSM projects with varying levels of profitability both today and in the future. Sensitivity analysis can be used to test the regimes' expected performance about changes in profitability, which is determined by price and cost variations. The main takeaway is that choosing a payment schedule based solely on a fixed AETR is insufficient because it could alter depending on various pricing and cost scenarios. To reach its goal AETR, the ISA has a wide range of fiscal instrument combinations. Some of these will perform better or worse depending on certain profitability conditions (Hegwood, 1982).

The 1994 Implementing Agreement's Annex 8 recommends that the ISA consider implementing either a royalty system or a combination of profit-sharing and royalty systems. The OEWG is evaluating four payment plans. Before 2020, no precise royalty rates were mentioned when the ISA hired the Material Systems Lab at the Massachusetts Institute of Technology (MIT) to prepare a report on the options for a payment system. To reach its goal AETR, the ISA has a wide range of fiscal instrument combinations. Some of these will perform better or worse based on various profitability circumstances. It is significant to remember that the rates put forth by MIT are predicated on the assumption that contractors will pay a 25% corporate income tax in the state that is sponsoring them. The fact that sponsorship agreements exist that altogether waive CIT raises severe doubts about this presumption (Pecoraro, 2019).

There are various options. The first one is a fixed-rate royalty of 5% ad valorem alone. A royalty calculated as a percentage of the resource's value is called an ad valorem royalty. The most prevalent type of royalty is this %, which is often paid to the gross value of production without considering production expenses. When ad valorem royalties are imposed at a set rate, the government is paid a predetermined portion of the production value.

The second option is an ad valorem-only royalty divided into two phases (temporary). Option 2 suggests varying the royalty rate, raising it after a certain period: 2% for stage 1 and 6% for stage 2. This contrasts Option 1, where the royalty rate (percentage) remains constant. This option's rationale is that the contractor will have recovered most or all of its upfront expenses by the second term, giving it more significant revenue that can be subject to taxes (Lodge, Segerson, & Squires, 2017).

The third option is a combined 18.5% profit share and 2% ad valorem royalty. This is the sole option for providing revenue and a portion of the profits (usually calculated as revenue minus costs) to the ISA. It is also the standard method for creating a fiscal regime for land-based mining, generally known as the "tax/royalty" system. The fourth option is a two-stage, escalating ad valorem royalty exclusive. For stage 1, the rate is 2%, and for stage 2, the rate varies according

to the mineral prices of each nodule component, ranging from 5 to 9% (Wilde, Lily, Craik, & Chakraborty, 2023).

A government can receive a bigger fiscal take when a factor increases and a lower take when a factor declines when ad valorem royalties are imposed at a progressive rate or, more appropriately, a variable rate. Usually, production quantities or mineral prices are related to the rate.

3. Deep Seabed Mining financing and Generative AI's impact

The section outlines the impact generative AI may have on financing deep-seabed mining and the opportunities and challenges that it may provide. The section will outline the financing options and the impact of generative AI on supporting financing for exploration and mining activities. The final part of the section will be related to possible revenue-sharing options to repay these financial loans.

3.1 Financing options for mining

Financial development has been significant in recent years, given the increasing importance of public and private mining corporations. The bond market has seen a massive increase in bond issuance by mining corporations. Generally, base metal industries have been utilizing these financing vehicles, given the significant size of their projects. Bond financing has been limited in the area of precious metals mining, with a few notable examples being the bonds issued by Newmont and Placer Dome and the 1994 gold-backed issue by Australia's Normandy Poseidon.

Large-scale, high-risk mining projects have been successfully financed in several nations using the sizable market for syndicated project loans. This is especially relevant to corporations in less developed countries, such as Africa, that may face challenges in obtaining conventional loans. These can access the market for syndicated project loans and other financing options. General financing can be divided into debt and equity-related financing that supports the development of mining operations. Equity financing is the exchange of a stake in the corporation for a financial contribution, and these financing options may be in the form of common shares. This implies that the holders assume both the business's potential benefits to succeed and the financial risks. In contrast to an investment in common shares, preferred shares may provide certain voting rights, liquidation priority, and preferential dividend payments. This enables the provision of equity financing benefits while also limiting some of the risks related to joint share equity investments. Convertible financing instruments provide the right to interest, and principal repayment is granted to convertible holders on a predetermined basis. Throughout the instrument's life, the holder may exchange the debt for shares in the issuing firm or occasionally a parent company, either continuously or intermittently. This is especially the case for riskier investments, as in subsea mining, which may encounter operational and regulatory challenges (Wakefield & Myers, 2018).

A crucial part of the financing for mining operations is that mezzanine capital provides senior debt to finance mining projects. These bonds represent financial securities that are bearer and negotiable, and they are paid at a fixed or variable rate. The sponsor and senior lender of the project have to negotiate on the adequate debt-to-equity ratio, which is considered to be in areas such as risk, market expectation, and the debt-to-equity ratio for such projects. The type and final destination of the commodity play another crucial role in financing, as it will indicate the market and certainty of monetizing the commodities. This may be in the form of an unconditional long-term contract that outlines stability, while spot contracts may pose a relatively risky risk. Conventional debt-to-equity ratios are typically lower than 2:1 before any additional investments by the sponsors (Willaert, 2020).

Most mining firms require some form of debt finance when trying to expand, acquire, or create a new project that requires a sizable capital investment. If recourse finance is employed, the lender of the money has security over all of the company's assets and recourse to the cash flow from all

of its operations for repayment (Martino & Parson, 2013). The lender's primary concerns then center on the company's overall financial standing, how the new debt will compare to the whole amount of debt, and the company's potential capacity to service the entire debt in the future. Even though it has reduced transaction costs, a prominent mining firm may fund a project using corporate debt and stock on its balance sheet. However, this is only sometimes a desirable option. The corporation's potential to grow is limited by the amount of capital it has committed to the project's growth throughout the mine, which puts the entire amount at risk and burdens the balance sheet. Mining corporations are increasingly looking to project finance to finance new expansions and acquisitions instead of taking on projects on their own financial sheet. Only the project's cash flows will repay the capital investment made under these borrowings. The corporation as a whole will not be the lenders' exclusive option. Greater leverage lowers the total cost of capital even while interest rates are more significant than in conventional business finance. A crucial part of these projects is that the risk of insufficient liquidity of the corporation rests with the lender and not the corporation itself. Because of this, businesses are eager to move forward with projects that have the potential to be heavily leveraged or financed partially or entirely on their own merits. Furthermore, project finance differs from corporate finance because it can be viewed as off-balance sheet debt. This means that a high-cost project can be developed without significantly affecting the mining company's balance sheet, going over corporate debt limitations, or raising gearing ratios (Gerber & Grogan, 2020).

It enables a mining firm to investigate competitive investment alternatives and finance projects beyond its means while maintaining current banking lines. It restricts a project's risks to the business. Increasing the degree of investment leverage also raises the project's return on capital. In the worst situation, the project's scope or the sponsor's credit can be so bad that they cannot raise enough money to finance the project at a fair price. Then, project financing can be the sole workable option for funding the endeavor.

Because project financing is complicated and expensive to set up, it will only sometimes result in a lower after-tax cost of capital. It is organized on contracts that each party involved must negotiate. Transaction costs will be greater than traditional financing due to the required legal fees for establishing the project structure, investigating and resolving associated tax and legal concerns, and preparing the requisite project ownership, loan documents, and other connected contracts. Additionally, project funding usually necessitates a larger time commitment from management (Shen, 2018).

When reviewing the project's economics, project finance providers will closely examine the discounted cash flow or net present value analysis. This is the project's future cash flow value expressed in the present currency. Cash flow and sensitivity run the discounted value of the future cash flows in the base scenario, and they should always be greater than the total amount of outstanding debt. This ratio is referred to as a project life cover ratio (PLCR) to the end of the project's economic life or a loan life cover ratio (LLCR), depending on discounted cash flows to the end of the loan period. These are expressed as:

LLCR=" " "NPV of future cash flow to the end of the loan" /"Debt outstanding"

PLCR=" " "NPV of future cash flow to the end of the project" /"Debt outstanding"

Minimum base case cover ratios for projects that are particularly vulnerable to market risks could be as low as 1.75. That is to say, the project is expected to have 75% more cash on hand than what is needed to pay back the loan. Minimum ratios for less hazardous projects could range from

1.25 to 1.5%. Should the loan life cover ratio drop below one, there isn't enough money in the project to repay the loan. Lenders will also check the debt service cover ratios (DSCR) to see if the available cash flow can cover debt service for a given time frame. The typical minimum values fall between 1.2 and 1.4:1. Lenders will calculate the proportion of economically recoverable reserves that remain after the loan is paid back, as they also want to ensure that the project will continue to be profitable after the planned majority of the loan has been repaid. A buffer of 1.5 to 2 times the loan life is typical.

The rate of return a group of investors needs to assume project risk is known as the cost of capital. It assesses if the return to investors is greater than the percentage return they could receive from a comparable investment opportunity and is typically stated as the weighted cost of funds (Blanchard, Harrould-Kolieb, Jones, & Taylor, 2023).

Because debt financing has payback commitments whereas equity does not, there are differences in the methods used to estimate the costs of each. The cost of equity for a project can be estimated using the capital asset pricing model. Like with any investment, an investor will only buy a riskier asset if he anticipates receiving a rate of return commensurate with the level of risk he is willing to take. The necessary rate of return increases with risk. The capital-asset-pricing model expresses the needed rate of return as the risk-free rate plus a risk premium:

Two variables affect the risk premium. The incremental riskiness of an asset in a diversified portfolio is measured by its beta. The relationship between an asset's returns and those of the market portfolio is reflected in beta, which gauge an asset's riskiness. The market risk premium is the difference between the projected return on the market portfolio and the risk-free rate. A security's return follows the market portfolio if its beta is 1.0. The stock typically rises by 10% if the market portfolio also does. A stock will gain or fall less than the market if its beta is less than 1.0%. On the other hand, A stock with a beta of higher than 1.0% will increase or fall faster than the market. Although there has been much discussion on the role of derivatives in mining financing, several of these instruments can be utilized to lower the project's risk exposure. These are typically hazards related to funding costs, currency fluctuations, and volatility in commodity prices. Executives from mining companies and investment managers have been debating the utility of these products, especially when it comes to hedging commodity price risk, a lot lately. Fund managers argue that hedging denies shareholders the opportunity to benefit from price increases in the market. Executives from mining companies, however, argue that they have a fiduciary duty to safeguard the business and its investors from the negative consequences of low market prices. This discussion will likely go on for a while (Poisel, 2012).

However, in general, lenders are hesitant to finance a project with debt if there is no hedging to ensure, based on best-case scenarios, a minimum loan life cover ratio. Without adding to the controversy, it should be mentioned that several initiatives that would have otherwise been unprofitable or marginal have secured funding thanks to derivative instruments. When these tools are used strategically, projects have achieved lower funding costs. Mine finance is a complex process with many moving parts that can be misinterpreted. They should be more frequently used. Although mining financing structures have similar characteristics, each sponsor's and the project's unique structure must be considered. That's the area with the obstacles and the riches.

3.2 Generative AI for deep seabed mining financing

In the world of investment banking, automation and AI are nothing new. Indeed, natural language processing (NLP) methods and machine learning/deep learning algorithms have been extensively utilized for many years to support trade automation, enhance risk management, and conduct investment research. Nevertheless, a significant portion of the tasks in the transaction life cycle still require using valuable human resources, even after billions of dollars have been spent on automating them. However, many tasks may be automated using large language models (LLMs),

saving costs and increasing productivity for dealing with the complex nature of subsea deep mining projects.

Generative AI has yielded significant productivity gains of more than 14%, with additional benefits being time reduction and the enhancement of work quality by employees. The financial industry is going ahead with proofs-of-concept (POCs) and trials that have indicated significant potential, with recent solutions providing clients with investment advice based on LLMs. Another critical area is the development of tools for assisting regulators with enhancing their operational procedures. Similar activities were conducted to determine whether central bank communications are either dovish or hawkish in terms of their decisions on interest rates (Feichtner, 2019).

When output production effort is high and validation is reasonably straightforward, generative AI can be highly productive. When used in investment banking, this capability can improve front-office staff members' performance in various tasks, such as research, trading, decision support, marketing, and sales. Pitch books, industry reports, investment theses, performance summaries, due diligence reports, and other documents are typically a laborious process, and generative AI may relatively easily compile these quickly. In addition to improving analytical skills, electronification procedures, and client call transfer rates, generative AI can assist in lowering the cost of content development. Additionally, generative AI is being used by investment institutions like Goldman Sachs to assist engineers and coders in producing reliable code more quickly. With more parameters being trained on these LLMs, their competence is only expected to increase.

The underlying business's intrinsic complexity will probably affect the productivity increases. There is a prediction that the investment banking division (IBD) will see the most gains, followed by the equity market and trading of fixed income, currencies, and commodities (FICC). Given that it entails more repeated work, the IBD—which encompasses stocks and debt issuance, mergers and acquisitions, and advisory—may benefit most from generative AI. Most of the benefits arise from productivity gains and more intrinsic analysis. The technology can assist in creating preliminary deal structures and compliance, appraisal, and due diligence. Generative AI can help draft prospectuses, term sheets, and legal documentation in the underwriting and issuance domains (Feichtner, 2019).

Generative AI might significantly impact the trading industry. Trading has already undergone significant transformation because of automation and low-latency trading infrastructure, which may increase market efficiency and lower transaction costs. NLP and sentiment analysis are tools that traders use to optimize trading strategies, create synthetic data for risk modeling, and assess markets. There is the expectation that the application of generative AI to these tasks might greatly shorten the time needed to detect abnormalities, comprehend market mood, and place orders more quickly and widely.

Generative AI has the potential to significantly assist traders in the field of equities trading by facilitating speedy analysis, summarizing company and industry fundamentals, running valuation models, backtesting trading methods, and providing customized trading advice to institutional and retail clients. On the other hand, because FICC trading may also entail swaps or derivatives, a wide range of trading tactics, and risk criteria, it frequently necessitates complicated analysis and valuation. Furthermore, because FICC markets often represent higher systemic risk, they are subject to greater regulatory scrutiny. Although this gives room for generative AI to track bond rates, evaluate credit ratings, and deliver insights in real-time, the unpredictability and volatility of the market would necessitate ongoing verification from knowledgeable professionals. When generative AI is compared to stock trading, its distinct characteristics might reduce productivity gains.

Choosing the scale and focus. There might be a variety of benefits to LLMs. Besides the lauded benefits, executives should consider the possible simplicity of implementation and the related hazards.

They are utilizing increases in productivity. Banks will probably need to restructure their personnel to more purpose-driven duties as the early use cases take shape. Cutting less on routine tasks may make it possible for young talent, like junior traders, to advance quickly and acquire more essential skills (Blanchard, Harrould-Kolieb, Jones, & Taylor, 2023).

The next step is the evaluation, reduction, and control of risks. The outputs of generative AI may need continuous validation for biases, accuracy, and hallucinations—that is, the creation of confident responses not based on evidence from the real world. Banks might need to revamp their current risk frameworks, risk governance, and overall readiness for a more dynamic approach to risk management. Another critical opportunity is enhancing shareholder confidence. Scaling generative AI applications may depend on establishing the outputs' trustworthiness and persuading partners, clients, staff, and regulators of their applicability. It will be crucial to align stakeholder interests and ensure responsible and ethical AI practices are followed.

Another challenge is incorporating generative AI into currently used tools, technologies, applications, and systems. Executives ought to think about how these AI technologies will work in the larger framework of cloud migration, data and analytics strategy, operations, and digital transformation. It is essential to combine generative AI with current digital infrastructure and AI. Leaders must monitor how future technology, like quantum computing, can augment the multiplicative power. Sharing server and computational demands and hardware resources among different technologies and applications will represent another challenge. Another crucial step is monitoring developments to obtain a competitive edge. Increased inventiveness and originality ought to result from generative AI. However, the ability to use generative AI to get a competitive edge in fields like cost management may decline as LLMs become more commonplace.

Furthermore, corresponding with authorities may represent a significant opportunity and challenge. Regions will probably offer new standards for generative AI about data privacy, copyrights, and intellectual property concerns. Investment banks should implement new compliance procedures and use caution when using customer and market data. In order to create new policies that will benefit all parties, banks should proactively collaborate with regulators on these issues. Another critical area is collaborating on execution. Investment banks have found that fintechs and digital companies have been good partners. Generative AI will probably call for both horizontal and vertical alliances. Big banks could need to consider the classic build vs. buy choice. Smaller institutions might find it more difficult to form collaborations and might need to come up with different models.

3.3 Deep seabed mining revenue sharing agreements

Generative AI may play a critical role in the financing of deep seabed mining activities, increasing both efficiency and supporting growth. Governments typically aim to maximize their revenues, which falls to the ISA in the case of deep seabed mining. The expectation is that the resources may be limited and non-renewable, and the maximization of revenue from these operations plays an essential role.

In order to support these deep seabed mining operations, investments need to be drawn. Generally, the financing shall support that the operator may recoup the full cost of their investment in addition to a return on capital while also considering that the government may aim to maximize its profit (Ardron, Ruhl, & Jones, 2018).

Progressivity is the automatic adjustment of the government's portion of total earnings to the profitability of mining ventures; it rises in the case of high profits and falls in the case of poor profits. For instance, the average effective tax rate rises from 45% to 50% when profits increase

from $50 to $100. This is particularly crucial for metals like manganese, copper, and cobalt, whose prices are volatile due to the growing demand for essential minerals. Theoretically, progressive fiscal policies benefit governments and investors alike. It lessens taxes on marginal earnings for investors, which lessens the distortion of investment decisions. Governments, or in this case, the ISA, receive a higher portion of the benefits from extremely profitable enterprises.

While profit-based taxes may generate significant profits in later project cycles, royalty-based revenue streams incur revenues when production begins. As the ISA does not have to finance public services, unlike governments of nations with extensive land mining, the timing of income is potentially less important. In contrast to land-based mining, there is also no delay in production timetables.

Both taxpayers and regulatory agencies find it straightforward to comprehend, communicate, and oversee a basic payment system. This idea is particularly crucial in light of the time the ISA will take to increase its financial and human resources to successfully collect payments from DSM. Another crucial area is ensuring robustness to profit-shifting for deep seabed mining. According to IMF estimates, resource-rich developing nations in Africa lose between USD 470 and USD 730 million in annual tax revenues from mining due to corporate tax avoidance. By creating a payment schedule that aligns with the ISA's administrative capacity and utilizing fiscal tools that are less vulnerable to profit-shifting and tax base erosion, this loss can be reduced to the barest minimum.

Important findings from the IGF financial model for DSM provide the basis of the quantitative study of the four choices. The MIT model is the source of the IGF model's fundamental assumptions on capital expenditure, operating expenditure, project life cycle, production level, and rates. The IGF model's underlying assumptions differ in a few ways. Three distinctions stand out, though the majority are minor.

First, the IGF model makes different assumptions about the IRR that the processor requires, which influences the amount of DSM profit that is attributable to the area rather than the jurisdiction of the processor. Preliminary estimates from the first company investigating commercial nodule extraction are the basis of this particular assumption in the MIT model. Since it is trying to sell nodules to a processor that has never processed this material before, this company, being a first mover, will undoubtedly encounter adverse terms. Nonetheless, it is realistic to anticipate that nodule processors will eventually have economics comparable to those of independent land-based mining refineries (Feichtner, 2019).

These refineries usually charge processing (treatment and refining) fees instead of taking a cut of the profits (or losses) made by mining corporations. This adds even more uncertainty to the mix, underscoring the need for the ISA to create a fiscal regime that can support first movers' economics without giving away enormous sums of money to businesses that want to enter an established industry that could be highly successful. The IGF model takes a stance between the MIT model and assumes a typical, fixed return to the processor.

Second, sensitivity analysis is used by the IGF model to display the results in terms of AETR as a spectrum. Sensitivity analysis is a technique for evaluating the business' expected performance in relation to variations in profitability as determined by pricing and cost fluctuations. While various regimes may lead to the same AETR, underlying conditions and regimes may lead to significant changes. However, if these presumptions alter, the AETR of the two options will also, particularly if the progressivity of these options varies. It is crucial to consider fiscal regimes that are resilient to a wide range of assumptions about the future profitability of DSM projects, given the degree of uncertainty surrounding the DSM industry (Thompson, Miller, Currie, Johnston, & Santillo, 2018).

The third option is not calculated as an income tax by the IGF model but rather as a cash flow tax. How investment charges and interest expenses are handled distinguishes a cash flow tax from an income tax, despite both being taxes on profit. Rather than using depreciation allowances, a cash flow tax allows capital expenditures to be immediately expensed. Typically, a cash flow tax uses a fixed uplift on negative cash flows to account for the cost of capital, disallowing interest payments as a deduction. When collecting a portion of the economic rent from an extractive project, a cash flow tax is far more effective than an income tax. Generally, it would be better served by implementing a more straightforward and efficient cash flow tax system rather than an income tax system, as it does not function as a government income tax.

Important players in the DSM management process are the sponsoring nations. Non-state actors are only permitted to apply for a mining license if they are supported by a state, as per UNCLOS Article 153(2)(b). It is the sponsoring state's responsibility to ensure the contractor abides by the conditions of the contract and its UNCLOS duties (Article 139). Sponsoring states have the right to recoup CIT from contractors in exchange. They are expected to partially finance their monitoring operations with at least some of this revenue.

There are concerns over the reasonableness of assuming that contractors will pay their sponsoring states 25% CIT when, in reality, they may pay much less or no tax at all. It could be added to this point that sponsoring states have other options for reducing or exempting earnings taxes besides CIT. They may also provide reduced or no withholding tax on outgoing payments through sponsorship agreements, double tax treaties, or domestic law. There are various challenges in general that States that sponsor contractors impose minimal or no CIT. Certain sponsorship arrangements are completely exempt from CIT. This demonstrates the danger of "forum shopping," whereby contractors pick a sponsoring state with low taxes to lower their overall tax burden. Deepsea miners are far more mobile and can base themselves wherever taxes are lowest, in contrast to land-based miners, restricted to the nation where the resource resides and the tax regime that applies (Glasby, 2002).

Additionally, the sponsorship agreements are concealed by contractors and sponsoring states, making it hard to determine whether or not CIT is being charged and how much. Due to this lack of contract transparency, it is impossible to ascertain contractors' whole tax burden. When a payment scheme is based on an unverifiable target AETR, the ISA may find it difficult to ensure sustainability. There have been recommendations for imposing taxes on capital gains resulting from transferring or selling DSM-related exploration and mining rights. A firm may experience a capital gain or loss when it sells or transfers an asset. The gain is the entire amount obtained from the sale or transfer, less the buying price.

It appears that the taxation of the transfer of mining rights related to resources in the area complies with the legal mission of the ISA. The ISA is specifically given the option to select either a royalty system or a mix of a royalty and profit-sharing system under Section 8(1)c) of Annex 1 of the Implementing Agreement. A portion of the proceeds from the sale or transfer of a mining right are subject to a capital gains tax. Since a tax on the sale or transfer of mining rights is a feature of most land-based fiscal regimes (see the next section), not applying such a tax would give DSM a comparative advantage over land-based mining. Section 8(1)(b) further requires that the payment rates be within the range of those for land-based mining.

The nation where the seller is located may tax the gains if the ISA does not tax the proceeds from the transfer of mining rights or, at the very least, create a sourcing right in the region. In that scenario, the contractor might attempt to arrange the deal so that the seller is domiciled in a country that does not impose capital gains taxes, avoiding having to pay taxes anywhere. Countries, where sellers are located, may tax gains from the transfer of mining rights if the ISA does not tax them or at least does not create a sourcing right in the relevant area. The contractor

might then attempt to arrange the deal so that the seller is domiciled in a country that does not have capital gains taxes, sparing them from having to pay taxes elsewhere.

Capital gains are taxed in two different ways. There are two ways to do this: either as a distinct capital gains tax or as an income item subject to a more broadly applicable profit share, like Option 3, which was previously mentioned. In either case, the ISA must establish the right to tax both direct and indirect transfers of DSM assets. The nation where the resource is located conventionally has the authority to collect capital gains tax on the sale of any land-based mining asset, right, or interest related to that asset under domestic law and tax treaties (Ardron, Ruhl, & Jones, 2018).

If the license or asset is sold indirectly through a chain of ownership, the process may increase in complexity. Selling mine shares or shares in the foreign business that owns the mine is known as an indirect transfer. For instance, a partial or complete change of ownership of the DSM operation may occur when the foreign corporation that owns the sponsored entity sells out a portion of its shares. Even if the ISA is not informed, the sale may occur outside the sponsoring state.

The majority of nations' tax systems include capital gains taxation. Numerous nations impose capital gains taxes on their citizens, and some have laws expressly designed to tax non-residents' capital gains, provided the earnings originate from property within their borders. The purpose of indirect transfers laws is to tax gains resulting from the sale of shares or a similar stake in an entity, which can be established overseas or onshore, provided that the gains are primarily attributable to real estate within the nation. Immovable property is defined as land, buildings, factories, mines, and associated permits and rights.

International tax laws also support the taxation of capital gains at source in offshore indirect transfers. The UN and the OECD's models of bilateral tax treaties do this in their article 13(4), which is given in the box below. Although the ISA will not sign bilateral tax treaties and the area is not a sovereign nation, one may argue that natural resources should be subject to the same source taxation laws (Glasby, 2002).

Since the companies holding the licenses and their shareholders will be registered in other jurisdictions, all alienations of mining assets, licenses, and rights in the context of DSM must occur outside. Consequently, all sales of mining assets and associated licenses will take place outside of the country. The parties may still negotiate the sale of the license itself. Still, it is anticipated that the majority of transactions will include the sale of the license holder's shares or even of intermediary activities, changing the ownership of the corporate chain. It is crucial to consider the imposition of tax on offshore indirect transfers if the ISA chooses to levy a type of capital gains tax on the sale of mining assets along with any associated licenses and rights.

4. Conclusion

The deep sea is a challenging habitat for life but also encounters mountain ranges, plateaus, volcanic peaks, gorges, and enormous abyssal plains that represent a significant challenge for the exploration of minerals. The minerals specific to the deep ocean include most of the minerals encountered on land and are typically enriched. Deep seabed mining has attracted significant attention in order to satisfy the growing demand for minerals across the globe and the ever more challenging environments encountered to exploit these resources. Deep seabed mining represents a different domain, given that most of the resources are encountered in international waters that, according to international law, may not belong to a single specific nation. This represents a considerable challenge for international financing of deep seabed mining, requiring funding providers to navigate the challenging environments from a regulatory and risk perspective. Generative AI may provide some considerable opportunities related to supporting the financing of deep-seabed mining companies, improving risk assessment, and navigating the challenging

regulatory environment. Furthermore, generative AI may significantly support companies in enhancing operational efficiency and improving profitability from their activities.

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ASSESSMENT OF THE CARBON FOOTPRINT OF A TOURISM ENTERPRISE IN KAZAKHSTAN IN THE CONTEXT OF SUSTAINABLE TOURISM

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Abstract

Sustainable tourism is part of the Sustainable Development Goals, ensuring decent work, economic growth, responsible consumption and production, and the creation of sustainable economies. Tourism in Kazakhstan is in its infancy and is generally profit-driven without adequate environmental protection. This has resulted in unsustainable use of natural resources, particularly energy and water, with negative impacts on the climate. In order to promote sustainable tourism development, we assessed the carbon footprint of a pilot tourist facility - one of the typical holiday homes in the Bayanaul National Park in the Pavlodar region (Kazakhstan) - based on data for 2022. The aim of the study is to identify the contribution of tourism to climate change and to develop proposals to reduce this negative impact in the context of achieving sustainable development criteria in the activities of tourism enterprises. To determine greenhouse gas emissions in our study, we used the currently widely used Greenhouse Gas Protocol. Basic information for the calculations was collected using a questionnaire. The calculations revealed that the total greenhouse gas emissions of the holiday home were 530 tonnes of CO2-eq, of which more than half (57%) were attributable to scope 3 (emissions in the tourism product value chain: purchasing goods and services to serve tourists). Indirect Scope 2 emissions associated with the purchase of electricity amount to 119 tonnes of CO2-eq. (22.5%). Direct emissions (scope 1) of the facility are related to heating in wintertime with coal and amount to 108 tonnes of CO2-eq. (20.5%). It was recommended for the district tourist administration to track the carbon footprint calculations for other large tourist facilities and conduct outreach to their owners to ensure that measures are taken to reduce the impact on the climate.

Keywords: sustainable tourism, carbon footprint, environmental sustainability,

greenhouse gases.

JEL Codes: Q54; Q56; Z32; Q01

Introduction

Sustainable tourism is an essential approach that seeks to balance the economic benefits of tourism with the need to protect the environment and support local communities, as well as preserve cultural heritage (Guo et al., 2019; Kurniawan, 2024) (Kumar & Thakur, 2023). Sustainable tourism policy plays a crucial role in addressing global environmental issues and promoting sustainable development (Guo et al., 2019). In addition, sustainable tourism can contribute to the preservation of cultural heritage and natural landscapes by promoting sustainable management practices (Stanikzai, 2024).

Environmental sustainability is one of the main directions of sustainable tourism. Considering the criteria approved by the Global Council for Sustainable Tourism (GSTC), in addition to assessing the environmental impact of tourism, the management of resources, waste and emissions, including greenhouse gases, and mitigation of climate change are important. Along with this, the calculation of the carbon footprint is a critical aspect of environmental sustainability, as it quantifies the total greenhouse gas emissions associated with a product or

service throughout its life cycle, allowing the development of targeted strategies for reducing emissions and optimizing resources (Zhao et al., 2017). Research also shows that rapid development of society can lead to pollution of natural resources, which highlights the importance of assessing the carbon footprint and potential of tourism to ensure sustainable tourism practices (Gangji, 2024).

The carbon footprint of tourism is of serious concern in the context of global climate change, as the industry contributes significantly to greenhouse gas emissions (Wang et al., 2017). The UN World Tourism Organization estimates that carbon emissions from tourism activities will exceed 6.5 billion tons by 2025 (Yong-lian et al., 2021).

Addressing the carbon footprint of tourism requires a multifaceted approach that includes improved measurement techniques, public education and the implementation of low-carbon strategies. The need to halve carbon emissions from the tourism sector by 2030, as outlined in the Glasgow Declaration on Climate Action for Tourism, underscores the urgency of this issue (Wang, 2024).

Accommodation facilities, especially hotels, are energy-intensive establishments that contribute significantly to greenhouse gas emissions. According to the World Travel and Tourism Council (WTTC), accommodation accounts for about 21% of the total carbon footprint of tourism, which underscores the need for effective measurement and management strategies (Grosbois & Fennell, 2011).

In addition to direct emissions from energy use, the carbon footprint of accommodation facilities also covers indirect emissions related to the supply chain, including the production and transportation of goods and services. Research by Liu et al., 2017 highlights that indirect carbon emissions can account for about 50% of total emissions associated with tourist accommodation (Liu et al., 2017).

Chan, 2021 notes that hotels face numerous challenges in reducing their carbon footprint, including a lack of awareness and understanding of carbon accounting methods, as well as psychological barriers to implementing sustainable practices.

In addition, the type of placement significantly affects its carbon footprint. Studies show that different types of accommodation, such as hotels, hostels and eco-houses, have different levels of energy efficiency and carbon emissions (Dwyer et al., 2010). Eco-friendly accommodation options that prioritize sustainability through energy-efficient methods and renewable energy sources can significantly reduce their carbon footprint compared to traditional accommodation options. This is especially true in protected areas where the conservation of natural resources is of paramount importance.

Tourism in Kazakhstan is at an early stage and is focused, as a rule, on making a profit without proper environmental protection. The consequence of this development is the irrational use of natural resources, in particular energy and water, which negatively affects the climate (Yessim et al., 2023; Yessimova et al., 2024). Currently, the carbon footprint of Kazakhstan's tourism sector is becoming an increasingly important area of research as the country strives to develop its tourism industry while taking care of environmental sustainability. However, the development of tourism infrastructure and services has not yet reached its full potential, which means that environmental impacts, including carbon emissions, are still insufficiently assessed (Abdrakhmanova et al., 2022). The need for sustainable tourism practices is highlighted by the conclusions that discuss the problems and prospects of sustainable tourism in Kazakhstan (Allayarov et al., 2018). They stress that the growth of the tourism sector must be accompanied by strategies to minimize environmental impacts, including carbon emissions. This is in line with the broader goals of the Government of Kazakhstan, which has initiated programs aimed at

strengthening the tourism sector while promoting sustainability (Overview of sustainable tourism development strategies: insights from the Republic of Kazakhstan, 2024).

For the targeted development of sustainable tourism, we assessed the carbon footprint of a pilot tourist facility – one of the typical accommodations in Bayanaul National Park of Pavlodar Region (Kazakhstan) according to data for 2022. This work was carried out in Kazakhstan for the first time. The purpose of the study is to identify the contribution of tourism to climate change (1) and to develop proposals to reduce this negative impact in the context of achieving sustainable development criteria in the activities of tourism enterprises (2).

Materials and methods

To determine greenhouse gas emissions, our study used the currently widely used Greenhouse Gas Protocol (The Greenhouse Gas Protocol, 2004; 2011; 2013). One of the key components of the PC Protocol is its emphasis on the life cycle perspective when accounting for emissions (Laurent & Olsen, 2012).

The Protocol standard divides emissions into direct and indirect, taking into account their source and place in the production chain: direct – from own assets, indirect – from related companies.

The Greenhouse Gas Protocol identifies three main emission scope areas: 1) scope 1 - direct emissions originating directly from sources owned or controlled by the company (for example, from burning fuel in boilers or vehicles); 2) scope 2 - indirect emissions from the production of purchased energy (electricity, steam, heat) that the company consumes; 3) scope 3 - other indirect emissions that cover the entire life cycle of a company's products or services, from extraction of raw materials to recycling, and include 15 different categories. The assessment of emissions in accordance with the Greenhouse Gas Protocol was carried out in three scopes (Scope-1,2,3), allowing to estimate both direct and indirect greenhouse gas emissions (International standard, 2018; WRI and WBCSD, 2015).

The basic information for the calculations was collected using a questionnaire. The questions related to energy consumption, heating, wastewater, as well as transport used by the company. To assess indirect emissions, questions about purchased goods and services, the life cycle of goods and services, transportation of raw materials and waste generation are included.

The reporting period covers one year: from January 1 to December 31, 2022. This is the first report for the included departments, so it will be considered as the base report for all subsequent years.

The object of the study is the accommodations of recreation center located in the Bayanaul State National Natural Park in the Pavlodar region in the north-east of Kazakhstan. The territory of the recreation center is 3.2 hectares of land. The room fund consists of 62 rooms located in the main building and detached houses.

When determining the carbon footprint, taking into account the production profile of organizations, calculations were made only of carbon dioxide (CO2-eq.). Other greenhouse gases – methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride - were not taken into account.

The basic formula used to calculate the carbon footprint (tons of CO2-eq.):

GHG emissions = Activity data (unit of activity) x emission factor (tons of CO2-eq./unit of activity)

Results and discussion

As a result of calculations, it was revealed that the total greenhouse gas emissions of the holiday home amounted to 530 tons of CO2-eq., of which more than half (57%) accounted for scope 3 (emissions in the value chain of a tourist product: the purchase of goods and services to serve tourists). Indirect emissions from scope 2 related to the purchase of electricity amount to 119 tons of CO2-eq. (22.5%). Direct emissions (scope 1) of the facility are associated with heating in winter with coal and amount to 108 tons of CO2–eq. (20.5%) (Table 1, Figure 1).

Table 1 - Results of the inventory of greenhouse gases (tons of CO2 eq) of covers 1, 2 and 3, for the holiday home

Sources of GHG	Tons of CO_2 eq.
Total (scope 1 + scope 2)	227
Total (scope 1 + scope 2 + scope 3)	529
Scope 1	108
Mobile sources	-
Stationary sources	108
Scope 2	119
Purchased electricity, market method	119
Scope 3	302
Category 1: Purchased goods and services	53
Category 3: Fuel and electricity life cycle (emissions not included in scope 1 or 2)	52
Category 4: Transportation of raw materials and purchased goods	108
Category 6: Waste generated	90

The main source of direct GHG emissions for the scope of 1 of recreational center is the burning of coal (108 tons /year), the organization does not have its own transport. The necessary electricity (121,466 kWh/year) is purchased from the territorial electric grid company from the national grid (scope 2).

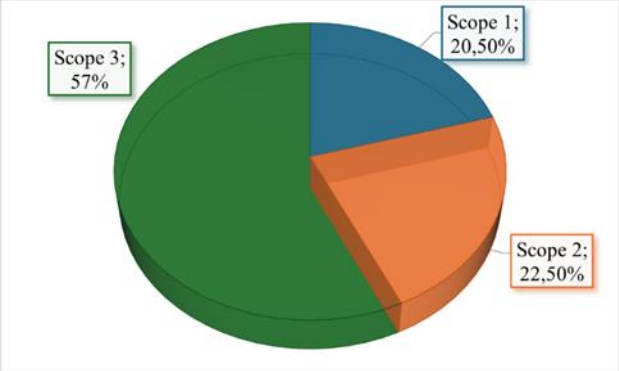

Figure 1 – Percentage ratio of greenhouse gas emissions scope of the recreation center

The main sources of indirect emissions in scope 3 include category 4 emissions (transportation, including the arrival of visitors) – 108 tons of CO2-eq. (35.7%) category 6 "Waste generated" - 90 tons of CO2-eq. (29.7%). Category 1 "Purchased goods and services" and category 3 (energy) account for 53 tons of CO2-eq. (17.4%) and 52 tons of CO2-eq. (17.2%), respectively (Figure 2).

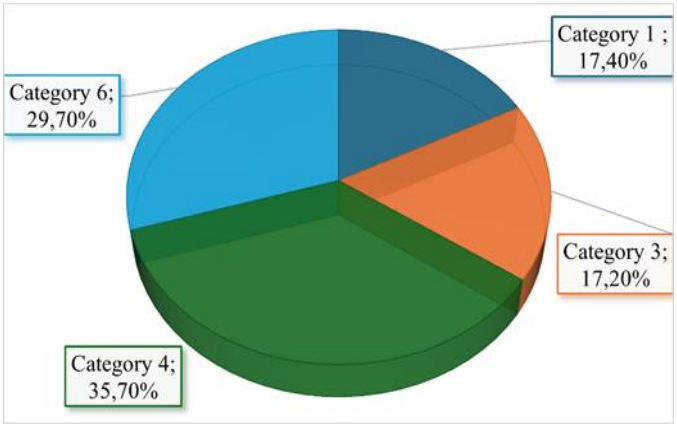

Figure 2 – Percentage ratio of the 3 greenhouse gas emissions scope categories of the recreation center

Based on the results of the carbon footprint analysis, the tourist site administration was offered recommendations for its reduction.

The first event is related to improving energy efficiency in accommodation facilities. The holiday home is a significant source of carbon emissions due to energy consumption for heating, cooling and lighting. It is proposed to introduce energy-efficient technologies such as LED lighting, energy-saving energy consumption systems, which can significantly reduce energy consumption. In addition, the use of renewable energy sources such as solar or wind energy can help accommodation facilities achieve carbon neutrality.

The second event is dedicated to promoting sustainable practices among tourists: it is recommended that measures be taken to educate tourists about their environmental impact, which will encourage responsible travel choices.

The third event is the development of low-carbon travel products. Creating low-carbon travel products such as ecotours will help attract environmentally conscious travelers (Xia et al., 2022).

Event four: Community participation and stakeholder collaboration. The involvement of local communities in tourism planning and management is crucial for the development of sustainable tourism, as joint management between travel agencies, environmental organizations and local

communities can lead to effective climate change initiatives (Zeppel, 2012). By involving stakeholders in decision-making processes, tourism can be developed in a way that respects local culture and the environment while minimizing carbon emissions.

Event five: Monitoring and reporting on emissions. Regular measurement and reporting of carbon emissions can help tourism businesses identify key areas for improvement (Li et al., 2020). By setting clear indicators and accountability, stakeholders can monitor progress towards achieving the Sustainable Development Goals and make necessary adjustments.

In conclusion, reducing the carbon footprint in the tourism sector requires a multifaceted approach that encompasses sustainable transportation, energy-efficient accommodation, tourism education, low-carbon product development, community engagement and effective monitoring. By implementing these measures, the tourism industry can contribute to global efforts to combat climate change while promoting sustainable tourism that benefits local communities and ecosystems.

Our further research provides for work on sectoral diagnostics of the carbon footprint (a set of tourist enterprises in the Pavlodar region), setting targets for its reduction, developing standard measures for the implementation of projects that reduce the carbon footprint, including offset projects. All these measures comply with the policy of introducing criteria for sustainable tourism into the daily practice of industry development in the Republic of Kazakhstan.

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FINANCIAL DEVELOPMENT AND INCOME INEQUALITY: EVIDENCE FROM TURKIYE

Esra SOYU YILDIRIM

Abstract

Income inequality has become an increasingly serious economic and social problem in both developed and developing countries in recent years. This problem is an important factor limiting global sustainable development. There are many ways to tackle income inequality. One way is to encourage the development of the financial sector. However, there is a debate on the effectiveness of financial sector development in promoting economic growth and reducing income inequality. Moreover, particular attention has been paid to the role that strong financial sector development plays in reducing income inequality.

Therefore, the present study analyses the relationship between financial development indicators and income inequality in Türkiye for the period 1987-2021. ARDL bounds test approach is used in the study. According to the findings, FIA (Financial institutions access index), FID (Financial institutions depth index) and FME (Financial markets efficiency index) variables have a positive sign in the long run. In other words, financial development indicators (FIA, FID, FME) increase income inequality. On the other hand, FIE (Financial institutions efficiency index), FMA (Financial markets access index) and FMD (Financial markets depth index) variables have a negative sign. In other words, financial development indicators (FIE, FMA, FMD) decrease income inequality.

Keywords: Income inequality, Financial development, ARDL, Türkiye

JEL Codes: G20, O15, C10

1.Introduction

Rising income and wealth inequality in most countries in recent decades poses one of the greatest challenges for policymakers in both developed and developing countries. While a certain level of inequality is essential to provide incentives in a well-functioning economic system, extreme inequality is seen as a major threat to long-term growth and prosperity (Kim & Lin, 2023). Increasing income inequality hinders the development of innovation, weakens the rule of law and social capital (Kirschenmann et al., 2016). It can also lead to sociopolitical unrest and financial and economic crises. This negatively affects macroeconomic stability and sustainable growth (Barro, 2000; Nolan & Valenzuela, 2019; Kim & Lin, 2023). Given these devastating consequences, it is a necessity to identify the sources of income inequality and take measures accordingly.

Growing income disparity is a serious issue. In the majority of developed and emerging nations, income inequality has increased. On its causes, there is still disagreement, nevertheless. The effect of financial development on income disparity is one aspect that has recently attracted a lot of attention in the literature. On the connection between financial development and income disparity, there are differing opinions, nevertheless (De Haan & Sturm 2017).

Prudent development of the financial sector is necessary to tackle income inequality. This is because there are debates about the effectiveness of financial sector development in promoting economic growth and reducing income inequality. Strong financial sector development can play a role in reducing income inequality, but it can also lead to an increase in income inequality. It can be explained as follows:

- Faster and more sustainable economic growth is facilitated by the development and sound management of the financial sector. First, work opportunities are created by simple access to financial resources. As a result, the impoverished people invests more. Second, by giving them access to financing, it helps the impoverished create more human capital. Lastly, because high inflation is particularly detrimental to people on fixed incomes, the growth and sound management of the financial sector can also aid in protecting the indexed income of a particular population segment by facilitating easy access to financial resources during such times (Shahbaz et al., 2015).
- The impoverished will remain outside of the financial system even as it grows because they will not have the same access to credit as the wealthy. As a result, as the financial sector grows, income inequality will rise (Kapingura, 2017). Furthermore, from the standpoint of financialization, the quick expansion of the financial sector takes resources away from manufacturing, damages industrial investment, and increases shareholder power and management's focus on short-term profits (Onaran et al., 2011, Tridico, 2017; Kim & Lin, 2023).

In the literature, it is possible to find a sufficient number of studies analysing the relationship between financial development and income inequality (see Table 1). Although the results obtained are quite controversial, two main theoretical frameworks on the relationship between financial development and income inequality come to the fore. The first one is the inverted-U relationship between financial development and income inequality based on the Kuznets hypothesis. The second is that income inequality will decrease with increasing financial development.

The main objective of this study is to determine how financial development will affect income inequality in Türkiye. For this purpose, firstly, the gap in the literature has been identified. In the current study, 6 sub-indicators of financial development (depth of financial institutions (FID), access to financial institutions (FIA), efficiency of financial institutions (FIE), depth of financial markets (FMD), access to financial markets (FIA) and efficiency of financial markets (FME)) were used. A wider range of analyses has been conducted. This difference is not found in the reviewed literature. The reason for focusing on Türkiye in the sample is that Türkiye is categorised as a developing country and the impact of financial development on income inequality may be more pronounced in such countries than in developed countries. Understanding the effects of financial development on income inequality in Türkiye can make important contributions to the literature in this field. Against this background, ARDL bounds test is applied to analyse the relationship between these variables. The findings are evaluated and policy recommendations are presented.

In the first part of the study, theoretical information is given holistically. The second section provides a literature review. The third section presents the data set and methodology. The fourth section presents the results of the analyses. In the last section, conclusion, evaluation and discussion are given.

2.Literatüre Review

In the reviewed literature, there are many studies on the relationship between financial development and income inequality. The studies on this subject are primarily theoretical in nature. It is noteworthy that empirical studies were conducted later. In this context, it is possible to see some of the studies in the literature on the subject in Table 1.

Table 1. Selected prior studies on the association between financial development and income inequality

Author(s)	Region/sample period	Technique	Variables	Findings

Shahbaz & Islam (2011)	Pakistan/ 1971 -2005	ARDL	GINI, FD, GDP, INF, TO	Financial development reduces income inequality.
Topuz & Dağdemir (2016)	94 countries/ 1995-2011	Panel	GINI, FİNGEL	While financial development reduces income inequality in high-income countries, it increases it in low, lower-middle-income and upper-middle-income countries.
Kapingura (2017)	South Africa/ 1990 - 2012	ARDL	GINI, FD, INF, Export, GDP, GOV	Financial development increases income inequality.
De Haan & Sturm (2017)	121 countries/ 1975-2005	OLS	GINI, FD	Financial variables increase income inequality.
Cong Nguyen et al. (2019)	21 emerging countries/ 1961–2017	FMOLS, DOLS	GINI, INF, FD, GDP, GovExp/GDP	There is an inverted U curve relationship between financial development and income inequality.
Destek, Sinha & Sarkodie (2020)	Türkiye/ 1990-2015	ARDL	GINI, INF, FD	Financial development and banking sector development have an inverted U-shaped relationship with income inequality.
Younsi & Bechtini (2020)	BRICS/ 1990– 2015	Pedroni panel	GINI, GDP, INF, FD	There is an inverted U-shaped relationship between financial development and income inequality.
Kavya & Shijin (2020)	85 countries/ 1984 -2014	GMM	GINI, FDI, GDPPC, INF, URB, Trade	There is an inverted U-shaped relationship between financial development and income inequality in high-income countries; a U-shaped relationship in middle- and low-income countries.
Pata (2020)	Türkiye/ 1987-2016	CCR and FMOLS	GINI, FD, INF, URB, K	An inverted-U shaped relationship was found between financial development and income inequality.
Türkmen & Özbek (2021)	E7/ 1988-2016	AMG	GINI, FDI, GDP	While an increase in the financial development index reduces income inequality in Brazil, Mexico and Türkiye, it increases income inequality in China, Indonesia and Russia.
Sawadogo & Semedo (2021)	28 sub-Saharan African countries/ 2004-2016	Finite mixture	FI, GINI, IQ	In countries with high institutional quality, financial inclusion reduces income inequality.
Tekbaş (2022)	ASEAN-5/ 1992-2014	Dumitrescu -Hurlin causality	GINI,GDPPC, DPC	The effect of financial development on income inequality is not statistically significant.
Yılmaz Özsoy (2023)	41 developed and developing countries/ 2017	Canonical correlation	FD, GINI	There is a high level of correlation between financial development and income inequality.
Verma & Giri (2024)	Asian economies/ 2005-2019	FMOLS, ARDL, Granger causality	GINI, GDPPC, INF, CB, DA, OLH, DCP	In the long run, income inequality is greatly affected by financial variable indicators. There is also a one-way causality from financial participation indicators to income inequality.

Not: GDPPC: real national income per capita, DPC: private sector credit ratio in GDP used as a proxy for financial development, K: gross fixed capital stock per capita, TO: openness to trade, FI: Financial inclusion index, CB, number of bank branches per 100,000 adults; DA: number of deposit account per 1,000 adults, OLH: outstanding loan from commercial banks to household sector, DCP: domestic credit to private sector, IQ: institutional quality indicators.

When we group the studies into panel and single country examples, the following situation emerges:

- In a multi-country example, Topuz & Dağdemir (2016), De Haan & Sturm (2017), Türkmen & Özbek (2021) found that financial development increases income inequality; while studies such as Topuz & Dağdemir (2016), Türkmen & Özbek (2021), Sawadogo & Semedo (2021), Verma & Giri (2024) found that financial development decreases income inequality. Cong Nguyen et al. (2019), Younsi & Bechtini (2020), Kavya & Shijin (2020) found an inverted U relationship between the two variables.
- In the single country example, Kapingura (2017) found that financial development increases income inequality, while Shahbaz, & Islam (2011) found that financial

development reduces income inequality. Destek, Sinha & Sarkodie (2020) and Pata (2020) found an Inverted U-shaped relationship between the two variables.

The current study used the Türkiye sample. In the literature reviewed, Destek, Sinha & Sarkodie (2020) and Pata (2020) used the Türkiye sample and reached an inverted U-shaped result.

When the literature is examined, especially when looking at the variables used, the sub-components of financial development are not taken into account. This is perceived as a deficiency or inadequacy. The impact of the efficiency, depth and accessibility of the financial sector on the GINI index may vary. Therefore, it is necessary to evaluate the impact of various components of the financial sector on income inequality. This study aims to address the research gap in the literature.

3.Data Set and Method

3.1.Data

The aim of the study is to evaluate the impact of FD on the GINI index in Türkiye using the annual data set of 1987-2021. While the dependent variable is GINI, the independent variables are depth of financial institutions (FID), access to financial institutions (FIA), efficiency of financial institutions (FIE), depth of financial markets (FMD), access to financial markets (FIA) and efficiency of financial markets (FME). Contrary to the existing body of knowledge, Türkiye is analysed using six different financial development metrics. The data in this study relate specifically to banking activities carried out by financial institutions. The FID metric quantifies the proportion of pension funds, insurance premiums, mutual funds and bank loans allocated to the private sector. FIA provides data on the density of bank branches and ATMs per 100,000 adults. The Financial Institution Efficiency (FIE) metric covers information on loan-deposit margin, return on assets, costs to total assets and non-interest income to total banking sector income. Financial market data are mostly related to equity markets and debt securities. FMD aggregates the market capitalisation of financial and non-financial corporations, global government debt securities, publicly traded equities and the ratio of total debt securities to GDP. The Financial Market Efficiency (FME) metric includes the stock market turnover ratio. On the other hand, the Financial Market Access (FMA) metric measures the total number of lenders and market capitalisation per 100,000 adults and omits the ten largest companies (IMF, 2024).

Table 2. Variables, Definitions, Measurements and Sources

Variables	**Measurements**	**Sources**
GINI	Gini index	WB
FID	Financial institutions depth index	IMF
FIA	Financial institutions access index	IMF
FIE	Financial institutions efficiency index	IMF
FMD	Financial markets depth index	IMF
FMA	Financial markets access index	IMF
FME	Financial markets efficiency index	IMF

Note: To acquire more resilient outcomes, the variables are converted into their natural logarithmic form.

Table 3. Descriptive statics

	GINI	FIA	FID	FIE	FMA	FMD	FME
Mean	1.618362	-0.641376	-1.354479	-0.332391	-0.523418	-0.684806	-0.078962
Median	1.616869	-0.876059	-1.304746	-0.262931	-0.496223	-0.592681	0.000000
Maximum	1.647383	-0.230544	-1.140113	-0.215737	-0.388929	-0.347751	0.000000
Minimum	1.584331	-1.018761	-1.628816	-1.024819	-0.760706	-1.195979	-0.421448
Std. Dev.	0.015537	0.320642	0.147761	0.159374	0.105036	0.262950	0.150689
Skewness	-0.427787	0.150954	-0.472410	-2.765031	-1.004746	-0.837597	-1.511928
Kurtosis	2.659713	1.183003	1.882846	11.64545	2.954917	2.364377	3.471496

Jarque-Bera	1.236378	4.947581	3.121879	153.5996	5.891804	4.681680	13.65877
Probability	0.538919	0.084265	0.209939	0.000000	0.052555	0.096247	0.001082
Sum	56.64267	-22.44816	-47.40677	-11.63368	-18.31964	-23.96822	-2.763669
Sum Sq. Dev.	0.008208	3.495577	0.742335	0.863606	0.375109	2.350849	0.772048
Observations	35	35	35	35	35	35	35

As seen in Table-3, according to Jarque-Bera test statistics, FIE and FME do not have normal distribution, while other variables have normal distribution.

3.2.Method

The ARDL limits test possesses distinct characteristics in comparison to alternative cointegration tests. The ARDL bounds test, developed by Pesaran et al. (2001), serves as a technique for assessing data sets with varying orders of integration. The explanatory variables may be zero-order (I(0)) or first-order (I(1)) integrated, however the dependent variable must be exclusively first-order (I(1)) integrated. It is crucial to verify that neither the dependent nor the independent variables are concurrently second-order integrated (I(2)).

This methodology presents significant advantages over alternative methods. Initially, the analysis may be conducted on variables exhibiting varying levels of integration, I(1) and I(0). This method is equally efficacious when applied to samples of relatively modest size. The ARDL bounds test mitigates residual correlation issues through suitable lag selection methods, hence reducing the endogeneity problem. Furthermore, the methodology employed in this research yields unbiased estimates and statistically significant t-values, irrespective of the potential endogeneity of specific explanatory variables (Menegaki, 2020).

Initially, the Augmented Dickey-Fuller (ADF) test, a prevalent method for assessing data stationarity (Tunçsiper & Biçen, 2013), was employed. The limits test was subsequently performed to the created model, and cointegration was ascertained by comparing the F-statistic results with the critical values established by Pesaran et al. (2001). Subsequent to the identification of cointegration, long-term coefficients are computed using the ARDL model. Ultimately, short-run coefficients are computed utilizing the Error Correction Model (ECM). The Schwartz Information Criterion (SIC) was employed to ascertain the optimal lag length in model estimations. Multiple diagnostic assessments were conducted to evaluate the model's validity and suitability. The tests encompass the Breusch-Godfrey autocorrelation LM test, the Jarque-Bera normality test, the ARCH variance test, the Ramsey RESET model specification error test, and the CUSUM and CUSUM-SQ stability tests. These diagnostic tests are essential for evaluating the resilience and dependability of the model, hence enhancing the correctness of the results.

4.Empirical Findings

The initial phase of analyzing multivariate time series data typically entails performing unit root tests to evaluate the stationarity of the data. As previously stated, the ARDL estimate method requires the series to be either first order integrated (I(1)) or stationary (I(0)), whereas series that are second order integrated (I(2)) or higher are inappropriate for this approach. This study employed the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to investigate unit roots. The analysis findings are presented in Table 4.

Tablo 4. ADF and PP Unit Root Test Results

		ADF				**PP**				
		Level		**First Difference**		**Level**		**First Difference**		
		Test ist.	Prob	Test ist.	Prob	Test ist.	Prob	Test ist.	Prob	Sonuç
Constant	**GINI**	-1.6718	0.4360	-7.4925	0.0000	-1.62913	0.4572	-7.3013	0.0000	I(1)
	FIA	-0.4081	0.8967	-4.9663	0.0003	-0.5485	0.8691	-5.0172	0.0003	I(1)
	FID	-1.3469	0.5962	-6.6948	0.0000	-1.2479	0.6419	-6.7135	0.0000	I(1)
	FIE	-3.1876	0.0295	-7.3755	0.0000	-3.3135	0.0220	-8.7733	0.0000	I(0)

	FMA	-2.2668	0.1880	-5.1765	0.0002	-2.2777	0.1846	-5.1365	0.0002	I(1)
	FMD	-1.7269	0.4091	-7.9748	0.0000	-1.7176	0.4136	-8.5858	0.0000	I(1)
	FME	-18.870	0.0001			-2.3259	0.1700	-6.3830	0.0000	I(0)
Const. + trend	**GINI**	-1.4510	0.8267	-8.1180	0.0000	-1.1235	0.9100	-8.0635	0.0000	I(1)
	FIA	-1.6665	0.7441	-4.8889	0.0021	-1.8885	0.6384	-4.9465	0.0018	I(1)
	FID	-2.4166	0.3650	-6.6164	0.0000	-2.3750	0.3852	-6.7207	0.0000	I(1)
	FIE	-3.8421	0.0262	-7.3049	0.0000	-3.8670	0.0248	-8.6552	0.0000	I(0)
	FMA	-1.4200	0.8367	-5.3634	0.0007	-0.9819	0.9334	-8.8780	0.0000	I(1)
	FMD	-2.6233	0.2730	-7.9898	0.0000	-2.4769	0.3367	-12.851	0.0000	I(1)
	FME	-16.749	0.0000			-1.7927	0.6861	-6.8631	0.0000	I(0)

As shown in Table 4, the results of the unit root tests performed on the series indicate that some of the variables analysed in the analysis are stationary (I(0)), while most of them are non-stationary (I(1)). To clarify, it is important to note that all time series used in the empirical study are stationary after first differencing. This means that none of the variables are integrated of order 2 (I(2)). This means that there is no problem in using the ARDL approach for the series.

In the context of the ARDL bounds test, which is similar to unit root tests, the appropriate lag length is determined using the Schwartz Information Criterion (SIC). This choice is made due to the limited number of observations as suggested by Pesaran and Pesaran (1997). Based on the analysis, it can be concluded that the ARDL (3, 3, 0, 3, 2, 3, 1) model is the most appropriate choice. Table 5 shows the estimation results of the ARDL (3, 3, 0, 3, 2, 3, 1) model and the results of the diagnostic tests conducted on the model.

Table 5. ARDL Selected Model: ARDL (3, 3, 0, 3, 2, 3, 1) Estimation Results

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
GINI(-1)	-0.292165	0.179178	-1.630585	0.1340
GINI(-2)	1.023216	0.149428	6.847558	0.0000
GINI(-3)	-0.194548	0.116259	-1.673406	0.1252
FIA	0.073420	0.021781	3.370861	0.0071
FIA(-1)	-0.053071	0.020976	-2.530045	0.0299
FIA(-2)	-0.070110	0.025537	-2.745463	0.0206
FIA(-3)	0.107321	0.017350	6.185651	0.0001
FID	0.104207	0.034023	3.062812	0.0120
FIE	-0.059718	0.013398	-4.457153	0.0012
FIE(-1)	-0.035606	0.015427	-2.308017	0.0437
FIE(-2)	-0.048916	0.014945	-3.272993	0.0084
FIE(-3)	-0.034598	0.013604	-2.543213	0.0292
FMA	-0.228241	0.044180	-5.166194	0.0004
FMA(-1)	0.118688	0.029966	3.960754	0.0027
FMA(-2)	-0.125969	0.035049	-3.594095	0.0049
FMD	-0.047852	0.015352	-3.117045	0.0109
FMD(-1)	-0.062100	0.016813	-3.693594	0.0042
FMD(-2)	0.009971	0.013081	0.762279	0.4635
FMD(-3)	0.019947	0.013878	1.437237	0.1812
FME	0.051784	0.017894	2.893957	0.0160
FME(-1)	0.103758	0.030659	3.384268	0.0070
C	0.704159	0.190038	3.705362	0.0041
Diagnostic test results				
Normality (JB)	2.397640 (0.30)			
B-G Serial Cor. LM	1.956565 (0.20)			
Heteroskedasticity (Breusch-Pegan-Godfrey))	2.054957 (0.11)			

Ramsey RESET	1.803140 (0.104)
F-stat	20.67181 (0.000)
R2	0.97

Based on the diagnostic test results presented in Table 5, it can be seen that the ARDL (3, 3, 0, 3, 2, 3, 1) model shows no autocorrelation according to the Breusch Godfrey LM test. Moreover, the model shows variance changes in accordance with the Breusch-Pegan-Godfrey test and is free from functional form problems as indicated by the Ramsey RESET test. Furthermore, based on the findings of the Jarque-Bera test, it can be concluded that the residuals in the model have a normal distribution. Following the estimation of the ARDL model with lag orders (3, 3, 0, 3, 2, 3, 1), a bounds test analysis was performed to determine the existence of a long-term equilibrium link. To ascertain the cointegration relationship among variables in the ARDL limits test, it is essential to compare the F statistics with the critical values of the bounds proposed by Pesaran et al. (2001). Furthermore, when the sample size is constrained, it is essential to assess the F statistics in accordance with the critical values established by Narayan (2005). If the F statistic exceeds the critical value, it is suitable to reject the null hypothesis and hence affirm the presence of cointegration. If the F statistic value is below the lower bound, the null hypothesis cannot be rejected. The observed outcome signifies a lack of cointegration. When the F statistics reside between established upper and lower limits, the interpretation of the cointegration relationship becomes unclear. The findings of the ARDL limits test are displayed in Table 6.

Table 6. ARDL bounds testing results

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-stat	**9.498574**	10%	1.99	2.94
		5%	2.27	3.28
		2.5%	2.55	3.61
		1%	2.88	3.99

According to the results presented in Table 6, the F statistic value (9.498574) is greater than the upper critical value at the 1% significance level. This result indicates the existence of a long-run cointegration relationship between the variables in the model. In other words, according to the ARDL bounds test results, there is a long-run cointegration relationship between financial variable indicators and GINI index.

Table 7. Short-run error correction regression estimation results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GINI(-1))	-0.828668	0.097919	-8.462770	0.0000
D(GINI(-2))	0.194548	0.072037	2.700677	0.0223
D(FIA)	0.073420	0.009312	7.884382	0.0000
D(FIA(-1))	-0.037211	0.009821	-3.789062	0.0035
D(FIA(-2))	-0.107321	0.012666	-8.473124	0.0000
D(FIE)	-0.059718	0.006165	-9.687305	0.0000
D(FIE(-1))	0.083514	0.008872	9.413259	0.0000
D(FIE(-2))	0.034598	0.006302	5.489682	0.0003
D(FMA)	-0.228241	0.020695	-11.02853	0.0000
D(FMA(-1))	0.125969	0.016909	7.449990	0.0000
D(FMD)	-0.047852	0.007619	-6.280853	0.0001
D(FMD(-1))	-0.029918	0.006583	-4.544796	0.0011
D(FMD(-2))	-0.019947	0.006857	-2.908800	0.0156
D(FME)	0.051784	0.011480	4.510660	0.0011
CointEq(-1)*	-0.463496	0.040780	-11.36576	0.0000

According to the results presented in Table 6, the F statistic value (9.498574) is greater than the upper critical value at the 1% significance level. This result indicates the existence of a long-run cointegration relationship between the variables in the model. In other words, according to the ARDL bounds test results, there is a long-run cointegration relationship between financial variable indicators and GINI index.

Moreover, in order to analyse the impact of financial variable indicators on the GINI index, it is crucial to assess the long-term coefficients of the ARDL model. To fulfil this objective, Table 8 presents the results of the long-run coefficient estimation for the ARDL model.

Table 8. Lon-run error correction regression estimation results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
FIA	0.124184	0.044795	2.772274	0.0197
FID	0.224829	0.049019	4.586576	0.0010
FIE	-0.385844	0.101759	-3.791730	0.0035
FMA	-0.508141	0.124583	-4.078731	0.0022
FMD	-0.172675	0.063172	-2.733404	0.0211
FME	0.335584	0.096808	3.466504	0.0061
C	1.519233	0.084614	17.95489	0.0000

According to Table 8, FIA, FID, FIE, FMA, FMD and FME variables, i.e. each of the financial variable indicators, are statistically significant. While FIA, FID and FME variables have a positive sign in the long run, FIE, FMA and FMD variables have a negative sign. Therefore, it can be argued that the relationship between financial indicators and the GINI index is a relationship that yields beneficial results.

To assess the reliability of the research findings, the CUSUM and CUSUM of Squares structural break tests described by Brown et al. (1975) were calculated. This was done to account for any changes in the Turkish economy during the period analysed. Figure 1 shows the results of the CUSUM and CUSUM of Squares tests.

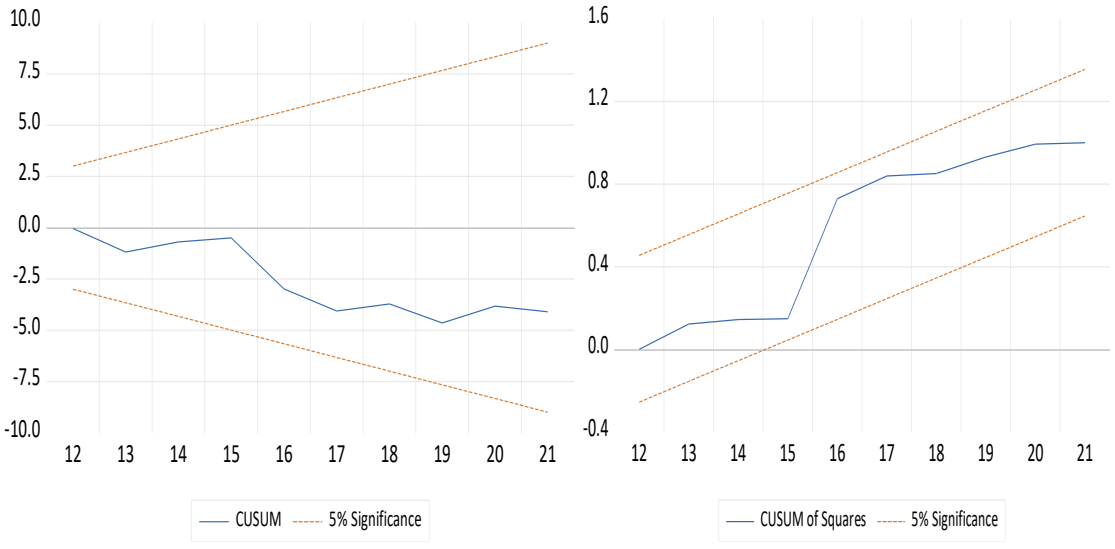

Figure 1. CUSUM and CUSUM of Squares Test Results

Figure 1 displays the outcomes of the CUSUM test and the CUSUM of Squares test; the left panel illustrates the former, while the right panel depicts the latter. The test statistics are observed to lie

within the 5% confidence interval based on the findings from both test outcomes. The estimated parameters stay inside the critical limits. Consequently, it can be inferred that the predicted parameters are unaffected by potential alterations in the data period.

5.Conclusion and Assessment

The present study analyses the relationship between financial development indicators and income inequality in Türkiye for the period 1987-2021. ARDL bounds test approach is used in the study. According to the findings;

- *The variables FIA (Financial institutions access index), FID (Financial institutions depth index) and FME (Financial markets efficiency index) have a positive sign in the long run. In other words, financial development indicators (FIA, FID, FME) increase income inequality.* The advancement of financial institutions and markets in Türkiye suggests that this progress may only benefit specific parts of society. Particularly when affluent people have enhanced access to financial services and utilize financial tools like asset investments more efficiently, this may exacerbate income disparity. In Türkiye, expanding access to and the depth of financial markets may result in the upper-income group exploiting available opportunities more, potentially exacerbating income distribution inequality. In this context, it is essential to broaden access to a larger proportion of the financial system and enhance the inclusivity of these services.
- *The variables FIE (Financial Institutions Efficiency Index), FMA (Financial Markets Access Index) and FMD (Financial Markets Depth Index) have a negative sign. In other words, financial development indicators (FIE, FMA, FMD) reduce income inequality.* The effective operation of financial institutions and markets in Türkiye could provide more optimal utilization of financial resources, allowing broader populations to benefit from these services. Enhancing access to finance, particularly for small and medium-sized firms, may enable lower income groups to derive greater advantages from financial services. The effective operation of the financial system may reduce income inequality by enhancing access to financial resources for small investors and businesses. The efficiency of financial institutions and markets in Türkiye must be enhanced, and these systems should be structured to encompass a larger population.

Based on these findings, the following policy recommendations can be made: (i) In formulating policies to enhance financial access in Türkiye, measures must be implemented to ensure that benefits are not only conferred onto the upper-income demographic. In this environment, the promotion of financial literacy is essential, and low-income populations should be incentivized to engage with banking and financial systems. The efficiency of financial institutions can facilitate the provision of lower-cost financial services. Reforms aimed at enhancing the efficiency of financial markets and institutions in Türkiye can ensure that lower-income segments derive greater benefits from these services, hence mitigating income inequality. (iii) To guarantee that financial services extend to broader demographics in Türkiye, the proliferation of innovative financial services, including digital banking and mobile payment systems, may effectively mitigate income disparity. Financial access initiatives can be established particularly in rural regions and for marginalized populations.

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THE IMPACT OF AI ON CLIMATE CHANGE & A SUB-SAHARAN ANALYSIS

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Abstract

Climate change is still a problem for society. Even while more people are aware of the problem, as a species, we have not yet adopted the drastic measures necessary to reduce carbon emissions. As the world consumes the carbon budget meant to keep us on course for an Earth warming of 1.5°C, we must use a diversified approach. AI needs to be included in the strategy. At the same time, the focus of this article is limited to one industry of many that require change; similar studies on the drawbacks of AI have been presented. The transportation, business, residential, and agricultural sectors can have benefits and drawbacks. Artificial intelligence has limitations that need to be acknowledged and controlled. Moreover, accepting AI's limitations should not imply rejecting its application when it makes sense to help with the challenging data issues associated with climate change. The issue is that this harm is unlike any other—not just in terms of its magnitude but also in that it is irreversible. It would be foolish to ignore the effects of climate change. Sub-Saharan Africa can benefit greatly from deploying AI technology to solve climate change issues by strengthening resilience, advancing resource management, and promoting sustainable development. To fully realize this promise, though, several critical issues about data infrastructure, local knowledge, morality, and legal frameworks must be resolved.

Keywords: AI regulations, Climate change, Legal analysis, Interdisciplinary study

JEL Codes: Q50, Q54

1.Introduction

Reports in the media suggest that robots will replace humans in our employment and that drones could learn how to conduct attacks on their own using machine learning. More pressing worries regarding the bias associated with algorithms used in criminal sentencing and facial recognition software have been noted by academics. All of these scenarios include different types of artificial intelligence (AI). Artificial Intelligence (AI) is a vague concept that has gained popularity recently. It outlines a collection of methods to use technology to approximate some facet of human or animal cognition. AI is available in a wide variety of formats. Machine learning is the most widely used prediction-making technique, and it works best with enormous volumes of data and processing power. The reaches of artificial intelligence (AI) has reached many facets of society, ranging from more commonplace applications in Google searches to more complex ones in criminal bail sentencing, driverless cars, e-commerce, digital advertising, and medicine. These methods, like most technical advancements, have the potential to produce both positive and negative results (Clarke, 2019).

This paper aims to present a more upbeat view of artificial intelligence (AI). It was written with the Yale Journal on Regulation's symposium on Regulating the Technological Frontier. It aims to remind its readers that artificial intelligence (AI) can be helpful even in the face of flaws and that specific applications, like weather pattern prediction, are less contentious than others. That technology can help solve some of the problems of society today.

It specifically looks at climate change, a huge issue in and of itself and ideal for more AI use. A federal circuit court has found that in the absence of action, the changing climate would bury cities, trigger catastrophic natural disasters, and imperil vital food and water supplies (Wairegi, Omino, & Rutenberg, 2021).

Carbon emissions "rose 1.7% in 2018 and hit a new record," despite abundant and consistent scientific evidence of the need to lower our global carbon emissions due to increased worldwide energy demand. The United States only managed to temporarily reduce global carbon emissions to levels comparable to the 8% experts estimate are required yearly to meet climate change targets during a pandemic and economic shutdown.

Most experts concur that concentrating on just four sectors, electricity, transportation, agriculture, and buildings, can significantly impact decarbonizing society. Only one is covered in this article: electricity. It is not meant to comprehensively analyze AI's uses in the energy sector. However, this article provides several policy considerations as more AI and climate-related suggestions surface. It shows some examples of how AI might be used to lower carbon emissions in the electric power industry (van der Vlist, Helmond, & Ferrari, 2024).

Climate change is among the most difficult issues confronting humanity. However, more pressing issues in an election cycle tend to take center stage in politics because the worst effects are more likely to manifest later. Experts in behavior even point out that people tend to downplay the worst threats to society as self-defense. Denial has a great psychological impact, yet it has minimal effect on one's grandkids. This section offers a succinct overview of climate change. It highlights the data and technical obstacles it faces and illustrates general AI climate applications that lower greenhouse gas emissions.

As a worldwide issue, climate change requires both adaptation to its consequences and reduction of carbon emissions. International scientists have collaborated to investigate the causes and effects of global warming, and they have concluded that the "dominant cause" of the extraordinary rises in global temperature during the Industrial Revolution has been human-caused increases in greenhouse gas emissions. According to a 2018 Special Report published by the Intergovernmental Panel on Climate Change (IPCC) of the United Nations, keeping global warming to 1.5°C will be essential to mitigate its adverse effects on ecosystems and human health and welfare (Taljaard & Gerber, 2022).

In order to avert the dire ramifications that would follow a two °C increase in global temperature, the IPCC estimated that greenhouse gas pollution would need to drop by 45% by 2030 and 100% by 2050. The report acknowledges that significant and swift reductions in emissions would be necessary to achieve these ambitious targets, along with "unprecedented changes in all aspects of society." Since transportation accounts for 29% of all carbon emissions in the US, closely followed by energy (28%), industry (22%), business and residential structures (12%), and agricultural (9%), significant adjustments to society will be required on many fronts. Both adaptation and mitigation techniques have been created by scientists, researchers, and politicians, with differing levels of political acceptance.

AI seems ideally suited to tackle these profound problems brought on by climate change. An overview of artificial intelligence (AI) and several instances of its application to prevent permanent environmental harm are given in this section. In today's world, artificial intelligence has become commonplace. What started with data scientists in the 1950s has become a widely used word. However, most AI articles still start by stating that the phrase is vague and can have many meanings. As was previously noted, artificial intelligence (AI) can be thought of as a collection of methods intended to simulate some feature of human or animal cognition through the use of machines. The fact that humans are not entirely aware of how our intellect functions may contribute to the difficulty in understanding this elusive idea. It might be simpler to embrace the gray areas of AI if we acknowledge the limitations of our current understanding. Our limited

understanding may also help to explain why, in contrast to the vast capacities of the human brain, artificial intelligence (AI) is frequently defined using examples that show the various types of cognitive tasks that computers can perform. These tasks include speech or facial recognition, problem-solving, and natural language processing. These examples are specific and narrow.

Therefore, it is crucial to first create distinct conceptual boundaries, if not precise definitions, between the following three fundamental concepts: data, analytics, artificial intelligence, and machine learning. These can be viewed as layered but separate notions, even if large data is necessary for all three to function. In the past, data analytics included people collecting enormous amounts of data to combine and examine its "commonalities" to identify correlations between variables. Humans make assumptions, and the data is "queried to test" those assumptions. Data analytics helps with payment settlement, operations, and forecasts in the power industry. Some argue that data analytics can accomplish most of what utilities need without the expense and complexity of AI and machine learning (Kőkuti, 2023).

However, there are situations when the added expense and complexity of AI and machine learning make sense. Machine learning is a common component of modern data analytics, enabling the process to go beyond simple data analysis by generating hypotheses, testing them, and developing them autonomously. Machine learning refers to a group of methods that use enormous volumes of data to train algorithms and allow for ongoing algorithmic improvement. The data is provided by humans, as are certain important parameters. However, the algorithm guesses what information to look for at each pass and then iterates the next estimate based on how well the prior guess performed.

The federal government may do some of this nonproprietary work and make it available to the larger scientific community. While researchers work to create helpful climate AI, this could help to reduce unnecessary duplication. These partnerships may run into well-known problems concerning client privacy, intellectual property rights, and trade secrets. Due to the extremely private and sensitive nature of the data, private utility data containing identifiable information might not be eligible for such a data-sharing project.

Climate change is one of the most important issues facing humanity in the twenty-first century in sub-Saharan Africa. The increasing rise in global temperatures as a result of greenhouse gas emissions from human activities highlights the pressing need for creative ways to both slow down the rate of warming and prepare for the effects already being felt. Artificial intelligence (AI) has emerged as a powerful tool with the potential to address various aspects of the climate crisis (Rolnick et al. 2022, 1). This research paper examines the role of AI in tackling climate change, with a particular focus on applications and challenges in Sub-Saharan Africa.

The rapid advancement of AI capabilities, driven by increased data availability, algorithmic improvements, and growing computational power, has enabled new approaches to climate modeling, emissions reduction, and adaptation strategies. Machine learning techniques, especially deep learning methods based on artificial neural networks, have demonstrated remarkable performance across diverse domains. AI offers tools to enhance our understanding of risks, optimize mitigation efforts, and develop targeted adaptation measures when applied to climate-related challenges.

However, implementing AI solutions for climate change faces unique obstacles in Sub-Saharan Africa. Limited regulatory frameworks, insufficient data infrastructure, and a lack of local AI expertise present significant barriers to adoption. Additionally, ethical considerations surrounding data privacy, algorithmic bias, and equitable access to AI technologies must be carefully navigated.

This research paper comprehensively analyzes AI applications for addressing climate change, examines the specific challenges and opportunities in Sub-Saharan Africa, and offers policy

recommendations to support responsible AI development and deployment in the region. By leveraging AI capabilities while addressing key obstacles, Sub-Saharan African nations can enhance their climate resilience and contribute to global mitigation efforts.

2. Chinese AI regulations

Lessons from China's approach to implementing AI could help Africa navigate this space. China's AI market, valued at $23.196 billion in 2021, is projected to triple to $61.855 billion by 2025, with the Chinese government projecting that AI will generate $154,638 million in income annually by 2030. However, China is not just interested in AI spreading and its creative applications. It has also been quietly setting the standard and leaving its stamp on the regulatory landscape for AI. China enacted and implemented three separate regulatory measures at the municipal, regional, and national levels in 2022. This trend continued into 2023 when China enacted national-level laws to crack down on deepfake and generative technology in just January (Roberts, et al., 2021).

China's Deep Synthesis Provisions became operative on January 10, 2023, as a component of the government's endeavor to fortify its oversight of deep synthesis technology and services. The provisions apply to both "deep synthesis service providers" and "deep synthesis service users". The first group consists of businesses that help them technically and provide deep synthesis services. The second group comprises entities and persons who generate, replicate, disseminate, or exchange information through sophisticated synthesis.

The laws define profound synthesis as technologies that use generative and/or synthetic algorithms, like virtual reality and deep learning, to produce text, graphics, audio, video, or virtual scenes (Smuha, 2021). Because of these laws' extensive reach, producing AI-generated material for 1.4 billion people will drastically alter. China's rule goes further than the UK's, which also plans to outlaw the production and distribution of deepfake videos without permission. The policy establishes guidelines for each step of the deepfake use process, including development, labeling, and distribution.

Furthermore, the law allows for the possible suppression of naturally captured content. Being one of the first nations to impose a deepfake regulation, there are concerns about whether China will use this law to further police freedom of expression too extensively. Nevertheless, discussions about what can be done to address the harms advocated by this technology are reviving. Whatever your position on the matter, the legislation does establish a precedent that may be partially repeated in other legal systems. We will learn more about implementing these laws this year (Tallberg, Lundgren, & Geith, 2024).

The Internet Information Service Algorithmic Recommendation Management Provisions went into effect on March 1, 2022. This law is comparable to the DMA and DSA laws passed by the EU. The guidelines, which China's Cyberspace Administration drafted, mandate that companies offering AI-based tailored suggestions in mobile applications respect user rights, such as shielding children from damage and enabling users to add or remove tags related to their traits. The three primary categories of the regulation's requirements are information service norms, user rights protection, and general provisions. Because they are expected to comply, the regulations impact US and foreign businesses that utilize algorithms and machine learning in their websites or applications operating in China. Several important clauses have to be taken into account (Sheehan, 2023).

Online service providers who also engage in online news must apply for special licensing under Article 13, which forbids the algorithmic creation of false information. Because it mandates that online service providers attend to the interests of senior consumers, particularly about fraud prevention, Article 19 provides additional protection for the elderly. Among many other things, the rule forbids phony profiles, faking traffic figures, and promoting material that is addicting.

Other less apparent clauses, which represent China's stance on AI ethics, require businesses to maintain conventional wisdom, spread good vibes with vigor, and prevent or lessen disagreements or conflicts. Like the DSA, China's recommender law requires more audits and openness for recommendation algorithms. As part of this regulation, China has established an algorithm registry to help learn about algorithms and ensure they operate within reasonable bounds. The security evaluation of registered algorithms is part of the registry. Nevertheless, it is unclear how much helpful information on black box technologies this registry will be able to offer. In the interim, such documentation and comprehension efforts are akin to those of the DSA and other EU laws, such as the EU AI Act.

China recently approved temporary generative AI regulations on May 23, 2023, effective August 15, 2023. The regulations are founded on five central tenets that aim to balance innovation and legal governance. China's essential socialist ideals must be upheld by generative AI, which cannot jeopardize national security or interests, encourage discrimination and other forms of violence, or spread false information (Hine & Floridi, 2024). It is vital to take action to stop discrimination originating from generative AI based on race, religion, country, area, gender, age, employment, and health. Generative artificial intelligence must uphold intellectual property rights and corporate ethics to prevent unethical competition and the disclosure of trade secrets. It is also necessary to take action to increase dependability, accuracy, and transparency. In order to facilitate this, the regulations mandate that generative AI providers perform data processing operations in a manner that maximizes the authenticity, accuracy, objectivity, and diversity of training data while adhering to legal data sources, protecting intellectual property rights, and obtaining consent for the use of personal information.

In addition to these laws that directly target AI, China's Personal Information Protection Law (PIPL), a government data privacy law, has implications for automated decision-making technology. It aims to secure personal information and address difficulties with personal data leakage. Adopted on August 20, 2021, and coming into effect on November 1, 2021, the PIPL imposes requirements on international firms operating in China and Chinese organizations to safeguard Chinese residents' privacy and personal information (Calzada, 2022). According to the law, any information, whether electronically or otherwise recorded, pertaining to a known or identifiable natural person within the People's Republic of China is considered "personal information" (PI). Similar to the EU's GDPR, PI does not include anonymized data that is non-reversible once anonymized and cannot be used to identify a specific natural person. The following are some of the primary contributions made by the PIPL, together with guidelines about impact assessments and automated decision-making (Cheng & Zeng, 2023).

More rights are granted to data subjects on how their data is used. They can ask to have their data edited or removed, have its usage restricted, or have their prior consent revoked. Stricter guidelines for data transmission and sharing, which your company and any joint data controllers from outside parties may need to meet to pass data evaluations. Required security measures must be used when processing and storing the PI, and authorized staff members handling the PI must get training; when the amount of PI is above the threshold established by the Cybersecurity Administration of China (CAC), mandatory data localization is required (Feng, 2019).

The following regulations apply to companies and people who process personal data in China or outside the country, provided the following requirements are met. It provides goods or services to natural persons in China, or personal information is processed. Furthermore, the analysis and evaluation of the behavior of natural persons in China or other situations specified by laws and administrative rules is granted. The processing of personal information by natural persons for domestic or personal purposes is exempt from the law. This covers situations requiring immediate action to safeguard people's lives, health, or property. Aside from these exceptions, personal information handlers who violate the PIPL may be fined up to 50 million RMB, confiscate their money (up to 5% of their yearly revenue), or shut down their firm (Cui & Qi, 2021).

The PIPL is important in regulating AI since it controls data, which is essential to AI. The PIPL operates in China, as recent instances demonstrate how the GDPR applies to AI in the EU. This is seen in China's deepfake regulation, which stipulates that organizations using deepfakes must abide by the country's current PIPL rules. China's Ministry of Science and Technology also released a New Generation Artificial Intelligence Code of Ethics on September 21, 2021, in addition to these rules. The National New Generation Artificial Intelligence Governance Professional Committee released the Ethics Code, which the Chinese Ministry of Science and Technology formed to investigate policy recommendations for AI governance. It offers guidance for natural and legal persons and other pertinent institutions and covers the entire life cycle of AI. The following are the primary contributions made by the Specification's general provisions. The first one is the enhancement of human well-being. This implies that AI systems ought to adhere to shared ideals, respect human rights and the core interests of society, foster harmony, enhance livelihoods, and adopt a sustainable strategy for the growth of the economy, society, and environment (Calzada, 2022).

The second is the promotion of justice and fairness. In order to advance equality of opportunity and justice, AI systems should be inclusive, effectively safeguard the rights and interests of those who engage with them, and distribute the advantages of AI throughout society. Respecting vulnerable populations and making accommodations where needed are important. The third is security and privacy protection. AI systems should respect user privacy and make sure that consent is sought before processing personal data. Data handling should be done safely, and personal privacy should be legally safeguarded. As seen above, the verticals of safety, privacy, and fairness are at the center of the Specification's general provisions. Management standards are urged to concentrate on the proper governance and use of authority in order to minimize AI hazards. The Specification also includes supply specifications that emphasize observing market regulations and making sure emergency plans are in place, as well as R&D specifications on data storage and use that center on security measures and equity (Cui & Qi, 2021).

Additionally, organizational management is encouraged to expand upon the Ethics Code and create policies that align with the requirements of the systems they employ by the organization and implementation rules. The federal government is not the only entity focusing on AI legislation; provincial and local governments are also involved. In contrast to national measures that are more restrictive, regional rules in China have offered a better balance between support for innovation and regulation. Regional laws seem to endorse industry and government best practices for advancing AI development. The province and local AI law in Shanghai and the Shenzhen Special Economic Zone are examined in this section (Dixon, 2023).

The provincial-level Shanghai Regulations, passed in September 2022 and enacted on October 1 of the same year, are intended to foster the growth of the AI industry. Regarding the creative advancement of AI, the rule is seen as industry promotion law. But the law also establishes a graded management system in light of AI's potential future effects. It implements sandbox supervision, which gives businesses a dedicated area to test and investigate new technologies. The Shanghai AI Regulation is unique because it allows for certain leeway for minor violations. This demonstrates a more significant commitment to promoting innovation and aims to continue encouraging the development of AI without burdening businesses or developers with the dread of strict regulation. This is accomplished by including a disclaimer that states that no administrative penalties will be applied for small infractions and that relevant municipal offices will compile a list of infraction behaviors. The rule also creates an Ethics Council to raise ethical awareness and act as a check and balance to the innovation-center strategy (Cheng & Zeng, 2023).

Like the Shanghai Regulations, the Shenzhen AI Regulation was passed in September 2022 and became operative on November 1, 2022, to advance the AI sector. The rule aims to encourage Chinese governmental entities, particularly those in the Shenzhen Special Economic Zone, to be at the forefront of AI adoption and research by increasing financing for these efforts. The policy

takes a risk-management approach to AI to support this expansion. It does this by permitting Shenzhen-based AI services and products deemed "low-risk" to continue their trials and testing without local regulations as long as international criteria are met. The regulation's Article 72 highlights the value of AI ethics and promotes risk assessments to find unfavorable consequences in systems and goods. The risk classification system will be developed and administered by the Shenzhen government. This is a significant development even though it's a local rule because Shenzhen is home to many AI and tech-related companies. Between 2021 and 2025, USD 108 billion is expected to be invested in this industry.

According to one perspective, China has observed how rules are increasingly being used to establish international norms and standards. In fact, China has been involved in some of the world's earliest enforcement of AI regulation, wanting to set that precedence for itself. However, there is disagreement about whether China's approach to AI regulation is a ploy for political advantage or a sincere attempt to limit the negative effects of AI system research and implementation. However, interpreting China's intentions in the AI regulatory arena in such a binary manner would be incorrect. China's efforts are undoubtedly driven by a desire to establish international norms. However, they also incorporate a multifaceted strategy aimed at regulating the negative effects of AI and comprehending "high-risk" algorithms rather than merely cataloging them. For instance, China is concentrating on the technical ramifications of digital services. In contrast, other regions of the world have prioritized bias and transparency, which is comparable to the goals of the DSA. Making a head start in this regard by trying to delve into the intricacy of black box technology and recommender systems through its algorithmic registry.

The regulatory landscape for AI in Sub-Saharan Africa is still in its early stages, with most countries lacking comprehensive frameworks to govern the development and deployment of AI technologies. This regulatory gap presents both challenges and opportunities for the region as it seeks to harness AI for climate change mitigation and adaptation.

Unlike regions such as the European Union, which has proposed the AI Act, or China, which has implemented various AI regulations, Sub-Saharan African countries have yet to establish cohesive national strategies for AI governance (Smuha 2021, 60), this lack of regulatory clarity can create uncertainty for AI developers and users, potentially hindering innovation and adoption in climate-related applications.

However, the absence of entrenched regulatory frameworks also provides an opportunity for Sub-Saharan African nations to develop forward-thinking policies that balance innovation with responsible AI governance. By learning from the experiences of other regions, African policymakers can create contextually appropriate regulations that address their specific needs and challenges (Tallberg, Lundgren, and Geith 2024, 220).

3.Methodology

This study employed an interdisciplinary approach, combining qualitative and quantitative data collection and analysis methods. A comprehensive literature review was conducted to identify the current state of AI applications in climate change mitigation and adaptation in Sub-Saharan Africa, as well as the analysis of the AI regulations and how these regulatory environments can be applied in Africa. This was done using a comprehensive review of academic publications, policy documents, and industry reports, which was conducted to establish the theoretical framework and identify key themes related to AI and climate change in Sub-Saharan Africa. This review encompassed global perspectives on AI for climate action and region-specific studies focusing on Sub-Saharan Africa. Additionally, Several case studies of AI applications for climate change mitigation and adaptation in Sub-Saharan Africa were examined. These case studies were selected to represent various sectors, including agriculture, renewable energy, water management, and disaster preparedness. The analysis focused on the implementation process, challenges encountered, and outcomes achieved. A survey was administered to a sample of stakeholders in

the region to gather information on the challenges and opportunities of AI adoption in climate change mitigation and adaptation.

This multifaceted approach allows for a comprehensive examination of the complex interplay between AI technologies, climate change challenges, and the specific socio-economic and regulatory context of Sub-Saharan Africa. By triangulating data from multiple sources and methods, the study aims to provide robust and nuanced insights into the potential impact of AI on climate change mitigation and adaptation in the region.

4.AI & Climate Change

Understanding the tradeoffs connected to these technical instruments will be critical if individuals accept artificial intelligence into the climate strategy. Like any new technology, artificial intelligence (AI) may be met with regulatory scrutiny, hefty initial expenditures, and mistrust.

It is possible that even well-established participants in the energy sector don't fully comprehend its potential and constraints, which makes it challenging for them to feel as at ease as those who depend on the existing quo. The following are some of the main tradeoffs that come with using AI more frequently to handle climate challenges related to electricity: (1) environmental implications, (2) data privacy, (3) investment and procurement, and (4) accountability. It also offers normative suggestions within each tradeoff for the best action with AI that best balances the conflicting demands of the public interest, consumers, and industry. AI can enhance grid efficiencies and minimize electricity use, but it can also be a significant electricity consumer. More than 2% of the world's electricity is used by data centers, and by 2025, analysts project that percentage to increase to between 21% and 8%. These figures could rise even more, according to a study that discovered artificial intelligence is using computer resources at an alarming rate. According to a study by the University of Massachusetts, developing a sizable AI model for handling human language can result in emissions that are around five times higher than those of the typical American car over its lifespan. The vast range of processing demands across the numerous varieties of AI may allay this worry. AI, as was previously mentioned, encompasses a wide range of methods, including machine learning. Depending on the intricacy of the task and the effectiveness of the used algorithm, each of these approaches has radically different computing requirements (Roberts, et al., 2021).

One of the most energy-intensive applications of AI, for instance, is the analysis of human language, which is the AI method assessed in the Massachusetts study. Thankfully, algorithms employed to lower the carbon intensity of the electric industry do not employ that strategy as much. The electric power industry may be able to prefer the less energy-intensive algorithms in order to lower emissions by being aware of the fluctuating energy demands. It will also be crucial to monitor how AI is applied in the oil and gas sector to improve productivity. The application of AI to fossil fuels may reduce the cost of emitting the associated emissions and provide them a competitive edge over less carbon-intensive resources, depending on the energy requirements of such algorithms. We must make sure that AI's benefits to the environment exceed its drawbacks before using it to tackle climate change. Thankfully, there are a few methods for doing that, three of which are covered below: Three things need to happen: (1) disclosure laws, (2) certification rules, and (3) more data exchange. The Allen Institute for AI suggested, as a first step, that AI researchers mention a range of computational and financial expenses in their reported results. Other academics also support the idea that more disclosure and exposure to environmental problems are needed. Recently, scientists created a carbon-emissions tracker for machine learning, which enables them to train their system with data and subsequently provide emissions totals. Researchers should disclose the amount of additional ecological expenses associated with AI, such as the raw materials required, heat and electrical waste produced, in addition to emissions. It is hoped that greater accountability and openness would encourage researchers to work harder to keep costs down and raise public awareness of the possible effects of algorithms.

To create a complete picture of the algorithm's possible effects, the Allen Institute of AI explicitly advises researchers to reveal data on carbon emissions, electricity consumption, real-time lapse, number of model parameters, and number of floating-point operations. Only when researchers are aware of the possible costs—a subject that is frequently left out of discussions on the training—can they weigh the advantages and disadvantages of an algorithm.

A second approach considers a certification requirement, imitating other environmental regimes. AI practices might be certified by the Allen Institute, which would designate carbon-neutral AI as "green" and noncarbon-neutral AI as "red." These badges, like those of other environmental certification programs, can have significant signaling implications that encourage businesses to internalize their electricity use. Similar to the regulation governing organic labels, this certification process may involve government authorities. However, there is a chance of greenwashing with these labels, much like with other environmental certification programs.

To minimize the environmental impact of AI's computational capacity, one last strategy would be to improve data sharing for algorithms connected to climate change. The primary input for algorithms is data, and the use of the data by one individual does not limit the use of the data by another. Because data is nonrivalrous, it can be considered a public asset in the same way that scientific knowledge is. The federal government may be a suitable partner for climate-related AI, just as it has a role to play in other areas of public goods. By acting as a clearinghouse for publicly accessible, anonymous electrical data, the federal government might reduce the amount of redundant duties associated with climate AI for the electric power industry, for example.

Congress began tackling these complex challenges back in 2005 by granting interested parties access to general smart-meter customer data. Following suit, the DOE and the White House introduced the Green Button Initiative in 2012. Customers of utility companies can now safely share their data with approved third-party service providers thanks to this effort. With approximately 3,000 utility and electrical suppliers in the US, the DOE reports that while about fifty utilities and suppliers of electricity have joined the project, there is still a long way to go. It's possible that the federal government may even centralize a few more phases in the process of creating high-quality AI. Energy is used in the processes of choosing, training, and deploying the model, as well as gathering, organizing, and splitting the data (Clare, et al., 2023).

The privacy implications of all this data are one of the unanswered questions in all applications of AI. For utilities, these are no less crucial questions. Because they have long-standing relationships with many of their customers—many of whom are captive ratepayers with no retail option—utilities are in a unique position of strength in this scenario. These consumers' data has always been accessible to utilities, and with the introduction of smart meters, access to more detailed data has increased. Concerns about privacy are especially bothersome with these smart meters. Smart meters are bidirectional, remotely accessible meters that can also be used to enable smart consumption and pricing applications of distributed resources such as rooftop solar. They can also convey voltage, current, and power information directly to utilities. If AI becomes stronger the more data it collects, then sharing data will be essential to putting AI technology into practice. In the US, there are currently about 86.8 million smart meters installed, making up roughly 56% of all meters. By 2030, that percentage is predicted to increase to 93%. "Smart sensor-equipped hardware and the deployment of advanced metering infrastructure (AMI) are enabling system operators to collect previously unheard-of volumes of data." This gives rise to worries about the personal data that can be obtained about people based on their activity patterns. These concerns include worries about unintentional or intentional monitoring, specifically targeted house invasions, profiling, behavior tracking, and identity theft. This presents new duties for the utilities as the data's custodians and poses significant queries regarding the handling, transferring, storing, and disposing of the data. Even in the setting of warrants for this data, the constitutionality of the government's access to this information has been questioned. The Seventh Circuit ruled in 2018 that gathering information from smart meters qualified as a Fourth

Amendment "search." Even though the data was gathered at fifteen-minute intervals, the court determined that it revealed information about the house that would not have been discovered by government agents conducting a physical search. Therefore, when [the utility company] gathers this data, it "searches" the houses of its people. However, after weighing the intrusion against the advancement of the lawful government interest in updating the electrical infrastructure, the court likewise decided that the search was reasonable. Contrary to what some state courts have said, a warrant was not necessary for this kind of data. Furthermore, the legislatures of at least one state have firmly opposed the need for warrants in order to access data from smart meters (Clarke, 2019).

These privacy issues directly contradict attempts to reduce redundant training and to make data sharing easier, which were previously mentioned and are thought to be essential to enabling a more modern grid. Stakeholders and policymakers may reduce the detrimental privacy implications of using all this energy data by taking a number of significant actions to resolve this dilemma. There are a minimum of two ways to support these kinds of partnerships: (1) strict protocols for encrypting energy data and (2) governing data ownership, both of which are covered in more detail below.

While addressing these issues about re-identification, the proposed Online Privacy Act of 2019 did not take a strong stand in favor of required anonymization. It did not require anonymization merely when it was not "an unreasonable amount of effort," but only where efforts to do so are "reasonable," a requirement that may prevent anonymization of vast volumes of data from smart meters. Controlling Ownership of Data. The regulation of data ownership, usage, and distribution would be a last resort. Customers of utility companies often have access to the data, although opinions on who owns the data and whether or not third parties can access it differ. Congress has already started to tackle these complex concerns, granting interested parties access to general utility-customer data, among other things.

One of the few states that specifically controls how smart-meter data is distributed is Colorado. Furthermore, a Massachusetts judgment pertaining to a proposed smart meter even took into account dividing ownership rights between the company and the customer according to who actually collected the data. Additionally, utilities are asked to implement the previously mentioned Green Button program, which gives customers quick and secure access to information about their electricity, natural gas, and water usage in a format that is user-friendly and computer-friendly. Utility users can access their data through this program, and if they so want, they can share it with others (Taljaard & Gerber, 2022).

Every day, AI systems utilize data to make crucial judgments about public policy. Therefore, most academics concur that some level of oversight is necessary. Professor Solow-Niederman goes one step further and argues that the regulation of AI algorithms is more appropriate than the regulation of data. However, she concedes that administrative law will need to change in order to properly control AI algorithms. The speed, intricacy, and unpredictability of AI would make it challenging to implement traditional prescriptive laws. Regulating the ownership of the data used in AI algorithms would be a smart place to start, as it will take time for public policy to require control of AI algorithms. This will ensure that AI applications are being created with the public interest in mind.

Funding is a crucial policy tool for encouraging the application of AI to climate challenges. Three source categories—private nonutilities, private regulated utilities, and public entities—may have financial difficulties, which are covered in this section. One-third of our nation's utilities are regulated. Therefore, they will face particular difficulties when integrating AI. Through ratemaking requests, state public utility commissioners (PUCs) approve the investments made by regulated utilities. These PUCs frequently have a low opinion of newly developed technology, are obligated to accept only the least expensive option, and only offer utilities a rate of return on

capital expenditures—not running costs. This presents challenges for utilities looking to leverage AI more broadly in three areas: cost, accounting treatment of AI investments, and future technologies.

Why aren't all the utilities utilizing AI if it can be a low-cost diagnostic tool for the electric business to lower greenhouse gas emissions? The challenges of achieving cost recovery for cutting-edge technologies might be part of the solution. State PUCs make the decisions about cost recovery for utility investments, including those in innovative technologies. The regulatory treatment of developing technologies is a significant aspect in the growth of AI to boost efficiencies across the power industry, given the requirement for many utilities to secure regulatory approvals of their expenditures in order to get cost recovery.

New technologies are constantly evolving and have not yet been thoroughly tested. Both nuclear power plants and combined-cycle natural gas plants were formerly seen as developing technology. Energy storage, smart meters, and renewable energy have been the hottest new technologies in the electrical industry during the past ten years, with differing degrees of success in terms of cost recovery.

Although there are a lot of commercial and financial prospects associated with emerging technologies, investors and regulators may become nervous due to a lack of knowledge about these technologies. Without evidence of recovering those expenditures, utilities may find it difficult to convince regulators to approve investments in power-grid infrastructure. Moreover, a lot of these new technologies' value propositions include difficult-to-quantify long-term savings or avoided expenditures. Apart from PUC reluctance, investors could also see these uncertainties negatively in their projected returns on investment (Smuha, 2021).

Examples of approved technologies that fell short of their potential further impede efforts to assist these emerging technologies. Customers may lose millions of dollars as a result of such missteps; Duke Energy's botched attempts to modernize and construct two nuclear facilities cost ratepayers more than $3 billion. In a related story, ratepayers in Southern California lost $3.3 billion due to a botched approval process for a nuclear repair project. Ratepayers' perception of the project's lack of success can be nearly as detrimental as its total failure, even in cases where it is not a full disaster. These setbacks frequently linger in the memory and can be devastating later.

There are a few tactics that can assist in protecting these investments, even though AI technology will occasionally suffer the same fate as these other new technologies. First, a large portion of the expenditures associated with software and hardware may be classified as more routine capital expenses. A line item would almost never refer to "AI"; instead, it would always refer to the more benign charges associated with computers. Second, by charging consumers upfront, utilities can shield themselves from the unpredictability of developing technologies. Third, state legislators have the authority to impose AI usage requirements, protecting the PUC from the majority of the investment risk. There have been estimates that utility investment in smart meters has more than doubled over the previous ten years as a result of some jurisdictions adopting this technique.

Emerging technologies frequently suffer from being perceived as riskier than incumbent technologies, which have years to work on efficiency improvements, as well as being more expensive. Novel research, design, testing, and production are some examples of how these extra expenses could manifest. Economic reasons like economies of scale also contribute significantly to cost increases for startups. And these expenses can really be very high. For instance, research discovered that in just six years, new medical technologies increased hospital costs by 25%. Another example is provided by renewable technologies. For many years, producing solar energy costs a lot more than using traditional energy sources like natural gas. The fact that solar power was still in its infancy and lacked the infrastructure necessary to make it really compete with conventional gas is at least partially to blame for that expense. However, because of the recent surge in demand for solar energy, costs have decreased to the point that they are now comparable

to those of conventional energy production. These days, the cost of wind power, particularly onshore wind power, rivals that of fossil fuels (Smuha, 2021).

Similar to this, using AI could come with a high learning curve. The use of AI may necessitate the purchase of new hardware and software, pay for cloud services, energy and data centers, pay for labor, training, system and business-process integration, and other costs. Additionally, training electricity-sector models to function as intended can be quite expensive as researchers strive to collect, purify, and utilize data. Similar to other developing technologies, it might be crucial to create a return on investment plan that accounts for some of the harder-to-quantify advantages of applying AI to the electrical industry, such as increased productivity, lowered expenses, fewer laborers needed, and more accurate outcomes. Comparing Operating vs. Capital Cost Accounting. The final reason AI may not completely benefit utilities is because of how it is classified in accounting. Regulated utilities obtain a healthy rate of return from their capital investments. This can provide them a perverse incentive to invest in new buildings (like natural gas plants) rather than in projects that could lower our energy use (like energy efficiency), as has been mentioned many times.

AI has the potential to produce a similarly illogical outcome. The majority of studies have demonstrated that a firm can save money by switching to commercial cloud computing instead of handling data domestically. However, because there are currently no financial incentives for utilities to adopt certain developing technologies, like cloud computing, they have historically been hesitant to do so. Utilities are encouraged to keep making capital investments through cost recovery for capital expenditures. However, consumers of commercial cloud computing frequently pay a monthly fee for these services, which in the realm of regulated utilities constitutes "operating expenses." Operating expenses, in contrast to capital expenses, are usually not recoverable through cost. As a result of this accounting classification, several utilities choose to conduct their internal data administration locally, which is a less-than-ideal outcome.

Rather, in 2016, the National Association of Regulatory Utility Commissioners (NARUC) adopted a resolution to review the accounting treatment of external cloud computing, hoping to remove the financial incentive to utilize the less efficient internal data management service. RESOLVED That NARUC encourages State regulators to examine whether regulatory accounting treatment for on-premise and cloud computing should be similar, given that both would be funded by a utility's capital budget and be eligible to earn a rate of return.

Illinois and New York are leading the way in allowing service-based emerging technologies to recover costs. Utilities in New York were authorized by the NY Public Service Commission (PSC) to capitalize software service prepaid contracts (Roberts, et al., 2021).

To put it simply, the PSC gave the utility companies permission to record the whole amount of the service contract as a regulatory asset in the rate base and prepay it in full. Illinois adopted an alternative strategy. The Illinois Commerce Commission suggested allowing utility companies to pay in advance for cloud services in January 2019. However, the Commission was about to approve a portion of the revenue from pay-as-you-go services, in which the utility pays according to how much it really uses the service. Following three years of proceedings, the Illinois Commerce Commission finally rejected the proposal on July 15, 2020, stating that it did not include the required consumer protection provisions.

Two commissioners voiced strong disapproval of Illinois's decision to remain "on the sidelines" rather than take the lead on this matter, pointing out the missed chance to guarantee regulatory certainty regarding the treatment of these external cloud computing services as assets, the environmental advantages that were forfeited, and the exaggerated worries about consumer protection given that these expenses would still need to be examined for "ordinary prudence and reasonableness." There hasn't been a significant reaction to the NARUC resolution outside of these two states. The Critical Infrastructure Protection Reliability Standards may be a barrier to

the use of virtualization and cloud computing services, but FERC has acknowledged the potential advantages of these technologies in relation to bulk electric system operations and has issued a Notice of Inquiry to gather feedback on these technologies' advantages and disadvantages. Therefore, in order to fully benefit from AI, nations might want to give such external cloud computing accounting choices more careful thought.

The remaining private participants in the electricity market, such as merchant plants, academic institutions, business owners, and startup renewable energy firms, are referred to as nonutilities. For instance, a global consortium of scholars has established an institution named "Climate Change AI." Climate Change AI aims to create cross-disciplinary teams and foster discussion on best practices for applying machine learning to climate change domains in order to facilitate work at the nexus of climate change and machine learning. These private companies might be more reliant on grants and support from the public sector for climate change and AI. However, it appears that the most recent wave of AI technology has brought with it a new flood of financing. With the backing of startup capital and corporations, AI investments are rising. Some might have the support of powerful, politically engaged corporations. The average early-stage financing for AI or machine learning firms was approximately $4.8 million in 2010, according to Forbes magazine. However, overall funding rose to $11.7 million in 2017, and AI raised over $9.3 billion in 2018, marking an all-time high for the field (Cui & Qi, 2021).

Public funding is essential to the success of AI for climate, in addition to commercial investment. All levels of government should search for ways to invest in AI related to climate change and modify their procurement practices to better utilize this technology. For instance, the EU government has been vigilant in securing funds for projects pertaining to artificial intelligence in recent years. Additionally, the US government has started to play a more active role in the application and advancement of AI. The Department of Energy has spent billions of dollars on new energy infrastructure that integrates AI technology to increase energy efficiency during the past ten years.

The final areas of concern are certification, safety, and responsibility. There are at least two parts to this. Initially, care must be taken to stop organizations from calling anything "AI" in order to get money, recover costs, and gain widespread acceptance. Second, procedures must be followed to guarantee that AI is operating as planned, which can necessitate using more explainable AI. Since no one can fully predict how AI will perform, it is currently very difficult to conduct "quality control" on it before releasing it onto the electrical grid. Steer clear of AI-Washing. The first issue is the so-called "AI-washing." It is crucial that AI not be treated as a catch-all for all issues regarding data processing, much like whitewashing and greenwashing. Despite being established since the 1950s, artificial intelligence has emerged from its AI winter in full bloom. Since AI has become more widely used and less obscure, many people can now benefit from its cache. Some claim that the phrase is used too loosely, with some equating it with machine learning. Some claim that a large portion of what some associate with AI can be achieved through data analytics. Mislabeling activities as artificial intelligence (AI) could undermine the credibility of real-world AI applications and limit prospects for real-world and forward-thinking (Tallberg, Lundgren, & Geith, 2024).

In the event that organizations designate their operations as "AI" in order to be eligible for specific benefits, AI may lose its meaning. Furthermore, it could call into question the validity of AI if organizations attempt to fit their operations into an "AI" box when such designation is dubious. Seeking the assistance of the Federal Trade Commission (FTC) could be one way to address this issue. Protecting consumers and competition by stopping unfair, deceptive, and anticompetitive business activities through advocacy, law enforcement, and education without unreasonably impeding lawful business operations is the mandate of this government agency. The FTC has the authority to investigate false or deceptive AI claims, publish guidelines instructing businesses on how to prevent deceptive labeling, and demand cooperation from parties asserting to employ AI.

The FTC has already regulated other sectors where label misuse is rampant and is also considering legislation to prevent bias in algorithms.

AI that can be explained. The credibility of the algorithm itself is impacted by the second issue. Trust in the system is essential if we are to make significant policy decisions on the output of climate AI. There is a global search for explainable AI (XAI), but it is especially important in areas where privacy and civil rights are concerned. A common definition of XAI is machine learning with the goal of addressing the decision-making process of AI systems and getting them to generate clear justifications and explanations. In summary, it provides an explanation for decisions by answering the "why?" question that most people have.

Explainability is crucial for AI in the electric sector as well, even though it's especially crucial in situations when AI is making decisions that impact a person's freedom. Because there is so much intricate processing involved in making a choice, it is challenging to understand how a neural network selects from inputs and makes its final judgment. This indicates that one of the main reasons AI has not been widely used in the electric power sector is the necessity for trials to confirm reliability.

AI in the energy and other climate-related sectors will need to become more transparent in order for its users to understand why the algorithm arrived at the conclusions it did, to be open to criticism, to reveal unknowns, and to allow for the correction of problematic training data.

This section does not imply that these are the only compromises. In fact, they only touch the surface of the complexity of the issues that will need to be addressed to more fully apply AI to address climate difficulties, given the space limits of an article. However, a good place to start for additional conversation is by recognizing and addressing the consequences of climate-related AI for the environment, privacy, investment, and accountability (Taljaard & Gerber, 2022).

The application of AI technologies to address climate change challenges in Sub-Saharan Africa presents both significant opportunities and unique obstacles. This section examines the current state of AI adoption for climate action in the region, highlighting key areas of impact, challenges, and potential solutions.

The first is related to climate modeling. AI techniques, particularly machine learning algorithms, have significantly enhanced climate modeling capabilities globally. In Sub-Saharan Africa, these advancements offer the potential to improve the accuracy and resolution of climate projections, which is crucial for informed decision-making on adaptation and mitigation strategies (Rolnick et al. 2022, 5).

However, the application of AI-enhanced climate models in Sub-Saharan Africa faces challenges related to data availability and quality. Many countries in the region lack comprehensive historical climate data and have limited weather monitoring infrastructure. To address this, initiatives are underway to combine satellite data with ground-based observations and leverage AI techniques to fill data gaps and improve the spatial and temporal resolution of climate information. One of the most famous cases is the improvements related to season forecasting. The CONFER project (Co-production of Climate Services for East Africa) is using AI and machine learning techniques to improve seasonal forecasts in East Africa. By combining traditional climate models with AI algorithms, the project aims to enhance the accuracy and lead time of predictions for rainfall patterns, which is crucial for agricultural planning and water resource management (CONFER 2023). As the case outlines, there is limited regulatory risk, but it presents a transboundary challenge given that rainfall patterns and climate events are happening across borders, requiring external entities to share these data.

Another critical area of AI regulations in Sub-Saharan Africa relates to agriculture and food security. Agriculture is a critical sector in Sub-Saharan Africa, both in terms of economic importance and vulnerability to climate change impacts. AI applications in agriculture offer

significant potential to enhance resilience and productivity in the face of changing climatic conditions. AI-powered precision agriculture techniques can optimize resource use, improve crop yield predictions, and provide early warning systems for pests and diseases (Rolnick et al. 2022, 35). To enhance food security and protect ecosystems, machine learning algorithms, for instance, can monitor crop health, soil moisture, and changes in land use by analyzing satellite photos. Food security represents a critical area where Chinese AI regulations have had a significant focus, especially in terms of data hosting for critical infrastructure. While individual farms may not fall under this classification, overall data on food security and agricultural performance may be considered to fall within this category.

While there is currently limited access to technology and digital infrastructure in rural areas, it presents a significant barrier to the widespread adoption of AI-powered agricultural solutions. Additionally, ensuring that small-scale farmers can benefit from these technologies without exacerbating existing inequalities is a key concern. One of the solutions is to develop mobile-based AI applications that can function with limited connectivity, and partnering with local agricultural extension services to provide training and support can help bridge the technology gap. Initiatives like Digital Green in Ethiopia are using AI-powered video recommendations to disseminate best practices to smallholder farmers, demonstrating the potential for inclusive AI adoption in agriculture (Digital Green 2022).

Another key area for AI regulations is renewable energy integration. The transition to clean energy sources is crucial for reducing greenhouse gas emissions in Sub-Saharan Africa. AI plays a vital role in optimizing renewable energy systems and improving grid efficiency, particularly in the context of decentralized and off-grid solutions that are well-suited to many parts of the region.

Machine learning algorithms can forecast renewable energy generation from solar and wind sources, enabling better integration of these variable resources into power systems (Rolnick et al. 2022, 15). AI-powered smart grid technologies can balance supply and demand in real time, reducing waste and improving overall system efficiency. In Kenya, the company SunCulture is using AI to optimize solar-powered irrigation systems for smallholder farmers. The AI algorithms analyze weather data, soil conditions, and crop water requirements to automatically adjust irrigation schedules, improving water use efficiency and crop yields (Sun Culture 2023).

There have been several challenges, such as the development of AI solutions for renewable energy integration in Sub-Saharan Africa being hindered by limited access to high-quality energy data and a lack of local expertise in both AI and energy systems engineering. An alternative that has been outlined is investing in data collection infrastructure and capacity-building programs that combine energy sector knowledge with AI skills, which can help address these challenges. Regional collaborations, such as the African Development Bank's Desert to Power initiative, can provide platforms for knowledge sharing and joint development of AI solutions for renewable energy (African Development Bank 2022).

Disaster management is a crucial area in which AI regulations should be applied. Artificial intelligence (AI) has a critical role to play in disaster preparedness and response as climate change intensifies and increases the frequency of extreme weather occurrences in Sub-Saharan Africa. In order to forecast the possibility and possible consequences of natural disasters like floods, droughts, and storms, machine learning models can examine both past data and present circumstances (Rolnick et al. 2022, 45). AI-powered early warning systems can help communities prepare for and respond to climate-related disasters more effectively. Additionally, in the aftermath of disasters, AI can assist in damage assessment and resource allocation for recovery efforts. For example, the FEWS NET (Famine Early Warning Systems Network) is incorporating machine learning techniques to enhance its food security forecasting capabilities in Sub-Saharan Africa. By analyzing satellite imagery, weather data, and socio-economic indicators, the system

provides early warnings of potential food crises, allowing for more timely and targeted interventions (FEWS NET 2023). The challenge is that the effectiveness of AI-based disaster preparedness systems depends on the availability of reliable data and the ability to communicate warnings to vulnerable populations, which can be limited in many parts of Sub-Saharan Africa. In order to overcome this, developing partnerships between national meteorological agencies, telecommunications companies, and local communities can help improve data collection and dissemination of warnings. Initiatives like the TAHMO (Trans-African Hydro-Meteorological Observatory) project are working to expand weather monitoring networks across Africa, providing crucial data for AI-powered early warning systems (TAHMO 2023).

5.Conclusion

The problem of climate change still affects civilization. Although people are becoming more conscious of the issue, we have not yet, as a species, taken the extreme measures required to reduce our carbon emissions. We must continue to employ a diversified approach as the globe eats away at the carbon budget intended to keep us on track for an Earth warming of 1.5°C. AI must be incorporated into the plan. Although this article only focuses on one of the many industries that need to change, comparable research on the tradeoffs of AI's

Regarding the transportation, commercial, residential, and agricultural sectors, there could be advantages and disadvantages. The limitations of artificial intelligence must be recognized and moderated. Furthermore, acknowledging AI's limits shouldn't mean avoiding its use where it makes sense to assist in addressing the complex data difficulties related to climate change. The problem is that this harm is unique from all others, not only because of its size but also because it cannot be undone. Ignoring the effects of climate change would be unwise. The application of AI technologies to address climate change challenges in Sub-Saharan Africa holds immense potential for enhancing resilience, improving resource management, and supporting sustainable development. However, realizing this potential requires addressing significant challenges related to data infrastructure, local expertise, ethical considerations, and regulatory frameworks.

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GREAT RECESSION VS CORONAVIRUS: EVALUATING HEALTH AND ECONOMIC CRISIS IMPACT

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Abstract

The Great Recession and the Coronavirus Pandemic represented two major economic shocks experienced by world economies in the 21st century. These two crisis periods carried uncertainties regarding risk estimation and possible outcomes and dragged economies into recession. They created the need for large-scale monetary and fiscal policies. These crises, which have similarities, differed in terms of root causes. The global crisis was characterised as an infection of the financial system due to the mortgage crisis, excessive leverage and low-quality retail loans. Economic stagnation due to the coronavirus pandemic, on the other hand, was defined as a global shock caused by the policies implemented to contain the disease. The coronavirus triggered the biggest global economic crisis that the world economy has experienced in about a century. While the Great Recession was a result of the existing structural problems of economies, the pandemic created a global state of war. The nature-based nature of the health crisis has created great uncertainty in terms of the consequences and duration of the pandemic, and pessimistic expectations about the future have shaped the economy. Isolation practices put in place to prevent the spread of the disease during the pandemic suspended global trends in the following period. Travel bans were imposed and world trade came to a standstill. Although there are some similarities in terms of their outcomes, determining the character and policy responses to economic and health crises, understanding the mechanism of crises, and drawing lessons from the past will help to find the most effective solution in a possible situation. In this study, the effects of both crises on economic indicators will be examined in depth and comparative analyses will be presented.

Key Words: Financial crises, crisis management, public health

JEL Codes: G01; H12; I18

Introduction

The 2008 Global Crisis and the 2019 Coronavirus Pandemic represent two major economic shocks experienced by world economies in the 21st century. The 2008 global crisis as a financial crisis and the COVID-19 pandemic as a health crisis differ in terms of their origins. The 2008 global crisis, as a mortgage crisis, was characterised as an infection of the financial system due to excessive leverage and low-quality mortgage loans. The coronavirus viral outbreak, on the other hand, has been described as a global economic shock caused by the policies implemented to control the disease (Spatt, 2020). The COVID-19 pandemic created economic stagnation as a result of a global epidemic completely outside the economic system. In particular, this pandemic triggered the biggest global economic crisis that the world economy has experienced in about a century. Countries have been dragged into serious inequality within themselves and on a global scale. In addition, the vulnerabilities that existed in emerging economies before the pandemic have deepened. The global crisis was triggered by the bursting of the bubble in the US real estate market as a result of the high debt levels of households (ETH Zurich, 2021; World Bank Group, 2022). In other words, while the coronavirus pandemic caused by the SAR-CoV-2 virus created

an exogenous shock in the economy, the global financial crisis is expressed as an endogenous shock originating from within the system that started in the US mortgage market. Therefore, while the global financial crisis is in a sense the result of the existing structural problems of economies, the pandemic has created a situation of global war. The nature-based nature of the health crisis has also created an uncertain situation in terms of the consequences and duration of the pandemic. The isolation practices put in place to prevent the spread of the disease during the pandemic period also suspended global trends in the following process. Countries closed their borders, bans were imposed on travel, including airlines, and world trade came to a standstill. Therefore, it is possible to state that industrial production, consumption expenditures, total business stocks and unemployment suffered more serious blows in the early stages of the pandemic (Li et al. 2022). Unlike the global crisis, there was a greater decline in social work during the pandemic period; while the decline in teleworking and some basic jobs was relatively moderate, it was also temporary (Shibata, 2021). In addition, the coronavirus pandemic created a simultaneous collapse in the supply and demand side of the economy, while the Great Recession penetrated the entire system as the accumulated risks that started in financial markets began to unravel. In sum, nearly ten years after the Great Recession of 2008, a second major economic recession hit households, firms, financial institutions and policymakers socially and economically. While the economic impacts of both crises are similar to some extent, they diverge at some points. Within the scope of this study, economic crisis and health crisis phenomena will be discussed in the context of the Great Recession and the Coronavirus pandemic. The causes, consequences and similarities of the crises will be evaluated comprehensively, and a projection of possible future crises will be presented.

Economic Crisis: 2008 Global Financial Crisis

The Global Financial Crisis refers to the period of extreme stress and pressure in global financial markets and banking systems between the second half of 2007 and early 2009. During the global crisis, the fall in the US housing markets spread to the rest of the world through highly integrated financial markets. This process was characterised by the collapse of several financial institutions, large and small, millions of job losses and deep recessions across the globe. It was even characterised as the deepest recession period since the Great Depression of 1929.

It is also possible to go back to earlier periods for the roots of the global crisis. The US becoming the centre of financial capital and the international flow of financial assets dates back to the period after the 1973 Arab Oil Embargo, when the world capitalists invested their accumulated capital in the New York Stock Exchange and US banks, making the US the centre of financial capital. This put the US at the top of the imperialist pyramid and led to the US economy being seen as an invincible power for the capitalist system in the late 20th century (ICSS, 2009). This process of accumulation, which lasted until 1973-74, was increasingly dominated by the transnationalisation of production, and under the increasing role of monopoly enterprises, capital spread almost all over the world. However, since profits started to be generated through financial mechanisms in this period, a process was entered that led to the formation of housing and stock bubbles, creating instant millionaires, which led to social instability in society (ICSS, 2009; Lapavitsas, 2013). The global crisis also stemmed from this short-term profit motive. Therefore, the current conjuncture just before the financial crisis created an economic environment that discouraged real investment and led to the withdrawal of high-quality borrowers from the lending market (Neal, 1997).

In the years leading up to the global financial crisis, economic conditions in the US and other countries were quite favourable. Economic growth was stable, while inflation, unemployment and interest rates remained relatively low. In this favourable environment, house prices also increased strongly. The prospect of rising house prices encouraged households in the US to buy and build houses (Australian Bureau of Statistics, 2010). At the same time, since the mid-1990s, the revolution in digital technology and the impact of the development of information technology have led to several trends, such as increased productivity, shorter business cycles, flexible labour

markets and lower unit costs. This process was accompanied by a decline in real wages. Households integrated financial markets to meet their consumption and investment needs (Monthly Review, 2001; Wolff, 2016). This technological revolution created a situation of overvaluation in internet-based company shares. The potential profitability of Internet technology increased the investment appetite; there was a serious demand even for shares that did not have a sustainable business model and could not generate profits. In the early 2000s, this unsustainable speculative bubble burst and an economic recession was experienced in 2001. The origins of the crisis also lie in the low interest rate policy implemented by the FED to overcome the economic recession in the early 2000s. Policies aimed at short-term interest rates reduced the costs of floating-rate mortgage loans and led to an increase in housing demand and, accordingly, housing prices (Polat, 2018).

The ratio of financial assets to GDP, which is known as financial deepening, reached 359% in 2007. In 2000, only 11 markets had a financial asset-to-GDP ratio exceeding 350 per cent, whereas by the end of 2007, this number had risen to 25, with some emerging economies such as China and South Africa joining the ranks. This means borrowers with wider access to capital, more efficient pricing, portfolio diversification and risk sharing. However, as experienced during the Great Recession, it sometimes manifested itself in the form of unhealthy increases in government debt and asset market values. In 2007, global capital flows also increased significantly, rising by 19 per cent over the previous year to reach USD 11.2 trillion. This figure was higher than the compound growth rate of the post-1990 period. Cross-border loans and deposits, hedge funds, private equity funds and insurance companies have also proliferated. Banks have chosen to finance their liquidity needs from global markets rather than national markets. The increase in capital flows has also led to foreign ownership. In fact, between 2002 and 2007, one out of every four debt securities and one out of every five equities were owned by foreign investors (Blankenburg and Palma, 2009; McKinsey & Company, 2008).

The democratisation process in financial markets was accompanied by a series of trends such as flexible regulations of governments, institutions' disregard for risk, large-scale resource transfers to the US and other economies from emerging economies such as China, and an expanding pool of lendable funds due to relatively low-cost loans. Expectations that house prices would continue to rise during this period paved the way for excessive borrowing. Although many of the mortgages were at or above the purchase value of the house, it was hoped that rising house prices would lead to a profit upon sale. As mentioned earlier, the disregard for risk and credit incentives despite risk led to the creation of asset-backed securities comprising thousands of individual mortgage loans of varying quality and to the spread of risk. Banks thought that they were not taking any risk in doing so; it was assumed that even if one or more of the loans, which were divided into small pieces with the new financial instruments they had developed, defaulted, the impact would be very small (Keeley and Love, 2010). The warming structure of the US economy was accompanied by a rise in inflation. At this point, astronomically rising house prices created a surplus in the supply of real estate, and to rein in the economy, interest rates were raised. Increasing interest rates led to loan defaults and created a liquidity crunch in bank balance sheets. At this point, housing demand started to decline and at the same time, mortgage securities started to lose value rapidly. Eventually, a financial crisis started in mid-2007 and escalated sharply in September 2008, creating turbulence in financial markets. In addition to equity markets, private debt markets also suffered serious losses and major financial institutions, including large financial institutions, underwent restructuring processes. This crisis created a unique situation extending to the financial sector on the one hand and the real sector on the other. The 2008 Great Recession primarily affected developed countries, and the US and EU countries were dragged into recession. At the end of 2007, a series of urgent measures were taken to improve financial markets and institutions to control the recessionary process that the US economy entered into. China, on the other hand, emerged from this economic devastation alive and strong. It even supported growth

in an emerging economy. The late 2008 and early 2009 global turbulence gave way to a V-shaped economic recovery (Reinhart, 2022).

Health Crisis: 2019 Coronavirus Pandemic

The coronavirus pandemic has created a serious fear of death, turmoil and distress worldwide. Although the pandemic phenomenon, whose impact is felt in daily life with Covid 19 and has become frequently repeated, seems to be a part of the modern world, the world has struggled with a series of deadly epidemics. Pandemics such as the plague, Spanish Flu, HIV, and Ebola have brought about many negative financial and psychological situations, from the collapse of political regimes (Sampath et al., 2021). Although pandemics, which reach large masses and carry the risk of death, have been experienced since the primitive periods of history, a single definition accepted as a term has not been possible. However, for a disease to be characterised as a pandemic, it has been emphasised that it must spread to large geographical areas through transmission with high attack rates. In addition, it was stated that the virus, which spreads exponentially through transmission, should be novel, in other words, it should define diseases associated with new and/or at least new variants of existing organisms (Morens et al., 2009).

According to Pitoya (2020), pandemics that affect the whole world repeat themselves within about a century. The coronavirus pandemic caused by the SARS-CoV-2 virus also had these basic characteristics and showed a rapid spread worldwide after it was detected in China in December 2019. On 30 January 2020, the World Health Organization (WHO) declared it as a Public Health Emergency International (PHEIC) and on 11 March 2020 as a pandemic. The point to be emphasised at this point is that health crises, including the coronavirus pandemic, are not events that will be solved only with antiviral treatments, vaccines and health protocols. Pandemics, which also have economic and political consequences, create traumas in society and create social problems with the effect of limitations and gaps in access to health services. In addition, these health crises deepen existing structural problems in economies, and efforts to alleviate the burden of disease create additional damage (Pitoya, 2020; WHO, 2024). Reinhart (2022) emphasised that the coronavirus pandemic differs greatly from past health crises, and what makes this crisis unique is the comprehensive quarantine, international travel bans and bans on public events imposed by governments around the world. Although the coronavirus crisis did not start as a financial crisis, there was a transition towards a financial crisis. The closure and restriction measures introduced in the fight against the disease created a financial system that faced collapses in production, an increase in unemployment and poverty, and non-performing loans worldwide.

In its report published in June 2020, the International Monetary Fund (IMF) revealed that while the effects of the pandemic continue, it is just as difficult to revitalise economic activities. Although comprehensive shutdown and restriction measures were ended in many economies in May and June of the relevant year, the recovery process showed a highly asymmetric distribution among countries (IMF, 2020). Therefore, the pandemic first created a shock wave on the world economy and deepened the existing inequality among countries. Unlike economic crises, this health crisis first led to a significant increase in private and public debt levels with the effect of interventions to prevent the spread of the disease (World Bank Group, 2022). The pandemic has affected economic activities in a wide spectrum from tourism to medical supplies, electronics to financial markets, and food energy. It caused disruptions in the global value chain due to border controls. In particular, partial or complete closures in non-core and more service-oriented sectors such as entertainment, food and beverage have affected socio-economic groups in different ways. Sectoral closures have led to layoffs for relatively low-income workers who do not have the opportunity to work remotely (Jackson and Weiss, 2020; Pangallo et al., 2024). In summary, although the coronavirus pandemic as a health crisis does not create an economic crisis on its own, the negative effects of the disease on public health and measures to mitigate these effects create a process leading to recession. At this point, comparing the coronavirus pandemic with the global crisis in terms of its economic effects is very important in terms of understanding the crisis

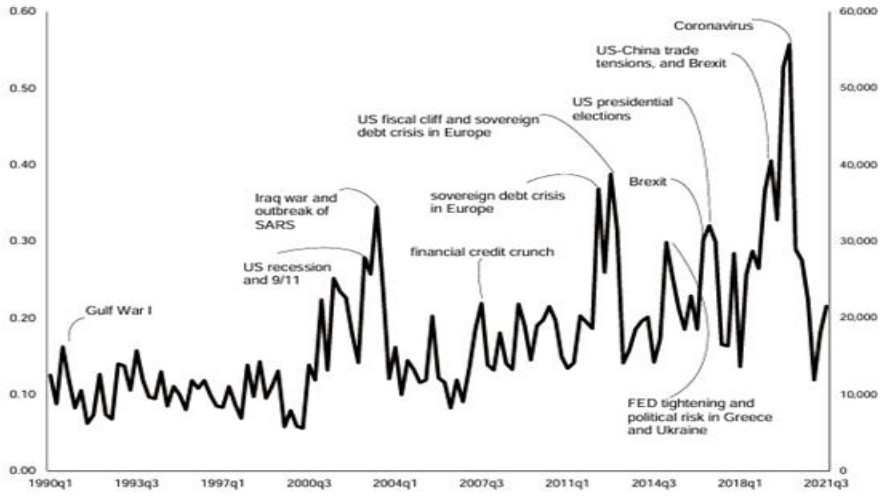
mechanisms, the relationship between public health and economic indicators, and the possible long-term consequences.

Economic Impacts of the 2008 Global Crisis and the Coronavirus Pandemic

Strauss-Kahn identified three important similarities in both crises. Firstly, he emphasised that the phenomenon of ***uncertainty*** leads to a process that estimates possible risks difficult or even impossible. Before the 2008 global crisis, subprime loans provided to Americans with low creditworthiness concealed the existing risks, while derivative financial instruments transferred this risk to economic agents. Until the asset bubble burst, the amount and location of the risk remained unknown; a process that could not be solved in the short term, including policy responses, was entered into. During the pandemic crisis, almost half of the world trade was suspended, businesses stopped their activities, there was a sudden increase in unemployment, and there was no prediction as to how long this process would continue due to the lockdown in economies (Strauss-Kahn, 2020).

Ahir et al. (2022) created the 'World Uncertainty Index' based on the frequency of the word 'uncertainty' used in the quarterly reports of the 'Economist Intelligence Unit' for 143 countries since 1952. The index has risen around major global events such as the Gulf War, the Euro Debt Crisis, the Brexit vote and the Covid-19 pandemic. The level of uncertainty was found to be higher, especially in emerging economies. In Figure 1, Ahir et al. present the fluctuation trend of the World Uncertainty Index depending on social events such as political, economic and public health. In this picture, it is seen that the highest uncertainty is felt especially during the coronavirus pandemic. Many economies simultaneously entered into a multi-layered process of health shocks, domestic economic disruptions, declining external demand, and a reversal in capital flows. The extreme uncertainty in global growth forecasts depended on the intensity of the measures implemented to contain the course of the pandemic. Changes in spending patterns, fluctuating commodity prices, and the extent of supply disruptions have been important factors in this context (Long and Ascent, 2020).

Figure 1. Uncertainty Index



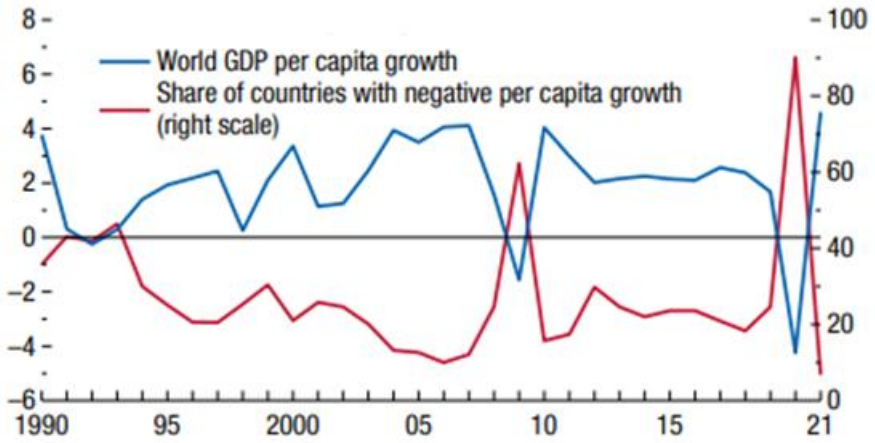
Source: Ahir et al, 2022

Another similarity between the global financial crisis and the coronavirus pandemic was the **massive collapse** of economies (Strauss-Kahn, 2020).

Figure 2 shows the growth in world GDP and the share of countries with negative growth in per capita income in the 1990-2021 time period, including the global financial crisis and the coronavirus pandemic. It was found that both global events turned GDP growth figures into negative in the period depicted, and this effect was felt more intensely during the pandemic

period. Especially during the pandemic period, the uncertainty about the spread of the disease created structural changes in the behaviour of households and firms, causing supply chain disruptions, bankruptcies and a decrease in investments (Long and Ascent, 2020, p.6).

Figure 2. GDP Growth and Recessions

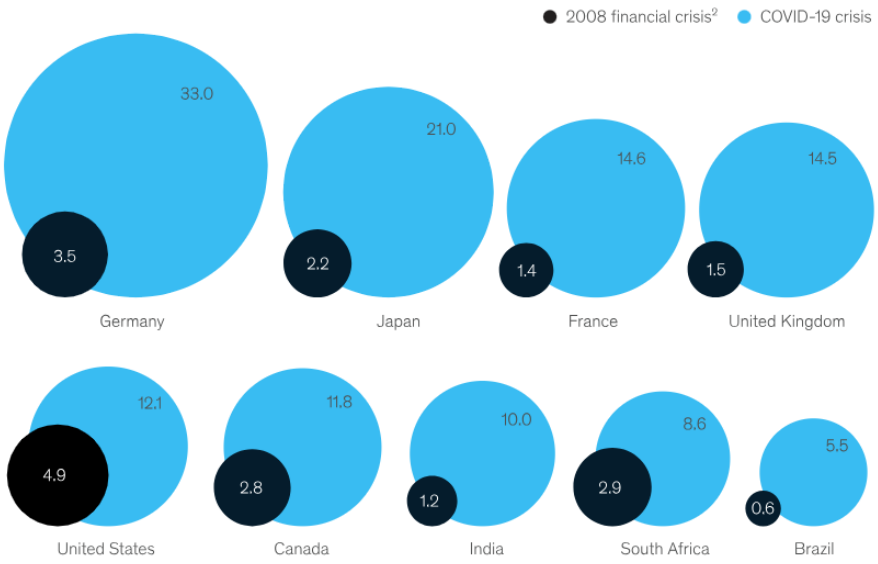


Source: Long ve Ascent, 2020

The monetary and fiscal policies implemented to limit the economic impact of the Great Recession and the coronavirus pandemic are remarkably similar in scope and scale. The US Government Accountability Office (GAO), the highest audit agency of the US federal government, stated in its 2021 bulletin that the Great Recession that began in the US in December 2007 was the worst downturn since the Great Depression. In this context, GAO implemented an $800 billion Recovery and Reinvestment Act to support economic recovery, while at the same time assigning several additional responsibilities to ensure transparency in spending. A Troubled Asset Relief Program was also launched to address the housing crisis. A series of adjustments were made to maintain stability in the country's housing finance system. The pandemic period was similarly a period of large-scale support packages for households, businesses, the health system, states and local governments. Federal government expenditures included vaccine development, vaccine distribution, lending to small businesses, unemployment payments, social benefits, tax deferral, housing protection, and a range of support packages (GAO, 2021).

The European Central Bank launched a €750 billion temporary purchase program under the Emergency Purchase Program. In particular, it aimed to stabilize the risks in the euro area and to equally support the citizens of the euro area and its institutions, including firms, banks and governments (ECB, 2020). Even with the lessons learned from the global financial crisis, governments have been quick to introduce emergency fiscal stimulus programs (Duncan, 2020). Figure 3 shows the economic responses to the 2008 financial crisis and the coronavirus pandemic in Germany, Japan, France, the United Kingdom, the United States, Canada, India, South Africa and Brazil about GDP. According to a report by McKinsey & Company (2020), the size of the economic stimulus provided in just two months was larger than that of the financial crisis, and for some economies even ten times larger.

Figure 3. Policy Responses to the 2008 Global Crisis and Coronavirus Pandemic in Selected Countries (% GDP)



Source: McKinsey & Company, 2020

In sum, both crisis periods analyzed in this study created a large-scale uncertainty environment and made the markets fragile. This environment of uncertainty shook investor and consumer confidence, leading to significant declines in the supply and demand side of the economy and subsequently to economic stagnation. There have been large-scale public interventions to address the negative effects of the crisis. The global financial crisis period brought about a sudden recession in the economy, followed by a recovery period after 2010. The outbreak of this crisis, especially in financial markets, brought important regulations in this area to the agenda. In particular, a series of regulations were put in place to strengthen capital buffers and reduce procyclicality in leveraged financial instruments, limit foreign exchange risk and eliminate maturity mismatches, improve regulation and supervision mechanisms for large-scale and highly connected institutions, increase supervision of the financial system, and align banks' capital adequacy with current market risks (IMF, 2018). Similarly, the coronavirus pandemic was the world economy's deepest recession since the Great Depression of 1929, and the recovery process was just as rapid. Unlike the financial crisis, the recovery from this health crisis was the result of large-scale public monetary and fiscal policies as well as efforts to develop vaccines and drugs. Since there were no pharmaceutical interventions to treat the disease in the first months of the pandemic, sudden shutdown and lockdown measures were put in place. The result of these non-pharmaceutical interventions was a period of stagnation, while the containment of the disease led to recovery. However, the long-term effects of this health crisis are not yet fully known. Estimates for OECD countries suggest that the health crisis could result in the loss of about 3 million of the workforce, at an economic cost of about $141 billion. It was emphasized that even if they could return to the workforce, there would be a decline in terms of working hours. Therefore, the declines in quality of life and labour force participation are projected to create economic and social welfare costs (Gonzalez and Suzuki, 2024).

Therefore, it is important to keep in mind that health crises, in addition to their economic effects, can have long-term negative effects on human capital through the destruction of public health. Therefore, public responses to health crises are not unidirectional as in an economic crisis. Comprehensive interventions, such as improving the health system and making health care equal and accessible to all, should not be ignored. At the same time, experience has shown that the planet is periodically shaken by pandemic-like health crises and that these external shocks are not preventable events. Therefore, while there are leading signals for economic crises, health crises occur suddenly and unexpectedly. At this point, while it is relatively possible to predict the possible effects of economic crises, the uncertainty is greater for health crises. For health crises that cannot be prevented or predicted, the measures that can be taken should rather be to create

buffers that can finance public health expenditures and sudden public needs against any emergency. In addition, it is crucial to meet the technological and digital infrastructure requirements that enable rapid transformation in the event of a shock.

Conclusion

The 2008 Great Recession and the 2019 Coronavirus Pandemic have created a series of trends on a global scale: declining GDP levels, rising unemployment, rising public debt levels, and shrinking foreign trade volumes. While both crisis periods brought sudden and unexpected shocks to economies, this uncertainty shook consumer and investor confidence. The first public response to recessions has been expansionary monetary and fiscal policies to stimulate recovery in both crisis periods. While emergency interventions are important for recovery, structural adjustments that will enable economic transformation are more essential at this point. Public support to stimulate both supply and demand led to inflation and unsustainable public debt, and the importance of structural transformation was realized with the transition to recovery. The 2008 global crisis experience revealed the importance of transparency and regulation in financial markets, while the coronavirus pandemic highlighted the importance of equal and accessible healthcare services for all. Again, these two crises have shown that global integration is necessary for economic growth, but at the same time, it is also dangerous if it turns into a dependency relationship. Border controls to prevent the spread of disease, especially during the health crisis, created a deadlock for economies highly dependent on imports of energy, raw materials and intermediate goods.

In sum, although the root causes of these crises are different, they have had similar outcomes and similar interventions to address them. At this point, structural and institutional arrangements such as turning to alternative energy sources such as renewable energy, ensuring food security, creating buffer zones against possible disruptions in the supply chain, strengthening the technology infrastructure, improving the quality of public services and ensuring their fair distribution for all, and keeping public debt levels at sustainable levels should be implemented. Taking these measures when the economy is functioning normally, rather than in times of crisis, will disperse the panic in the event of an unexpected situation.

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SUSTAINABILITY AND BUSINESS STRATEGY: THE ROLE OF SUSTAINABLE PROCUREMENT IN RENEWABLE ENERGY ADOPTION

Soubhik Kumar BARDHAN

Abstract

The incorporation of sustainable procurement practices plays a crucial role in promoting both environmental sustainability and economic efficiency, particularly in the adoption of renewable energy sources and technologies. Sustainable procurement is about sourcing goods and services in a way that not only ensures value for money but also minimizes environmental impacts and promotes social benefits. By considering the long-term effects of procurement decisions, businesses can contribute to the broader goal of sustainability while maintaining operational effectiveness. This article explores various strategies and policies that businesses can adopt to facilitate the transition to renewable energy. It emphasizes the benefits and challenges of this transition, focusing on the importance of strategic procurement policies. Key factors driving the adoption of renewable energy include regulatory frameworks, organizational leadership, market demand, and advancements in technology. Each of these factors plays a critical role in shaping how businesses approach renewable energy and integrate it into their operations. Through a detailed review of current practices, the article highlights best practices for sustainable procurement and how these practices can positively impact business performance. Businesses that adopt sustainable procurement practices are better positioned to meet sustainability goals, enhance their brand reputation, and foster innovation. Ultimately, the findings underscore the importance of aligning procurement strategies with sustainability objectives, emphasizing the need for policy support, capacity building, and collaboration with stakeholders. By adopting these practices, businesses can achieve substantial environmental and economic benefits, contributing to a more sustainable and efficient future.

Keywords: Sustainable Procurement, Renewable Energy Adoption, Business Strategy, Environmental Sustainability

JEL Codes: Q01, Q42, M14, L21

Introduction

The growing field of sustainable procurement is playing a crucial role in advancing renewable energy adoption. As the urgency to address climate change intensifies, businesses worldwide are turning to sustainable procurement strategies to support the shift to a low-carbon economy. This article delves into how thoughtful procurement policies can accelerate the use of renewable energy, helping to achieve both environmental and economic objectives [1]. The push for renewable energy, including solar, wind, and biomass, is largely driven by the global commitment to reducing greenhouse gas emissions. Beyond the environmental advantages, renewable energy also fosters economic growth by creating jobs, strengthening energy security, and decreasing dependence on fossil fuels [2]. Sustainable procurement practices guide organizations in sourcing renewable energy and adopting technologies that improve energy efficiency, thereby reducing their environmental footprint. By incorporating sustainability criteria into procurement decisions, companies can promote greener products and services in the market, driving innovation and supporting broader sustainability targets.

1.1. Benefits and Challenges of Implementing Sustainable Procurement

Implementing sustainable procurement offers numerous benefits, particularly in promoting renewable energy adoption. By incorporating sustainability into procurement decisions,

organizations can drive demand for cleaner technologies, reduce environmental impact, and ultimately save costs over time [1]. Beyond the financial gains, sustainable procurement enhances an organization's social responsibility and strengthens its reputation, as consumers increasingly seek transparency and ethical practices. Companies committed to sustainability often gain a competitive edge by exceeding stakeholder expectations and meeting regulatory standards [3].

However, several challenges hinder the widespread adoption of sustainable procurement. A key issue is the lack of awareness and understanding among procurement professionals, as many lack the necessary training and resources to integrate sustainability effectively. Additionally, internal resistance to change is a significant barrier. Shifting organizational culture towards sustainable practices can be met with pushback at various levels, from leadership to frontline staff, requiring strong leadership and clear communication to overcome [4]. External obstacles include the lack of reliable data on suppliers' sustainability performance, making it difficult to make informed decisions. The absence of standardized sustainability reporting further complicates efforts, leading to inconsistencies in comparing suppliers. Despite these challenges, sustainable procurement remains a crucial strategy for organizations aiming to align with long-term environmental and social goals.

1.2. Strategies to Overcome Challenges

To address the challenges of implementing sustainable procurement, organizations must adopt a focused and strategic approach. One key strategy is to establish clear procurement policies that incorporate sustainability criteria and standards. This ensures that decision-making processes consistently prioritize environmental and social considerations. Additionally, companies should invest in training programs to equip procurement professionals with the skills and knowledge necessary for sustainable practices [1].

Collaboration is another vital element in overcoming procurement challenges. By partnering with suppliers, industry bodies, and other stakeholders, organizations can share knowledge, develop common sustainability standards, and create a stronger, unified effort. These partnerships can help streamline procurement processes and amplify the impact of sustainability initiatives. Embracing technology is also crucial. Digital tools and e-procurement platforms offer real-time data on suppliers' sustainability performance, enabling more transparent and informed procurement decisions. This technological integration can enhance efficiency and accountability throughout the supply chain [5]. Overall, a strategic approach to sustainable procurement can help organizations effectively navigate challenges while achieving significant environmental and economic benefits. By prioritizing sustainability in procurement decisions, organizations not only contribute to renewable energy adoption but also drive positive change across industries.

2. Key Drivers of Sustainable Procurement

This section discusses the key drivers that influence the adoption of sustainable procurement practices across organizations. It explores how regulatory frameworks, leadership commitment, market demand, and technological advancements collectively push businesses toward integrating sustainability into their procurement strategies. By understanding these drivers, organizations can better navigate the shift toward more environmentally responsible procurement processes.

2.1. Regulatory Frameworks

Regulatory frameworks play a crucial role in advancing sustainable procurement by setting the legal and policy foundation that organizations must follow. These regulations mandate the inclusion of sustainability criteria in procurement processes, pushing organizations toward more environmentally responsible practices [6]. A prominent example is the European Union's Green Public Procurement (GPP) policies, which require public authorities to account for environmental considerations when making purchasing decisions. This policy framework has been key in promoting the use of renewable energy technologies across EU member states [5].

Beyond the EU, national and regional regulations worldwide are shaping sustainable procurement. In the United States, several federal initiatives require government agencies to purchase energy-efficient and eco-friendly products, establishing a standard for sustainable procurement that influences the private sector as well. These policies not only increase the demand for renewable energy technologies but also serve as a model for companies to integrate sustainability into their own procurement strategies. Through such regulatory mechanisms, governments are driving both public and private organizations to prioritize environmental sustainability, fostering a shift toward greener procurement practices [7].

2.2. Organizational Leadership

Leadership plays a vital role in driving sustainable procurement practices within organizations. When top management is committed to sustainability, it can have a direct impact on procurement strategies, shaping policies that prioritize environmentally friendly technologies and renewable energy sources. Leaders who champion sustainability set the tone for the organization, embedding a culture that values and practices responsible procurement. This influence extends across the organization, encouraging employees at all levels to consider the environmental implications of their purchasing decisions [8].

Leadership commitment can take several forms, such as establishing ambitious sustainability targets, providing resources for employee training, or creating dedicated teams focused on sustainability initiatives. These efforts help integrate sustainability into the organization's operations, ensuring that it becomes a core consideration in procurement processes. By fostering a sustainability-driven culture, leadership not only influences current procurement practices but also positions the organization as a forward-thinking entity dedicated to long-term environmental responsibility.

2.3. Market Demand

The growing demand for sustainable products and services is a powerful force behind the adoption of sustainable procurement. As consumers become more environmentally aware, they increasingly expect companies to embrace sustainable practices. This shift in consumer preferences is driving organizations to integrate sustainability into their procurement strategies, especially when it comes to renewable energy technologies and eco-friendly products [9].

The rise of green consumerism has created new opportunities for businesses to tap into markets focused on sustainability. Companies that adapt to this demand can gain a competitive edge by enhancing their brand image and attracting customers who prioritize environmental responsibility. By aligning their procurement processes with market expectations, organizations not only meet consumer demand but also contribute to larger environmental sustainability efforts. This market-driven push toward sustainability strengthens both corporate performance and long-term environmental goals, making it a crucial factor in procurement decisions [3].

2.4. Technology Advancements

Technological advancements play a crucial role in driving sustainable procurement by making renewable energy solutions and eco-friendly products more accessible and cost-efficient. Innovations in solar, wind, and biomass energy have significantly lowered the barriers to adopting these sustainable alternatives. Additionally, the development of energy-efficient technologies and environmentally friendly materials has made it easier for organizations to incorporate sustainability into their procurement decisions [10].

Digital technologies like blockchain and artificial intelligence are also revolutionizing procurement processes. These tools enhance transparency, efficiency, and accountability, helping companies implement sustainable practices more effectively. For instance, blockchain can provide a tamper-proof record of transactions, ensuring that sustainability criteria are upheld

throughout the supply chain [11]. Similarly, AI-driven analytics can optimize procurement decisions by identifying sustainable options and tracking supplier performance. Together, these technological advancements make sustainable procurement not only feasible but also more streamlined and reliable for organizations looking to meet their sustainability goals.

3. Barriers to Sustainable Procurement Implementation

Implementing sustainable procurement practices faces several key challenges, despite its potential to drive environmental and economic benefits. This section discusses some common barriers that often complicate efforts to fully integrate sustainability into procurement processes.

3.1. High Initial Costs

One of the major hurdles in adopting sustainable procurement is the significant upfront costs involved, particularly with renewable energy technologies. Despite offering long-term savings and environmental benefits, the initial financial outlay is often too high for many organizations, especially small and medium-sized enterprises (SMEs) that may lack the resources [10]. To overcome this challenge, financing mechanisms such as subsidies, tax incentives, and low-interest loans are essential to help organizations manage the initial investment and facilitate the shift towards sustainable practices.

3.2. Knowledge Gap

A lack of expertise among procurement professionals presents another significant barrier. Sustainable procurement requires a deep understanding of complex issues like environmental impacts, life-cycle costing, and sustainability criteria. Many professionals do not possess the necessary skills or knowledge to integrate sustainability into their procurement processes. To address this gap, organizations must invest in training and development programs to equip their teams with the tools they need to implement sustainable procurement effectively. Collaborating with academic institutions and industry associations can further support capacity-building efforts.

3.3 Cultural Resistance

Resistance to change within organizations is a common obstacle [12]. Implementing sustainable procurement often requires a fundamental shift in mindset and organizational culture, which can be difficult to achieve. This resistance may arise at all levels of the organization, from top management to procurement teams and general employees. To overcome this, companies need to engage all stakeholders, promote clear communication about the benefits of sustainability, and foster a sense of ownership toward sustainability goals. Strong leadership and transparent decision-making are essential in cultivating a sustainable culture [8].

3.4. Inadequate Data

Another challenge is the lack of reliable data on the sustainability performance of suppliers, making it difficult for organizations to make informed procurement decisions. Without standardized metrics or comprehensive data, organizations struggle to assess the sustainability of their suppliers, leading to inconsistencies [1]. To address this issue, it is crucial to develop standardized reporting frameworks and tools that offer greater transparency. Leveraging technologies such as blockchain and AI can help organizations improve data accuracy and streamline decision-making, ensuring that sustainability criteria are met across the supply chain [11].

4. Best Practices for Businesses to Incorporate Sustainable Procurement

This section discusses key strategies that businesses can adopt to successfully incorporate sustainable procurement into their operations. From engaging with governments to shape policy, to leveraging technology and fostering collaboration across the supply chain, these approaches

provide a comprehensive framework for organizations aiming to enhance their sustainability efforts.

4.1. Policy Advocacy and Support

One of the most impactful ways businesses can contribute to sustainable procurement is by actively collaborating with governments to shape and influence policy. Rather than waiting for regulations to dictate actions, companies can work closely with policymakers to promote standards that encourage the integration of sustainability into procurement practices. By engaging in dialogue with government entities, businesses can advocate for incentives such as tax breaks, subsidies, or grants to support the adoption of renewable energy and environmentally friendly technologies [5]. In addition, businesses can push for the creation of favorable regulations that not only reward sustainable procurement but also fund research and development in green technologies. Such partnerships can ensure that both private and public sectors align their sustainability goals and work together toward a more environmentally responsible future [7].

4.2. Building Capacity

For sustainable procurement to become deeply embedded within an organization, it is essential to build the capacity of its procurement teams. Businesses should prioritize continuous training and development programs that equip procurement professionals with the knowledge and skills necessary to integrate sustainability into their daily operations [13]. These programs can cover critical topics such as life-cycle assessment, environmental impact analysis, and applying sustainability criteria during the procurement process. Furthermore, partnerships with educational institutions and certification programs can help to further enhance the expertise of procurement staff. By investing in the professional growth of their teams, businesses can ensure a more seamless and knowledgeable adoption of sustainable procurement practices, driving better long-term results [4].

4.3. Collaboration and Partnerships

Another effective strategy for fostering sustainable procurement is through building partnerships across the supply chain. Collaboration with suppliers, industry peers, and even competitors can create opportunities to share best practices, establish common sustainability standards, and leverage collective buying power [3]. By engaging with industry associations and stakeholders, businesses can work together to develop more sustainable solutions and align procurement strategies with broader environmental goals. Platforms such as industry coalitions or buyer alliances offer businesses the opportunity to collaborate on renewable energy procurement, for example, driving significant progress in sustainable practices across industries [14]. Through these partnerships, companies can scale their sustainability efforts more efficiently and establish stronger environmental accountability throughout their supply chains.

4.4. Leveraging Technology

Technology is a powerful enabler in advancing sustainable procurement strategies [15]. Businesses should harness digital tools such as blockchain and artificial intelligence to increase transparency and efficiency in their procurement processes. Blockchain technology, for example, can provide a secure and immutable record of supplier transactions, ensuring that sustainability criteria are consistently met throughout the supply chain [11]. Artificial intelligence, on the other hand, can be utilized to analyze large datasets, helping companies make more informed procurement decisions by identifying the most sustainable suppliers. E-procurement platforms further enhance this capability by providing real-time data on environmental performance, enabling businesses to monitor and evaluate the sustainability impact of their purchasing decisions with greater accuracy [5].

4.5. Monitoring and Evaluation

For sustainable procurement efforts to be truly effective, businesses must commit to ongoing monitoring and evaluation of their procurement activities. Establishing clear metrics, such as tracking the percentage of renewable energy used or the reduction in carbon emissions, allows companies to measure the success of their sustainability efforts over time [16]. Regular reviews of procurement processes ensure that businesses can identify areas for improvement and adjust their strategies accordingly. By consistently gathering data and assessing performance, organizations can not only refine their procurement practices but also achieve their long-term sustainability goals. Monitoring and evaluation should be seen as a continuous process that fosters accountability and transparency, ultimately helping businesses to stay on track in their sustainability journey [8].

5. Conclusion

Sustainable procurement is an essential component in the global effort to combat climate change and drive the adoption of renewable energy. This paper has outlined the benefits of sustainable procurement, emphasizing its role in reducing environmental impact, fostering economic growth, and enhancing organizational reputation. While the challenges to implementation—such as high upfront costs, lack of expertise, resistance to change, and inadequate data—are significant, they can be overcome with strategic planning and action. Key drivers, including regulatory frameworks, leadership, market demand, and technological advancements, highlight how organizations can integrate sustainability into procurement processes to meet growing environmental and societal expectations.

By adopting well-defined policies, fostering collaboration, and leveraging advanced technologies, businesses can significantly reduce their environmental footprint while benefiting from long-term economic gains [17]. The need for capacity building among procurement professionals and the use of transparent monitoring and evaluation mechanisms also reinforce the importance of a structured approach to sustainable procurement. Ultimately, as businesses increasingly align their procurement strategies with sustainability goals, they contribute not only to the global transition toward renewable energy but also to a more sustainable and resilient future for all.

As organizations continue to refine their practices, partnerships between the public and private sectors will become increasingly important [18]. Working together, they can shape policies that incentivize sustainable procurement and create a more conducive environment for innovation. In conclusion, the journey toward sustainable procurement may be challenging, but it is a necessary and achievable path for businesses seeking to make a lasting impact on both the environment and society. Through persistent effort, clear leadership, and ongoing adaptation, companies can lead the way in the global shift toward a low-carbon economy.

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UPHOLDING UN SGD GOAL #2 IN THE CONTEXT OF GLOBAL CONFLICTS: THE CASE OF THE POST 2023 FAMINE IN GAZA

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Absract
The Integrated Food Security Phase Classification (IPC) Famine Review Committee released its conclusions and recommendations on the Gaza Strip in March 2024. The IPC March 2024 report indicates a catastrophic situation of acute famine facing over 1.1 million people in Gaza. The IPC Acute Food Insecurity Scale is the globally recognised standard for food insecurity. The IPC Scale is from Phase 1 to Phase 5, the last one being the catastrophic food insecurity that can lead to deaths amongst the most vulnerable segments of the population, mainly children. The famine in Gaza is classified as Phase 5. Of the IPC Phase 5 famine-struck population of 1.1 million people in Gaza, 2-4 children are dying every day due to starvation. The United Nations Sustainable Development Goals (UNSGDs) 2030, Goal 2 aimed to eradicate global hunger facing almost 2.2 billion of the world's population in some forms. The conflict in Gaza has exacerbated the bleak situation of global hunger due to conflicts. The complexity and challenges surrounding the conflict in Gaza have led to the starvation and death of thousands of innocent people. The conflict has also landed before the UN's International Court of Justice (IPC) for a possible ruling of genocide. This paper examines the historical and geopolitical elements leading to this Phase 5 famine in Gaza and its implications under international law.

Keywords: UNSGD 2023, UN SGD, UNSC, UNGA, UNWRA, Oxfam, Famine, Gaza, IPC Scales, ICJ, Global Conflict & Famine, Child Hunger, Global Hunger, UN SGD-2

Introduction

The United Nations ("UN") was founded in 1945 and has 193 nation-state members. The UN plays a crucial role in maintaining international order through the instruments of International Law, articulated through various UN bodies and agencies around the world (United Nations 2024).

The UN adopted 17 sustainable development goals ("SGDs") with the unanimous support of its member states in 2015 (Nations 2017). These 17 SGDs did not emerge from a vacuum. The UN has been working diligently since the June 1992 Rio Summit to come up with a plan that would address the deprivation and poverty facing the world while protecting our natural resources and natural environment for future generations. The UN SGDs are unachievable in the wake of increased global conflicts, lack of engagement with civil society, colonisation of natural resources by global powers from developing countries and so on. Amir Khorram-Manesh (2023) successfully argue that peace and justice or their lack of them are the major factors hindering the implementation of the UN SGDs across the world (Khorram-Manesh 2023).

The latest conflict in Gaza resulted in 1200 civilian deaths by an attack on unarmed Israeli civilians in contravention of International Law by Hamas on Oct 7th, 2023. Israel started the indiscriminate bombing of Gaza that has resulted in over 42,000 civilian Palestinians killed and over 92,000 seriously injured. There are over 10,000 Palestinians incarcerated in Israeli prisons since the start of this conflict (Khatib, McKee, and Yusuf 2024).

According to the United Nations Relief & Work Agency (UNWRA) statement issued in July 2024, out of the total 2.1 million Palestinians impacted by the war on Gaza, over 1.8 million are the most vulnerable and in dire need of shelter, medical aid, food and water (UNRWA 2024).

A group of 40 leading scientists of the world recently published a paper and called for the immediate cessation of the killings in Gaza (London et al. 2024).

"By the end of May 2024, around 1.7 million people, representing 75% of Gaza's population, had been displaced [1]. Nearly half are crammed into the far southern strip, currently under ongoing

attack by the Israeli military [2]. More than 80,000 people have been injured and, of people killed for which there is complete information, more than half were women ($n = 4959$) or children under 18 years of age ($n = 7797$)[1]. About 17,000 children are estimated to be orphaned or separated from their parents/families [3,4,5] (London et al. 2024, 2)."

This catastrophic humanitarian crisis has also led to unprecedented hunger among the displaced 1.8 million Gazans who are starving to death as Gaza has been choked off from humanitarian aid and most of the Gaza Strip has been reduced to rubbles. This paper examines the starvation in Gaza in the light of UN SGD-2 and international humanitarian law.

Background to the Gaza conflict

The present conflict in Palestine did not start on October 7th, 2023, as popularly emphasized by some Western media but started with the Zionist movement to establish an independent state on the Arab lands of Palestine with the help of the British Empire in the early 1900s (Finkelstein 1991).

The infamous "Belfour Declaration" rests on the British Colonial Office (Foreign Office) letter to Lord Rothschild dated November 2nd, 1917. The letter stated the British Government's alliance with the Zionist Federation and the British Cabinet providing support for the Zionist movement to establish a state on existing Palestinian lands (UN Archive 2017).

During the post-First World Period (1917 onwards), at the dismantling of the Ottoman Empire, Palestine was amongst the Ottoman territories placed under the British Mandate by the League of Nations in 1922. The principal purpose of the Mandate was to allow a transitionary period for the state of Palestine to organise and establish itself. The Mandate envisioned an Arab Palestinian state emerging post-Mandate as a unified state, without any mention of the Zionist state of Israel. The historical facts document the British intentions to disregard the provisions of the Mandate in favour of the Zionist federation since the Belfour Declaration predates the League of Nation's Mandate of 1922.

The British Empire followed through with the Belfour Declaration using their Mandate to support the Zionist movement for the state of Israel (UN 2024b). The British tabled the Palestine Mandate question before the UN, which was only two years old at the time, after a quarter of a century since assuming the mandate. The United Nations ("UN") General Assembly ("UNGA") adopted the resolution "Palestine Plan of Partition with Economic Union – General Assembly resolution 181 (II) Future government of Palestine" during its one hundred and twenty-eighth plenary session on November 29th 1947, creating two states of Arab Palestine and Jewish Israel (UN 2024a).

The 1948 Arab-Israel war is documented as the "Naqaba" or mass movement in contemporary history. The attacks by the Zionists from Israel resulted in thousands of Arab civilian deaths and mass dislocation of Palestinians from their homelands. The UN Resolution of 1947 resulted in the Zionist state of Israel but failed to ensure and establish a separate state for the Palestinians.

There are over 131 UN resolutions regarding Israel's violation of international law concerning the rights of Palestinian people and their rights to self-determination. None of the UN resolutions have resulted in any actions to stop the atrocities and dehumanisation of the Palestinian people by the Zionist regime of Israel since Naqaba of 1948.

Brief Literature review- UN SGD-2 & Gaza

Scholars familiar with the UN SGDs and their implication for the safety and prosperity of the world took notice of the ongoing humanitarian crisis in Gaza including the acute hunger facing its population due to the atrocities being committed by the Israeli regime against the people of Gaza.

Hassoun et al. successfully argued that armed conflicts adversely impact the civilian population from the production, provision, storage and access to food resources (Hassoun et al. 2024). Houssan et al. also highlighted the work of the IPC Fammine Review Committee's work on Gaza and the exacerbation of famine in Gaza due to the Israeli Defence Forces ("IDF") blockade on any food relief from reaching the population of Gaza. Hassoun et al. also highlighted the crisis-

level famine situation is an exponential growth of Israel's stringent blockade of food and other life-saving supplies to the Gaza Strip since 2007. Hassoun et al. have argued that UN SGD-2 goals have been set back dramatically due to the impact of war on Gaza and have implications for the region as a whole.

Lara Nasreddine and Lamis Jomaa in their 2024 report highlight the impact of famine on the children of Gaza (Nasreddine and Jomaa 2024). The work highlights the work of the UN Relief and Works Agency for Palestine Refugees in the Near East (UNRWA) and its effort to manage the famine in Gaza, especially the children, to the UN SGD-2 goals for the region. Nasreddine and Jomaa (2024) relied on the work of Horino, M · Bahar, L · Al-Jadba, G · et al.(Horino et al. 2020) and concluded that,

"UNRWA programmatic decision to provide a status update on food insecurity and its link with food-aid receipt, diet, and nutritional status of children in the Gaza Strip, has unpredictably become a baseline assessment of these variables, evaluated 1–3 months before the conflict of October 2023. The findings showed that an alarming proportion of Palestinian refugee children about to enter first grade and their households (n=3229) were experiencing moderate-to-severe food insecurity (75%). This estimate is higher than that reported by previous assessments conducted in Gaza, the last being performed in 2018–21, where the prevalence ranged between 60% and 64% (Nasreddine and Jomaa 2024)."

According to a report published by Cost of the War Project and quoted by Brett Wilkins in his article published recently (Wilkins 2024), the United States taxpayers have spent over $22.7 billion in weapons and assistance provided to Israel in its genocidal war in Gaza.

On October 2nd, 2024, Ninety-nine American healthcare professionals who volunteered in Gaza since the outbreak of the latest conflict on October 7th 2024, wrote a letter to US President Joe Biden (American Medical Professionals 2024). The letter equivocally condemns the Hamas attack on unarmed Israeli civilians on October 7th 2023. The letter also states the neutral observer status of the medical professionals entering Gaza for humanitarian assistance and observations. Some of the direct observations made by leading surgeons and doctors from the organisation are even difficult to read, in terms of their factual and blunt reporting of the extreme trauma faced by the most vulnerable segment of the Gazan population, the children. Dr. Mark Perlmutter, who is a leading US orthopaedic and hand surgeon, serving with the volunteers wrote this heartbreaking comment, "*Gaza was the first time I held a baby's brains in my hand. The first of many."*The letter provides details about extreme malnutrition and starvation among the children in Gaza. The most scathing comment in the letter is a direct appeal to the humanity of the US President Biden and Vice President Harris. It states,

"President Biden and Vice President Harris, we wish you could see the nightmares that plague so many of us since we have returned: dreams of children maimed and mutilated by our weapons, and their inconsolable mothers begging us to save them. We wish you could hear the cries and screams our consciences will not let us forget. We cannot fathom why you continue arming the country that is deliberately killing these children *en masse*.

Horino et al. published a comprehensive study in 2020 about the UN SGD-2 and hunger in Gaza (Horino et al. 2020). The study is grounded in real-time clinical data collected from the Gaza population and is one of the leading studies on the topic of malnutrition and hunger facing the most vulnerable population of Gaza. The study provides an excellent benchmark to examine the prevalent catastrophic famine in Gaza in light of the UN SGD-2, and the aim to eradicate hunger by 2030 in a war-torn place like Gaza. The conclusive scientific evidence found by Horino et al. gives a bleak picture of Gaza's vulnerable population's food insecurity pre-Oct 2023 war. It states,

"In the Gaza Strip, where ~1.4 million Palestinians reside, there are high prevalences of anaemia and multiple micronutrient deficiencies (MNDs), including those of iron, zinc, vitamins A, B_{12}, D, and E, ranging from 11.4% to 84.7% among pregnant women and 2.9% to 70.9% among

preschool children. Dietary diversification and adequate food fortification are framed in policies but remain aspirational goals (Horino et al. 2020)."

University of Bonn, Center for Development Research (ZEF) published a research paper by Von Braun et al. in May 2024 (von Braun et al. 2024). The research is centred around UN SGD-2 and the costs of ending hunger. One of the key findings of the research is that the year 2015 was the last year for the declining rate of hunger in the world and since the year 2020, global conflicts and climate change have exacerbated the increase in hunger in the world, especially in the conflict zones of the global south (von Braun et al. 2024, 1).

The research by Von Braun et al. found Integrated Food Security Phase Classification (IPC) to be a reliable benchmark for hunger classification amongst a population. Based on the IPC 2024 classification on Gaza, Von Braun et al. concluded,

"In Mach 2024, the IPC projected that during the projection period (mid-March to mid-July 2024), the entire population of 2.2 million people is expected to be experiencing acute food insecurity, with 265,000 people in Phase 3 ("crisis"), 854,000 in Phase 4 ("emergency") and 1,107,000 in Phase 5 ("catastrophe") (IPC, 2024). More than half a million people in Gaza were starving, and nine out of ten ate less than one meal a day (also) according to the World Food Programme (von Braun et al. 2024, 5)."

Norwegian Refugee Council (NRC) published statistics collected from Gaza by fifteen international humanitarian aid organisations. According to NRC, Israel has been blocking 83% of the food and humanitarian aid from reaching Gaza since the start of the conflict in Oct 2023 (NRC 2024).

Agboklou et al. published research in 2024 about the impact of global conflict on UN SGD-2 (Agboklou, Özkan, and Gujrati 2024). The findings of Agboklou et al. are consistent with research from other scholars about the difficulty of reaching the UN SGD-2 eradication of hunger from the world by 2030 with the increase in global conflicts. Agboklou et al. noted that:

"This increase in the number of conflicts is therefore correlated with the number of people suffering from severe food insecurity, which is also rising sharply. Many regions of the world have suffered, and some continue to suffer, from the damaging effects of armed conflict. For decades, conflicts in Asia, the Middle East, Central Africa, the Sahel, the Horn of Africa and, more recently, Ukraine and the Israeli military operation in the Gaza Strip have been exacerbating the deteriorating living conditions of millions of people around the world (Agboklou, Özkan, and Gujrati 2024, 5)

International law & hunger in Gaza

International Human Rights Law and International Humanitarian Law are commonly referred to as human rights during times of peace in the case of the former and human rights during the conflict in the case of the latter. This misconception has been removed by the various international judicial bodies such as the International Court of Justice (ICJ), the UN Commission on Human Rights and the UN Human Rights Council. Any violation of rights protected by either the human rights law or the humanitarian law can constitute genocide. Israel is a signatory state to the UN Convention on the Prevention and Punishment of the Crime of Genocide since March 9th, 1950.

Considerable scholarship has emerged from the legal as well as human and humanitarian rights scholars since the indiscriminate killings of over 42,000 civilians and over 97,000 injured Palestinians in Gaza. Over 16,000 children in Gaza have been killed. Over 62,000 civilians have starved to death in Gaza since the start of the conflict in Oct 2023 (Ćerimović 2024).

These figures have been disputed by Israel and some of the major Western media organisations. What is most interesting is the dehumanization of male deaths in Gaza. It is as if all males killed, injured or detained by IDF are automatically assumed to be 'Hamas terrorists" since IDF proclaims it to be so. It is equally astonishing that the world is silent on this presumption of guilt about every male Palestinian killed in Gaza.

International humanitarian law for conflicts and by extension International human rights law seems to apply to both IDF and Hamas when it comes to the protection of civilians in Gaza and

Israel. While condemning the actions of Hamas against the Israeli civilians on October 7th, 2023, the events post-October 7th, 2023, suggest that the actions of the State of Israel and IDF may have crossed the threshold of genocide against the Palestinian population of Gaza.

On February 29th, 2024, IDF opened indiscriminate fire on unarmed civilians waiting in line to get food from a relief truck and killed 118 people while wounding many others. Initially, IDF refused to accept any responsibility for the indiscriminate killing of starving civilians, it later justified the killing by stating that the civilians waiting in line to receive food were a suspected threat (Whyte 2024).

Oxfam published a scathing report against Israel's weaponising food against the starving Palestinian population of Gaza since IDF's operations started in Gaza on October 8th 2023 (Oxfam 2024). The report highlights the 'total siege' of Gaza as follows:

"Israel's actions are also undermining international aid by its continued military assault inside Gaza, unparalleled in terms of intensity, brutality and scope – and which Israeli leaders themselves have called a 'total siege' (Oxfam 2024)".

On August 5th 2024, Israel's Finance Minister Bezalel Smotrich, who is a key member of the Israeli Cabinet stated that Israel is justified in blocking humanitarian aid to the Palestinian population in Gaza even at the cost of the entire population in Gaza dying of starvation (Staff 2024). No condemnation or retraction of the statement by Smotrich was made by the Israeli cabinet or the Israeli prime minister to date. Intentional starvation of civilians is a war crime under the UN Convention on the Prevention and Punishment of the Crime of Genocide 1948, to which Israel is a signatory state.

In Dec 2023, South Africa filed an application of the convention on the prevention and punishment of the crime of genocide in the Gaza Strip (SOUTH AFRICA v. ISRAEL) at the International Court of Justice (ICJ) at the Hague. The ICJ in its ruling, stated that:

"The Court notes that the most recent developments in the Gaza Strip, and Rafah in particular, 'would exponentially increase what is already a humanitarian nightmare with untold regional consequences', as stated by the United Nations Secretary-General (Remarks to the General Assembly on priorities for 2024 (7 Feb. 2024)).

This perilous situation demands immediate and effective implementation of the provisional measures indicated by the Court in its Order of 26 January 2024, which are applicable throughout the Gaza Strip, including in Rafah, and does not demand the indication of additional provisional measures.

The Court emphasizes that the State of Israel remains bound to fully comply with its obligations under the Genocide Convention and with the said Order, including by ensuring the safety and security of the Palestinians in the Gaza Strip (ICJ 2024, 5)."

The July 2024 ICJ judgment goes at length to explore, observe and establish the starvation and hunger faced by the Palestinian population in Gaze due to the atrocities and restrictions imposed by the IDF that do not preclude incessant and indiscriminate bombing of Gaza and international humanitarian relief operating in Gaza to provide food and humanitarian aid.

The Court's remarks about the famine and starvation in Gaza due to the Israeli actions include the Court's acknowledgement of the IPC Acute Food Insecurity Analysis of March 2024. The Court states in paragraph 19 of its decision:

"The IPC acute food insecurity analysis conducted in December 2023 warned of a risk that Famine may occur by the end of May 2024 if an immediate cessation of hostilities and sustained access for the provision of essential supplies and services to the population did not take place. Since then, the conditions necessary to prevent Famine have not been met and the latest evidence confirms that Famine is imminent in the northern governorates and (is) projected to occur anytime between mid-March and May 2024 (ICJ 2024, 8)."

The July 2024 detailed judgment by the Honourable ICJ negates all arguments of the so-called 'Self-Defense" used by Israel and its Western allies as the Court relied upon its legal memory dating back to the 1922 British Mandate. The Honourable Court also relied on the legal definition

under international law regarding occupation forces and examined the behaviour of the State of Israel during the period from 1967 till the present conflict in Gaza. The Honourable Court also confirmed its jurisdiction and ability to adjudicate the matter (ICJ 2024, 24–28).

Regrettably, the countries supporting Israel in its genocidal war against the people of Gaza do not consider the killing, starvation and displacement of over 2.2 million as an act of genocide. The continued starvation and hunger facing the people of Gaza is genocide and catastrophic annihilation of humanity being played out in real time right before the eyes of the world. It may be the best-documented genocide in recent human history.

Pulitzer Prize-winning journalist Seymour Hersh recently wrote an article about the state of Gaza after a year of war (Hersh 2024). Seymour exposed the 1968 massacre of My Li (Vietnam) by the US troops and the pictures from the massacre shocked the consciousness of the world. In 2004, Seymour Hersh also exposed the abuse and human degradation of prisoners at the US Army-run Abu Ghuraib prison in Iraq by the US military. Seymour Hersh notes in his article, an important fact that speaks to the inertness of the world, towards the massacre of over 42,000 Palestinian men, women and children, who are all presumed to be members of Hamas without distinction. Seymour Hersh writes,

"As the journalist who broke the stories of the My Lai massacre in South Vietnam and the photographs of sexual abuse of prisoners in Iraq's infamous Abu Ghraib prison by untrained American Army Reserve prison guards, I understand that soldiers in combat do horrid things, including rape and murder, to noncombatants. But the Abu Ghraib photos were circulated only among the members of the unit on duty; they were not meant for outsiders, including the Army chain of command. It was understood that their actions, if made known to higher-ups at headquarters, would lead to prosecution.

That was not the case with the photos taken in Gaza and passed around widely, including among the soldiers' commanding officers. Such evidence of enduring corruption among the officer class may be impossible to cure in the short term, given the degradation of Israel's political and military leadership today (Hersh 2024)."

Approximately 75,000 tons of bombs have been dropped on 365 square kilometres of land that comprises Gaza with its 2.2 million inhabitants, which includes almost a million children. Gaza is one of the most densely populated places on earth. As a comparison, the city of London received 18,300 tons of German bombs between 1940-1941, and the Allies dropped over 45,000 tons of bombs on the German population to bring the war to an end (Calli 2024).

Over 300,000 homes have been destroyed in Gaza with almost 70% of its 365 square kilometers rendered rubble. There are no schools, no agriculture or food sources, no clean or running water, no health facilities, no mosques, no churches, and no universities left for those who are still alive. IDF shuttles the remaining living population, which is injured and hungry from one corner of the Gaza Strip to another while bombing any and every living being in sight.

The catastrophic situation in Gaza facing its remaining population is constant hunger and imminent death at the hands of the IDF forces with their indiscriminate bombing. The UN Security Council with the American, British and French veto of every effort to secure a ceasefire makes it impossible to end this suffering for the people of Gaza.

The UN SGD-2 seems like an illusionary goal, faced with the challenges of global conflict in Gaza and other war zones in the world. The world is unable to stop Israel from this relentless pursuit of destruction and come to the negotiating table and reach a solution that will not only restore the internationally recognised right of the Palestinian people to self-determination but will also ensure the safety and peace for the people of Israel.

Conclusion

The war in Gaza and the killing of over 42,000 civilians including 16,000 children poses a moral question for the entire world's humanity. The hunger and starvation facing the people of Gaza has resulted in over 62,000 deaths linked to starvation making the UN SGD-2 goal of eradicating hunger an impossible task by 2030.

The role of global conflicts and climate change is proving to be a decisive factor in undermining the efforts of the global communities that still support the UN SDGs as a realistic target by the year 2030.

The humanitarian crisis in Gaza is a test case that can show us which nations believe in respecting International Human Rights Law and International Humanitarian Law in its entirety. The United Nations with all its limitations is still the only forum and source where the nations of this world can sit and resolve difficult issues through diplomacy and adherence to the norms of International law.

Actions like calling the entire UN body 'antisemitic bile' and declaring the UN Secretary-General as the *persona non grata*, are not only contemptuous of stately behaviour and norms of international diplomacy, rather they reflect the insidious nature of those aiming to continue the path of endless war and destruction with no peace in sight.

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HISSE SENEDI GETIRILERINDE ENFLASYON VE BELIRSIZLIĞI: BORSA İSTANBUL ANALIZI

Ömer ESEN

Durmuş Çağrı YILDIRIM

Emre AKYURT

Özet

Bu çalışmada, 2006:1 – 2024:4 döneminde Türkiye'deki enflasyon ve enflasyon belirsizliğinin Borsa İstanbul'da işlem gören hisse senedi getirileri üzerindeki etkisi incelenmektedir. İncelenen dönem, Türkiye ekonomisinde açık enflasyon hedeflemesi ile önemli yapısal değişimlerin yaşandığı ve finansal piyasaların derinleştiği bir süreci kapsamaktadır. Analizlerde, Türkiye'deki hisse senedi getirilerini temsilen en yüksek işlem hacmi ve piyasa değerine sahip ilk 100 şirketin performansını yansıtan BİST100 endeksi getirileri kullanılmaktadır. Bu çalışmada, enflasyon belirsizliği ARCH/GARCH modelleri ile analiz edilmiştir. Değişkenler arasındaki uzun dönem ilişkilerini tespit etmek amacıyla Johansen eşbütünleşme testi kullanılmış, uzun dönem katsayıların analizi için ise FMOLS, DOLS ve CCR yöntemlerine başvurulmuştur. Yapılan analizler sonucunda, Türkiye'de enflasyon ve enflasyon belirsizliğinin hisse senedi getirileri üzerinde pozitif etkisi olduğu belirlenmiştir. Özellikle, enflasyon belirsizliğindeki artışın, enflasyon artışından daha fazla hisse senedi getirilerini yükselttiği saptanmıştır. Bu bulgular, enflasyonist bir ortamda hisse senetlerinin güvenli bir yatırım aracı olduğunu ortaya koymaktadır.

Anahtar Kelimeler: Enflasyon, Enflasyon Belirsizliği, Hisse Senedi Getirisi, Borsa İstanbul

INFLATION AND UNCERTAINTY ON STOCK RETURNS: A STUDY ON BORSA ISTANBUL

Abstract

This study examines the impact of inflation and inflation uncertainty on stock returns in Turkey during the period 2006:1 - 2024:4. The period analyzed covers a period of significant structural changes in the Turkish economy with explicit inflation targeting and financial deepening. The returns of the BIST100 index, which reflects the performance of the top 100 companies with the highest trading volume and market capitalization, are used to represent stock returns in Turkey. This study employs ARCH/GARCH models to analyze the phenomenon of inflation uncertainty. The Johansen cointegration test is used to determine the long-run relationship between the variables, while the FMOLS, DOLS and CCR methods are used to analyze the long-run coefficients. The analysis reveals that inflation and inflation uncertainty have a positive impact on stock returns in Turkey. Notably, an increase in inflation uncertainty is found to increase stock returns more than an increase in inflation. These findings suggest that equities are a safe investment instrument in an inflationary environment.

Keywords: Inflation, Inflation Uncertainty, Stock Return, Borsa Istanbul

1. Giriş

Ekonomik karar birimlerin yatırım, tüketim ve tasarruf gibi karar alma süreçlerini etkilemeyecek kadar düşük ve istikrarlı bir enflasyon oranı olarak ifade edilen fiyat istikrarının sağlanamadığı bir ekonomik yapı, tüm sektörleri ve makroekonomik unsurları olumsuz bir biçimde etkileyerek ekonominin temel yapılarına ciddi maliyetler yüklemektedir (TCMB, 2013). Bu noktadan yola çıkarak, enflasyon ile sermaye piyasaları arasında negatif bir korelasyon olacağını ileri süren çalışmalar, bu durumu iki temel argümanla açıklamaktadır. İlk olarak, enflasyon dönemlerinde gelecekteki ekonomik performansa ilişkin beklentilerin bozulması ve satın alma gücündeki düşüş nedeniyle toplam talebin zayıflayarak şirket kârlarının azalmasına yol açmasıdır. İkinci olarak, enflasyon risk priminin artması, iskonto oranlarının yükselmesine neden olur ve bu da hisse

senetlerinin bugünkü değerinin düşmesine yol açar (Ammer, 1994; Hatipoğlu, 2021). Bu durum, enflasyonun işgücü, kredi ve dış piyasa faktörlerini içeren karar alma ve yatırım süreçlerini etkileyerek maliyetlerin artmasına yol açabilir, bu da nihayetinde kararların ertelenmesine veya tamamen vazgeçilmesine sebep olabilir. Bu etkiler, ekonomik aktörlerin genel stratejilerini, harcama alışkanlıklarını ve finansal durumlarını ciddi bir şekilde etkileyerek ekonomik dengede değişikliklere yol açabilir. Böylece, işgücü maliyetleri üzerinde baskı oluşturarak işletmelerin kâr marjlarını daraltabilir ve istihdam politikalarını olumsuz etkileyebilir. Aynı zamanda, enflasyonun kredi maliyetlerini artırması, borçlanma maliyetlerini yükseltebilir ve bu da hem bireylerin hem de işletmelerin finansal durumunu olumsuz etkileyebilir. Dış piyasalarda meydana gelen maliyet artışları ise uluslararası ticaret dengesini etkileyerek ekonomiyi daha geniş bir perspektiften etkileyebilir (Düldül, 2021). Enflasyonun beslenmesine ve dengesiz bir şekilde ilerlemesine neden olan önemli etkenlerden biri, enflasyonun kendi doğası gereği yarattığı belirsizliktir (Esen ve Akın, 2023). Bu belirsizlik, bir dizi kanal aracılığıyla ekonomiyi etkileyebilmektedir. Faiz oranlarının uzun vadede yükselmesi ve ekonomik değişkenlerin gelecekteki beklenen değerlerindeki belirsizliğin artması, piyasalar üzerinde olumsuz etkiler yaratabilir. Belirsizliğin arttığı yüksek enflasyonist dönemlerde, yatırımcılar sermayelerinin satın alma gücünü korumaya daha fazla önem verirler ve bu süreçte, enflasyona karşı korunabilecekleri yatırım araçları arayışına girerler (Bozkurt ve Kaderli, 2024). Belirsizlikten kaçınmak isteyen bireyler ve şirketler, kaynaklarını reel varlıklara (yatırıma) yönlendirmek yerine finansal varlıklara yönelerek belirsizlik riskini azaltma eğilimindedirler. Ayrıca, enflasyon belirsizliğinin faiz oranlarını artırıcı etkisi, yatırımcıların beklenen getiri oranlarını yükseltmesi nedeniyle reel varlıklara olan yatırımları da düşürebilmektedir. Benzer şekilde, bu süreçte bireyler de yatırım kararlarını erteleyebilir ve hatta vazgeçebilirler (Oltulular ve Terzi, 2011).

Literatürdeki tartışmalara bakıldığında hisse senedi getirileri ile enflasyon arasındaki ilişki uzun yıllardır araştırılmaktadır. Hisse senetleri geleneksel olarak enflasyona karşı iyi bir koruma olarak kabul edilmiştir, çünkü hisse senetleri, gerçek getirileri enflasyondan etkilenmemesi gereken fiziksel varlıklara karşı taleplerdir. Nominal getiri oranları ile beklenen enflasyon arasındaki ilişkinin varlığına dair fikirlerin temelini atan çalışmaların başında olan Fisher'ın (1930) Nominal faiz oranının enflasyon oranının gelecekteki değerlerine ilişkin mevcut bilgileri tam olarak yansıttığını varsayan hipotezi, hisse senedi getirisi-enflasyon ilişkisi için de geçerli olabileceği iddia edilmektedir. Böylece finansal varlıklardaki beklenen nominal faiz oranlarının beklenen enflasyonla bire bir hareket etmesi gerektiği ileri sürülmektedir (Choudhry, 2001; Lee, 2010). Geleneksel görüş ve Fisher hipotezine karşıt olarak, literatürde yer alan birçok ampirik çalışma, enflasyon ile hisse senedi getirileri arasında negatif bir ilişki olduğunu göstermektedir (Fama ve Schwert, 1977; Fama, 1981).

Türkiye ekonomisi, özellikle son yıllarda yüksek enflasyon oranları ve bu oranların dalgalanmaları ile dikkat çekmektedir. Bu makro ekonomik dengesizlikler, finansal piyasalar üzerinde önemli etkilere sahiptir ve hisse senedi getirileri bu etkilerden dolaylı ve dolaysız olarak etkilenebilir. Türkiye'de enflasyon ve enflasyon oynaklığının hisse senedi getirileri üzerindeki etkisini anlamak, yatırımcılar ve politika yapıcılar için büyük önem taşımaktadır.

Türkiye'deki yüksek ve değişken enflasyon oranları, yatırımcıların beklentilerini ve piyasa dinamiklerini şekillendirmede kritik bir rol oynamaktadır. Enflasyonun yüksek olduğu dönemlerde, özellikle büyüme potansiyeli yüksek sektörlerdeki şirketler, fiyatlarını artırarak kârlarını koruyabilirler ve bu durum hisse senedi getirilerini olumlu etkileyebilir. Ayrıca, enflasyonun nominal hisse senedi getirilerini artırması, yatırımcıların reel getirileri değerlendirmesine de bağlı olarak olumlu algılanabilir.

Enflasyon belirsizliğinin etkisi ise daha karmaşıktır. Yüksek volatilite, ekonomik belirsizlik ve risk algısını artırarak yatırımcı güvenini zayıflatabilir ve bu durum yatırımcıların daha temkinli davranmasına ve daha az riskli varlıklara yönelmesine yol açabilir. Ancak, volatilite aynı zamanda yatırımcılara yüksek getirili fırsatlar da sunabilir. Türkiye'de son yıllarda gözlemlenen

yüksek enflasyon volatilitesi, hisse senedi piyasalarında dalgalanmaların artmasına neden olmuştur. Bu dalgalanmalar, deneyimli yatırımcılar için stratejik fırsatlar yaratabilir ve doğru zamanda yapılan yatırımlar yüksek getiriler sağlayabilir. Özellikle Borsa İstanbul gibi gelişmekte olan piyasalarda, enflasyon volatilitesinin hisse senedi getirileri üzerindeki etkisi daha belirgin olabilir. Gelişmekte olan piyasalarda enflasyon volatilitesinin yarattığı fırsat ve riskler, yatırımcıların stratejilerini etkiler ve piyasa dinamiklerini şekillendirir. Bu bağlamda, enflasyon volatilitesinin yüksek olduğu dönemlerde, yatırımcıların bu dalgalanmalardan kaynaklanan fırsatları değerlendirerek daha yüksek getiriler elde etmeleri mümkündür.

Yükselen enflasyon oranları, birikim ve tasarruf sahiplerini varlıklarının reel değerini koruma konusunda ciddi zorluklarla karşı karşıya bırakabilir ve varlıklarının değerinde reel olarak bir azalma yaşanmasına neden olabilir. Türkiye'de, enflasyonun artması, bireylerin tasarruflarının alım gücünü azaltarak ekonomik güven duygusunu zedeler. Bu durum, yatırımcıları varlıklarını korumak ve değerini artırmak için alternatif yatırım araçlarına yönelmeye zorlayabilir. Para politikalarında sıklıkla başvurulan daraltıcı politikalar sonucu faiz oranlarının artırılması, tüm birikimlerini gayrimenkul gibi büyük ve nispeten likit olmayan yatırımlara yönlendiremeyen yatırımcıları borsa ve döviz gibi daha likit yatırım araçlarına yönlendirebilir. Türkiye'de, bu süreçte yatırımcılar paralarının değerini koruma ve artırma potansiyeline sahip, yüksek getiri sağlayabilecek şirket hisselerine yönelebilirler. Bu şirketler, enflasyonist ortamda maliyetlerini yönetme ve fiyatlarını artırma becerilerine sahip olduklarından, karlarını artırabilir ve bu karları yatırımcılarına yansıtabilirler. Enflasyonun ve enflasyon belirsizliğinin artışı her zaman olumsuz sonuçlar doğurmaz. Aksine, doğru yatırım kararları ve stratejileri ile bu durumdan kazanç sağlanabilir. Türkiye'de, enflasyon dönemlerinde genellikle iyi performans gösteren sektörler ve şirketler belirlenerek, bu alanlara yapılan yatırımlar sayesinde yatırımcılar avantaj elde edebilirler. Özellikle, enerji, gıda ve ihracat odaklı sektörler enflasyonist dönemlerde daha dirençli olabilir ve yatırımcılara karlılık sağlayabilir. Türkiye ekonomisinde enflasyonun yüksek olduğu dönemlerde, bireysel yatırımcılar ve portföy yöneticileri, enflasyonla başa çıkma stratejileri geliştirerek portföylerini çeşitlendirebilirler. Bu bağlamda, enflasyonun ve volatilitenin artışının yaratabileceği fırsatlar, dikkatli analizler ve stratejik yaklaşımlarla değerlendirilebilir, böylece yatırımcılar enflasyonist ortamda bile kazanç sağlayabilirler. Türkiye'de özellikle döviz, altın ve hisse senetleri gibi enstrümanlar, enflasyona karşı korunma aracı olarak öne çıkabilir ve bu araçlar doğru yönetildiğinde yatırımcılara önemli getiri sağlamaktadır.

2. Literatür İncelemesi

Ampirik literatürün kapsamlı bir incelemesi, enflasyon ve enflasyon belirsizliğinin hisse senedi getirileri üzerindeki etkisi konusunda bir fikir birliği olmadığını ortaya koymaktadır. Enflasyon oranları ile borsa endeksleri arasındaki ilişkiyi inceleyen geniş bir literatür bulunmasına rağmen, bu alanda farklı bulgular rapor edilmiştir. Bu bağlamda, bazı çalışmalar (Akyol, 2020; Boamah, 2017; Coşkuner ve Özer, 2024; Horasan, 2008; Karamustafa ve Karakaya, 2004; Sayılgan ve Süslü, 2011; Zügül ve Şahin, 2009) enflasyonun hisse senedi getirileri üzerinde olumlu etkiler yarattığını ve hisse senetlerinin enflasyona karşı etkin bir korunma aracı olduğunu öne sürerken; diğer çalışmalardan (Elmahgop ve Sayed, 2020; Geske ve Roll, 1983; Kusumaningtyas vd., 2021; Liu ve Serletis, 2021, vb.) elde edilen bulgular, hisse senedi getirilerinin enflasyona karşı bir korunma sağlamadığını, yani enflasyonun hisse senedi getirileri üzerinde ya negatif bir etkisi olduğunu ya da hiç etkisinin bulunmadığını göstermektedir.

Bu çalışmalar arasında, Liu ve Serletis (2021), Ekim 1982 - Temmuz 2020 döneminde G7 ve EM7 ekonomilerinde enflasyon, enflasyon belirsizliği ve hisse senedi getirileri arasındaki ilişkiyi incelemektedir. Çalışmada, VARMA, GARCH ve BEKK modelleri kullanılmıştır. Enflasyon ve enflasyon belirsizliğinin özkaynak getirileri üzerindeki etkilerinin ülkeler arasında farklılık gösterdiğini bulmuştur. Genel olarak, enflasyonun özkaynak getirileri üzerinde karmaşık ve

zamanla değişen etkileri olduğu, ancak çoğu durumda olumsuz bir etki yarattığı sonucuna varılmıştır.

Geske ve Roll (1983), 1947:Q1-1980:Q1 döneminde ABD'de mali ve parasal politikaların hisse senedi getirileri ve enflasyon arasındaki ilişkileri nasıl etkilediğini araştırmaktadır. Bulgular, parasal politikaların hisse senedi getirileri ve enflasyon üzerinde önemli bir etkisi olduğunu ve enflasyonun artması durumunda parasal sıkılaştırma politikalarının hisse senedi piyasalarını olumsuz etkilediğini ortaya koymaktadır.

Yener ve Tekin'in (2018) çalışmasında, 1998 yılı 1. çeyreğinden 2016 yılı 4. çeyreğine kadar olan dönemde BRICS, G7 ülkeleri ve Türkiye'deki hisse senedi piyasaları ile ekonomik büyüme arasındaki nedensellik ve eşbütünleşme ilişkileri analiz edilmiştir. Araştırmada, hisse senedi endeksleri ile Gayri Safi Yurtiçi Hasıla (GSYİH) arasındaki kısa ve uzun vadeli ilişkileri incelemek için Johansen Eşbütünleşme ve Granger Nedensellik testleri kullanılmıştır. Çalışma, genel olarak hisse senedi endekslerinden GSYİH'ya doğru tek yönlü ilişkiler olduğunu ve serilerin uzun vadede birlikte hareket ettiğini bulmuştur. Bu sonuç, hisse senedi fiyatlarının artışının ekonomik büyümeyi de beraberinde getirdiğini göstermektedir. Ayrıca, enflasyon ve hisse senedi piyasası arasındaki ilişki, hisse senedi fiyatlarının ekonomik büyüme üzerinde olumlu bir etkiye sahip olduğunu ve enflasyonun bu ilişkiyi zayıflatabileceğini öne sürmektedir.

Jareño ve Navarro (2010), İspanyol Borsası'nda listelenen firmaların enflasyon şoklarını fiyatlara yansıtma kapasitelerini incelemiştir. 1993-2005 dönemine ait veriler kullanılarak yapılan çalışma, Dividend Discount Model (DDM) ve Stone'un iki faktörlü modeli gibi ekonometrik yöntemleri uygulamıştır. Bulgular, firmaların enflasyon şoklarını fiyatlara yansıtma kapasitelerinin sektörler arasında büyük farklılık gösterdiğini ortaya koymuştur. Hisse senedi getirilerinin nominal faiz oranı değişikliklerine duyarlılığını azalttığı sonucuna varmışlardır. Bu bulgu, yüksek enflasyon yansıtma kapasitesine sahip firmaların hisse senedi getirilerinin enflasyon ve faiz oranı değişikliklerine daha az duyarlı olduğunu göstermektedir. Yani, firmalar enflasyon şoklarını fiyatlarına yansıtabildiklerinde, enflasyonun hisse senedi fiyatları üzerindeki olumsuz etkisi azalmaktadır.

Sönmez ve Noyan'ın (2022) çalışması, Türkiye'deki hisse senedi getirileri, enflasyon ve ekonomik büyüme arasındaki ilişkiyi incelemiştir. 2008-2022 yılları arasındaki veriler kullanılarak gerçekleştirilen çalışmada, BIST 30 ve BIST 100 endeksleri ile Tüketici Fiyat Endeksi (TÜFE) ve Gayri Safi Yurtiçi Hasıla (GSYİH) değişkenleri analiz edilmiştir. Çalışmada wavelet uyum analizi yöntemi tercih edilmiştir. Araştırma bulguları, hisse senedi getirilerinin enflasyondan bağımsız olduğunu ve enflasyona karşı güvenli bir liman teşkil ettiğini ortaya koymuştur. Ayrıca, ekonomik büyüme ile hisse senedi getirileri arasında pozitif bir ilişki ve karşılıklı etkileşim bulunmuştur. Özellikle 2015 yılına kadar güçlü olan bu etkileşim, 2015 sonrası dönemde zayıflamıştır. Bu bağlamda, hisse senedi getirilerinin ekonomik büyüme ile ilişkili olduğu, ancak enflasyonla anlamlı bir ilişki taşımadığı sonucuna varılmıştır.

Eyüboğlu ve Eyüboğlu (2018) çalışmasında, 2006:01-2016:11 döneminde enflasyon oranı ile hisse senedi getirileri arasındaki ilişkiyi araştırmıştır. Çalışmada, enflasyonun farklı sektörler üzerindeki etkilerini incelemek amacıyla 15 Borsa İstanbul sektör endeksi analiz edilmiştir. Serilerin aynı düzeyde durağan olmaması nedeniyle, eşbütünleşme analizi Sınır testi kullanılarak gerçekleştirilmiştir. Elde edilen bulgular, çalışmaya dahil edilen tüm sektör endeks getirilerinin hem kısa hem de uzun vadede TÜFE ile bağlantılı olduğunu göstermektedir. Özellikle, TÜFE'de gerçekleşen artış 11 endeks'in getirileri üzerinde olumsuz etkiler yarattığı sonucuna varılmıştır. Kullanılan ekonometrik modeller arasında ARDL modelleri ve Sınır testi bulunmaktadır. Sonuç olarak, enflasyonun hisse senedi getirileri üzerinde önemli bir etkiye sahip olduğu ve bu ilişkinin hem uzun hem de kısa dönemde geçerli olduğu ortaya konulmuştur.

Ayaydın ve Dağlı (2012) tarafından yapılan çalışmada, aralarında Türkiye'nin de bulunduğu 22 farklı gelişmekte olan piyasalarda hisse senetlerinin getirileri üzerindeki etkileri değerlendirmek

için panel veri analizi yöntemi kullanılmıştır. Çalışmada, 1994-2009 yılları arasındaki veriler kullanılmıştır. Kullanılan ekonometrik modeller arasında sabit etkiler modeli (SEM) ve tesadüfi etkiler modeli (TEM) yer almaktadır. Ampirik bulgular, enflasyon oranının artışı ise, alt orta gelir düzeyindeki piyasalar örnekleminde hisse senedi getirisini pozitif yönde etkilemiştir. Çalışma, enflasyon oranı ile hisse senedi getirileri arasında genellikle pozitif bir ilişki olduğunu ortaya koymaktadır.

Mukherjee ve Naka (1995) çalışmalarında, 1971:01-1990:12 dönemi arasında Japonya'nın Tokyo Borsası'nda, döviz kuru, para arzı, tüketici fiyat endeksi, sanayi üretimi, uzun vadeli devlet tahvili faiz oranı ve kredi faiz oranı gibi çeşitli makroekonomik değişkenler ile Tokyo Borsası Tüm Hisse Senedi Endeksi arasındaki dinamik ilişkiler detaylı bir şekilde ele alınmıştır. Çalışmada, Eşbütünleşme Testi ve Vektör Hata Düzeltme Modeli kullanılmıştır. Çalışma neticesinde, borsa endeksi ile döviz kuru, sanayi üretim endeksi ve para arzı değişkenleri arasında pozitif ilişkiler bulunmuştur. Ancak enflasyon ile ters yönlü bir ilişki gözlenmiştir. Ayrıca, borsa endeksinin devlet tahvili faiz oranıyla negatif, kredi faiz oranıyla ise pozitif ilişkilere sahip olduğu tespit edilmiştir.

Adusei'nin (2014) çalışmasında, Gana Borsası'ndan (GSE) Ocak 1992-Aralık 2010 dönemine ait veriler kullanılarak enflasyon ile hisse senedi getirileri arasındaki ilişki incelenmiştir. Çalışmada, veriler üzerinde birim kök testleri, ARDL eşbütünleşme yaklaşımı ve Hata Düzeltme Modelinde Granger Nedensellik testi uygulanmıştır. Adusei, kısa vadede enflasyon ile hisse senedi getirileri arasında negatif ve istatistiksel olarak anlamlı bir ilişki bulurken, uzun vadede bu ilişkinin pozitif ve anlamlı olduğunu tespit etmiştir. Nedensellik yönü açısından, enflasyondan hisse senedi getirilerine tek yönlü bir nedensellik olduğu, yani enflasyonun hisse senedi getirilerini uzun vadede dengeye doğru yönlendirdiği sonucuna varılmıştır. Bu bulgular, enflasyonun hisse senedi getirilerinin önemli bir belirleyicisi olduğunu ve Gana Borsası'nda enflasyonun hisse senedi fiyatlarını kısa vadede olumsuz etkilerken uzun vadede olumlu etkilediğini göstermektedir.

Karamustafa ve Karakaya (2004), 1995:01 - 2003:06 yılları arasında yaptıkları çalışmada Türkiye'de İstanbul Menkul Kıymetler Borsası (İMKB) performansı üzerinde enflasyonun etkilerini incelemiştir. Çalışmada, borsa performansını değerlendirmek için işlem hacmi, piyasa değeri, işlem miktarı, sözleşme sayısı, işlem gören şirket sayısı ve endeks değeri gibi farklı göstergeler kullanılmıştır. Enflasyon ölçümü için Tüketici Fiyat Endeksi (TÜFE) seçilmiştir. Ayrıca, enflasyonun borsa performansı üzerindeki kısa ve uzun dönem dinamiklerini incelemek amacıyla "Johansen-Juselius Koentegrasyon Testi" (JJ) ile oluşturulan "Hata Düzeltme Modeli" (ECM) uygulanmıştır. Araştırmanın bulguları, uzun vadede enflasyon oranı ile pay senetleri arasında kısmen negatif bir ilişki olduğunu ortaya koymuştur. Kısa vadeli analizlerde ise, enflasyonun işlem hacmi ile pozitif bir ilişki gösterdiği, işlem miktarı üzerinde ise belirgin bir etkisinin bulunmadığı sonucuna ulaşılmıştır.

Sayılgan ve Cemil Süslü (2011), 1999-2006 döneminde Türkiye ve diğer gelişmekte olan ülkelerde enflasyonun hisse senedi getirileri üzerindeki etkisini incelemişlerdir. Çalışmada, Borsa İstanbul (BIST) ve diğer gelişmekte olan ülkelerin verileri kullanılarak, panel veri analizi yöntemi uygulanmıştır. Sonuçlar, enflasyonun hisse senedi getirileri üzerinde pozitif bir etkisi olduğunu göstermektedir.

Yıldırım, Ögel ve Alhajrabee (2020), Ocak 2013 - Mart 2020 döneminde Türkiye'deki enflasyon ve faiz oranlarının Borsa İstanbul'un BİST Mali endeksi getirileri üzerindeki etkisini incelemişlerdir. Çalışmada, enflasyonun hisse senedi getirileri üzerinde doğrudan bir nedensellik ilişkisi bulunmamış, ancak hisse senedi getirilerinden enflasyona doğru bir Granger nedensellik ilişkisi tespit edilmiştir. Bu sonuç, enflasyonun hisse senedi getirileri üzerinde anlamlı bir etkisi olmadığını, ancak hisse senedi getirilerinin enflasyon üzerinde etkili olduğunu göstermektedir. Bu da hisse senedi getirilerinin enflasyonu öngörmede kullanılabileceğini göstermektedir.

Horasan (2008), 1990-2007 döneminde Türkiye'de enflasyonun hisse senedi getirileri üzerindeki etkisini incelemiştir. Çalışmada, İMKB 100 endeksi ve üretici fiyat endeksi (ÜFE) verileri kullanılarak yapılan zaman serisi analizi sonucunda, enflasyon ve hisse senedi getirileri arasında pozitif bir ilişki bulunmuştur. Bu sonuç, enflasyon artışının hisse senedi getirilerini olumlu yönde etkilediğini göstermektedir.

Yurttançıkmaz (2012), Çalışmasında 1994:1-2010:12 dönemi için Türkiye'de enflasyon ve döviz kuru değişimlerinin hisse senedi performansına olan etkisini araştırmaktadır. Bu çalışmada, Tüketici Fiyatları Endeksi (TÜFE), döviz kuru ve İMKB 100 endeksi verileri kullanılarak zaman serisi analizi ve Granger nedensellik testi gerçekleştirilmiştir. Elde edilen sonuçlar, Türkiye'de enflasyonun İMKB endeksi üzerinde belirgin ve olumlu bir etki yarattığını ortaya koymaktadır.

Boamah (2017), G7 (Kanada, Fransa, Almanya, İtalya, Japonya, Birleşik Krallık ve Amerika Birleşik Devletleri) ve BRICS (Brezilya, Rusya, Hindistan, Çin ve Güney Afrika) ülkelerinde hisse senedi getirileri ile enflasyon arasındaki ilişkiyi incelemektedir. 1991-2014 dönemini kapsayan bu çalışma, nominal faiz oranlarının beklenen enflasyonla birebir hareket ettiğini öne süren Fisher etkisini test etmek amacıyla koentegrasyon ve vektör hata düzeltme modelleri kullanmıştır. Sonuçlar, her iki ülke grubu için de hisse senedi getirileri ile enflasyon arasında uzun vadeli pozitif bir ilişki olduğunu göstermiştir.

Züğül ve Şahin (2009), Ocak 2004 - Aralık 2008 döneminde Türkiye'de enflasyon ve bazı makroekonomik değişkenlerin İMKB 100 endeksi üzerindeki etkisini incelemişlerdir. Çalışmada, tüketici fiyat endeksi (TÜFE), döviz kuru, M1 para arzı ve mevduat faiz oranı verileri kullanılarak yapılan analizler sonucunda, enflasyon ile İMKB 100 endeksi arasında pozitif bir ilişki olduğu tespit edilmiştir.

3. Model ve Veri Seti

Bu çalışmada, Türkiye'de enflasyon ile hisse senedi getirileri arasındaki ilişkiyi ve bu ilişkide enflasyon volatilitesinin etkilerini incelemek amacıyla 2006:01-2024:04 dönemine ait aylık Tüketici Fiyatları Endeksi (TÜFE) verileri ile BİST 100 Endeksi getirileri kullanılmaktadır. Veriler, Türkiye Cumhuriyet Merkez Bankası Elektronik Veri Dağıtım Sistemi TCMB EVDS üzerinden alınmış aylık frekansta elde edilmiştir.

Tablo 1: Veri Kaynağı ve Tanımları

Değişkenler	Sembol	Ölçü Birimi	Veri Kaynağı
Tüketici Fiyatları Endeksi	ENF	Yıllık % Değişim (2003=100)	TCMB (2024)
BİST 100 Endeks Getirisi	BIST100GTR	Kapanış Fiyatlarına Göre (27-12-1996=9,76)	TCMB (2024)

Enflasyon belirsizliği, çalışma kapsamına dahil edilmek üzere ARCH/GARCH modelleri kullanılarak ayrı bir analizle ölçülmekte ve bu şekilde elde edilen enflasyon volatilitesi değişkeni, hisse senedi getirileri üzerindeki etkilerin analizine dahil edilmektedir. Bu yaklaşım, enflasyonun hisse senedi piyasası üzerindeki dinamik etkilerini daha detaylı ve kapsamlı bir şekilde incelemeyi mümkün kılmaktadır. Çalışmada, enflasyon ve enflasyon belirsizliği ile hisse senedi getirileri arasındaki ilişkinin sınamasında kullanılan model eşitlik (1)'deki gibi tanımlanmıştır.

$$BIST100GTR_t = \beta_0 + \beta_1 ENF_t + \beta_2 Enf\_Bsız_t + \varepsilon_t \quad (1)$$

Eşitlik (1)'de yer alan değişkenler ve değişkenlere ait açıklamalar şu şekildedir: ENF, 2003 yılını baz alarak oluşturulan Tüketici Fiyatları Endeksi'ni temsil etmektedir. BIST100GTR ise Borsa İstanbul 100 Endeksi Getirilerini ifade etmektedir. Enf_Bsız ise ARCH/GARCH modelleri ile

hesaplanan enflasyon belirsizliğini (volatilitesini) göstermektedir. Bunun yanı sıra, 'ε' hata terimini belirtmektedir. Çalışmada kullanılan değişkenlere ait tanımlayıcı istatistikler ise Tablo 2'de gösterilmektedir.

Tablo 2: Tanımlayıcı İstatistikler

	BIST100GTR	ENF
Örneklem Dönemi	2006M01 - 2024M04	2006M01 - 2024M04
Gözlem Sayısı	220	220
Ortalama	7.201359	2.502345
Medyan	7.063000	2.284500
Maksimum	9.860000	4.449000
Minimum	5.728000	1.383000
Std. Sapma	0.889843k	0.711485
Çarpıklık	1.154666	1.418393
Basıklık	4.192221	4.137229
Jarque-Bera	61.91536*	85.62260*

*, ** ve *** sırasıyla %1, %5 ve %10 önem seviyesinde istatistiksel olarak anlamlı olduğunu göstermektedir.

Tablo 2'de görüldüğü üzere, serilere ilişkin verilerin dağılımı hakkında bilgi veren çarpıklık, basıklık ve normallik sınamaları dikkate alınmıştır. Elde edilen analiz sonuçlarına göre, hem BİST 100 endeks getirisi serisinin hem de enflasyon değişkeninin çarpıklık değeri 0'dan büyük, yani sağa çarpık (sağdan çarpık) bir dağılım gösterdiği görülmektedir. Basıklık ise, dağılımın iki kuyruğunun birleşik boyutlarının, yani sivriliğinin veya basıklığının bir ölçüsüdür. Basıklık, kuyruklardaki olasılık miktarını ve dolayısıyla bir dağılımın diklik derecesini ölçer. Normal dağılıma sahip bir veri setinin basıklık değeri genellikle 3'e eşit kabul edilmektedir. Hesaplanan basıklık değeri 3'ten büyük olduğunda, veri kümesinin normal dağılımdan ziyade sivri özellikler gösterdiği anlaşılmaktadır. Basıklık değeri 3'ten küçük olduğunda ise, dağılımın normalden daha basık olduğu ve açık kuyruklara sahip olduğu belirtilmektedir (Choi ve Lee, 2021). Bu noktada hem BİST 100 endeks getirisi serisinin hem de enflasyon değişkeninin basıklık analizi sonuçlarına göre, bu değerin 3'ten büyük olduğu ve serinin sivri bir dağılım gösterdiği anlaşılmaktadır. Bir diğer normal dağılım göstergesi olan Jarque-Bera olasılık değerleri, her iki seri için kritik değerleri 0.05'ten küçüktür. Bu durum, serilerin normal dağıldığını ifade eden H_0 hipotezinin reddedilmesine ve dolayısıyla serilerin normal dağılıma uymadığını göstermektedir.

4. Empirical results

4.1. Belirsizlik Değişkeninin Tahmin Edilmesine İlişkin ARCH-GARCH Analizi

Enflasyon ve enflasyon belirsizşiğinin hisse senedi getirileri üzerindeki etkisini inceleyen bu araştırmada, tahmin sürecine başlamadan önce, her bir değişkenin zaman serisi özellikleri incelenmeli ve serilerin durağan olup olmadığı, durağan ise hangi düzeyde durağan oldukları belirlenmelidir. Bu çalışmada, Genişletilmiş Dickey-Fuller (ADF) ve Philips-Perron (PP) birim kök testleri kullanılarak serilerin durağanlık düzeyleri sınanmakta ve sonuçlar Tablo 3'de sunulmaktadır.

Tablo 3: Birim Kök Testi Sonuçları

Değişkenler	ADF Birim Kök Testleri			
	Düzeyde		Birinci Farkında	
	Sabitli	Sabitli & Trendli	Sabitli	Sabitli & Trendli
ENF	-0.8437	-2.2245	-10.7456***	-10.7892***
BIST100GTR	2.3109	0.0428	-13.8565***	-14.2534***
Değişkenler	PP Birim Kök Testleri			

	Düzeyde		Birinci Farkında	
	Sabitli	Sabitli & Trendli	Sabitli	Sabitli & Trendli
ENF	-0.3977	-1.7419	-10.6067***	-10.5741***
BIST100GTR	2.2925	-0.0292	-13.8565***	-14.2574***

***, ** ve * sırasıyla %1, %5 ve %10 önem seviyesinde istatistiksel olarak anlamlı olduğunu göstermektedir.

Tablo 3'te gösterilen sonuçlar, her iki değişkenin de düzeyde birim kök içerdiğini, ancak birinci fark alındığında durağan hale geldiğini göstermektedir. Bu bulgular, serilerin düzeyde durağan olmadığını, fakat birinci farklarının alınmasıyla durağanlaştığını ortaya koymaktadır. Bu noktadan hareketle ilk olarak, enflasyon belirsizliğinin sınanmasında kullanılacak model ARIMA modelidir ve burada "I" harfi, bütünleme (integration) derecesini ifade etmektedir. Eğer belirsizlik serisi hesaplanan değişkenin I(1) olduğu tespit edilirse, serinin durağan hale getirilmesi için birinci farkının alınması gerekmektedir (Uğurlu, 2014). Bu nedenle, analizlerde serilerin birinci farkları alınarak kullanılmaktadır.

Durağanlık analizlerinin ardından enflasyon serisinde ARCH etkisinin tespit edilmesi amacıyla ARCH- LM (ARCH Lagrange Multiple) testi yapılmaktadır. Belirsizliğin ele alınacağı seride ARCH etkisinin varlığını sınamadan evvel ARIMA modellerinin kurulup, anlamlı olup olmadıkları incelenmelidir. Enflasyon serisinin seviyede durağan olmadığı, birinci derece farkı alındığında durağan hale geldiği tespit edildiğinden, ARIMA modelinde "i" değeri 1 olarak belirlenmiştir. ARCH-LM testinde, her bir serinin ortalama denkleminin belirlenmesinde otoregresif ve hareketli ortalama süreçleri (ARMA) kullanılmış ve enflasyon serisi on iki (12) gecikmeye kadar incelenmiştir. Akaike (AIC) ve Schwarz bilgi kriterlerine göre en uygun model seçilmiştir. Bu analizlerde elde edilen bulgular, ARIMA modellerinin test edilmesinde seçilen ARMA (0,1) modelinin en uygun model olduğunu göstermektedir.

Tablo 0: ARMA Modelinin Tahmin Sonuçları

	SIC	AIC
Tahmini ARMA modellerinin sayısı	25	25
Yakınsak olmayan tahminlerin sayısı	0	0
Seçilen ARMA modeli	(0,1)	(3,3)
Bilgi kriterleri değeri:	-1.41015139443	-1.48913941893

ARCH — LM testinde her bir seriye ilişkin ortalama denklemin tespiti için otoregresif ve hareketli ortalama süreçleri (ARMA) kullanılmıştır. Bu bağlamda, enflasyon serisi on ikinci (12) gecikmeye kadar incelenmiş ve Akaike'nin (AIC) ile Schwarz'ın (SIC) bilgi kriterlerine göre en iyi model belirlenmiştir. Yapılan analizler sonucunda elde edilen bulgular, ARIMA modellerinin testlerinde ARMA (0,1) modelinin en uygun model olduğunu göstermektedir.

Tablo 5: Serinin ARMA (0,1) Modeli İçin Sonuçları

	Parametre Tahmini	Std. Hata	t- ist.	Olasılık
C	0.010048	0.010258	0.979617	0.0000
MA(1)	0.300697	0.048056	6.257166	0.0000
SIGMASQ	0.013270	0.000759	17.47284	0.0000

Akabinde, ortalama denklemlerde ARCH (Autoregressive Conditional Heteroskedasticity) etkisinin varlığını sınamak amacıyla ARCH — LM testi uygulanmaktadır. Bu test, enflasyon serisine ilişkin ortalama denklemlerde ARCH etkisinin olup olmadığını belirlemek için kullanılmaktadır. Enflasyon serisinin dinamik yapısının analiz edilmesi ve seride mevcut olabilecek heteroskedastisitenin tespiti açısından önemli olan bu test, serinin zaman içinde değişen varyans yapısını ve olası volatiliteyi ortaya çıkarmaya yönelik yapılmaktadır. ARCH —

LM testi sayesinde, enflasyon serisinin varyansının sabit olup olmadığı ve varyanstaki değişikliklerin ekonometrik modellemeler için dikkate alınması gerekip gerekmediği analiz edilmektedir.

Tablo 6: ARMA (0,1) için ARCH — LM Testi Sonuçları

F- ist.	F-Olasılık (1,216)	$T*R^2$	χ^2 -Olasılık (1)
4.357474	0.0380	4.310856	0.0379

Tablo 6'de ARCH LM testine ilişkin tahmin sonuçları detaylı bir şekilde sunulmuştur. Enflasyon serisindeki volatiliteyi, yani belirsizliği belirlemeye yönelik gerçekleştirilen ARCH LM testi sonuçlarına göre sıfır hipotezi reddedilmiş ve ARCH etkisi olduğu ortaya konmuştur yani, enflasyon serisinin volatilite içerdiği açıkça belirtilmektedir. Bu sonuçlar, enflasyon serisinin zaman içerisinde değişkenlik gösterdiğini ve bu değişkenliğin öngörülemeyen şoklar veya ekonomik dalgalanmalar nedeniyle oluştuğunu göstermektedir. Bu nedenle, enflasyon serisinin dinamik yapısını daha iyi anlayabilmek ve modelleyebilmek için ARCH modellerinin kullanımı gerekliliği vurgulanmaktadır.

Dördüncü adımda, ortalama denklemlerde ARCH etkisinin varlığı tespit edildikten sonra, uygun ARCH ve GARCH (Generalized Autoregressive Conditional Heteroskedasticity) tipi modellerin seçimine odaklanılmaktadır. Bu aşamada, çeşitli ARCH ve GARCH modelleri incelenmekte ve enflasyon belirsizliklerinin analizi için en uygun model belirlenmeye çalışılmaktadır. Yapılan analiz ve model karşılaştırmaları sonucunda, enflasyon belirsizliklerini en iyi açıklayan modelin GARCH (1,1) modeli olduğu tespit edilmiştir. Bu bulgu, GARCH (1,1) modelinin, enflasyon belirsizliklerinin dinamik yapısını ve varyansın zamana bağlı değişkenliğini en iyi şekilde yakalayabildiğini göstermektedir. Dolayısıyla, enflasyon belirsizliklerine ilişkin öngörülerde ve politikaların şekillendirilmesinde GARCH (1,1) modelinin kullanılması önerilmektedir.

Tablo 7: Enflasyon Serisinin GARCH (1,1) Modeli Sonuçları

	Parametre Tahmini	Std. Hata	z-ist.	Olasılık
C	0.006917	0.006745	1.025420	0.3052
MA(1)	0.297777	0.047859	6.222031	0.0000
Vairance Equation				
RESID(-1)^2	0.034326	0.005553	6.181729	0.0000
GARCH(-1)	0.965674	0.005553	173.9079	0.0000

Tablo 7'de, enflasyon serisine ilişkin olarak hesaplanan GARCH (1,1) modeline ait raporlama süreci detaylı bir şekilde gösterilmektedir. Bu aşamada, modelin uygunluğu ve performansı değerlendirilmiştir. Daha sonra, modelde olası ARCH etkisinin varlığını yeniden tespit etmek amacıyla ARCH-LM testi uygulanmıştır. Bu testin sonuçları, modelin içsel heteroskedastisite içerip içermediğini belirlemeye yönelik olup, elde edilen bulgular Tablo 8'de sunulmaktadır. Bu süreç, modelin geçerliliğini ve güvenilirliğini pekiştirmek için önem arz etmektedir.

Tablo 8: GARCH (1,1) için ARCH — LM Testi Sonuçları

F- ist.	F-Olasılık F(1,216)	$T*R^2$	χ^2 -Olasılık (1)
0.595769	0.4410	0.599631	0.4387

Tablo 8'da yer alan ARCH LM testine ilişkin tahmin sonuçlarına göre, sıfır hipotezi reddedilememektedir. Bu da seride ARCH etkisi olmadığını, serinin volatilitesinin giderildiğini göstermektedir. Bu bulgudan hareketle, GARCH (1,1) modelinin mevcut oynaklığı en uygun şekilde modellediği anlaşılmaktadır.

GARCH (1,1) modelinin seçilmesinin ardından, enflasyon serisinin aylık koşullu varyans değerleri hesaplanmıştır. Elde edilen koşullu varyans serisi, modelde belirsizlik değişkeni olarak kullanılmaktadır. Bu belirsizlik değişkeninin oluşturulması amacıyla, aylık koşullu varyans değerlerinin yıllık ortalaması 2006:01-2024:04 dönemini kapsayacak şekilde hesaplanmıştır.

4.2. Modelin Tahminine İlişkin Eşbütünleşme Analizi

Birim kök testleri sonucunda değişkenlerin bütünleşme derecelerinin aynı olduğu yani aynı seviyede durağan olduğu tespit edilmiş ve değişkenler arasında uzun süreli bir ilişkinin olup olmadığı eş bütünleşme testleriyle incelenmiştir. Araştırmanın bu aşamasında değişkenler arasında uzun dönemli bir ilişkinin olup olmadığı Johansen (1991, 1995) yaklaşımı çerçevesinde araştırılmaktadır. En uygun gecikme uzunluğu, Johansen eş-bütünleşme testini gerçekleştirmeden önce belirlenmelidir. Bu nedenle, değişkenler arasında uygun gecikme uzunluğunu belirlemek vektör otoregresif (VAR) modeli tahmin edilir. Sonuç olarak, Johansen eş-bütünleşme testi için optimum gecikme uzunluğu, FPE (Final prediction error), AIC (Akaike information criterion) ve HQ (Hannan-Quinn information criterion) temel alınarak 2 şeklinde belirlenmiştir. Uygun gecikme uzunluğunu belirledikten sonra, eş bütünleşme ilişkilerinin varlığını ve sayısını belirlemek için Johansen eş-bütünleşme testi analiz edilir. "2" gecikme uzunluğu için İz ve Maksimum Öz-değer istatistikleri gibi iki teste dayanan Johansen eş-bütünleşme testinin sonuçları Tablo 10'da rapor edilmiştir.

Tablo 10: Johansen Eşbütünleşme ve Tanısal Testlerin Sonuçları

Johansen Eşbütünleşme Testleri						Sistem Tanılama	
H_o	H_1	λiz İstatistiği	Kritik Değer %5	λmaks İstatistiği	Kritik Değer %5	Otokorelasyon	Değişen Varyans
r = 0	r ≥ 1	26.5170*	24.2759	18.0530*	17.7973	2.935767	42.80885
r ≤ 1	r ≥ 2	8.46403	12.3209	5.98432	11.2248		
r ≤ 2	r ≥ 3	2.47971	4.12990	2.47971	4.12990	(0.9668)	(0.2021)

*, sıfır hipotezinin %5 önem düzeyinde istatistiksel olarak reddedildiğini göstermektedir. Kritik değerler (c.v.) MacKinnon-Haug-Michelis'e (1999) dayanmaktadır. "r" eşbütünleşme ilişkilerinin sayısını belirtmektedir. Parantez içindeki sayılar p değerlerini temsil etmektedir.

Tablo 10 üzerindeki eşbütünleşme analizi sonuçları, Enflasyon ile Bist100 Endeks Getirisi arasında hem maksimum özdeğer hem de iz test istatistiklerinin %5 anlamlılık düzeyinde eşbütünleşme olmadığına dair H0 hipotezinin reddedildiğini ve bu nedenle her iki test tarafından değişkenler arasında bir eşbütünleşme ilişkisi olduğu göstermektedir. Tablo 4.11'de görüldüğü üzere iz istatistiği 26.5170 olup, 24.2759'luk kritik değerin üzerindedir. Bu nedenle, sıfır hipotezi (r=0) %5 anlamlılık düzeyinde reddedilmektedir. Benzer şekilde, maksimal özdeğer testi için de eşbütünleşme olmadığına dair boş hipotezin (λmax = 18.0530>17.7973) %5 anlamlılık düzeyinde reddedildiği görülmektedir. Bu sonuçlar, Enf ve Bıst100gtr serilerinin bir eşbütünleşme ilişkisine sahip olduğuna dair kanıt sağlamaktadır. Yani Enflasyon ile Bist100 Endeks getirileri arasında uzun dönemli bir ilişki olduğu gözlemlenmektedir. Genel model uygunluğunu değerlendirmek amacıyla otokorelasyon, değişen varyans ve normallik testlerini içeren bir dizi tanısal test uygulanmıştır. Bu testlerin sonuçlarına göre, olasılık değerlerinin %5'in üzerinde olduğu tespit edilmiştir. Bu durum, modelde otokorelasyon ve değişen varyans problemlerinin bulunmadığını ve kalıntıların normal dağıldığını göstermektedir. Tablo 4.11'da belirtildiği üzere, tanısal testlerin ciddi bir şekilde ihlal edildiğine dair herhangi bir kanıt bulunmamaktadır.

Değişkenler arasındaki eşbütünleşme ilişkisini ortaya koyan bulgulara dayanarak, uzun dönem katsayı tahmincileri olan Tamamen Geliştirilmiş En Küçük Kareler (FMOLS), Dinamik En Küçük Kareler (DOLS) ve Kanonik Eşbütünleşik Regresyon (CCR) yöntemlerinden faydalanılmıştır. DOLS, FMOLS ve CCR tahmin sonuçları, Tablo 11'de yer almaktadır.

Tablo 11: Uzun Dönemli Eşbütünleşme Katsayılarının Tahmin Sonuçları

Değişkenler	DOLS		FMOLS		CCR	
	Katsayı (std. hata)	t-ist.	*Katsayı (std. hata)*	t-ist.	*Katsayı (std. hata)*	t-ist.
C	4.12670 * (0.0918)	11.1742	4.0531* (0.2688)	15.0740	4.0535* (0.2671)	11.5262
ENF	1.02596* (0.0918)	3.08285	1.0514* (0.0904)	11.6268	1.0522* (0.0912)	11.5262
ENF_BSIZ	42.1933* (13.6864)	15.1879	43.177* (13.6920)	3.15347	43.036* (13.5793)	3.1692

*, %1 önem düzeyinde istatistiksel olarak anlamlı olduğunu göstermektedir.

Tablo 11'deki katsayılar incelendiğinde, Değişkenlerin %1 önem düzeyinde anlamlı olduğu gözlemlenmektedir. DOLS yöntemi uzun dönemde Enflasyon (ENF) üzerinde meydana gelen %1'lik bir artış BİST100 Endeksi Getirilerini %1,02596 oranında arttırmaktadır. FMOLS yöntemi uzun dönemde Enflasyon değişkeni üzerinde meydana gelen %1'lik bir yükseliş BİST100 Endeksi Getirilerini %1,0514 oranında arttırmaktadır. CCR yöntemine göre ise, Enflasyon oranlarında yaşanan %1'lik bir yükselişin BİST100 Endeksi Getirilerini %1,0522 oranında yükselttiği gözlemlenmektedir. Bu sonuçlar Türkiye'de enflasyonun ve enflasyon belirsizliğinin uzun dönemde Borsa İstanbul 100 Endeksi Getirilerini pozitif yönde etkilediğini ispatlamaktadır.

Sonuç ve Değerlendirme

Bu çalışmada, 2006:01 – 2024:04 dönemini kapsayan veri seti kullanılarak, enflasyona ilişkin volatilitenin ölçülmesi için ARCH-GARCH modelleri uygulanmıştır. Değişkenler arasındaki uzun dönemli bir eşbütünleşme ilişkisini test etmek amacıyla Johansen Eşbütünleşme testleri kullanılmış, uzun dönem katsayılarının tahmininde ise DOLS, FMOLS ve CCR modelleri tercih edilmiştir. Bu yöntemlerin uygulanması, enflasyon ve hisse senedi getirileri arasındaki karmaşık ilişkilerin daha derinlemesine anlaşılmasına katkıda bulunması beklenmektedir. Johansen Eşbütünleşme analizi, çoklu zaman serisi değişkenleri arasındaki uzun dönemli denge ilişkilerini tespit edebilme ve birden fazla eşbütünleşme vektörünü eşzamanlı olarak belirleyebilme avantajlarına sahiptir. Bu yöntem, veri setlerinde trend ve mevsimsellik gibi bileşenleri dikkate alarak daha uyumlu ve güvenilir tahminler sağlamaktadır.

Çalışmada, Türkiye'nin 2006 yılı sonrası açık enflasyon hedeflemesi stratejisinin benimsendiği dönemde enflasyon belirsizliği ve enflasyon oranlarının BIST100 Endeksi getirileri üzerindeki etkisi incelenmiştir. DOLS yöntemi ile yapılan analiz sonuçlarına göre, enflasyondaki artışlar BIST100 Endeksi getirilerini artırmaktadır. FMOLS yöntemi kullanılarak yapılan analizler de benzer şekilde, enflasyondaki artışların BIST100 Endeksi getirilerini yükselttiğini göstermektedir. CCR yöntemi ile elde edilen sonuçlar da enflasyondaki artışların BIST100 Endeksi getirilerini artırdığını ortaya koymaktadır. Bu bulgular, Türkiye'de enflasyon oranının uzun dönemde Borsa İstanbul 100 Endeksi getirilerini pozitif yönde etkilediğini ispatlamaktadır.

Aynı zamanda Türkiye'deki enflasyon belirsizliğinde (volatilitesinde) yaşanacak olan artışlar da BİST 100 Endeksi getirilerini pozitif etkilemektedir. Özellikle, enflasyon belirsizliğinin (volatilitesinin) artışının, enflasyonun artışından daha fazla hisse senedi getirilerini artırdığı belirlenmiştir. Dolayısıyla, hisse senetlerinin enflasyonist bir ortamda güvenli bir liman niteliği taşıdığı ortaya konmuştur. Bu durum şu şekilde açıklanabilir, yatırımcıların enflasyon beklentileri ve ekonomik belirsizlikler karşısında hisse senedi piyasasında daha hızlı tepki verdiğini göstermektedir. Örneğin, yüksek enflasyon dönemlerinde yatırımcılar, paralarının değer kaybetmesini engellemek amacıyla daha fazla risk alarak hisse senetlerine yönelebilirler. Bu da BİST 100 endeksinde ani yükselişlere yol açabilir. Aynı şekilde, enflasyon oranlarının düşmesi ve ekonomik istikrarın sağlanması, yatırımcıların güvenini artırarak hisse senedi piyasasına olan ilgiyi de sürdürebilir.

Enflasyon ve enflasyon belirsizliğinin (volatilitenin) artışına farklı bir açıdan bakıldığında, tasarruf sahiplerinin ve yatırımcıların varlık değerlerini koruma konusunda zorluklarla karşılaşabilecekleri görülmektedir. Bu tür ekonomik koşullarda, yatırımcıların varlıklarını genellikle uzun vadeli gayrimenkul yatırımları yerine, daha likit olan borsa gibi kısa vadeli yatırım araçlarına yönlendirmelerine neden olabilir. Yatırımcılar, bu süreçte varlıklarını, finansal kaynaklarını kendilerinden daha etkili bir şekilde yöneteceğine inandıkları portföy yönetim şirketlerine veya yatırım fonlarına aktararak, enflasyon ve enflasyon volatilitesine karşı koruma sağlamayı hedefleyebilirler. Bu çalışmanın bulguları, literatürdeki mevcut araştırmalarla uyumlu olup, enflasyon ve hisse senedi getirileri arasında uzun dönemli bir ilişki olduğunu ve bu ilişkinin pozitif yönde olduğunu ortaya koymaktadır. Adusei (2014), Ayaydın ve Dağlı (2012), Boamah (2017), Sayılgan ve Süslü (2011), Tekin ve Yener (2018), Yurttançıkmaz (2012) ve Zügül ve Şahin (2009) tarafından yürütülen çalışmalar, bu sonuçları destekler niteliktedir. Bu bağlamda, söz konusu çalışmaların bulguları, enflasyon ile hisse senedi getirileri arasındaki ilişkiye dair elde edilen sonuçların güvenilirliğini artırmakta ve literatürdeki bilgi birikimine önemli katkılarda bulunması beklenmektedir.

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KÜRESEL YEŞİL EKONOMİ ENDEKSİ VE TÜRKİYE'NİN KONUMU

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Özet

Bilindiği üzere sürdürülebilir kalkınma, bugünün ihtiyaçlarını gelecek kuşakların ihtiyaçlarını karşılama yeteneğinden ödün vermeden giderme çabasıdır. Sürdürülebilir kalkınmanın bir alt disiplini ve tamamlayıcısı olan yeşil ekonomi ise; çevreyi tahrip etmeden sürdürülebilir kalkınmayı sağlamayı amaçlamakta, çevresel riskleri ve ekolojik kıtlıkları azaltmayı hedeflemektedir. Yeşil ekonominin temeli; düşük karbon ekonomisine geçiş, yenilenebilir enerji kaynaklarının yaygınlaşması, var olan doğal varlıkların verimli kullanılması ve kapsayıcılıktır.

Yeşil ekonomi ve sürdürülebilir kalkınma alanlarında toplumsal bilinci artırmak ve bu değerleri savunmak için kurulmuş bir sivil toplum örgütü olan Dual Citizen, 2010 yılından bu yana iki yılda bir Küresel Yeşil Ekonomi Endeksi (GGEI)'ni yayınlamakta ve iklim değişikliğinin yaratacağı krizleri gündeme getirmeye çalışmaktadır. İklim değişikliği ve sosyal eşitlik, sektörün karbonsuz hale getirilmesi, piyasalar ve ÇYS (çevresel, sosyal ve kurumsal yönetişim) yatırımı ve çevre sağlığı olmak üzere 4 boyutla tanımlanan endeks; 160 ülkenin yeşil ekonomi performansını 18 gösterge üzerinden ölçmektedir.

Bu çalışmanın amacı, Türkiye'nin Küresel Yeşil Ekonomi Endeksi performansını değerlendirmektir. Çalışma dâhilinde; öne çıkan bazı ülkeler ve Türkiye'nin GGEI skorları incelenmek suretiyle, bir durum değerlendirilmesi yapılacaktır. Çalışma esnasında, 2022 yılında yayınlanan son endekste Türkiye'nin toplam değer açısından 160 ülke arasında 0.399 puan ile 140. sırada yer aldığı tespit edilmiştir. Çalışma sonucunda; mevcut göstergelerin iyileşme ve kötüleşme nedenleri araştırılmış, gerek küresel gerekse yerel bazda daha yeşil bir ekonomi adına çözüm önerilerine yer verilmiştir.

Anahtar Kelimeler: Sürdürülebilir kalkınma, yeşil ekonomi, Küresel Yeşil Ekonomi Endeksi

JEL Kodları: Q01, Q56, Q57

GLOBAL GREEN ECONOMY INDEX AND TURKIYE'S POSITION

Abstract

As it is known, sustainable development is the effort to meet today's needs without compromising the ability of future generations to meet their needs. Green economy, which is a sub-discipline and complementary to sustainable development, aims to achieve sustainable development without destroying the environment and to reduce environmental risks and ecological scarcities. The basis of the green economy is transition to a low carbon economy, expansion of renewable energy sources, efficient use of existing natural assets and inclusiveness.

Dual Citizen, a non-governmental organization established to raise public awareness and advocate for green economy and sustainable development, has been publishing the Global Green Economy Index (GGEI) every two years since 2010 and has been trying to bring to the agenda the crises caused by climate change. The index is defined by 4 dimensions: climate change and social equity, decarbonization of the sector, markets and ESG (environmental, social and corporate governance) investment and environmental health; it measures the green economy performance of 160 countries through 18 indicators.

The aim of this study is to evaluate Turkiye's performance in the Global Green Economy Index. Within the scope of the study, a situation assessment will be made by examining GGEI scores of some prominent countries and Turkiye. During the study, it's determined that in the last index published in 2022, Turkiye ranked 140th among 160 countries with 0.399 points in terms of total value. As a result of the study, the reasons for the improvement and deterioration of the current indicators're investigated and solutions're proposed for a greener economy both on a global and local basis.

Keywords: Sustainable development, green economy, Global Green Economy Index

JEL Codes: Q01, Q56, Q57

1. Giriş

1970'li yıllara kadar, ekonomik büyüme ve kalkınma faaliyetleri sonucu ortaya çıkan kirliliğin, oluştuktan sonra giderilmesi yöntemi benimsenmiştir. Bu yaklaşımda öncelik ekonomik büyüme ve kalkınmaya verilmiş, çevre sorunlarının çözümü sürekli ertelenmiştir (Yalçın, 2016, s. 751). Sanayileşme süreciyle birlikte giderek artan hammadde ihtiyacı, bilhassa fosil yakıtların aşırı kullanımı vb. uygulamalar; çevre ve doğal kaynaklar üzerinde baskı oluşturacak boyutlara ulaşmıştır. Günümüzde fosil yakıtlara dayalı üretimi benimseyen kahverengi ekonomiden, çevre dostu yeşil ekonomiye doğru bir geçiş süreci yaşanmaktadır (Kutluay Tutar, Ekici ve Tutar; 2021, s. 2890).

Birleşmiş Milletler Çevre Programı (UNEP) 2011 Yeşil Ekonomi Raporu'nda şu ifadeleri kullanmıştır: *"Yeşil olmak için bir ekonominin sadece verimli değil, aynı zamanda adil olması da gerekir. Adalet özellikle düşük karbonlu, kaynakları verimli kullanan ve sosyal açıdan kapsayıcı bir ekonomiye adil geçişin sağlanmasında; ulusal ve küresel düzeyde eşitlik boyutlarının tanınması anlamına gelir."*

Dual Citizen yeşil ekonomi ve sürdürülebilir kalkınma alanlarında toplumsal bilinci artırmak ve bu değerleri savunmak amacıyla, 2010 yılında kurulmuş bir sivil toplum örgütüdür. Bu örgüt ilk Küresel Yeşil Ekonomi Endeksi (GGEI)'ni kuruluş yılında yayınlamış ve iklim değişikliğinin yaratacağı krizleri gündeme getirmeye çalışmıştır. GGEI, bu alanda yayınlanan ilk endekstir. 2010 yılında sadece 27 ülkeyi inceleyen endeks, 2022 yılında yayınlanan son raporunda 160 ülkeyi ele almıştır.

Türkiye'nin Küresel Yeşil Ekonomi Endeksi performansını değerlendirmeyi amaçlayan bu çalışma; giriş kısmı haricinde yeşil ekonomi kavramı, literatürden örnekler, Küresel Yeşil Ekonomi Endeksi (GGEI) ile sonuç ve öneriler bölümlerinden oluşmaktadır.

2. Yeşil Ekonomi Kavramı

Yeşil ekonomi tabiri ilk kez; 1989 yılında ekonomistler David Pearce, Anil Markandya ve Edward Barbier tarafından İngiliz Çevre Bakanlığı için hazırlanan ve halk arasında *"Pearce Raporu"* olarak bilinen, *"Blueprint for a Green Economy"* adlı kitabın başlığında kullanılmıştır. Bu kitap daha ziyade sürdürülebilir kalkınma kavramına odaklanmış, yeşil ekonomi kavramı tanımlanmamıştır (Önder, 2018, s. 16). Yeşil ekonomi, çevresel riskleri ve ekolojik kıtlıkları azaltmayı hedefleyen ve çevreyi bozmadan sürdürülebilir kalkınmayı sağlamayı amaçlayan bir ekonomidir.

UNEP'e göre yeşil ekonomi; bir yandan çevresel riskleri ve ekolojik sorunları ortadan kaldırırken, diğer yandan insan refahını artırmaya ve sosyal eşitliği sağlamaya çalışan bir büyüme stratejisidir (Özçağ ve Hotunluoğlu, 2015, s. 313). Sosyal açıdan da kapsayıcı olan yeşil ekonomi, düşük karbonlu kaynakları etkin bir şekilde kullanmaktadır (Gevher ve Acet, 2023, s. 227). Yeşil ekonomi; insanın doğa üzerindeki yıkıcı etkisini minimuma indirmeyi, doğayla uyum içerisinde ve insani ölçekte asgari üretim ve tüketim kalıplarını esas alan bir ekonomik anlayıştır (Yılmaz, 2022, s. 69–70).

Yeşil ekonomi; büyüme-kalkınma süreçlerinin ve sürdürülebilir bir yaşamın, gerek siyasal gerek sosyoekonomik gerekse ekolojik manada tamamlayıcısı konumundadır (Yalçın, 2016, s. 750). Ekonomik büyüme ile çevresel sürdürülebilirlik arasında çok önemli bir bağ kuran yeşil ekonomi; sürdürülebilir kalkınmaya, çevreyi tahrip etmeden ulaşmayı hedeflemektedir (Özçağ ve Hotunluoğlu, 2015, s. 314). Geleneksel refah ve büyüme anlayışına getirilen eleştirel yaklaşımlardan biri olan ve sürdürülebilir kalkınmanın bir alt disiplini olarak ele alınan yeşil ekonomi; doğal kaynakları verimli kullanmak ve nihai ürünleri üretim döngüsüne geri döndürmek suretiyle, toplumun ekonomik refahını korumaya odaklanmıştır (Yılmaz, 2022, s. 69).

Yeşil ekonomi kavramının temelinde, sürdürülebilir kalkınma kavramı vardır. Zira yeşil ekonomi; bir yandan çevresel riskleri ve ekolojik kıtlıkları azaltırken, diğer yandan sosyal eşitliği ve insan refahını artırmaktır. Bu nedenle yeşil ekonomi koşullarında; hem gelir ve istihdam yükselmekte, hem de enerji ve kaynak verimliliği artmaktadır. Öte yandan karbon emisyonları / salınımları[1] ve kirlilik oranları düşmekte, biyoçeşitlilik kaybı azalmaktadır. Küreselleşen dünyada sosyoekonomik ve çevresel zorluklar karşısında adeta kurumsal bir cevap niteliğinde olan yeşil ekonominin; eşit gelir dağılımı, sosyal adalet ve kaynak verimliliğinin artırılması, ekolojik esnekliğin korunması gibi amaçları vardır (Al, 2019, s. 115).

Yeşil ekonomiyi oluşturan sektörel faaliyetler, sadece ekolojik düzene zarar vermeden gerçekleştirilen enerji üretiminden ve tarımsal faaliyetlerden ibaret değildir. Çevreci bir zihniyetle doğanın zarar görmesini engelleyen, doğal alanları koruyup onaran ve endüstriyel üretimi doğayla uyumlu bir hale dönüştüren tüm faaliyetler; yeşil ekonominin bileşenleridir. Yeşil ekonomi, geleneksel üretim tarzının yol açtığı ekolojik sorunlar ile iklim değişikliği gibi daha kalıcı ve sürdürülebilir kalkınmayı engelleyici sorunların azaltılmasına ve / veya ortadan kaldırılmasına yardımcı olmaktadır. Özünde sürdürülebilir kalkınma ve yeşil ekonomi, birbirini ikame eden değil tamamlayan kavramlardır (Günaydın, 2015, s. 505, 506).

3. Literatürden Örnekler

Yeşil ekonomi endeksine ilişkin literatür incelendiğinde, GGEI kapsamında ülkelerin 2010 yılı öncesine ait verilerinin bulunmadığı tespit edilmiştir. Daha uzun bir dönemi kapsayan Türkiye'ye özgü bir yeşil ekonomi endeksine rastlanmasa da, geçtiğimiz 10 yılda yeşil ekonomi ve Türkiye'nin yeşil ekonomi performansının değerlendirildiği çalışma sayısı büyük ölçüde artmıştır.

Nahman ve diğerleri (2016) tarafından yapılan çalışmada; ülkelerin yeşil ekonomi performanslarını ölçmek için, sosyoekonomik ve çevresel boyutlarda 26 göstergeye dayanan bir bileşik endeks geliştirilmiştir. Söz konusu endeks bir ülkenin yeşil ekonomi performansının, hem zaman içinde hem de diğer ülkelerle karşılaştırılmasını sağlamaktadır. 193 ülkeden gelen veriler üzerinde test edilen ve ayrıştırma (yani tek tek bileşenlere ilişkin puanların ilk bakışta görülebilmesi) imkânı verecek şekilde oluşturulan bu endeks sayesinde, belirli endişe alanlarını kolayca tespit edip ele almak ve her bir alandaki ilerlemeyi izlemek mümkün olacaktır.

Velame ve Teixeira (2017) tarafından yapılan çalışmada; 20 Latin Amerika ülkesinin yeşil ekonomi ve sürdürülebilir kalkınma performansını ölçmek amacıyla, 2006-2013 dönemini kapsayan bir yeşil ekonomi endeksi hesaplanmıştır. Dünya Bankası veri tabanından elde edilen verilerle yapılan çalışmada; yeşil ekonominin 3 boyutunu temsilen kişi başına düşen GSYİH, Gini endeksi ve fosil yakıt tüketimi değişkenleri ele alınmıştır.

Al (2019) tarafından yapılan çalışmanın amacı, Türkiye'nin yeşil ekonomi performansını ölçüp değerlendirmektir. Çalışmada yeşil ekonominin ekonomik, sosyal ve çevresel olmak üzere 3 farklı boyutunu temsil ettiği düşünülen 22 değişkene ilişkin sayısal verilerden hareketle; 2002-

[1] Emisyon; bir kaynaktan yayılan ve çevre için zararlı etkileri olan her türlü katı, sıvı ve gaz atıktır.

2015 dönemini kapsayan bir yeşil ekonomi endeksi hesaplanmıştır. Elde edilen endeks değerlerine göre, Türkiye'nin söz konusu dönemdeki yeşil ekonomi performansı artmaktadır. Bu artışta özellikle sosyoekonomik göstergelerdeki olumlu gelişmelerin payı büyüktür, çevresel göstergelerin katkısı ise nispeten sınırlı kalmıştır.

Yıldız (2021) tarafından yapılan çalışmada, Türkiye'nin yeşil ekonomi konusunda mevcut durumu incelenmiş ve birtakım politika önerilerinde bulunulmuştur. Çalışma sonucunda; Türkiye'nin mevcut performansı değerlendirildiğinde özelikle yenilenebilir enerji alanında bazı kazanımlar elde edilmiş olsa da, yeşil ekonomik sistemin toplumsal ya da kamusal alanda zihinlere yeterince yerleştirilemediği anlaşılmıştır.

Küçük ve Yüce Dural (2024) tarafından yapılan çalışmada; Türkiye'nin Avrupa Yeşil Mutabakatı[2] çerçevesindeki yeşil ekonomi performansını belirlemek amacıyla, Yeşil Ekonomi İlerleme Endeksi geliştirilmiştir. Türkiye'nin sürdürülebilir bir ekonomiye geçiş için ne kadar hazır olduğunu belirlemek amacıyla, 2011-2020 yılları arasında 13 yeşil ekonomi göstergesinin incelendiği çalışmada; bulgular ülkenin yeşil bir ekonomiye doğru ilerlediğini gösterse de, bu ilerleme Avrupa Yeşil Anlaşması'nın belirlediği kriterleri karşılama noktasında yetersiz kalmaktadır. Bilhassa yüksek sera gazı emisyonları, Türkiye için ciddi riskler oluşturmaktadır.

4. Küresel Yeşil Ekonomi Endeksi (GGEI)

160 ülkenin yeşil ekonomi performansını 18 gösterge üzerinden ölçen Küresel Yeşil Ekonomi Endeksi (GGEI), 4 temel boyutla tanımlanmaktadır: İklim değişikliği ve sosyal eşitlik, sektörün karbonsuzlaştırılması; piyasalar ve ÇYS (çevresel, sosyal ve kurumsal yönetişim) yatırımı ve çevre sağlığı. GGEI; günümüzde uluslararası kuruluşlar, ÇYS yatırımcıları, şirketler ve politika yapıcılar tarafından ülkelerin yeşil ekonomi performansı ile kendi ticari ya da kurumsal gündemleri arasındaki bağlantıları değerlendirmek ve anlamak amacıyla kullanılan; uluslararası alanda türünün en yaygın referans kaynağıdır.

Tablo 1: Küresel Yeşil Ekonomi Endeksi

	2016	**2018**	**2022**
İsveç	0.776	0.760	0.799
İsviçre	0.676	0.759	0.781
Norveç	0.691	0.703	0.747
Danimarka	0.618	0.680	0.742
İzlanda	0.636	0.712	0.713
Avusturya	0.652	0.647	0.711
Finlandiya	0.678	0.699	0.688
Almanya	0.660	0.689	0.674
Türkiye	0.496	0.487	0.399

Kaynak: Dual Citizen LLC, Eylül 2024.

[2] 1 Aralık 2019 tarihli bu politika paketi; AB ülkelerinin net sera gazı emisyonlarının 2050 yılına kadar sıfırlanmasını, ekonomik büyümenin doğal kaynaklardan bağımsız olarak gerçekleşmesini ve bu hedefte hiçbir bölgenin geri plana atılmamasını öngörmektedir.

160 ülkeyi kapsayan bu son GGEI, ulusal sürdürülebilirlik performansını ölçmeye yönelik yeni bir yaklaşımı temsil etmektedir. 18 göstergenin her biri için, hem her ülkenin 2005'ten 2020'ye kadar kaydettiği ilerleme derecesine hem de küresel olarak belirlenmiş sürdürülebilirlik hedeflerine olan uzaklığına bakmaktadır. 2022 yılında yayınlanan son endekste; İsveç 0.799 puan ile yine en iyi performans gösteren ülke olurken, diğer Avrupa ülkeleri (Almanya ve Birleşik Krallık dâhil) de endeksin üst sıralarında yer almıştır. Buna karşın en çok karbon salınımı yapan ülkelerin hiçbiri, bu endekste iyi performans gösterememiştir. Örneğin Çin 0.528 puan ile 58. sırada, ABD 0.567 puan ile 38. sırada, Hindistan 0.394 puan ile 144. sırada ve Japonya 0.547 puan ile 47. sırada yer almıştır.

Sektörün karbonsuz hale getirilmesindeki başarı açısından da hikâye aynıdır. Dünyanın en çok sera gazı salan ülkeleri (Almanya ve Birleşik Krallık hariç), bu son endekste kötü performans göstermiştir. Avrupa Birliği ve Çin; yeşil enerji yatırımı ve inovasyon noktasında lider olmaya devam ederken, endeksin piyasalar ve ÇYS boyutunda 25. sırada yer alan ABD geride kalmıştır. Çevre sağlığı boyutunda ise, 160 ülkeden sadece 5'i Dünya Sağlık Örgütü tarafından belirlenen hava kalitesi standartlarını karşılamaktadır.

2022 yılında yayınlanan bu son endekste, Türkiye toplam değer açısından 160 ülke arasında 0.399 puan ile 140. sırada yer almaktadır. Endeksin esas aldığı ve yukarıda bahsedilen 4 temel kriter üzerinden ülkelerin 2005-2020 yılları arasındaki ilerlemelerini ölçen alt endekste ise, Türkiye 0.426 puan ile 160 ülke arasında 130. sırada yer almaktadır. Bu sonuç, Türkiye'nin yeşil ekonomi ve sürdürülebilir kalkınma alanında belli oranda çaba harcadığını göstermektedir. GGEI, ülkelerin mevcut durumlarıyla endekste belirtilen 4 hedefe ulaşma noktasındaki mesafeleri için de ayrı bir alt endeks oluşturmuştur. Bu endekste ise Türkiye, 0.391 puan ile 160 ülke arasında 136. sıradadır.

İsveç, Norveç, Danimarka, İzlanda ve Finlandiya'dan oluşan Nordik ülkeleri; ulusal sera gazı salınım seviyelerini azaltarak, daha düşük karbon yoğunluğuna dayalı bir ekonomik yapıya geçmek ve istihdam seviyelerini yükseltmek amacıyla; karbon vergisini uygulamaya koymuştur. Bu ülkelerde karbon vergisinden elde edilen gelirin; büyük ölçüde çevresel inovasyonların desteklenmesi, yenilenebilir ve temiz enerji kaynaklarının teşvik edilmesi ve diğer vergilerde indirim sağlanması amacıyla kullanıldığı görülmektedir (Ercoşkun ve Kovancılar, 2023, s. 611).

5. Sonuç ve Öneriler

Kahverengi ekonominin tahribatlarına yönelik küresel bilinç artmış olsa dahi; mevcut potansiyelinin büyüklüğü gereği, küresel ekonomik etkisi halen fazladır (Özdemir, 2022, s. 16). Ya çevresel değerleri önceleyen ve sürdürülebilir enerjiye dayalı bir yeşil ekonomik sistem kurulacak, ya da düşük verimli ve sürdürülemez enerji kaynaklarına dayalı geleneksel kahverengi ekonomiye devam edilecek ve sorunlar tekrarlanacaktır (Kaypak, 2011, s. 27). Yeşil ekonomiye geçişle birlikte genel kabul gören inanç, kalkınmanın sürdürülebilirliğinin artacağı ve gelecek nesillere bırakılacak değerlerin hem onlara hem de onlardan sonrakilere yetecek bir refah düzeyi sağlayacağıdır (Kutluay Tutar ve diğerleri, 2021, s. 2902).

Yeşil ekonomiye geçiş süreci, şüphesiz birçok zorluklarla doludur. Mevcut ekonomik yapıların direnci, yeşil teknolojilere yapılan yatırımların maliyeti ve toplumun bu yeni yaklaşıma uyumu; bu zorluklar arasında sayılabilir. Ancak bu engeller; stratejik planlama, toplumsal farkındalığın artırılması ve uluslararası iş birliklerinin güçlendirilmesi yoluyla aşılabilir. Özellikle yenilenebilir enerji kaynaklarına geçiş, enerji verimliliğinin artırılması ve sürdürülebilir tarım uygulamalarının teşviki; yeşil ekonomiye geçişin temel taşlarını oluşturmaktadır.

Norveç, İsveç ve Hollanda gibi ülkelerin benimsediği yeşil ekonomi modeli; doğal kaynakları etkin bir şekilde koruyup kullanmayı hedeflemektedir. Bu doğrultuda hazırlanan politikalar; ormanlar, su kaynakları, madenler vb. doğal varlıkları tahrip etmemeye yöneliktir. İşte bu nedenle; inşaat çalışmaları ve yönetmelikler bir dizi şarta bağlı olup, enerji verimli olmak

durumundadır. Sıfır karbon hedefini benimsemiş bu ülkeler, iklim değişikliğiyle mücadele konusunda da lider konumdadır. Velhasıl bu örnek ülkelerde geliştirilen politika ve uygulamaların konunun uzmanları tarafından titizlikle incelenmesi, Türkiye gibi gelişmekte olan ülkelere de ilham verecek ve bir yol haritası çizecektir.

Dünya Bankası'nın mevcut sınıflandırmasına göre gelişmekte olan ülkeler kategorisinde yer alan Türkiye; ekonomik büyüme hedefine sürdürülebilir bir ölçüde devam etmek istiyorsa, yeşil ekonomik büyümeyi temel alan politikalar üretmelidir. Yeşil ekonomi konusunda ülkenin en büyük kazancı, yenilenebilir enerji alanındadır. Zira Türkiye yıllık güneşlenme süresinin fazlalığı, rüzgâr yoğunluğu ve yeraltı sıcak sularının bolluğu nedeniyle; güneş ve rüzgâr enerjisi ile jeotermal enerji gibi yenilenebilir enerji türleri bakımından oldukça yüksek potansiyele sahiptir. Lakin yeşil ekonomik sistemin toplumsal ya da kamusal alanda zihinlere yeterince yerleştirilemediği görülmektedir (Yıldız, 2021, s. 2, 8-9).

Eğitim ve bilinçlendirme programlarıyla, bireylerin ve işletmelerin çevre dostu uygulamalara daha açık hale gelmeleri sağlanabilir. Uluslararası düzeyde ise; iklim değişikliğiyle mücadele ve sürdürülebilir kalkınma hedeflerine ulaşmak için, ülkeler arası iş birlikleri ve politika uyumları hayati öneme sahiptir. Bu karmaşık süreci yönetebilmek için; politikacılar, iş dünyası liderleri ve sivil toplum kuruluşları arasında sağlam bir diyaloğun ve iş birliğinin oluşturulması gerekir. Böylelikle yeşil ekonomiye geçiş sadece bir ideal olmaktan ziyade, erişilebilir ve sürdürülebilir somut bir hedef haline gelecektir.

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THE IMPACT OF GREEN FINANCE ON ECONOMIC GROWTH: OPPORTUNITIES AND LIMITATIONS

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Abstract

Green finance has emerged as a pivotal element in the pursuit of sustainable economic growth, functioning as a financial methodology that directs investments into environmentally sustainable projects and enterprises. Nevertheless, this evolving field presents a number of challenges. The absence of a universally accepted definition of green finance, coupled with a paucity of information and awareness among stakeholders, presents a significant challenge. Moreover, the increasing demand for green finance products has given rise to concerns about market competition and the potential dilution of environmental benefits. As nations and institutions increasingly prioritise sustainable development, it is imperative that the limitations of green finance are understood and addressed if it is to advance effectively. This paper explores the multifaceted impact of green finance on economic growth, examining both its potential opportunities and inherent constraints. By addressing the current ambiguities and challenges, we aim to provide a comprehensive overview of how green finance can be better harnessed to support sustainable development and economic progress.

Keywords: Green Finance, Economic Growth, Sustainable Development, Green Investment, Environmental Protection, Climate Finance, Carbon Emissions.

JEL Codes: G15; O44; Q01; Q50; Q54

Introduction

In the face of increasing environmental challenges and the urgent need for sustainable development, green finance has emerged as a critical tool for aligning economic activities with environmental goals. Green finance generally refers to financial investments that support projects, policies, and technologies designed to promote environmental sustainability and combat climate change. It encompasses various financial instruments and strategies such as green bonds, green banking, and green insurance, all aimed at facilitating the transition to a low-carbon, resource-efficient economy.

Despite its growing importance, green finance remains a concept subject to various definitions and interpretations. The lack of a universally accepted definition has led to inconsistencies in how green finance is understood and applied in different contexts. Studies and reports prepared by institutions like the Infrastructure Development Finance Company (IDFC) and various academic researchers highlight the multifaceted nature of green finance. It not only includes investments in renewable energy but also efforts related to broader environmental issues such as pollution control and biodiversity conservation. This diversity in definitions and scope creates both opportunities and challenges in evaluating the real impact of green finance on economic growth.

One of the primary benefits of green finance is its potential to promote sustainable economic development. By directing investments toward green projects, green finance can stimulate technological innovation, enhance energy efficiency, and support the transition to renewable energy sources. These outcomes contribute to economic growth while simultaneously addressing critical environmental issues. However, the effectiveness of green finance is often limited by several factors. The lack of clear and standardized criteria for what constitutes a "green" investment can lead to uncertainty and potential misallocation of resources. Additionally, gaps in public awareness and understanding of green finance can hinder informed decision-making and market development.

Moreover, the growing demand for green finance products can sometimes lead to negative competition, where the focus shifts from genuine environmental benefits to short-term financial gains. This can weaken the effectiveness of green finance initiatives and dilute their potential impact on sustainability.

This study aims to comprehensively analyze the impact of green finance on economic growth, exploring both its opportunities and limitations. It begins by explaining the various forms of green finance and their roles in supporting environmental sustainability. It then examines how green finance contributes to economic growth through technological advancements, energy management, and environmental protection. Additionally, the study addresses the limitations of green finance, including definitional ambiguities, information gaps, and market competition. By providing insights into these issues, the study seeks to enhance understanding of the impact of green finance on economic development and propose strategies to overcome challenges, ultimately contributing to a more sustainable and economically viable future.

1. Green Finance

Green finance does not yet have a definitive and universally accepted definition. There are two main reasons for this. Firstly, many studies do not attempt to define the term; for example, IFC (2013) and Spratt and Griffith-Jones (2013) do not provide any definition on this matter. Secondly, significant differences are observed among the proposed definitions (Lindenberg, 2014). However, it is possible to look at the most comprehensive definitions available in the literature. Particularly, the report titled *"Mapping of Green Finance Delivered by IDFC Members in 2011,"* prepared by Niklas Höhne, Sumalee Khosla, Hanna Fekete, and Alyssa Gilbert as members of the IDFC (Infrastructure Development Finance Company), can be considered an important study that clarifies the scope of green finance. According to the report, green finance is a broad term encompassing financial investments made in sustainable development projects, environmentally friendly products, and policies aimed at creating a sustainable economy. In this context, green finance does not only include climate finance; it also encompasses investments aimed at broader environmental goals such as controlling industrial pollution, water purification, and biodiversity conservation. Mitigation and adaptation finance, on the other hand, refer to two specific areas related to climate change: mitigation finance covers investments made in projects aimed at reducing or preventing greenhouse gas emissions, while adaptation finance includes investments aimed at protecting goods and people from the impacts of climate change. One of the main objectives of the report is to categorize green finance around three main themes:

1.Green energy and reduction of greenhouse gas emissions, 2.Adaptation to climate change,

3.Other environmental goals.

Since it is challenging to categorize certain investments solely under one of these three themes, each theme has been subdivided into further subcategories. This approach also aims to prevent projects from being counted multiple times. The study *"South-Originating Green Finance: Exploring the Potential"* by Simon Zadek and Cassie Flynn also provides important definitions regarding green finance. This study highlights a significant source of green finance and the related policy elements that, though often underappreciated, need to be emphasized. However, in order for these resources to be effectively utilized, the definitions must be clarified. The terminology in this area is often ambiguous; terms like "climate finance," "green finance," "green investment," and "sustainable finance" are frequently confused with one another, or their differences remain unclear. This study aims to establish separate definitions for these four terms, providing a more robust analytical foundation for discussions.

Green investment generally refers to the overall capital cost of transitioning to a green economy in areas such as reducing greenhouse gas emissions, enhancing resilience, ensuring food security, and managing water, forests, transportation, and waste. In practice, a large portion of such

investments is directed towards the renovation of existing infrastructure and the construction of new projects. *The*

Green Investment report by the "Green Growth Action Alliance" states that green investment is closely associated with socially responsible investments or sustainable, long-term investment approaches. For example, the report highlights that Bloomberg New Energy Finance's definition of clean energy investments is limited to investments in energy infrastructure within the renewable energy sectors. These investments cover equipment, installation, and start-up costs but do not include operational costs. This provides a useful perspective, defined within a specific framework.

The terms green finance and green investment are often used interchangeably, but in reality, green finance encompasses a broader scope. Green finance includes the investments defined by organizations like Bloomberg New Energy Finance and also covers the operational costs of these investments. For example, project preparation and land acquisition costs often present significant financing challenges but are not included under the definitions of green investment. This example demonstrates that while the initial capital cost of a green investment might be 1 million USD, the total cost of green finance is generally higher and can vary significantly. However, adding these figures together would not yield an accurate result; it would lead to double counting. The correct calculation should include the overall cost of green energy to the consumer or taxpayer, or at least the additional cost of transitioning from dirty energy to green energy.

Therefore, a capital cost of 1 million USD does not fully reflect the actual cost of renewable energy to the consumer, citizen, government, or country. In fact, different calculations should be made based on the analysis units of "who pays," and as a result, different green finance figures should be obtained. For example, current discussions in the United Kingdom regarding the cost of green energy to consumers indicate that consumers are paying an additional amount on their energy bills for the transition to green energy. However, when this strategy generates employment and income, and these secondary economic effects lead to increased tax revenues, the cost to the country could be much lower. Moreover, if a competitive green industry is being developed, and considering pessimistic assumptions about oil and gas prices along with concerns about energy security, the net cost of green finance could be even lower. The measurement of green finance, therefore, varies depending on the perspective used, the parties making the payments, whether gross or net costs are considered, and whether these costs include secondary economic effects. The only certainty is that green finance is not the same as green investment and should encompass a much broader range of financial and economic flows.

The study also addresses detailed definitions of key terms:

Green investment refers to the capital cost of transitioning to a green economy in areas such as reducing greenhouse gas emissions, enhancing resilience, ensuring food security, and managing water, forests, transportation, and waste.

Green finance provides a broader framework than green investment. It not only covers capital costs but also includes operational costs such as project preparation and land acquisition.

South-originating green finance refers to a type of green finance that comes from countries outside the OECD, encompassing both private and public sector sources and including both cross-border financial flows and local financing.

Climate finance, unlike green finance or green investment, is specifically used to describe financial flows that are recognized under the United Nations Framework Convention on Climate Change (UNFCCC) process (Zadek & Flynn, 2013).

2. Green Finance Instruments

Traditional financial products, services, or instruments can acquire "green" qualities when used to provide funding for environmentally friendly investments, projects, or activities (Li et al., 2018). Examples of such green finance instruments include low-interest loans for environmental initiatives like tree planting in specific communities, syndicated loans for financing cross-border eco-friendly projects, green mortgage loans, financing for solar energy systems, and credit products for clean air vehicles. Green instruments are financial tools specifically designed for financing eco-friendly projects. The literature documents various green finance instruments, including green bonds, structured green funds, carbon market instruments, community-based green funds, green bond incentive programs, international climate funds, green venture capital, and green entrepreneurship funds (Ozili, 2022).

2.1.Green Banking

Green banking is an approach aimed at promoting environmentally friendly behaviors through financial activities. By adopting this method, the financial sector supports nature conservation efforts and contributes to environmental protection. Green banking operates by integrating operational innovations, changing stakeholder expectations, and technological developments. In India, leading banks in this field include State Bank of India, Punjab National Bank, Bank of Baroda, Canara Bank, ICICI Bank, DFC Bank, Kotak Mahindra Bank, IndusInd Bank, YES Bank, and HSBC Group. These banks promote green banking by offering their customers environmentally friendly financial services. Green banking focuses on environmental goals such as energy efficiency, renewable energy financing, and reducing carbon footprints. Additionally, providing loans for ecofriendly projects and connecting customers with sustainable financial solutions are fundamental strategies of green banking.

2.2.Green Insurance

The insurance sector plays a critical role in achieving sustainability goals as an important component of green finance. Although the insurance sector does not directly contribute to environmental damage, it supports green finance by providing risk management expertise and offering various approaches. For the fiscal year 2022-2023, the Insurance Regulatory and Development Authority of India (IRDAI) has promoted green insurance by offering a 15% discount on thirdparty insurance premiums for electric vehicle owners. Such policies help promote the adoption of eco-friendly vehicles while allowing the insurance sector to contribute to sustainability goals. Green insurance products are specifically designed to support environmentally friendly initiatives and projects. For example, insurance products for renewable energy facilities aim to manage risks encountered during the installation and operation of such facilities. This enables investors to invest in eco-friendly projects with greater confidence.

2.3.Green Bonds

Green bonds are debt instruments where the issuer commits to using the proceeds to finance environmentally friendly projects. These projects can include reforestation, combating climate change, developing energy-efficient products, and supporting sustainable commercial operations. Companies or financial institutions issuing green bonds enhance their reputations and gain opportunities to attract investors seeking environmentally friendly investment products. Additionally, they attract socially responsible investors, fulfilling their desire to align their investments with sustainability goals. The European Investment Bank and the World Bank pioneered this field by issuing the first green bonds in 2007. Since then, many businesses, banks, and financial institutions have begun issuing green bonds.

In India, the Securities and Exchange Board of India (SEBI) has introduced regulations for the issuance and listing of green bonds. These regulations require that the proceeds of the bonds finance environmentally friendly projects such as renewable energy use, climate change mitigation, biodiversity conservation, pollution reduction, and waste management. Green bonds are seen as a crucial source of financing in achieving global sustainability goals. They are particularly recognized as an important tool for supporting infrastructure projects in developing

countries and contributing to global climate change mitigation efforts. The risks and returns of green bonds should be carefully assessed, as such investments require both financial and environmental responsibility (Mishra & Kannaujia, 2023).

3. Effects of Green Finance on Economic Growth

Green finance is a financial approach aimed at providing funding for environmentally friendly projects and businesses. This approach channels capital into green industries, promoting sustainable economic and financial development. Within the framework of global sustainable development strategies, green finance is increasingly gaining importance in financial development practices across various countries (Barbier, 2011). The advancement of green finance plays a critical role in promoting technological innovation, supporting environmental protection, and facilitating economic development.

Shaw (1973) analyzed the effects of financial deepening on economic growth and proposed that this interaction creates a two-way feedback loop. In this loop, financial development supports economic growth, while economic growth, in turn, stimulates financial deepening (Shaw, 1973).

Cilliers et al. (2010) stated that green credit instruments could be important tools for quality urban planning, enhancing environmental values, and promoting sustainable economic development (Cilliers, Diemont, Stobbelaar, & Timmermans, 2010).Green credit instruments support sustainable development by providing quantitative data and support in these areas.

Menegaki (2011) examined the causality relationship between economic growth and sustainable energy in a study conducted across 27 European countries between 1997 and 2007. Green finance facilitates the reduction of the economy's carbon intensity by promoting economic growth, technological advancements, and energy transition (Liu, Chang, Yao, & Kang, 2023).

Among the new growth models emerging globally to achieve sustainable development goals, the concept of "green growth" has gained significant prominence. Green growth aims to promote economic growth while simultaneously prioritizing environmental protection, and this concept is increasingly featured in international policy discourses (OECD, 2011). Emerging as an alternative to traditional growth, green growth has particularly received broad acceptance in the international development field. Organizations such as the World Bank, the Organisation for Economic Co-operation and Development (OECD), the United Nations Environment Programme (UNEP), the United Nations Industrial Development Organization (UNIDO), and the Green Growth Knowledge Platform (GGKP) have published important reports on the theoretical developments of green growth and how they can be applied in practice, thereby creating a global agenda on the subject (Çanakçıoğlu, 2023).

Green investments play a critical role in reducing carbon emissions. In the early stages of economic development, capital investments aimed at accelerating industrialization are focused on increasing national production output while ignoring environmental drawbacks. However, in the later stages of the industrialization process, as predicted by the Environmental Kuznets Curve (EKC) hypothesis, there is a noticeable tendency towards making environmentally friendly investments. In this context, green investments emerge as a solution to carbon emission issues and environmental impact reduction. Additionally, investments in green technologies are anticipated to promote the transition to renewable energy and thus provide long-term environmental benefits.

Green investments also play a significant role in achieving the Sustainable Development Goals (SDGs). For example, the People's Republic of China (PRC) has issued green bonds and provided tax exemptions to promote the green bond market. This strategy aims to increase green investments and reduce environmental impacts. Additionally, the Bank of China has planned investments in clean coal technologies under its green bond financing programs, aiming to reduce the environmental effects of coal consumption. The PRC's 14th Five-Year Plan envisions the

promotion of various bond programs to encourage investments in green industries, clean transportation, and renewable energy.

Among the macroeconomic determinants of carbon emissions, natural resources are considered to make a significant contribution to emission levels. The industrialization process has increased the demand for natural resources, which is associated with carbon emissions. The burning of natural resources for electricity production can emerge as a factor that increases carbon release into the atmosphere. The negative effects of natural resource rents on environmental quality are a major concern in this context. Considering that a significant portion of China's electricity production relies on domestic coal reserves, an increase in coal-fired electricity generation could raise carbon emissions, making the control of natural resource rent levels important.

The impact of financial development on carbon emission levels presents a complex and multifaceted relationship. There is no consensus on the nature of this relationship, as financial development's effect on carbon emissions may be positive, negative, or neutral. Various theoretical approaches and findings exist to understand the effects of financial development on carbon emissions.

According to one view, financial development may increase carbon emissions. This perspective is based on the idea that the growth of the financial sector facilitates access to credit for private investments, and these credits can accelerate industrialization, leading to higher carbon emissions into the atmosphere. Additionally, financial development can provide households with more consumer credit opportunities, which might increase the demand for energy-intensive household appliances. This situation can lead to higher energy demand and, consequently, a rise in carbon emissions.

However, financial development can also help reduce carbon emissions. Relevant theories suggest that financial development may attract green foreign direct investments, which are associated with lower carbon emissions. Green investments can reduce carbon emissions by increasing investments in environmentally friendly technologies. Additionally, financial development can promote technological innovations by increasing research and development investments aimed at reducing carbon emissions. A well-developed financial sector has the potential to reduce carbon emissions by encouraging investments in environmentally friendly projects (Li, ve diğerleri, 2020).

The dual effects of financial development underscore the need to balance economic and environmental goals. While financial development can increase energy consumption, it can also reduce negative environmental impacts through green investments and technological innovations. Therefore, a comprehensive analysis that considers both positive and negative effects is necessary to evaluate the impact of financial development on carbon emissions. To achieve sustainable economic growth goals, it is important for the financial sector to focus on strategies that support green investments and reduce carbon emissions.

4. Environmental Economics and Green Finance: Methods for Addressing Negative Externalities

One of the fundamental principles of economics is that transactions between parties aim to achieve mutual gains. Free market mechanisms seek to maximize total gains by balancing supply and demand. However, these market systems do not always produce fair outcomes and can sometimes face issues known as "negative externalities." Negative externalities occur when economic activities impose costs on third parties that are not taken into account. In such cases, it is possible for the market to fail to produce the correct outcomes on its own.

Environmental economics focuses on developing various policy tools to address these negative externalities. One approach is regulations that restrict or ban activities causing pollution. This

approach can be exemplified by the environmental legislation implemented in the United States during the 1970s. However, direct regulations often do not provide sufficient room for flexibility and innovation. Therefore, the "Pigovian tax" approach proposed by Arthur Cecil Pigou, considered a pioneer in environmental economics, is also an important alternative. This approach foresees a tax that reflects the costs imposed by polluters on others.

As a modern adaptation of the Pigovian tax, the "tradeable emissions permits" system stands out. In this system, a limited number of permits are issued for emitting a specific pollutant, and these permits can be bought and sold through the market. This method provides an incentive to reduce pollution by utilizing market mechanisms. The Clean Air Act of 1990 in the United States implemented such a trading system to reduce sulfur dioxide emissions from power plants, and the system produced successful results at lower-than-expected costs.

Green finance involves the use of financial instruments to support environmentally friendly projects and reduce negative externalities. In this context, market-based approaches such as pollution trading and Pigovian taxes can enhance the effectiveness of green finance. The primary goal of green finance is to invest in projects that minimize environmental impacts in line with sustainable economic growth objectives. These financing strategies aim to balance environmental and economic goals by overcoming negative externalities using market mechanisms and ensuring a sustainable development process (Krugman, 2010). These methods demonstrate how environmental economics and green finance can work together and be effective in addressing environmental issues. Market-based solutions offer important tools for providing both environmental and economic benefits and play a critical role in achieving sustainable development goals.

5. Benefits of Green Finance

1. *Sustainable Energy Management:* Green finance provides financial support for reducing energy waste and developing renewable energy sources. This financial support encourages investments in technologies and projects that improve energy efficiency. Renewable energy projects can replace fossil fuels by using sources like solar energy, wind energy, and biomass, leading to significant improvements in energy management. Sustainable energy management supports long-term energy security and cost savings, offering both environmental and economic benefits.

2.*Enhanced Reputation:* Businesses can create a positive impression in society by taking environmental protection steps and investing in social responsibility projects. Green finance supports environmentally friendly initiatives and increases demand for these initiatives. More stakeholders prioritize businesses with ecofriendly practices, while governments may offer financial incentives for such projects. This contributes to strengthening the organization's reputation in the long term and gaining societal acceptance.

3.*Attracting Foreign Direct Investment:* Environmental protection is increasingly valued by international investors. Investors consider environmental and social costs and benefits when evaluating local projects. Issuing green finance instruments increases a country's potential to attract foreign direct investment. These investments help the country achieve its green economic growth goals and support the local economy.

4.*Environmental Protection:* One of the primary goals of green finance is to support environmental protection. This type of finance promotes environmental protection initiatives such as reducing pollution, combating climate change, protecting the ozone layer, and maintaining biodiversity. Eco-friendly projects are crucial for conserving natural resources and ensuring the sustainability of ecosystems, which is vital for the continued existence of living organisms (Mishra & Kannaujia, 2023)

Green finance contributes to achieving both environmental and economic goals, thereby helping to build a more sustainable future. The promotion of green finance plays a crucial role in balancing economic development and environmental protection.

6. The Impact of Green Finance on Economic and Ecological Development

Green finance primarily operates through government policy support and public willingness to invest in financial institutions. When funds are provided, financial institutions support green projects and green production through capital support, capital allocation, risk dispersion, and business supervision, thus supporting the ecological development of the economy. The core of ecological development lies in the growth of green industries. Financial institutions evaluate businesses in limited areas and production types, directing social capital flow to high-quality environmental protection enterprises and providing financial support to green industries. Green finance can enhance the environmental friendliness of business production, increase the output of green industries, and promote the ecological development of the economy. Capital allocation is a fundamental function of finance. Green finance can transfer capital from high pollution, high consumption, and overcapacity enterprises to those with low pollution and consumption, leading to efficient production. The financial market, through green finance, optimizes capital allocation, potentially encouraging businesses to use more funds to develop new technologies and products. This way, green finance achieves energy savings, emission reductions, and clean production goals.

The key to ecological development is green technology innovation. Technological innovation is often characterized by high risks and returns. Green finance gathers social capital to invest in green technology R&D. Investors with relevant rights and interests gain substantial profits from successful R&D while bearing the risks associated with R&D failures. Therefore, businesses feel secure in conducting green technology R&D. After securing the necessary financing, a business may exhibit lax behaviors due to information asymmetry between parties, which can lead to the loss of investment funds. At this point, financial institutions should supervise the funded businesses in real-time and require timely feedback from businesses. Banking plays a dominant role in China’s financial market, and green credit is a primary form of green finance. As creditors, banks can monitor a business's capital flow and understand its internal management and product operation procedures. Therefore, banks must ensure that business behaviors comply with standards and that businesses are audited while using the obtained funds for environmentally friendly production (Wu, 2022).

7. Limitations of Green Finance

1.*Definition Ambiguity:* Green finance faces issues due to the lack of a specific and universally accepted definition. The absence of clear consensus on the scope and criteria of green finance among different countries, institutions, and investors leads to ambiguity. This uncertainty makes it difficult for investors to determine which projects are genuinely "green" and provide environmental benefits. As a result, the lack of clear and standardized criteria can hinder investors from making safe and efficient choices when deciding to invest in green projects. Additionally, this situation can lead to a lack of transparency in the green finance market and make it vulnerable to potential fraud or misleading projects.

2.*Insufficient Information and Awareness:* Despite increasing interest in environmentally friendly investments, there are still gaps in general knowledge and awareness about green finance. Many individuals do not fully understand the scope, benefits, and risks associated with green finance. This lack of information makes it challenging for investors to make well-informed decisions regarding green finance tools and projects. Furthermore, it can hinder the development of green investment products and create an imbalance between the supply and demand for funds. The lack of education and information sharing can restrict the growth and effectiveness of the green finance market.

3.*Negative Competition:* As demand for green finance products increases, some market players may see this demand as an opportunity to increase their market share by referring to green initiatives. This can lead to a focus on market share and short-term financial gains rather than the genuine environmental benefits of green projects. Unhealthy competition may result in a decline in the quality of projects and the prioritization of sustainability goals. Such behavior in the green finance market can jeopardize the achievement of long-term environmental objectives by undermining genuine and effective sustainable practices (Mishra & Kannaujia, 2023).

These limitations of green finance can complicate the effective and efficient implementation of sustainable finance. To overcome these barriers, it is necessary to establish standardized definitions, increase information and awareness, and promote healthy competitive environments. These steps can help realize the potential of green finance and support sustainable economic growth.

Conclusion

Green finance represents a significant innovation in the field of environmental economics, offering a novel approach to addressing environmental challenges through financial mechanisms. The evolving definitions of green finance reflect the complexity and breadth of its scope, which encompasses investments in renewable energy and pollution control, as well as broader environmental goals such as biodiversity conservation and climate adaptation. Despite the varying interpretations and definitions of green finance, its overarching goal is evident: to direct financial resources towards projects and technologies that contribute to environmental sustainability and reduce negative externalities.

An analysis of green finance instruments reveals a diverse toolkit, including green bonds, green banking, and green insurance, each of which contributes to the advancement of sustainable development in a distinctive manner. These instruments provide indispensable support for environmentally friendly projects, offering financial incentives and reducing the risks associated with green investments. To illustrate, green bonds function as debt instruments that finance environmental projects, whereas green banking and insurance products support sustainable practices and mitigate environmental risks.

Nevertheless, green finance is constrained by a number of factors that must be addressed in order to enhance its efficacy. The lack of clarity surrounding definitions and criteria presents a challenge for investors, potentially resulting in a lack of transparency and the misdirection of funds. Furthermore, a lack of information and awareness about green finance impedes the capacity for informed decision-making, while negative competition in the market can erode the genuine pursuit of sustainability.

In order to surmount these challenges, it is imperative to establish unambiguous and uniform definitions, to heighten public awareness, and to encourage robust competition within the green finance sector. By addressing these limitations, green finance can more effectively contribute to sustainable economic and ecological development, thereby supporting a more resilient and environmentally responsible future.

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KENT İÇİ ULAŞIMDA TOPLU TAŞIMA ODAKLI GELİŞME

Ece KENDALOĞLU
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ÖZET

Günümüz kentlerinde hızlı bir şekilde artan ve kontrol altına alınamayan nüfus artışı sonrası gündeme gelen plansız kentleşme ile artan motorlu araç kullanımı kent içi ulaşım problemlerini de beraberinde getirmektedir. Bu durum kentlerin fiziksel alanda büyümesine ve dolayısıyla kentlerdeki yolculuk süre ve mesafelerinin uzamasına neden olmuştur. Hem ülkemizde hem de dünya kentlerinde kent içi ulaşım sorunlarını, trafik yükünü ve motorlu araç kullanımını azaltmak için toplu taşıma kullanımının teşvik edilmesi önem taşımaktadır. Bu nedenle kentlerde kompakt biçimde gelişme gerekliliği ortaya çıkmıştır. Sürdürülebilir kentlerin oluşturulmasında kentsel planlama ve gelişim stratejisi olan "Toplu Taşıma Odaklı Gelişme'nin" rolü büyüktür. Bu strateji, toplu taşıma sistemlerine odaklanan ve çevresinde yoğun, karma kullanımlı, sürdürülebilir ve erişilebilir alanlar oluşturmayı amaçlayan bir yaklaşımı ifade etmektedir. Bu araştırmada amaç, toplu taşıma odaklı gelişimin dünya örnekleri üzerinden tartışılmasıdır. Araştırmada toplu taşıma odaklı gelişme kapsamında sürdürülebilir, erişilebilir, yoğun ve karma kullanımlı kentsel alan kavramları üzerinde durulmuştur. Yöntem olarak, "Sürdürülebilirlik, Erişilebilirlik, Toplu Taşıma Odaklı Gelişme" anahtar kelimeleri çerçevesinde en çok atıf alan makaleler bağlamında toplu taşıma odaklı gelişim üzerine çalışılan, benzer nüfuslara sahip kentlere dair örnek çalışmaların alansal dağılımları karşılaştırılmıştır. Trafik yoğunluğunu azaltmanın, hava kalitesini iyileştirmenin, yürümeyi, bisiklete binmeyi ve toplu taşıma kullanımını teşvik etmenin en etkili yollarından biri olan toplu taşıma odaklı gelişmenin dünyanın çeşitli bölgelerinden uygulama örneklerinin ortak çözümleri ve farklılaştığı noktalar ele alınmıştır. Araştırmada elde edilen bulgularda, bu kentlerde trafik yoğunluğunu azaltmak, duraklar etrafında yüksek yoğunluklu yerleşim alanları ve ticari bölgeler oluşturmak, toplu taşımaya yürüme mesafesinde yaşam alanları yaratma hedefleri gerçekleştirilmek istenmektedir. İncelenen örneklerden anlaşılmıştır ki toplu taşıma odaklı gelişim stratejisine dair çözümler hem sürdürülebilir kentleşmeye katkı sağlamaktadır hem de daha yaşanabilir, erişilebilir ve ekonomik açıdan dinamik kentler oluşturulmasına yardımcı olmaktadır.

Anahtar Kelimeler: Kent İçi Ulaşım, Toplu Taşıma, Sürdürülebilirlik, Erişilebilirlik, Toplu Taşıma Odaklı Gelişme (TOD)

JEL Kodu: JEL: O21, JEL: Q01, JEL: R14, JEL: L92

ABSTRACT

The rapid and uncontrolled population growth in contemporary cities has led to unplanned urbanization, which, along with the increasing use of motor vehicles, brings about urban transportation problems. This situation has caused the physical expansion of cities, resulting in longer travel times and distances within urban areas. It is crucial to promote the use of public transportation to address urban transportation issues, traffic congestion, and the reliance on motor vehicles, both in our country and in cities around the world. Consequently, the necessity for compact urban development has emerged. The role of "Transit-Oriented Development," which is an urban planning and development strategy for creating sustainable cities, is significant. This strategy represents an approach focused on public transport systems, aiming to create dense, mixed-use, sustainable, and accessible areas around them. The objective of this research is to discuss transit-oriented development through global examples. The study emphasizes the concepts of sustainable, accessible, dense, and mixed-use urban areas within the framework of transit-oriented development. As a method, the spatial distributions of case studies on transit-

oriented development in cities with similar populations have been compared, based on the most cited articles under the keywords "Sustainability, Accessibility, Transit-Oriented Development." The common solutions and points of differentiation from various regions of the world regarding transit-oriented development, which is one of the most effective ways to reduce traffic density, improve air quality, and promote walking, cycling, and public transport usage, have been examined. The findings of the research indicate that the goals of reducing traffic congestion, creating high-density residential and commercial areas around stops, and developing living spaces within walking distance of public transport are intended to be achieved in these cities. From the analyzed examples, it has been understood that solutions related to the transit-oriented development strategy contribute to sustainable urbanization and help create more livable, accessible, and economically dynamic cities.

Keywords: Urban Transportation, Public Transport, Sustainability, Accessibility, Transit-Oriented Development.

JEL Codes: Codes; O21 Codes; Q01 Codes; R14 Codes; L92

1. GİRİŞ

Toplu taşıma odaklı gelişme, şehir planlamasında önemli bir kavram olarak öne çıkmaktadır. Hızlı bir şekilde artan nüfus, trafik sıkışıklığı ve çevresel sorunlar, şehirlerin sürdürülebilir bir şekilde büyümesini zorlaştırmaktadır ve bu durum da toplu taşıma sistemlerinin etkin kullanımını gerektirmektedir. Toplu Taşıma Odaklı Gelişme, duraklar etrafında yoğunlaşan yerleşim alanları ve ticari bölgeler oluşturmayı amaçlayarak, ulaşımın daha erişilebilir ve verimli hale gelmesini sağlamaktadır. Bu yaklaşım, yalnızca ulaşım altyapısının geliştirilmesi ile sınırlı kalmaz, aynı zamanda sosyal, ekonomik ve çevresel faktörleri de göz önünde bulundurarak bütüncül bir şehir tasarımı sunmaktadır. Yürüyüş mesafesinde yaşam alanları yaratmak, toplu taşımaya erişimi artırmak ve sürdürülebilir yaşam alanları oluşturmak, toplu taşıma odaklı gelişmenin temel hedefleri arasındadır.

Dünya genelinde Kopenhag, Stockholm ve Amsterdam gibi şehirler, Toplu Taşıma Odaklı Gelişme stratejilerini uygulamış ve bu sayede hem trafik yoğunluğunu azaltmış hem de yaşam kalitesini artırmıştır. Bu makalede, toplu taşıma odaklı gelişmenin temel ilkelerinin dünya genelindeki örnekleri üzerinden tartışılması amaçlanmaktadır. Sürdürülebilir, erişilebilir, yoğun ve karma kullanımlı kentsel alan kavramları üzerinde durularak; bu kavramların Toplu Taşıma Odaklı Gelişme ile olan ilişkisi incelenecektir.

2.1. Toplu Taşıma Odaklı Gelişme

Kentsel yayılma ve otomobil bağımlılığının olumsuz etkilerini en aza indirme hedefiyle geliştirilen Toplu Taşıma Odaklı Gelişme, “akıllı büyüme” stratejisi olarak kabul edilmektedir. Bu kapsamda değerlendirilmesinin sebebi, bölgesel sürdürülebilirliğin sağlanması, arazi kullanım dokusu ile ulaşım planlama stratejilerinin koordineli bir şekilde ele alınması ve kentsel altyapı sistemlerinin verimli kullanılması kriterlerini temel almasıdır (Curtis ve diğ., 2009).

Toplu Taşıma Odaklı Gelişme, ulaşım seçeneklerini en üst düzeye çıkarmak, insanlara transite yakın yaşam tarzı hakkında seçimler sunmak, kamu ulaşımını yaygınlaştırmayı esas alan arazi kullanım politikaları ve kentsel tasarım ve planlama konseptini içermektedir. Toplu Taşıma Odaklı Gelişme, sadece transit kullanımını değil, en temel ulaşım, yürüyüş ve bisiklet modlarının desteklenmesini içermektedir. Temelinde, ekonomik gelişmeyi ve akıllı büyümeyi teşvik etmek amacıyla toplu taşıma altyapısını kullanmak yatmaktadır. Sürdürülebilir topluluklar yaratarak tüm insanların eşit ulaşım ve barınma olanaklarına sahip olmasını da sağlamaktadır. İnsanların yürüdüğü, bisiklete bindiği ve toplu taşıma ile eriştiği alanların etkinliğini artırmayı hedeflemektedir (FTA, 2018).

Toplu Taşıma Odaklı Gelişme, bir toplu taşıma istasyonunu ya da durağını (tren istasyonu, metro istasyonu, tramvay durağı ya da otobüs durağı) çevreleyen istasyon çevresinde görece yoğun

yapılaşma ve merkezden uzaklaştıkça azalan yoğunluklu gelişmeyi göstermektedir. Gelişim bölgeleri; düşük yoğunluklu, orta yoğunluklu ve yüksek yoğunluklu olmak üzere 3 yerleşim özelliği şeklinde görülebilir. Düşük yoğunluklu geçiş alanlarında, dönüm başına 1-20 konut arasında değişen yoğunlukta konut kullanımlarını desteklemektedir. Arazi kullanım yapısı olarak, yeme-içme alanları, kreşler, sosyal tesisler, hafif raylı sistem istasyonları ve kavşakların yakınında gelişmektedir. Orta yoğunluklu transit gelişim alanlarında, dönüm başına 20-50 konut yoğunluğuna sahip arazi kullanımlarında etkindir. Bu alanlar genellikle konut ve ticari gelişim alanlarıdır. Çok katlı konut gelişim alanlarında zemin kat kullanımlarda perakende ve ofis kullanımları ile kentsel mekânda hareket kazandırmaktadır. Yüksek yoğunluklu gelişim alanlarında, transit istasyonlarına yakın mesafede bulunan yayaların yoğunlaştığı yüksek nüfuslu merkezi yerlerdedir. Bu alanlarda raylı sistemler geliştirilmiştir. Erişilebilirlik ve aktivite olanakları fazladır (FTA, 2018).

2.2. Toplu Taşıma Odaklı Gelişme ve Etki Alanı

Toplu Taşıma Odaklı Gelişme, bir toplu taşıma istasyonu ya da durağının merkezinde olduğu ve yaklaşık 400–800 metre yarıçapında bir daire ile çevrelendiği bir alana hizmet etmektedir.

- **400 metre**: Yürüyüş mesafesi olarak kabul edilen en yaygın ölçümdür.
- **800 metre**: Daha geniş bir erişim alanı, bisiklet veya diğer ulaşım araçlarıyla ulaşım için uygundur.

Şekil 1. TOD Etki Alanı

Toplu Taşıma Odaklı Gelişme etki alanı, yüksek yoğunluklu gelişim alanlarında, duraklara yakın mesafede bulunan yayaların yoğunlaştığı yüksek nüfuslu merkezi yerlerdedir. Bu alanlarda raylı sistemler gelişmiştir. Erişilebilirlik ve aktivite olanakları fazladır (FTA, 2018).

2.3. Toplu Taşıma Odaklı Gelişme Politikasının Amaçları

Toplu Taşıma Odaklı Gelişme, kompakt büyüme merkezleri geliştirmek için arazi kullanımı ve ulaşım planlamasını entegre etmektedir ve geçiş istasyonlarının her iki tarafında 400-800 m'lik etki alanı içinde, yani yürüme mesafesinde, aşağıdaki hedeflere ulaşmak istemektedir. Bu hedefler:

- Bölgede **yüksek yoğunluklu** bölgeler geliştirerek toplu taşıma kullanımını teşvik etmek,
- **Güvenli ve kolay ulaşım** için geliştirme alanı içinde yoğun bir yol ağı oluşturmak,
- **Kompakt** bir kentle kısa yolculuklar içeren bölgeler oluşturmak,
- **Yürümeyi** teşvik eden mahalleler geliştirmek,
- **Bisiklet** gibi motorsuz ulaşım ağlarına öncelik vermek,

- **Toplu taşıma** araçlarıyla tasarlanan kentsel gelişim alanları oluşturmaktır.

2.4. Erişilebilirlik

Erişilebilirlik, insanların ve ticari aktivitelerin istenilen tesislere, mallara ve aktivitelere ulaşabilme kolaylığı olarak tanımlanmaktadır (Bhat et al., 2000). Erişilebilirlik kentsel alanların önemli bir özelliğidir ve ulaşım ile arazi kullanım arasında önemli bir bağlantıdır (Martino, 2014). Kaygısız'a (2006) göre; erişilebilirlik en basit anlamıyla belli bir yere/varış noktasına ulaşabilme kolaylığı ve rahatlığıdır. Liu ve Zhu'e (2003) göre; erişilebilirlik, genel olarak bir seyahat türünde bir başka etkinliğin, başka bir yerden ulaşılabilmesi kolaylığı olarak da tanımlanabilir. Toplu ulaşım sistemlerine erişilebilirlik, belirli bir kentsel bölgeye hizmet eden ulaşım sistemlerinin kalitesi ve insanların bu sisteme erişim kolaylığı, bu toplu ulaşım sistemlerine erişilebilirliğin kapsamı olarak kabul edilmektedir. Toplu ulaşım erişimini en üst düzeye çıkarmak için kentsel alanlarda kompakt, karma arazi kullanımlı ve yaya dostu planlamalar yapmak gerekmektedir. Ulaşım sistemlerine rahat erişilebilen kentsel alanlarda yaşayan hane halkının özel araç sahipliliği ve özel araç kullanım oranı düşük olma eğilimindedir. Etrafındaki konut ve ticari alanların yoğunluğu artırılan bir toplu taşıma istasyonunda, yaya etkinliği ve toplu taşıma sistemini kullanan yolcu sayısı artmaktadır (Cervero ve diğ., 2004).

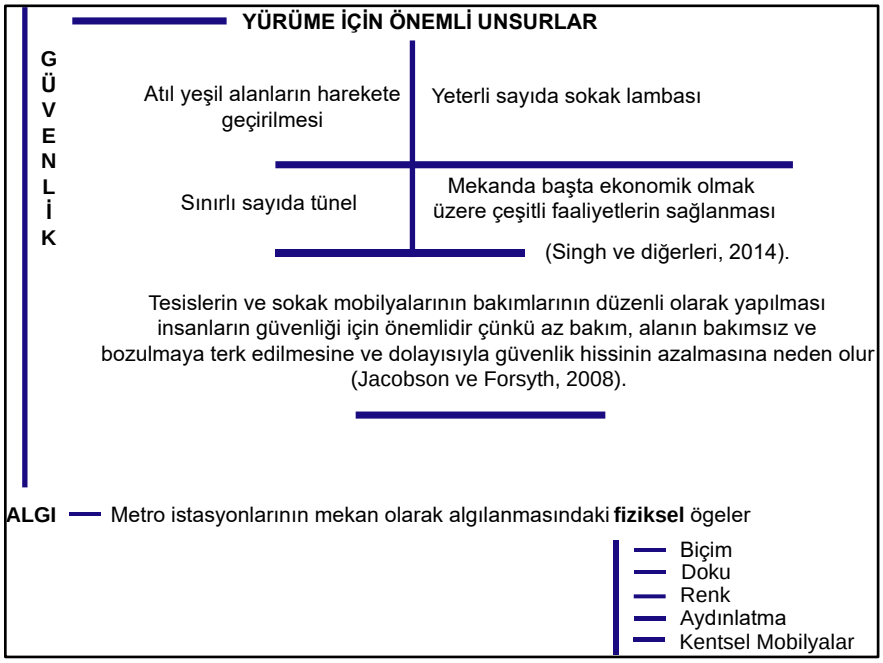
Toplu ulaşım sistemlerine erişilebilirlik belirli bir kentsel bölgeye hizmet eden ulaşım sistemlerinin kalitesi ve insanların bu sisteme erişim kolaylığı, bu toplu ulaşım sistemlerine erişilebilirliğin kapsamı olarak kabul edilmektedir. Toplu ulaşım erişimini en üst düzeye çıkarmak için kentsel alanlarda kompakt, karma arazi kullanımlı ve yaya dostu planlamalar yapmak gerekmektedir. Ulaşım sistemlerine rahat erişilebilen kentsel alanlarda yaşayan hane halkının özel araç sahipliliği ve özel araç kullanım oranı düşük olma eğilimindedir. Etrafındaki konut ve ticari alanların yoğunluğu artırılan bir toplu taşıma istasyonunda, yaya etkinliği ve toplu taşıma sistemini kullanan yolcu sayısı artmaktadır (Cervero ve diğ., 2004). Toplu taşıma, kentsel alanlarda bireylerin hareketliliği ve bağımsızlığı için önemli bir rol oynamaktadır. İnsanlara işe gitme, temel hizmetlere erişim sağlama ve çeşitli sosyal etkinliklere katılma imkânı sunarak birçok kişi için bir yaşam hattı görevi görmektedir. Ancak, toplu taşıma sistemlerinin tüm bireyler için fiziksel olarak erişilebilir olması, kapsayıcı ve adil şehirlerin oluşturulması açısından büyük önem taşımaktadır.

2.5. Yürünebilirlik

Toplu Taşıma Odaklı Gelişme, ulaşım istasyonlarında yürünebilirliği artırmak amacıyla ulaşım arzı ile arazi kullanım talepleri arasında bir denge sağlamak için bir teknik olarak benimsenmiştir. Nüfusun çoğunluğunun yüksek kalitede toplu taşımaya erişimini sağlamak için yoğun bir hızlı geçiş hattı ağı oluşturmayı hedeflemektedir. Transit istasyona daha yüksek yoğunlukta gelişim önererek kısa bir yürüme mesafesinde kolayca ulaşılabilecek insan ve hizmet sayısını en üst düzeye çıkarılabilir. Toplu Taşıma Odaklı Gelişme için en yakın yüksek kapasiteli transit istasyonuna önerilen maksimum mesafe, 15 ile 20 dakikalık bir yürüyüş olan 1 kilometre olarak tanımlanmıştır (ITDP, 2017). Toplu Taşıma Odaklı Gelişme, karma arazi kullanımları ve toplu taşıma hizmetlerinin iyileştirilmesi ile ilgilenirken, ikincisi istasyona fiziksel yakınlığa odaklanırken, birincisi yaya dostu bir ortam oluşturmaya çalışır (Vale, 2015; Renne, 2009). Dolayısıyla Toplu Taşıma Odaklı Gelişme, yürümeyi teşvik eden yapılı çevre ile ilgili kaygısı nedeniyle mekânın estetik detaylarına da dikkat ettiğinden, insanların memnuniyetine yönelik hizmetlere ulaşmak için seyahat ederken işlevlerin performansını artırır ve paradan ve zamandan tasarruf sağlar (Kamruzzaman 2014).

Yürüme için en önemli unsurlardan biri, yeterli sayıda sokak lambası, sınırlı sayıda tünel, bakımsız, âtıl veya terk edilmiş yeşil alanların harekete geçirilerek, mekânda başta ekonomik olmak üzere çeşitli faaliyetlerin sağlanması ile sağlanabilecek güvenliktir. 24 saat hareket sağlamak için yakınsanmış programlarda olanlar (Singh ve diğerleri, 2014). Örneğin, Renne'nin (2009) araştırmasına göre, bir kullanım kombinasyonuna sahip olan Berkeley şehri, mekâna çok

sayıda yaya çeken dükkanlar inşa ederek artan yürüme sıklığına ve ulaşım kullanımına yol açmaktadır.



Şekil 2. Yürüme İçin Önemli Unsurlar

3. Toplu Taşıma Odaklı Gelişmeye Dair Uygulama Örnekleri

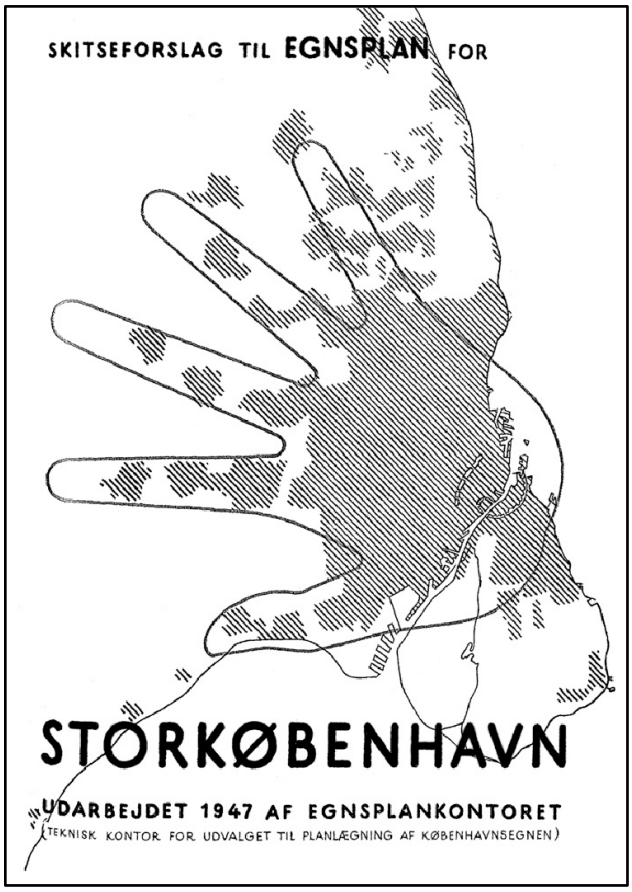
3.1. Kopenhag, Ørestad

Ørestad, Kopenhag'ın güneyinde yer alan bir şehirdir. 1990'ların ortalarında planlanmaya başlanmış ve 2000'lerin başında inşaatı tamamlanmıştır. Kopenhag Havalimanı'na ve şehir merkezine yakın konumu ile ulaşım açısından avantajlıdır. Ulaşım açısından bakılacak olursa, şehirdeki metro hattı, Ørestad'ı Kopenhag'ın diğer bölgeleriyle etkili bir şekilde bağlamaktadır. Bu, bölgenin ulaşımını kolaylaştırır ve toplu taşıma kullanımını teşvik etmektedir.

1947 Kopenhag Finger Plan

Danimarka'nın Kopenhag metropol alanının gelişimi için bir strateji sağlayan 1947 tarihli bir kentsel plandır. Plana göre Kopenhag, merkezi Kopenhag'ın yoğun kentsel dokusu olan 'avuç'tan uzanan S-tren banliyö tren hatlarına odaklanan beş 'parmak' boyunca gelişecektir. Parmaklar arasında, yeşil kullanımların tarım ve eğlence amaçlı arazi kullanımı amaçlanmıştır.

1947 Kopenhag Finger Plan, şehir planlamasında yenilikçi bir yaklaşım olarak kabul edilmektedir. Toplu taşıma sisteminin entegrasyonu, yoğun yerleşim alanları ve yeşil alanların korunması ile Kopenhag'ın sürdürülebilir bir şekilde gelişmesine katkıda bulunmuştur. Bu plan, günümüzde de birçok şehir için örnek teşkil eden bir modeldir.

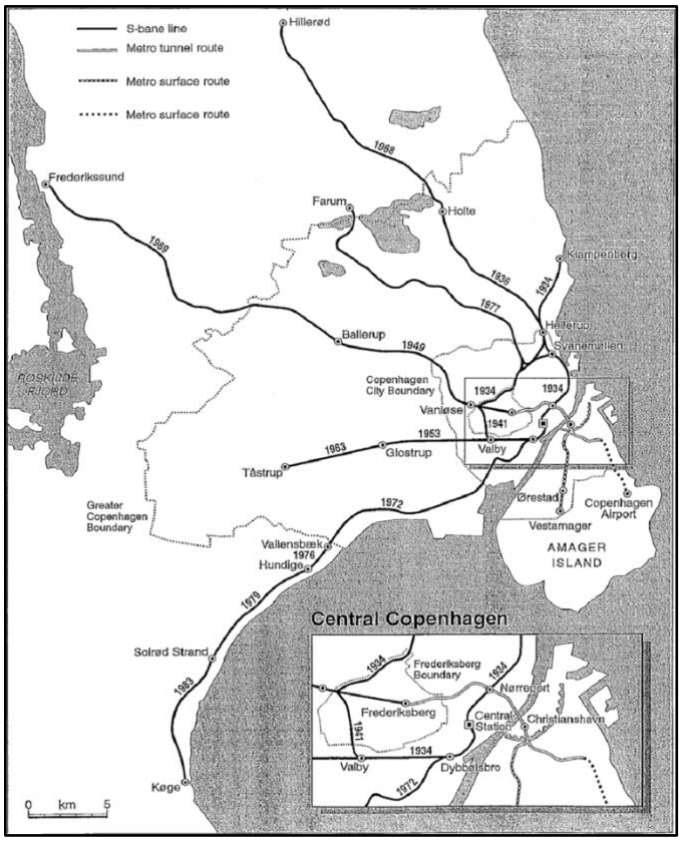


Şekil 3. 1947 Finger Plan

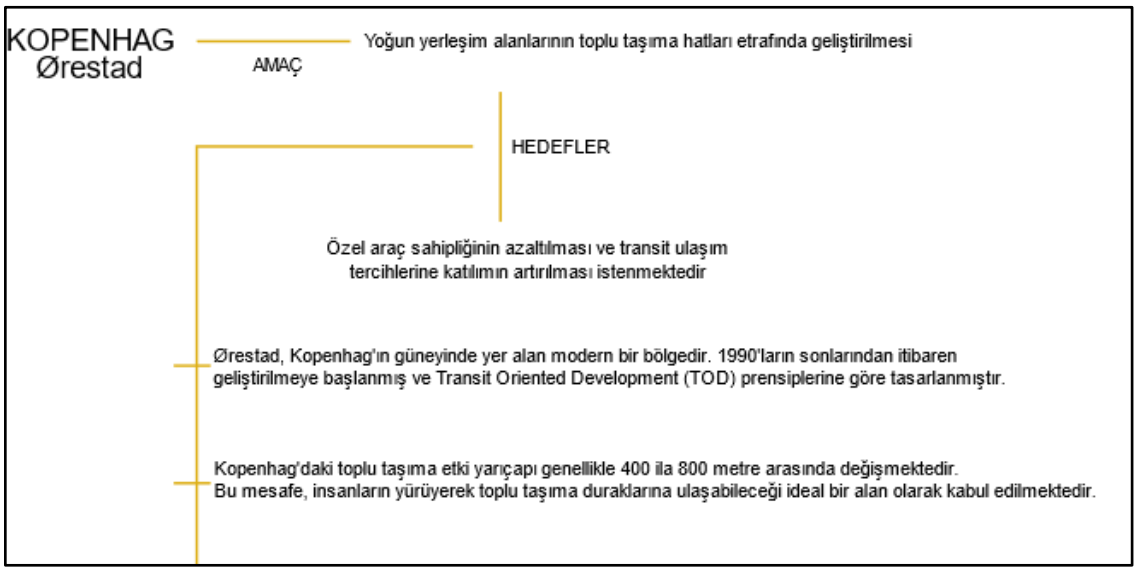
Kaynak: Egnsplankontoret (1947).

Ørestad, planlı sürdürülebilir Toplu Taşıma Odaklı Gelişmenin önemli ve başarılı bir çağdaş örneğidir. İş, konut ve perakende, eğitim ve eğlence tesislerinin planlanmasında Kopenhag'ın ünlü 1947 Parmak Planı'nın ilkelerini temel aldığı bilinmektedir. Finger Plan, düşük araç sahipliğinin olduğu ve raylı ulaşım için çok az rekabetin olduğu bir dönemde sunulmuşken, Ørestad'ın gelişimi, işe gidip gelenleri, sakinleri ve alışveriş yapanları toplu taşımayı veya bisikleti seçmeye çekmek zorunda kalmıştır.

- Metro duraklarının çevresinde 400-800 metre yarıçapında bir etki alanı oluşturulmuştur. Bu alan, konut ve ticari alanların yoğun olarak geliştirilmesine olanak tanımaktadır.
- Durakların etrafında konut, ofis, alışveriş merkezleri ve sosyal alanlar bir arada bulunmaktadır. Bu durum, insanların günlük ihtiyaçlarını yürüyerek karşılamalarını kolaylaştırmaktadır.,
- Ørestad, Kopenhag Metro'sunun M1 ve M2 hatları ile doğrudan bağlantılıdır ve bölgeye hızlı ve etkin ulaşım sağlamaktadır.
- Ørestad Metro İstasyonu, bölgedeki ana durak olup, çevresindeki alanların gelişimini büyük ölçüde etkilemektedir.



Şekil 4. Kopenhag, Ørestad



Şekil 5. Kopenhag Ørestad ve TOD Hedefleri

Kopenhag, bisiklet dostu şehirler sıralamasında önde gelen kentlerdendir. Kopenhag'ın bisikletle ilgili verilerine bakıldığında, Kopenhag'lıların %35'inin günlük ulaşımlarını bisikletle sağlandığı görülmektedir.

3.1.1. Kopenhag'da Bisiklet Köprüleri ve Tünelleri

Son 16 yılda Kopenhag'ta şehrin bisiklet kullanımını günlük bir ulaşım şekli olarak entegre etme ve teşvik etmesine yardımcı olan köprüler ve tüneller inşa edilmiştir. Bu köprüler irili ufaklı, bazıları hem tasarımı hem de mühendisliği açısından karmaşık ve sofistikeyken, diğerleri basit ve anlaşılırdır. Maliyeti veya boyutu ne olursa olsun, hepsi şehirde verimli ve kolay bisiklet sürmeyi sağlayan hayati bağlantılar sağlamaktadır.

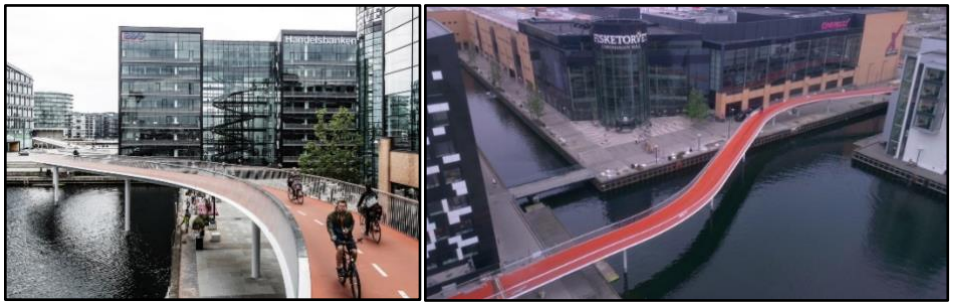
Langeliniebroen (2006)

Langeliniebroen, Østebro'yu Langelinie'ye bağlamak için tren rayları boyunca uzanmaktadır. Østebro tüneli gibi önemli bir bağlantıdır, çünkü kıyı boyunca karayolu ve tren altyapısının fiziksel engellerini aşan yollar bisikletliler için hayati hale gelmektedir (Şekil 6).

Şekil 6. Langeliniebroen Bisiklet Köprüsü (http-1)

Cykelslangen (2014)

Cykelslangen, Bryggebroen'u komşu bölgelere bağlayan, yalnızca bisikletlerin girebildiği, pas rengi, yükseltilmiş bir şerittir. Cykelslangen, açıldıktan kısa bir süre sonra pratik, zarif ve işlevsel tasarımıyla Kopenhag'ın kentsel simgesi haline gelmiştir. Hem işlevsel bir altyapı parçası hem de bisiklete ve sürücüsüne eğlenceli deneyimler yaşatmaktadır (Şekil 7).



Şekil 7. Cykelslangen Bisiklet Köprüsü (http-1)

Østerbro Tüneli (2015)

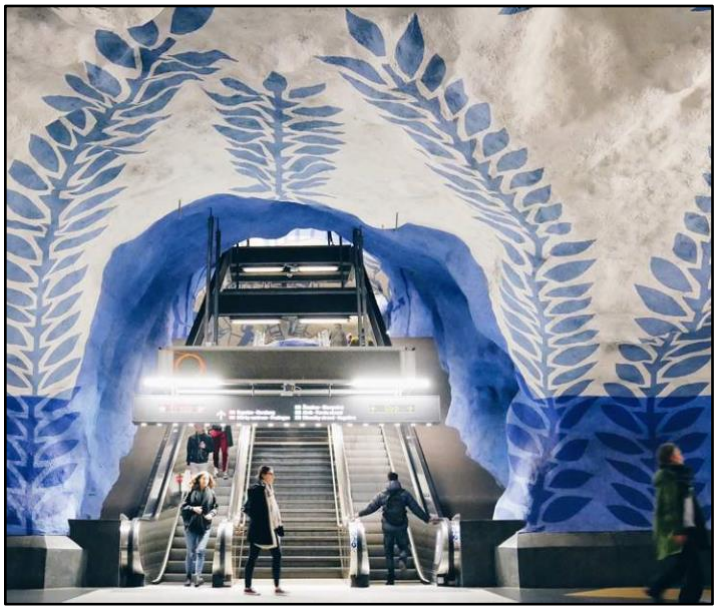
Østerbro Tüneli, Østerbro ve Nordhavn arasındaki sakinleri ve işçileri ayıran, büyük bariyere sahip, havadar ve iyi aydınlatılmış bir bağlantıdır. Tren raylarının altından geçen tünel, bir mahalleden diğerine kesintisiz bağlantı sağlayarak binlerce kullanıcıya zaman kazandırmaktadır (Şekil 8).

Şekil 8. Østerbro Bisiklet Tüneli (http-1)

3.2. Stockholm

İsveç'in başkenti olan Stockholm, toplu taşıma sistemini geliştirmek için çeşitli stratejiler benimsemiştir. Şehir, metro, otobüs ve feribot gibi birçok ulaşım aracını entegre eden bir sistem kurmuştur. Stockholm, İsveç'in başkenti olup, burada büyük bir metro sistemi bulunmaktadır.

- Bölgesel ölçekte planlama İsveç'te genel olarak zayıf olsa da, Stockholm koordineli raylı ulaşım ve kentsel gelişimin önde gelen bir örneğidir.
- Stockholm, 100 km'den fazla uzunluğa sahip olan bir metro sistemine sahiptir. Bu sistem, şehrin farklı bölgelerine hızlı ve etkili ulaşım sağlamaktadır (Şekil 9).
- Büyük Stockholm Metrosu, şehrin çeşitli bölgelerini birbirine bağlayan bir metro sistemidir. Metropolitan Area Transit System (Metro), üç ana hat (Kırmızı, Mavi ve Yeşil) arasında dağılmış yüzden fazla istasyonu olması nedeniyle çeşitli mahallelere ve varış noktalarına kolay erişim sağlayan kapsamlı bir ağ sunar.
- Konut, işyeri ve eğlence alanlarının bir arada bulunduğu karma kullanımlı bölgeler yaygındır.



Şekil 9. Büyük Stockholm Metrosu (Stockholms Tunnelbana)

3.3. Amsterdam

Şekil 10. Amsterdam Tramvay Durağı

- Amsterdam, tramvay, otobüs ve metro gibi çeşitli toplu taşıma seçeneklerine sahiptir. Bu sistemler, şehrin farklı bölgelerine hızlı ve etkili ulaşım sağlamakytadır.
- Amsterdam, bisiklet kullanımını teşvik eden bir şehir olarak bilinir. Geniş bisiklet yolları ve park alanları, insanların toplu taşıma ile entegrasyonu arttırmaktadır.
- Şehir, yaya dostu alanlar ve yürüyüş yolları ile doludur. Bu, insanların toplu taşımaya kolayca erişimini sağlar ve yürüyerek ulaşımı teşvik etmektedir.
- Amsterdam, sürdürülebilir ulaşım çözümlerine öncelik vererek çevre dostu projeleri destekler. Toplu taşıma ve bisiklet kullanımı, karbon ayak izini azaltma hedeflerine katkıda bulunmaktadır.

4. SONUÇ

Toplu Taşıma Odaklı Gelişme, şehir planlaması ve ulaşım politikaları açısından büyük bir öneme sahiptir. Ulaşım sistemlerini ve yapılaşmayı bir araya getirerek sürdürülebilir, etkili ve erişilebilir bir ulaşım ortamı oluşturmayı hedeflemektedir. Erişilebilirlik, Toplu Taşıma Odaklı Gelişmenin temel bir unsuru olarak karşımıza çıkmaktadır. Erişilebilirlik, insanların yaşadıkları yerden ulaşım araçlarına kolayca erişebilmelerini ve istedikleri hedeflere rahatlıkla ulaşabilmelerini sağlamak anlamına gelmektedir. Toplu taşıma ağlarının, istasyonların ve durakların planlanması ve tasarlanması sırasında dikkate alınmalıdır. Engelli bireyler, yaşlılar ve hareket kısıtlılığı olan diğer kişiler de dahil olmak üzere tüm toplum üyelerinin, toplu taşıma sistemlerine erişebilmesi ve kullanabilmesi önemlidir. Toplu Taşıma Odaklı Gelişme, metropol alanlar için en yaygın kullanılan kalkınma stratejilerinden biridir.

Araştırmada incelenen Toplu Taşıma Odaklı Gelişmeye dair dünyadaki uygulama örneklerine bakıldığında, birbirine yakın nüfuslardaki şehirlerin alansal dağılımları, ulaşım altyapıları, ekonomik ve sosyal etkileşimleri, etki alanlarının karşılaştırıldığı tablo aşağıda yer almaktadır (Tablo 1).

Şehir	Nüfus (2023)	TOD Uygulama Yılı	Alansal Dağılım
Stockholm	1.000.000	1990'lar	Şehir merkezi, çevre bölgeler
Kopenhag	800.000	2000'ler	Şehir merkezi, banliyöler
Amsterdam	900.000	1990'lar	Şehir merkezi, su kenarları

Şehir	Ulaşım Altyapısı	Duraklar	Etki Alanları
Stockholm	Geniş metro, tramvay ve otobüs ağı	100'den fazla metro istasyonu	Şehir merkezi, konut ve iş alanları
Kopenhag	Gelişmiş metro ve bisiklet yolları	30'dan fazla metro istasyonu	Şehir içi ulaşım ve bisiklet rotaları
Amsterdam	Geniş tramvay, metro ve bisiklet altyapısı	70'ten fazla tramvay ve metro istasyonu	Turizm, kültürel alanlar ve iş merkezleri

Şehir	Ekonomik ve Sosyal Etkileşim	Sürdürülebilirlik
Stockholm	Yeni iş fırsatları ve sosyal alanlar	Yeşil alanlar ve enerji verimliliği
Kopenhag	Sosyal etkileşim ve topluluk bağları	Yüksek bisiklet kullanımı ve yeşil alanlar
Amsterdam	Yerel ekonomi ve toplumsal etkileşim	Enerji verimliliği ve yeşil alanlar

Tablo 1. TOD ve Uygulama Örnekleri Sonuç Tablosu

Toplu Taşıma Odaklı Gelişme stratejileri, şehirlerdeki trafik yoğunluğunu azaltmayı, duraklar etrafında yüksek yoğunluklu yerleşim alanları ve ticari bölgeler oluşturarak toplu taşımaya erişimi artırmayı hedeflemektedir. Bu yaklaşım, toplu taşıma sistemlerinin etrafında yürüme mesafesinde yaşam alanları yaratmayı amaçlayarak, bireylerin günlük yaşamlarını kolaylaştırmakta ve ulaşım seçeneklerini çeşitlendirmektedir.

İncelenen örneklerden anlaşılmaktadır ki, Toplu Taşıma Odaklı Gelişme stratejileri sürdürülebilir kentleşmeye önemli katkılar sağlamaktadır. Bu stratejiler hem çevresel etkileri minimize etmekte hem de sosyal etkileşimi artırarak daha yaşanabilir alanlar oluşturmaktadır. Yüksek yoğunluklu yerleşim alanları ve ticari bölgelerin entegrasyonu, ekonomik açıdan dinamik kentlerin oluşmasına yardımcı olmakta, yerel ekonomileri canlandırmaktadır.

Sonuç olarak, Toplu Taşıma Odaklı Gelişme stratejileri, şehirlerin daha erişilebilir, sürdürülebilir ve yaşanabilir hale gelmesine katkıda bulunarak, modern kent yaşamının gereksinimlerini karşılamaktadır. Bu bağlamda, Toplu Taşıma Odaklı Gelişme uygulamalarının benimsenmesi, gelecekteki şehir planlaması için kritik bir öneme sahiptir.

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http-2: http://danishdesignreview.com/copenhagen-by-bike

SOCIO-ECONOMIC OPPORTUNITIES OF USING RENEWABLE ENERGY WITH THE HELP OF ARTIFICIAL INTELLIGENCE IN KAZAKHSTAN

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Abstract

This paper explores the socio-economic opportunities presented by the integration of renewable energy and artificial intelligence (AI) in Kazakhstan. As the country seeks to diversify its energy sources and reduce dependence on fossil fuels, the deployment of AI in the renewable energy sector offers a promising avenue for economic growth, enhanced energy efficiency, and environmental sustainability. The study examines the potential benefits of AI-driven solutions in solar, wind, and hydropower generation, along with the challenges and policy implications for their successful implementation.

The purpose of this study is to delve into the intersection of renewable energy sources and artificial intelligence in Kazakhstan. It aims to uncover the potential benefits, challenges, and overall impact on the country's economy and energy sector, offering a fresh perspective on this emerging field.

Research Methodology adopts a mixed-methods approach, incorporating both systematic review and comprehensive research methods. Data is gathered through academic databases, journals, relevant literature analysis, and case studies, which offer practical insights into the applications and outcomes of AI-driven renewable energy projects in Kazakhstan.

Originality/value of the research is unique in its focus on the intersection of artificial intelligence and renewable energy within the specific context of Kazakhstan. It offers valuable insights into how emerging technologies can drive economic growth and sustainability in a developing country and provides practical strategies for harnessing these opportunities. The study significantly contributes to the literature by providing a deep and comprehensive analysis of the economic implications and strategic opportunities associated with this integration.

The study's findings reveal that the application of artificial intelligence to renewable energy sources in Kazakhstan can significantly enhance energy efficiency, reduce costs, and increase the reliability of energy supply. Moreover, it identifies several key economic opportunities, including job creation, technological innovation, and the potential for Kazakhstan to become a regional leader in renewable energy. However, the research also underscores the challenges, such as the need for investment in infrastructure, training, and regulatory support, providing a practical roadmap for policymakers and industry professionals.

Keywords: Renewable energy, artificial intelligence (AI), economic opportunities, Kazakhstan, energy efficiency, sustainable development, green energy sector.
JEL Codes: P18

Introduction

Kazakhstan, the largest economy in Central Asia, has historically relied on its abundant fossil fuel resources, particularly oil, gas, and coal. However, the global shift towards cleaner energy sources and the need to address climate change have driven the country to explore alternative energy options. The government has set ambitious goals for increasing the share of renewable energy in the national energy mix. This transition to renewables offers socio-economic benefits, such as job creation, energy security, and economic diversification.

Artificial Intelligence (AI) emerges as a critical tool in this transition, capable of optimizing the generation, storage, and distribution of renewable energy. By integrating AI technologies with renewable energy systems, Kazakhstan has the opportunity to enhance energy efficiency, reduce costs, and create new markets. This paper discusses the potential socio-economic benefits of using AI in the renewable energy sector of Kazakhstan and the challenges that must be addressed to realize this potential.

Kazakhstan has significant potential for the development of renewable energy sources:

- Solar Power: The country's vast territory, with an average of 2,200-3,000 hours of sunshine per year, makes it ideal for solar energy projects.
- Wind Power: Kazakhstan's steppes and open plains provide optimal conditions for wind energy generation, especially in regions such as the Zhambyl and Akmola regions.
- Hydropower: The presence of major rivers, including the Irtysh and the Ili, offers opportunities for small and medium-scale hydropower projects.

The government aims to achieve 10% of total energy consumption from renewable sources by 2030 and up to 50% by 2050. However, integrating these energy sources into the national grid requires addressing issues of intermittency, forecasting, and efficient distribution—areas where AI can play a transformative role.

AI-Driven Opportunities in Renewable Energy

The application of AI in renewable energy systems can lead to significant improvements in efficiency and performance. The following are key areas where AI can provide socio-economic benefits in Kazakhstan:

- Energy Forecasting and Demand Management: AI can improve the accuracy of weather and energy production forecasts, which is crucial for solar and wind power generation. Machine learning models can predict energy output based on weather data, allowing for better grid management and balancing supply and demand. This leads to a more stable energy supply, reduces reliance on fossil fuel backup power, and minimizes grid disruptions.
- Optimization of Energy Storage Systems: The integration of AI into battery storage systems can optimize the charging and discharging processes, ensuring that renewable energy is stored efficiently and used when demand is highest. This is particularly important for addressing the intermittency of solar and wind energy. Enhanced storage capabilities can help Kazakhstan manage peak energy loads, improve energy access in remote areas, and reduce energy costs.
- Smart Grids and Grid Management: AI enables the development of smart grids that can automatically adjust energy flows, detect faults, and reroute energy in real time. These intelligent grid systems can integrate a higher percentage of renewable energy while maintaining grid stability. For Kazakhstan, which has a large and dispersed territory, smart grids are crucial for efficiently managing energy distribution across regions.
- Predictive Maintenance: AI-based predictive maintenance can extend the lifespan of renewable energy infrastructure by detecting faults and wear-and-tear before they lead to costly failures. For example, AI algorithms can analyze data from wind turbines or solar panels, identifying potential issues and scheduling maintenance before they become critical. This reduces operational costs and enhances the reliability of renewable energy systems.

Kazakhstan is poised to capitalise on significant economic opportunities by integrating artificial intelligence (AI) into the exploitation of renewable energy (RE) sources. Leveraging AI can enhance efficiency, optimise resource management, and drive innovation in the renewable energy sector, positioning Kazakhstan as a leader in sustainable energy. In his Address on September 1, 2023, Kassym-Jomart Tokayev emphasised that the application of artificial intelligence technologies requires special attention today[1].

Kazakhstan, a nation rich in natural resources, has embarked on a transformative journey towards sustainable energy development. As the global community increasingly prioritises environmental sustainability and the reduction of carbon footprints, Kazakhstan is strategically positioning itself to harness the power of renewable energy sources. The integration of AI into this sector presents

a significant opportunity to optimise energy production, enhance efficiency, and drive economic growth.

The country’s commitment to transitioning from a fossil fuel-dependent economy to a green economy is evident in its national policies and strategic initiatives. With vast expanses of land suitable for solar and wind energy generation, Kazakhstan has the natural advantages required to become a leader in renewable energy. AI technology, with its capabilities in data analysis, predictive maintenance, and real-time optimisation, offers an unprecedented opportunity to maximise the efficiency and reliability of renewable energy systems.

This integration is vital for meeting the growing energy demands in an environmentally sustainable manner and for fostering economic development. Adopting AI in renewable energy can lead to significant cost reductions, improved resource management, and the creation of high-skilled jobs. Moreover, it positions Kazakhstan as an attractive destination for foreign investments in the renewable energy sector.

This study highlights the current advancements, potential applications, and prospects of AI-enhanced renewable energy in Kazakhstan. By examining the synergies between AI and renewable energy, this paper underscores the transformative impact these technologies can have on Kazakhstan's energy landscape, paving the way for a sustainable and prosperous future.

Research methods. The research method used to examine the opportunities of utilising renewable energy sources with artificial intelligence (AI) in Kazakhstan involved a systematic and comprehensive approach. The following steps outline the methodology employed.

The initial step, defining the scope and objectives, involved clearly defining the scope and objectives of the literature review. The primary objective was to explore the integration of AI in renewable energy systems in Kazakhstan, focusing on identifying the benefits, challenges, and potential applications.A wide range of academic databases, journals, and relevant sources were identified to gather comprehensive information on the topic. Key databases included Web of Science, ScienceDirect, SpringerLink, and Google Scholar. Government reports, policy documents, and industry whitepapers were also considered to ensure a holistic understanding of the subject.

A systematic search strategy was developed using specific keywords and phrases related to the topic. Keywords included "artificial intelligence," "renewable energy," "wind power," "solar energy," "Kazakhstan," "energy optimisation," "predictive maintenance," and "smart grids." Boolean operators (AND, OR) were used to refine the search and retrieve relevant literature.

Inclusion and exclusion criteria were established to ensure the relevance and quality of the literature. Inclusion criteria included peer-reviewed articles, studies focusing on AI and renewable energy, and publications within the last 15 years. Exclusion criteria involved non-peer-reviewed sources, articles unrelated to Kazakhstan's specific context, and outdated publications.

The initial search yielded a large number of articles and documents. These were screened based on their titles and abstracts to assess their relevance. Full-text articles of selected studies were then reviewed to ensure they met the inclusion criteria. Duplicate articles were removed to streamline the review process.Data extraction involved systematically collecting relevant information from the selected literature. Key themes, findings, and insights were identified and categorised. The synthesis process involved organising the extracted data into coherent sections that addressed the research objectives, such as the benefits of AI in renewable energy, specific applications, challenges, and case studies from Kazakhstan.

A critical analysis was conducted to evaluate the findings' quality, reliability, and significance. This involved comparing different studies, identifying gaps in the existing literature, and assessing the findings' applicability to the context of Kazakhstan. The final step involved compiling the synthesised data and critical analysis into a structured literature review. The review was organised into sections that provided a comprehensive overview of the topic, including an introduction, main body, and conclusion.

By following this systematic research method, the literature review aimed to provide a thorough and insightful analysis of AI's integration into Kazakhstan's renewable energy systems, highlighting the opportunities, challenges, and future prospects.

Literature review. The transition to renewable energy and sustainable development has been a significant focus in recent years, particularly in Kazakhstan. Several studies have explored various aspects of this transition, including green hydrogen production, the green economy, CO2 emissions, and green building development [2], [3], [4], [5].

With Kazakhstan's increasing population and economic growth, the rising demand for energy for daily life and production is expected. However, the extensive use of fossil fuels has significantly depletednatural resources and contributed to global warming and climate change due to their high greenhouse gas emissions [6].Kalikov et al. (2020) analysed the concept of a green economy as a paradigm for sustainable development in Kazakhstan [2]. They examined the use of alternative energy as an integral part of the green economy. The study determined that the total capacity of renewable energy sources worldwide would increase significantly by 2024, necessitating the development of new financial instruments such as payments for ecosystem services and green banking. These elements are crucial for the transition to a green economy.Akhanova et al. (2020) developed a multi-criteria decision-making framework for building sustainability assessment in Kazakhstan, which could serve as a reference for policymakers and be adapted for use in neighbouring countries with similar climatic conditions [3].

Researchers have examined the effects of human-induced extreme events on green innovation and the consequences of natural extreme events from a global perspective in Central Asia [7],[8]. Carbon emissions cause a range of issues, such as glacier melting, rising sea levels, and ecological damage, that pose a substantial threat to human society [9].Global climate change poses one of the most significant challenges worldwide [10], [11]. As per the Paris Agreement, Kazakhstan has pledged to achieve an unconditional target of a 15% reduction in greenhouse gas (GHG) emissions by December 31, 2030, relative to 1990 levels, and a conditional target of a 25% reduction by the same date [12], [13]. Meanwhile, Kazakhstan is also confronting significant environmental issues [14]. Kazakhstan’s CO2 emissions, particularly in the context of the post-Kyoto Protocol era, have been a subject of analysis. Wang et al. (2019) constructed production-based CO2 emission inventories for Kazakhstan from 2012 to 2016 [4]. Their study revealed that while Kazakhstan’s emissions are relatively small compared to major emitters like China and the US, the country still faces significant pressure to reduce emissions and promote green development. The study suggested that both technological and policy actions are necessary for effective emissions control.

Renewable energy is considered a new solution to problems of climate change and represents the future of energy development[15].As Xin-gang and You (2018) described, renewable energy encompasses hydro, wind, solar, geothermal, and biomass [16]. It offers clear benefits over fossil fuels, including being renewable, clean, and having a low carbon footprint (Wang et al., 2019) [4].

AI technology is set to transform traditional corporate innovation models significantly. Improving the efficiency of green innovative technologies allows energy companies to meet environmental protection standards more quickly. It also helps lower the costs related to developing green patents and increases the production of green products [17]. AI technology serves as a catalyst, encouraging energy corporations to develop more green patents. As AI continues to advance and spread across various industries and fields [18], its potential has captured the interest of energy companies.

AI has the potential to increase company profits, elevate employment rates, and enhance operational efficiency. Proponents highlight the positive effects of AI technology on corporations; however, sceptics, as highlighted by Grashof and Kopka (2023), critically contend that AI may exert a detrimental influence on innovation efficiency alongside its benefits [19]. Thus, companies must establish a more robust AI innovation management model to fully prepare

for the challenges of using AI technology, including the aversion to AI replacing part of the workforce [20]. Nevertheless, the initial implementation costs, such as higher employee salaries, can be substantial. Despite these initial expenses, the overall profit gains generally exceed the costs of adopting AI technology [21].

The intermittent, chaotic, and random nature of renewable energy can impact the stability and reliability of the power system when integrated on a large scale into the distribution network [22]. Consequently, enhancing the accuracy of renewable energy predictions is vital for power system[23]. Numerous methods have been developed to improve the precision of renewable energy forecasts [24], [25].

Synthetic intelligence methods are extensively used in renewable energy prediction due to their ability to handle nonlinear and complex data structures [24], [26]. Their effective and appropriate application results in the creation of comprehensive and valuable systems with enhanced performance or unique features that traditional methods cannot offer [27]. Recently, the field of Artificial Intelligence in Renewable Energy (AI&RE) has been rapidly advancing [28]. AI-based technologies are being employed to address challenges related to integrating renewable energy into power systems, such as forecasting for solar and wind energy.

However, several challenges and bottlenecks remain, including the scope and accuracy of renewable energy predictions and the influence of specific geographical climates on these predictions. Additionally, the proliferation of publications in this field necessitates a comprehensive summary of the existing research.Xu et al. (2018) discussed the challenges and prospects of wind power generation in Kazakhstan, highlighting the environmental benefits and the need for policy support to incentivise the transition to greener technologies [29]. Additionally, Mukhamediev et al. (2020) developed a decision support system for optimising the placement of renewable energy generators using geospatial data, demonstrating the high potential for renewable energy development in Kazakhstan [5]. Moreover, Nurgissayeva et al. (2022) discuss the increasing significance of the private sector in public-private partnerships aimed at achieving sustainable development goals for the city [30]. They explain that these partnerships enhance the quality and efficiency of services typically provided by the government while alleviating the state budget's financial burden.

These suggestions must aim to address the existing challenges and propel future advancements in this dynamic landscape. For energy companies navigating the integration of AI technologies and RE, we pose the following research question: What are the effects of the AI adoption rate on RE within energy companies? How can the AI adoption rate be quantified to represent AI technology utilisation within green companies more objectively?

The literature on renewable energy and sustainable development in Kazakhstan indicates a strong focus on green hydrogen production, the green economy, CO2 emissions reduction, and green building development. The studies reviewed suggest that while there are significant challenges, including technical, economic, and policy-related barriers, there is also substantial potential for progress. Continued research and the development of supportive policies will be crucial for Kazakhstan to achieve its sustainable development goals.

The main part

Transition to a Green Economy in Kazakhstan

Over the past three decades, the Republic of Kazakhstan has successfully established one of the most advanced economies in the region. This economic progress is now being furthered through a strategic shift from an oil-dependent economy to a "green economy." The rationale for transitioning to the green economy is described in Table 1.

Table 1 – The rationale for transitioning to renewable energy in Kazakhstan

Rationale	Description
Exhaustion of Traditional Energy Sources	Traditional energy sources such as oil, gas, and coal are finite and may soon be depleted. New, more sustainable energy sources must be developed to ensure a stable energy future.
Negative Environmental Impact of Traditional Energy Sources	The use of coal and oil for energy production leads to the emission of large amounts of greenhouse gases, which cause climate change and air pollution. Renewable energy sources, such as solar and wind energy, have a much smaller environmental impact.
Technological Progress	Advancements in artificial intelligence and other cutting-edge technologies allow for efficient management and control of energy production processes, which can increase efficiency and market competitiveness.
Economic Benefits	Renewable energy sources are becoming increasingly competitive with traditional ones, especially considering the declining costs of production and the development of new technologies.
Political Support	Many governments around the world actively support, fund the development of renewable energy sources and recognise their potential to reduce dependence on energy imports and promote more sustainable development.
Note - author's own elaboration	

Table 2, titled "Dynamics of Renewable Energy Capacity Growth in Kazakhstan," provides a snapshot of the expansion of renewable energy infrastructure in Kazakhstan over a five-year period from 2018 to 2022. The data includes the number of renewable energy facilities and their total megawatts (MW) capacity each year.

Table 2 – Dynamics of renewable energy capacity growth in Kazakhstan

Year	Number of Objects	Total Capacity (MW)	Stage
2018	67	531	Rapid Expansion
2019	90	1,050	
2020	116	1,685	
2021	134	2,010	Consolidation and Optimisation
2022	142	2,021	
Note - author's own elaboration based on [36]			

In 2018, the number of renewable energy facilities was 67. This increased to 90 in 2019, marking a growth of 23 facilities, which is approximately a 34% increase from the previous year. In 2022, the number of facilities reached 142, adding 8 more, which is about a 6% increase from 2021. In 2018, the total capacity was 531 MW. It nearly doubled to 1,050 MW in 2019, an increase of 519 MW, representing a 97% growth from the previous year. In 2022, the total capacity slightly increased to 2,021 MW, adding 11 MW, which is a marginal increase of about 0.5% from 2021. The period from 2018 to 2020 saw a significant expansion in both the number of renewable energy facilities and their total capacity. The doubling of capacity from 531 MW to 1,050 MW in 2019 and the substantial increase to 1,685 MW in 2020 indicate a strong push towards enhancing renewable energy infrastructure. This rapid growth is likely driven by strategic national policies and increased investment in the sector. From 2021 onwards, the growth in the

number of facilities continued but at a slower pace compared to the previous years. The total capacity growth also slowed down significantly, especially in 2022, where the increase was minimal. This could indicate that the initial phase of rapid expansion has transitioned to a phase of consolidation and optimisation substantial increase in the early years suggests the effective implementation of supportive policies. The slower growth in later years may reflect the saturation of easily deployable projects and the onset of more complex integration challenges.
The deceleration in capacity growth highlights potential challenges, such as the need for enhanced grid infrastructure, storage solutions, and regulatory adjustments to support further expansion. However, it also presents opportunities to focus on improving the efficiency and integration of existing renewable energy capacities.

Table 3 – Investments for implementing the Green Economy Transition Concept in Kazakhstan

Period	**2020-24**	**2025-29**	**2030-39**	**2040-49**
Funding Needs as % of GDP	1.79	0.77	0.59	0.61
Average Annual Funding Needs (USD billion, 2010 prices)	5.5	3.0	3.0	3.8
Total Funding Over Period (USD billion, 2010 prices)	27.5	15.0	30.0	38.0
Note - author's own elaboration from [31]				

The data in Table 3 reveals a phased approach to investment in Kazakhstan's green economy transition. The initial years (2014-2017) focus on foundational investments, which ramp up significantly during 2018-2024 with the implementation of major projects. Post-2024, the investment stabilises, indicating a shift from heavy initial investments to sustaining and optimising existing projects while still growing in the long term to meet ongoing and future needs. This comprehensive investment strategy reflects the long-term commitment required for transitioning to a sustainable green economy.
This transition is supported by numerous national strategic documents and a variety of sectoral policies and plans developed over the last ten years. Notable legislative measures include The Law on Support for Renewable Energy Sources (2009) provides a framework for promoting and developing renewable energy sources within the country. The Law on Energy Saving and Energy Efficiency Improvement (2012) aims to enhance energy conservation and improve energy efficiency across various sectors. The Concept for Transition to a Green Economy (2013) outlines a comprehensive strategy for transitioning to a green economy, setting specific targets for increasing the share of renewable energy in electricity generation to 15% by 2030 and up to 50% by 2050, including alternative energy sources.
The Concept for Kazakhstan's Transition to a Green Economy is particularly significant as it establishes clear goals for the integration of renewable energy sources (RES) into the national energy mix. By 2030, the country aims to achieve a 15% share of renewable energy in electricity generation, with an ambitious target of 50% by 2050. These targets reflect Kazakhstan's commitment to reducing its reliance on fossil fuels and mitigating environmental impacts.Currently, Kazakhstan is in the process of preparing a Strategy for Transition to Carbon Neutrality by 2060. This strategy aims to further increase the share of renewable energy, not only in electricity generation but also in heat production. This holistic approach underscores the importance of renewable energy in achieving broader sustainability goals.
Support for renewable energy facilities in Kazakhstan is primarily facilitated through an auction mechanism. This mechanism plays a critical role in exerting downward pressure on the price of renewable energy, thereby making it more competitive. Additionally, it regulates the volumes of capacity introduction by considering the availability of flexible capacities, the electrical grid infrastructure, and the possibilities for integrating renewable energy into the power

system.Another limitation is that renewable energy investments remain unappealing to investors due to the low energy prices. Although energy prices in Kazakhstan are not directly subsidised, they are kept low because the regulatory system does not fully account for maintenance and replacement costs, nor the external environmental and climatic impacts. This results in renewable energy sources being less attractive in price compared to coal, which is abundant and inexpensive (Kazakhstan has some of the world's largest coal reserves). Consequently, coal contributes to over 70% of energy production and more than 20% of final consumption. However, the country's outdated, inefficient, and highly polluting coal-fired power plants place Kazakhstan among the top ten countries with the highest energy intensity [32].

The existing approach mandates the coordination of capacity delivery schemes for renewable energy facilities that are introduced outside the auction support mechanism. This coordination requires the inclusion of storage capacities to compensate for the variable nature of electricity production. Such a requirement ensures that the limits of renewable energy capacities are not exceeded, thereby maintaining the reliable operation of the Unified Power System of Kazakhstan and avoiding the risk of tariff deficits.

The continuous efforts to promote renewable energy are further bolstered by the decreasing costs of constructing renewable energy stations. This cost reduction is driven by ongoing technological advancements, increasing demand from investors, and economies of scale. These factors collectively create a significant impetus for renewable energy development in Kazakhstan.

AI in transitioning to the green economy

We systematically reviewed the documents and legislation and developed the following framework for the transition to the green economy (Figure 1). The suggested steps will help to develop the Innovation Ecosystem for fostering the usage of AI to boost the green economy. The innovation ecosystem is critical for fostering a thriving environment where artificial intelligence (AI) can flourish.

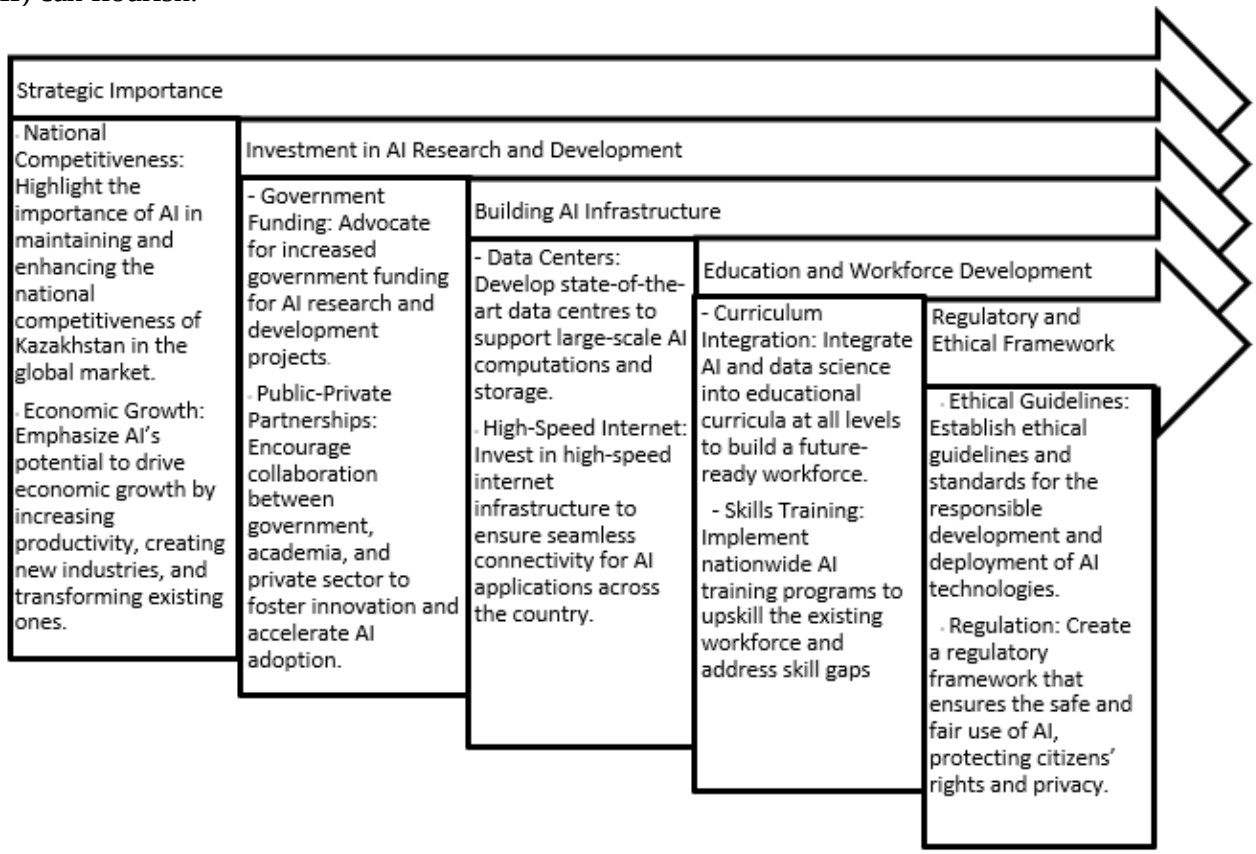

Figure 1 -Stages to transitioning to green technologies in AI

Note - Aauthor's own elaboration

Supporting the creation of AI startups and innovation hubs is vital to encourage entrepreneurial ventures in the AI sector. Innovation hubs can serve as incubators for new ideas, providing resources, mentorship, and networking opportunities for budding AI entrepreneurs. By fostering an environment that encourages experimentation and innovation, these hubs can significantly contribute to the growth and dynamism of the AI landscape. Providing funding and incentives for startups and companies working on cutting-edge AI solutions is crucial for the sustained growth of the AI sector. Financial support can come in the form of grants, loans, and tax incentives, which can lower the barriers to entry for new players and support the development of groundbreaking technologies. Incentives can also be tailored to encourage research and development, fostering a competitive edge in the global AI market.

Also, international collaboration is essential to harnessing AI technologies' full potential. Countries can benefit from shared knowledge and resources by building strong partnerships and participating in global initiatives. Fostering international collaborations with leading AI research institutions and technology companies is vital for exchanging knowledge and expertise. These partnerships can facilitate joint research projects, technology transfers, and the sharing of best practices. By collaborating with global leaders, countries can accelerate their own AI development and stay at the forefront of technological advancements.

It is important to understand that public awareness and engagement are key to ensuring that AI developments are transparent, inclusive, and aligned with societal values. Launching public awareness campaigns is essential to educate citizens about AI's benefits and potential risks. These campaigns can help demystify AI technologies, highlighting their practical applications and addressing common misconceptions. By providing clear and accessible information, awareness campaigns can foster a more informed and supportive public. Engaging with communities to gather feedback and ensure that AI developments align with societal needs and values is crucial. Community engagement can take various forms, such as public consultations, workshops, and town hall meetings. By actively involving citizens in the conversation, policymakers and developers can better understand public concerns and priorities, leading to more socially responsible AI implementations.

Building a robust innovation ecosystem, fostering international collaboration, and promoting public awareness and engagement are essential components of a comprehensive strategy to harness the potential of AI technologies. By focusing on these areas, countries can ensure that AI development is inclusive, sustainable, and aligned with broader societal goals.

By addressing these key areas, Kazakhstan can effectively harness the power of artificial intelligence, ensuring that its applications receive the special attention they deserve. This comprehensive approach will enable the country to leverage AI for sustainable development and improved quality of life for its citizens.

Optimising Wind Power Utilization with AI

The optimisation of wind power utilisation through artificial intelligence (AI) is being undertaken by a diverse range of stakeholders, including tech companies such as Siemens Gamesa, GE Renewable Energy, IBM, and Enel. Siemens Gamesa is a leader in wind turbine manufacturing, it integrates AI for predictive maintenance and dynamic optimisation of their wind turbines. GE utilises AI for wind forecasting and operational optimisation, enhancing the efficiency and reliability of their wind farms. IBM provides AI-driven solutions for energy management, including wind power optimisation. Enel Green Power, the Italian multinational, utilises AI to enhance the performance of its renewable energy assets, including wind farms.

Among the research institutions, the National Renewable Energy Laboratory (NREL), based in the United States, conducts extensive research on integrating AI with renewable energy technologies, including wind power [35]. Also, the Fraunhofer Institute for Wind Energy Systems (IWES), a German research institute, focuses on applying AI to improve wind energy systems' performance and reliability.

European Union (EU) funds numerous projects aimed at integrating AI into renewable energy systems, including wind power, through programs like Horizon 2020. China National Energy Administration (NEA) supports initiatives and research for the application of AI in renewable energy, particularly in the optimisation of wind farms. Global Wind Energy Council (GWEC) works with industry leaders to promote the use of AI in wind energy, enhancing the sector's efficiency and sustainability. The International Energy Agency (IEA) collaborates with various stakeholders to explore and promote AI applications in renewable energy, including wind power [33]. These entities collectively contribute to the advancement and implementation of AI technologies in wind power optimisation, driving forward the transition to more efficient and sustainable energy systems.

By harnessing AI's power, Kazakhstan can enhance its renewable energy capabilities and set a precedent for sustainable development in the region. This strategic approach aligns with global trends and positions the country as a forward-thinking leader in the energy sector [34].

The integration of AI with renewable energy sources presents a transformative opportunity for Kazakhstan. By focusing on efficiency, economic growth, and environmental sustainability, the country can leverage AI to maximise the potential of its renewable energy sector, driving both innovation and sustainable development.

For example, LLP "First Wind Power Plant" is the first project in Kazakhstan in the field of alternative energy development. The establishment of LLP "First Wind Power Plant" marked a significant milestone in Kazakhstan's energy sector, representing the country's initial foray into the development of renewable energy sources. This project was initiated as part of Kazakhstan's broader strategic goals to diversify its energy mix and reduce reliance on fossil fuels, in line with national policies aimed at fostering sustainable development.

The project received backing from the Kazakh government, which had been actively seeking to promote renewable energy as part of its long-term energy strategy. This support is evidenced by the implementation of key legislative measures such as the Law on Support for Renewable Energy Sources (2009), which aimed to create a favourable environment for the development of renewable energy projects. The Concept for Transition to a Green Economy (2013) further reinforced the importance of renewable energy, setting ambitious targets for increasing the share of renewable energy in the country's energy mix. The establishment of LLP "First Wind Power Plant" aligned with these policy objectives.

As the pioneer project in Kazakhstan's renewable energy sector, LLP's "First Wind Power Plant" set a precedent for subsequent renewable energy initiatives. It demonstrated the feasibility and benefits of wind energy, encouraging further investment and development in the sector. The project's success garnered recognition both domestically and internationally, highlighting Kazakhstan's commitment to sustainable energy solutions and its potential as a leader in renewable energy in the region.

The deployment of wind energy technology through LLP "First Wind Power Plant" introduced advanced renewable energy solutions to Kazakhstan. This technological advancement contributed to the country's knowledge base and expertise in managing and optimising wind energy resources. Economically, the project helped to diversify Kazakhstan's energy portfolio, providing a stable and renewable source of energy that complements the country's traditional energy resources (Figure 2). This diversification is crucial for enhancing energy security and achieving long-term sustainability.

LLP "First Wind Power Plant" stands as a landmark project in Kazakhstan's renewable energy journey, signifying the nation's commitment to exploring and developing alternative energy sources. Its establishment and success have paved the way for future renewable energy projects, solidifying Kazakhstan's position in the global shift towards sustainable energy.

Regarding the implementation of AI algorithms, it can analyse vast amounts of data to predict energy production and consumption patterns, leading to better resource allocation and reduced waste. Additionally, AI can anticipate equipment failures and schedule maintenance proactively,

minimising downtime and extending the lifespan of renewable energy assets. AI can enhance the functionality of smart grids by balancing supply and demand in real-time, ensuring stability and reliability in energy distribution. Furthermore, AI can optimise the use of energy storage systems, ensuring that excess energy generated from renewable sources is stored efficiently and utilised when needed.

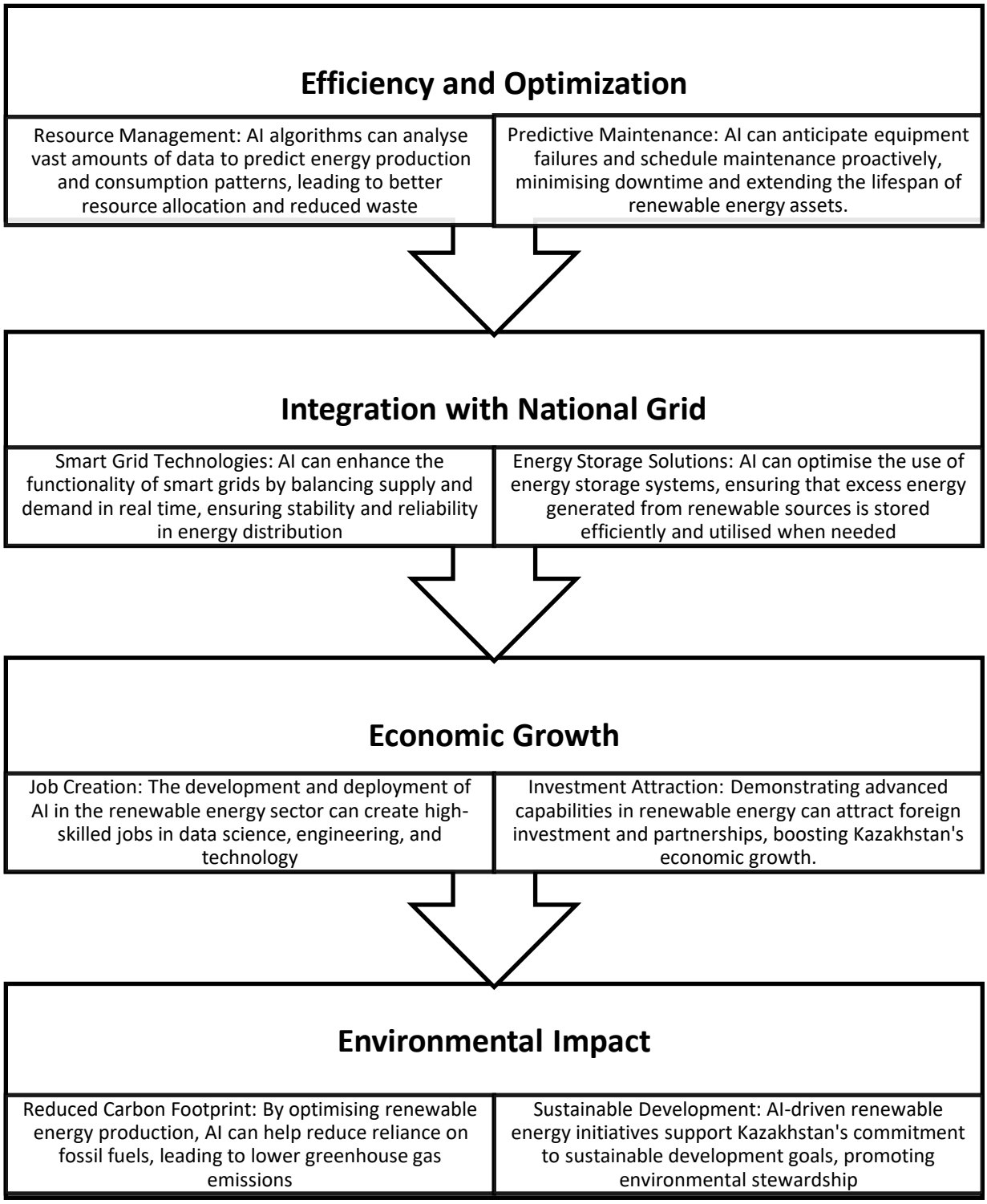

Figure2 – Opportunities for the utilisation of AI inrenewable energy
Note - Author’s own elaboration

Additionally, AI can anticipate equipment failures and schedule maintenance proactively, minimising downtime and extending the lifespan of renewable energy assets. AI can enhance the functionality of smart grids by balancing supply and demand in real-time, ensuring stability and reliability in energy distribution. Furthermore, AI can optimise the use of energy storage systems, ensuring that excess energy generated from renewable sources is stored efficiently and utilised when needed.The development and deployment of AI in the renewable energy sector can create high-skilled jobs in data science, engineering, and technology. Demonstrating advanced capabilities in renewable energy can attract foreign investment and partnerships, boosting Kazakhstan's economic growth. By optimising renewable energy production, AI can help reduce reliance on fossil fuels, leading to lower greenhouse gas emissions. AI-driven renewable energy initiatives support Kazakhstan's commitment to sustainable development goals, promoting environmental stewardship.

The development and deployment of AI in the renewable energy sector can create high-skilled jobs in data science, engineering, and technology. Demonstrating advanced capabilities in renewable energy can attract foreign investment and partnerships, boosting Kazakhstan's economic growth. By optimising renewable energy production, AI can help reduce reliance on fossil fuels, leading to lower greenhouse gas emissions. AI-driven renewable energy initiatives support Kazakhstan's commitment to sustainable development goals, promoting environmental stewardship.

Challenges and Policy Recommendations

Despite the potential benefits, there are challenges to the widespread adoption of AI in the renewable energy sector in Kazakhstan:

- Data Availability and Quality: The effectiveness of AI relies on the availability of high-quality data for training models. Kazakhstan needs to invest in data collection infrastructure, particularly in remote areas.
- Regulatory Framework: The development of clear regulations and standards for AI integration in the energy sector is essential. Policies should encourage innovation while addressing data privacy, cybersecurity, and ethical concerns.
- Investment in Technology and Infrastructure: Significant investment is required to develop AI capabilities and modernize the existing energy infrastructure. Public-private partnerships and international cooperation can play a key role in attracting necessary funding and expertise.

To overcome these challenges, the government of Kazakhstan should focus on creating a supportive policy environment, promoting research and development in AI and renewable energy, and fostering collaboration between industry, academia, and international partners.

Conclusion

The integration of artificial intelligence into the renewable energy sector presents a unique opportunity for Kazakhstan to achieve its socio-economic and environmental goals. By leveraging AI, the country can enhance the efficiency and reliability of renewable energy sources, driving economic growth and energy independence. The successful implementation of these technologies will require strategic investments, regulatory reforms, and capacity-building efforts. As Kazakhstan navigates its transition towards a more sustainable and diversified energy future, AI can serve as a key enabler of progress, contributing to a greener and more prosperous nation.

The integration of artificial intelligence with renewable energy sources in Kazakhstan holds immense potential for transforming the country's energy landscape. By leveraging AI technologies, Kazakhstan can optimise the efficiency, reliability, and sustainability of its renewable energy systems, particularly in wind and solar power. This technological synergy

addresses the growing energy demands and aligns with global sustainability goals, reducing reliance on fossil fuels and mitigating environmental impacts.

Kazakhstan's strategic initiatives and national policies have laid a strong foundation for this transformation. The support for renewable energy development and the adoption of advanced AI technologies positions the country as a leader in the transition to a green economy. The benefits are multifaceted: enhanced energy efficiency, significant cost reductions, improved resource management, and the creation of high-skilled jobs. Moreover, Kazakhstan's increasing attractiveness as a destination for foreign investment in the renewable energy sector underscores the economic potential of this integration.

As Kazakhstan continues to advance its renewable energy capabilities with AI, it contributes to global efforts in combating climate change and secures a sustainable and prosperous energy future for its citizens. The findings of this study underscore the critical role of AI in maximising the potential of renewable energy sources, highlighting a pathway towards a resilient, efficient, and sustainable energy system in Kazakhstan. The continued focus on innovation, investment, and international collaboration will be essential in realisingthis integration's full benefits, driving the nation's commitment to sustainable development.

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THEORETICAL ANALYSIS OF NEOLIBERAL INTERVENTIONS IN ENVIRONMENTAL ISSUES CREATED BY EXTERNALITIES

Mert KARA

Abstract

The environmental degradation caused by ongoing economic growth since the Industrial Revolution has significantly affected human life. The fact that this degradation is being addressed within the environment-economy framework and efforts are being made to produce political solutions shows that the degradation has become a serious issue. This study is broadly based on the theoretical analyses of economists who lived during the Neoliberal Era. First, externalities and environmental problems, defined under market failure, will be identified as the research problem. In the second part, which forms the core of the research, two main solutions will be addressed: a) Government intervention tools and b) Market-based solutions. Government intervention tools will include Pigouvian taxation, licenses, subsidies, and direct controls. In this context, the effects of externalities and environmental problems will be addressed within a system where the government is at the center. In other words, the government will always be the rule-maker and regulator at the core of the system. On the other hand, market-based approaches will examine the internalization of externalities, the Coase Approach, the Kaldor-Hicks Approach, and the Scitovsky Approach. Here, market-based solutions will be presented as alternatives to government interventions that face certain issues, involving agreements between parties and the ability to contract freely. Additionally, the disadvantages of each approach will be highlighted, and a conclusion will be made on which might be more effective.

Keywords: Externalities, Market failure, Environmental policy, Neoliberal intervention

Introduction:

Humanity is surrounded by two opposing behaviors: freedom and protection. These dual movements, brought about by behavioral characteristics, have led to a constant pollution problem accompanied by a continuous effort to mitigate it. This contradiction, where individuals pollute and communities seek solutions, shows that the problem is not only framed within a human-nature relationship but also within a human-to-human context. In this scenario, where advantages and disadvantages emerge, the impact of one person on another becomes significant. The concept of "externality" arises from this impact, where one individual's positive or negative actions affect another. Externalities are associated with the freedom aspect of individual behaviors. However, the protective instinct, which opposes freedom, brings into play the need for economic and political solutions to the externalities caused by individuals' influence over one another. The protective instinct seeks solutions to environmental pollution, which is one of the subcategories of externalities, and this is framed under the concept of market failure.

The theoretical approaches to addressing the externalities that cause environmental effects as a form of market failure are driven by this protective instinct. However, the aim of this study is not a philosophical examination of the anthropology of humanity but rather an analysis of the theoretical approaches of economists who reflect the neoliberal perspective. In other words, the research focuses not on positive applications in practice but on normative solutions for external issues. In some cases, the applicability of these normative solutions in real life will be discussed alongside criticisms of certain approaches. Thus, the main theme is not whether the proposed theoretical solutions eliminate environmental problems, but rather what these solutions are. The examined approaches will be presented under the main headings of government and market-based solutions, while highlighting their interrelations.

Market Failure Theory

Economics, according to some economists, is the "study of the nature and causes of the wealth of nations"[3]; according to others, it is the "science of the production and distribution of wealth"[4] As the neoclassical framework and demand-side perspectives emerged, economics became defined as the study of "the part of individual and social activities related to the acquisition and utilization of material necessities for welfare"[5] or as the science that "investigates the production, distribution, and exchange of wealth and services"[6] or simply as the science that "deals with human activities to secure livelihood"[7] Finally, economics has been described as the "science that studies phenomena from a price perspective"[8] (Davenport, 1968: 25). However, the definition provided in Lionel Robbins' 1932 work, *An Essay on the Nature and Significance of Economic Science*, remains commonly found in textbooks, defining economics as "the science that studies human behavior in the allocation of scarce and limited resources for alternative uses" (Robbins, 1945: 16). This definition asserts that economics is a science of choice and should be addressed through scarcity theory.[9] However, economics concerns itself with the consumption, production, and distribution of resources. In this sense, we need a market mechanism where individuals can meet their daily needs, producers can sell their products, and, as Polanyi asserts, the principle of exchange is upheld.

The market mechanism serves as the resource allocation process, where issues of consumption, production, and distribution between consumers and producers are addressed. In a market economy, consumers aim to maximize utility, while producers aim to maximize profit. In a perfectly competitive market with no intervention, if all conditions of perfect competition are met, utility, profit, and resource distribution occur efficiently on their own. This shows that, under the right assumptions, the market functions in a way that maximizes social welfare (Öztürk, 2004). In other words, the desirability of market activities is determined by the solution values of the maximum welfare problem. The maximum welfare within the scope of welfare economics corresponds to Pareto efficiency and market performance. This efficiency and maximum welfare correspond to the "first-best" resource allocation, that is, the Pareto-efficient distribution (Bator, 1958). Conversely, a market mechanism that does not meet Pareto-efficient distribution will be referred to as a "Market Failure Theory."

Market failure theory is divided into two types: structural and behavioral failures. Structural market failure arises when one or more of the conditions for perfect competition are not valid in a competitive market equilibrium. Structural factors include imperfect competition, the problem of asymmetric information, natural monopolies, public goods, and externalities, which form the basis of this study. The solution to structural market failure involves government intervention to correct the failure. According to this solution, the government acts as an independent administrative entity, intervening in the market through supervision, regulation, enforcement, or implementation. Behavioral market failures, on the other hand, occur when market enterprises act in ways that restrict or hinder competition. The distinction between these two types of failures

[3] Adam Smith (1723-1790)

[4] John Stuart Mill (1806-1873)

[5] Alfred Marshall (1842-1924)

[6] Henry Sidwick (1838-1900)

[7] Charles J. Bullock (1869-1941)

[8] Herbert J. Davenport (1861-1931)

[9] Frédéric Bastiat, explaining that human beings are social and engage in compulsory exchange, draws a market model in which the interest of producers is limited supply and intense demand, while the interest of consumers is intense supply and limited demand. This situation involves a 'scarcity theory' for the former (producers) and an 'abundance theory' for the latter (consumers). In terms of Political Economy, the 'scarcity theory' leads to a monopoly system, while the 'abundance theory' leads to free trade with the removal of all restraints (Frédéric Bastiat, Ekonomik Safsatalar, 2016, pp.15-25)

emerges in the interventions applied. While the government intervenes in structural failure through national regulators, behavioral failure is addressed through competition law (Benli, 2022).

In general, the primary objective of the market mechanism's resource allocation process is to achieve maximum welfare by ensuring the condition of Pareto efficiency. However, it is sometimes observed that the price, which is the most effective tool for ensuring efficiency in the market mechanism, does not ensure justice, equality, or fair distribution. As a result, market failures (such as imperfect competition, the problem of asymmetric information, incomplete markets, public goods, or externalities) arise. If these failures are not corrected, resources are wasted, and society cannot achieve maximum welfare. In these cases of inefficiency, the government intervenes in economic activities to ensure social welfare. However, in some cases, government intervention in market failures may negatively affect economic activities by serving its own interests. Some examples of such effects include "rent-seeking" where gains are obtained without effort, "political myopia" which leads to poor policy choices over time, "vote trading" and "fiscal illusion" (Özbilgi, 2020). In other words, government intervention against market failures can lead to new failures due to acting in pursuit of certain interests.

Theory of Externalities

Alfred Marshall (1842-1924), in his 1890 work *Principles of Economics*, which reached its 8th edition in 1920, distinguished between 'internal' and 'external' economies that constitute the overall scale of production in the industry. While defining external economies as factors from outside that may benefit the firm, such as better technology, he stated that internal economies are related to whether the firm manager decides to add a new line to the firm or whether it is worth bringing in a new machine (Marshall, 1920: 266). In his studies, Marshall considered external economies in terms of whether competition between firms would be disrupted. That is, by establishing a relationship between internal and external economies, if external economies in an industry benefited firms more, this could disrupt competitive conditions (Manisalıoğlu, 1971: 5). Therefore, external economies, depending on growth in the scale of production, would lead to monopolistic mergers and create 'natural monopolies' (Marshall, 1920: 284). According to Pigou, external economies illustrate the difference between marginal social value and marginal private net product, providing many examples of both negative and positive externalities (Pigou, 1932: 101-102). To bridge the gap between social and private costs, Pigou argued that contractual relationships cannot alleviate this difference, but the government can correct it through investments in these areas via 'extraordinary incentives' or 'extraordinary restrictions' (Pigou, 1932: 111).

It can be said that market efficiency is achieved when every consumer's welfare depends on their consumption decisions, and each firm's production is based on its input and output preferences. Achieving maximum welfare through one's preferences from both consumer and producer perspectives ensures Pareto efficiency, satisfying the 'first-best' condition of resource allocation. These determinations are made through price mechanisms. However, these assumptions do not always hold, and one consumer or firm may be affected by another consumer or firm. When the welfare (utility or profit) of an economic agent is 'directly' affected by the actions of another agent, an externality arises. This direct effect excludes money, the tool of market efficiency, from being part of the externalities. However, the external impact of one agent on another can also affect profits in monetary terms. This is known as a 'pecuniary externality' and does not lead to any market inefficiency (Hindriks & Myles, 2013: 224).

Externalities arise when consumers or firms interact in ways that do not involve the market. However, not every non-market interaction results in an externality. Externalities occur when individuals and firms ruthlessly pursue their self-interest without considering the effects of their

actions on others (Leach, 2004: 103). In more economic terms, an externality arises when the shape or position of one person's indifference curve depends on the consumption of others (Buchanan & Stubblebine, 1962: 371). This situation means that a firm increases its marginal private cost (PMC) by purchasing more raw materials to increase its output (q). This increase in output creates an externality, polluting the environment and negatively affecting the health of its neighbors. The harm caused is known as marginal damage (MD). The social marginal cost (SMC), which is the cost to society of increasing a firm's output, is found by adding the firm's own cost (PMC) and the unaccounted cost (MD). Conversely, the benefit a firm receives from producing an additional good is called the private marginal benefit (PMB). The benefit to society from producing an additional good is referred to as the marginal social benefit (SMB). The relationship between PMC-SMC or PMB-SMB provides us with the externality between agents (Leach, 2004: 104). This analysis will be explored in more detail later.

Government Intervention Tools for Externalities In a market mechanism where the Pareto efficiency condition cannot be met, firms create external costs and do not account for these costs. In such a situation, the government is forced to intervene by taking measures in the market. There are six instances where the government must intervene against these failures: imperfect competition, public goods, externalities, incomplete markets, imperfect information, unemployment, and other macroeconomic disturbances (Stiglitz & Rosengard, 2000: 83-93). Among these six market failures, only externalities will be addressed in this study. Under this heading, the government takes responsibility to eliminate these failures. The tools it will use to do so include taxes, licensing rights, subsidies and direct controls.

Taxation

Market inefficiency occurs when the distribution of resources fails to achieve Pareto efficiency. Thus, a gap arises between social benefit and private benefit, indicating market failure. The way to bridge this gap is through the use of taxes or subsidies (Hindriks & Myles, 2013: 236).

Pigouvian Taxation

According to Arthur C. Pigou, in the presence of a negative externality, a tax should be imposed on each unit of the good causing the negative externality until production is at an optimal level. In the case of a positive externality, subsidies should be provided for each unit of the good to the point where market equilibrium is restored (Öztürk, 2004: 177). This situation arises from the relationship between marginal social value and marginal private net product. Marginal private net product refers to the firm's average net product per unit, which corresponds to the supply price of the product. Marginal social net product, on the other hand, shows the contribution that a small increase in the product makes to national income (Pigou, 1932: 127). Hence, these two products should be equalized. If the marginal private net product is greater than the marginal social net product, a negative externality is present. Conversely, if the marginal private net product is smaller than the marginal social net product, a positive externality exists (Caldari & Masini, 2011: 717). In such a case, firms should be taxed by government intervention to eliminate the externality.

Looking more closely at Pigouvian taxation, the supply curve (MPC) represents the marginal cost of producing an additional unit of a good, while the demand curve (MSB) shows the benefit individuals gain from consuming an additional unit of the good. In a market without government intervention and externalities, equilibrium is found at point A, where the marginal social benefit (MSB) — which is represented by the demand curve — intersects with the marginal private cost (MPC) — the supply curve. In other words, the firm only considers its marginal private cost, not the marginal social cost, which includes the total cost. In the second scenario, where negative externalities are present, the supply curve shifts to the left, and the equilibrium moves to point B (Stiglitz & Rosengard, 2000: 130-131). Therefore, in a model with externalities, social welfare loss occurs, represented by the ABCD trapezoid in Figure 1.

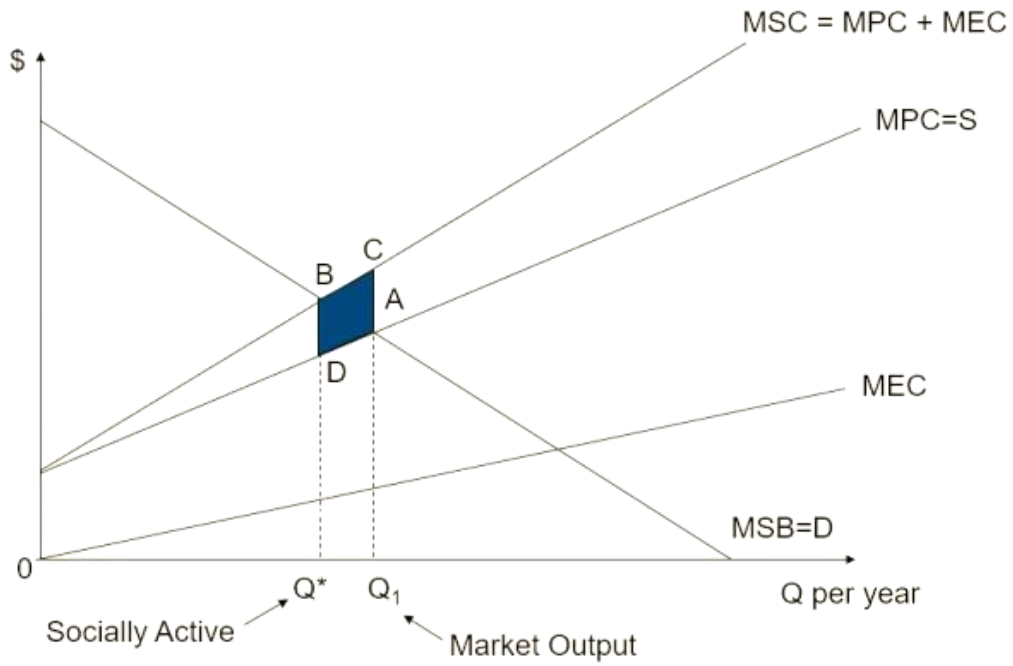

Figure 1: (Rosen, Gayer, 2008: 74)

When externalities arise at point B, efforts are made to correct market failure, and Pigouvian taxation comes into play. In Figure 1, social benefit is represented by AQ1 and social cost by CQ1, with the external cost shown by CA. In Figure 2, to eliminate the external cost, a Pigouvian tax equivalent to the abcd area must be imposed. In other words, the amount of tax is calculated by subtracting the social cost from the social benefit imposed on society. Thus, by internalizing the externality through taxation, both the welfare loss and the externality can be eliminated.

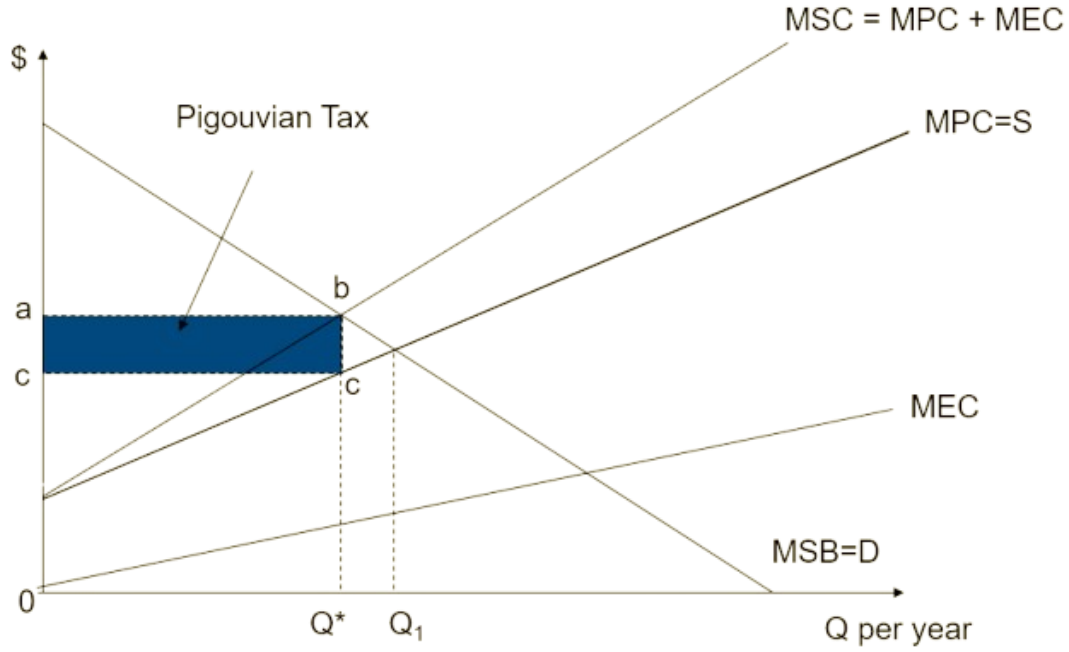

Figure 2: (Rosen, Gayer, 2008: 83)

When we examine the relationship between marginal private net product and marginal social net product, we can also determine the status of supply price and quantity. In the presence of negative externalities, production will always be above the optimal quantity due to excessive production. "The situation where marginal net product exceeds marginal social net product is the same as when the supply price is lower, and the quantity is higher" (Pigou, 1932: 127). Pigou also

emphasized diminishing, constant, and increasing returns, stating that private net product rises above social net product in markets under monopolistic competition, leading to inefficiency. In general, in simple competitive markets, when a firm follows the rising supply price (where marginal private net product is greater than marginal social net product), its actual output will be greater than what Pigou calls the "ideal output" and taxation must be applied to reduce it. Conversely, in industries with diminishing supply prices (where marginal private net product is smaller than marginal social net product), the actual output will be less than the "ideal output" Thus, maximum welfare is achieved when marginal net product equals marginal social cost (Caldari & Masini, 2011: 718).

Pigou's main goal is to maximize national income. The maximization of national income, which is synonymous with economic welfare, is Pigou's "maximization" problem. That is, Pigou focused on consumer and producer surpluses, aiming to achieve an ideal level of economic welfare. At this point, Pigou highlighted the misalignments in the economic system, particularly on the production side, and argued for the necessity of public intervention. He related his goal to the excess of private and social net products over one another. However, one of the most significant criticisms directed at Pigou is that his ideas remain theoretical and are difficult to apply in practice (Caldari & Masini, 2011: 718-720). For example, the amount of taxes and subsidies to be applied for externalities depends on the level of negative externality caused by the firm and the amount individuals affected by the externality are willing to accept (Özbilgi, 2020: 76). Therefore, a tax amount that does not affect the firm's profit will not act as a deterrent in addressing the negative externality it creates.

Licenses

It has been previously mentioned that firms, by emitting environmental pollutants, create negative externalities, and that the government intervenes through various policy options. These options include taxation, direct emission controls, and regulations (Leach, 2004: 113). Taxes adjust the cost of creating externalities, regulating the optimal level of output. Another form of intervention is tradeable emission permits. Compared to tax regulations, intervention through licenses is considered a simpler alternative to direct control. This is the legalization of producing externalities only up to the amount allowed by the licenses a firm holds (Hindriks & Myles, 2013: 239). Firms can trade permits for the total allowable pollution level among themselves. This alternative intervention tool for externalities is based on three assumptions:

1. Each firm must have a permit for every unit of pollution it emits.
2. The government grants a specific number of permits to each firm.
3. Firms are allowed to trade their permits in a competitive market (Leach, 2004: 115).

Calculating taxes, especially Pigouvian taxes, presents several challenges. The most significant of these challenges revolves around the issue of "information" When this tax system, which works in theory, is applied in practice, policymakers must have full information. Some economists argue that the view of tradeable licenses, considered an alternative to taxes, can overcome some significant problems. For example, the government may want to reduce emissions proportionally across all firms, but the cost of doing so may vary greatly between firms, and taxation may not reduce emissions at the lowest cost (Leach, 2004: 113). This proportional reduction would only be feasible if the government had full information about firms.

The problem of choosing between taxes and licenses, and deciding which to implement, revolves around two questions. The first question is what is needed to calculate taxes or determine the number of licenses. The second is what information is known when making decisions (Hindriks & Myles, 2013: 239-240). Calculating taxes requires knowledge of consumers' preference information and firms' production technologies. Moreover, the changing economic structure must

be monitored, and taxation should be adjusted accordingly. For licenses, what needs to be known is the determination of the total optimal level of externalities. The allocation of permits to firms will depend on the amount of total externality allowed. Determining the total level of externality, similar to the comprehensive information needed for personalized taxes, also requires having detailed knowledge. As a result, taxes and licenses are equivalent in terms of the need for information (Hindriks & Myles, 2013: 239-240).

Government-based but market-based “tradeable permits” create a specific amount of emission permits. These permits or rights are regulated under a specific “cap-and-trade system.” A limit is placed on the amount of pollution a firm can emit, and these emission permits (licenses) can be bought and sold in the market. The permits granted are limited to the amount of pollution the firm is allowed to emit. If the market price of a permit is higher than the marginal cost of reducing pollution, firms will sell their permits. Conversely, if the permit price is lower than the marginal cost of reducing pollution, firms will be eager to buy permits. The balance will be reached when the marginal cost of reducing pollution equals the market price of the permit (Stiglitz & Rosengard, 2000: 143).

One of the main problems with this system is that the market price of the permit may be lower than the cost of creating pollution. In such a case, firms will be willing to create pollution and will be more inclined to buy pollution permits. As a result, firms holding pollution rights will be able to comfortably operate within the framework of "pollution permits" Another problem with this system is that the price of pollution permits is dependent on the total pollution level, leading to issues in determining the price due to the variability of the pollution amount. In other words, the price firms must pay for pollution will remain uncertain. For example, the issue of pricing total carbon dioxide levels in the context of global warming, where the cost cannot be precisely determined, presents a significant challenge. Two things need to be clarified here: first, the changes in pricing for total pollution levels (carbon dioxide amounts), and second, the revaluation of already-traded pollution permits (Stiglitz & Rosengard, 2000: 144-145). In conclusion, although pollution permits are considered an alternative to intervention through taxation, this solution also has its own set of challenges and problems.

Subsidies

Subsidies are the exact opposite of taxes. Instead of taxing firms that trade in goods and cause environmental pollution, the government provides subsidies to these firms to encourage them to protect the environment (Leach, 2004: 88). Subsidies are essentially the mirror image of taxes (Stavins, 1998: 5). "A subsidy of one unit per reduced emission has the same desired effect" (Kohn, 1992: 77). The use of subsidies to reduce the level of harmful activities is a clear alternative to taxes (Baumol & Oates, 1975: 105). These explanations show that subsidies indeed have similarities to taxes. While taxes directly impose a cost on those who cause pollution, subsidies are financial aids provided by the government to encourage firms not to pollute the environment. In particular, in cases where negative externalities arise, a tax equal to the difference between marginal private cost and marginal social cost is applied, meaning that the externality is borne by the firm itself. Therefore, it can be said that when it comes to taxes, the marginal social cost does not change, but the problem is resolved by shifting private costs. However, when subsidies are applied, the marginal social benefit also moves.

In the explanation provided under the heading "Pigouvian Taxation" it was shown that marginal social benefit and marginal social cost are fixed. When an externality arises, marginal external cost is added to marginal private cost, creating marginal social cost. Thus, in the case of a negative externality, firms are taxed by the amount of the externality they create. In the case of a subsidy-

regulated externality, rather than imposing a tax for pollution, subsidies are provided to cover the costs incurred to reduce pollution. The market seeks to bring about efficient production conditions by supporting a subsidy that offsets the difference between the marginal social benefit and the marginal private benefit of reducing pollution (Stiglitz & Rosengard, 2000: 141-143). Pollution reduction subsidies reduce the marginal social cost of production and result in a lower level of pollution. However, in the subsidy process, the total benefits gained by those who finance the subsidies are also affected. Therefore, the benefit of reduced pollution resulting from the subsidies must exceed the cost of financing the subsidies.

Like taxes, subsidies proposed as a solution to externalities arising from environmental problems may be theoretically encouraging but can lead to economic inefficiency in practice (Stavins, 1998: 6). For example, the uncertainty of the daily performance of new equipment acquired by a firm to reduce pollution or the fact that the cost of the newly purchased equipment is less than the subsidy provided could attract an excessive number of new firms into the sector. In such a case, the situation could lead to a counterproductive outcome, where more emissions are produced in the subsidized situation compared to the unsubsidized scenario (Kohn, 1992: 77). Baumol and Oates compare the demand for subsidies by firms to a robber asking their victims for help to cover their expenses. Accordingly, they argue that the calls for subsidies by firms disadvantaged in terms of competition will increase. Additionally, they state that polluting firms, upon realizing the actions of the regulatory government, will plan to obtain greater incentives and become more inclined to pollute in order to secure larger subsidies (Baumol & Oates, 2012: 211). Thus, while the initial motive for eliminating pollution is driven by regulatory agencies, it becomes inevitable that firms will eventually seek subsidies. Accordingly, polluters will be more familiar with the subsidy measures imposed for pollution control than the regulating institutions (Kohn, 1992: 77). Again, when a firm acquires new emission-reducing equipment, the use of subsidies for regulatory oversight by the government will influence the firm’s decision on whether to use the equipment (Baumol & Oates, 2012: 212). If the subsidies fail to push enough firms into adopting new equipment, the firm may opt out of using the equipment. Thus, a deterministic situation emerges, where regulatory mechanisms and firm decisions become the sole determinants.

In general, subsidies are referred to in the literature as the "opposite of taxes" Imposing a tax on a waste-producing firm and encouraging the purchase of pollution-reducing equipment with subsidies are similar measures. However, in the case of subsidies, it can be said that, in the long-term competitive balance, they lead to more production and lower prices. Because subsidies create a situation that must be financed, the cost incurred is lower than the benefit gained from reduced pollution. In other words, with subsidies, the firm's optimal level becomes greater than it would be without incentives to reduce pollution (Stiglitz & Rosengard, 2000: 142). Thus, just as with taxation aimed at reducing pollution, subsidies also aim to achieve efficiency.

Direct Controls and Regulation - CAC

In practical economics, standards and direct controls can vary widely, not only as emission restrictions, but also as restrictions on pollution per unit of output or input, restrictions on the use of a polluting input or mandatory use of a particular pollution control technology. For example, while there are such output constraints in the literature, there is no example of such a regulation in any of the standards. This is because there is a 'diversity of firms' in real life. In other words, it is important to identify the conditions of more than one firm and to apply standards according to that firm. But in general, when economists refer to pollution standards, they universally speak of uniform restrictions on pollution emissions (Helfand, 1991: 622).

These standards, also called command and control (CAC), include a wide and varied set of regulations and are often confused with 'economic incentive systems'. In these two comparisons, the dividing line between command and control regulations and incentive-based policies is not very clear, but the clear difference is that the former is more crude and costly. CAC practices involving direct controls result in excessive costs, as empirical studies have shown. Economic incentive systems, on the other hand, seek to solve the problem at the least cost, utilizing environmental capacity to reduce control costs. Furthermore, economic incentives encourage the use of more effective and less costly emission reduction techniques (Cropper, Oates, 1992: 686). So, while the CAC method, which is less sensitive to cost, restricts emissions excessively, economic incentive systems concentrate their sensitivity more on cost and can apply less emission reduction than the CAC method. In general, the CAC system should be emphasized when we expect an improvement in environmental quality beyond the standard (Cropper, Oates, 1992: 699-700). Nevertheless, just like tax and subsidy instruments, incentives and the CAC method can be likened to different applications of similar objectives.

Economists who advocate direct controls and regulations argue that they provide greater certainty. For example, if firms are prohibited from emitting more than a certain level of pollution into the water, the level of pollution will be reduced if the pollution level is known. In other words, the relationship between the penalty and the pollution level will make the pollution level adjustable at the desired level with the necessary regulations (Stiglitz & Rosengard, 2000: 145-146). However, the first criticism faced by regulators in traditional CAC approaches is that information problems are too large. In a perfect information environment, this theoretical regulatory approach would lead to incomplete information between economic tools and regulatory approaches in real life (Cropper, Oates, 1992: 686). Another criticism of regulations is that they do not effectively reduce pollution. Because firms are diverse, some firms may face different marginal costs to reduce pollution compared to others (Stiglitz, Rosengard, 2000: 146-147). In other words, the fact that the standard applied to each firm is similar will be an obstacle to the effectiveness of different firms against pollution. Command and control regulations do this by setting uniform standards for firms. Focusing all companies on the same target can be both expensive and inefficient. Applying similar standards to firms may result in an efficient way of limiting pollution for some firms, but at a high cost for others, which may result in overly expensive methods being resorted to. Overall, the costs of controlling emissions can lead to different costs and efficiencies across firms and even across sources within the same firm (Stavins, 1998: 2).

A distinction should also be made between pollution permits and pollution regulations as interventions to reduce pollution. In the former, firms that buy pollution with licensing rights focus on the amount of pollution and the firm must buy the right in order to pollute more. While this is a performance-based method, the government only focuses on the outcome, i.e. how much pollution is produced. Pollution regulations, on the other hand, focus on standards, practices and inputs rather than performance (Stiglitz, Rosengard, 2000: 146). In the performance-based part of these two approaches to pollution abatement, it is easier to identify the equipment that certain firms have to implement, in terms of monitoring. However, the variability of the total pollution purchased through licensing rights and some problems in determining the price system make the regulation-based method more preferable. In addition, the fact that pollution regulations are more precise, traceable and process-oriented makes it a more positive choice.

Consequently, although the so-called command and control (CAC) standards are theoretically referred to as pollution regulations, in practice these regulations can vary widely. Nevertheless, if the practice is generalized, the most common are technology-based and performance-based standards. Technology-based standards specify the methods and equipment that firms must use

to comply with certain regulations. Performance-based standards, on the other hand, set a uniform control target for firms but give them latitude in how to achieve this target (Stavins, 1998: 2). In addition to various and broad regulations, these regulations are seen to provide more certainty in terms of emission reductions but are more costly. Empirical studies in the literature also show that this method reduces pollution more than the economic incentive system, but at a higher cost. Besides the excessive cost, the regulatory standards created for pollution reduction create 'uniform standards'. The fact that each firm is different from each other creates inefficiencies as well as excessive costs in terms of uniform standards. The solution to the problem of uniform standards lies in perfect information itself, but real life does not allow this.

Market-based Interventions to Externalities

Externalities, which are part of market failure, create costs for economic actors and pollution for nature itself. In order to prevent or stabilize these costs and pollution, the government imposes taxes, subsidies, direct controls and grants licensing rights. However, where government intervention is insufficient, market analysis is also needed. The most important of these are Internalization of Externalities, Coase Approach, Kaldor-Hicks Approach and Scitovsky Approach.

Internalization of Externalities

The government intervention tools for externalities discussed in the previous sections should not be surprising, as they are market-based. The subheadings under government intervention in externalities — taxes, subsidies, direct controls, and licensing rights — are all formed within the framework of price determination.[10] In addressing externalities, the government regulates market-like mechanisms through laws or administrative bodies, using the power of control and supervision to eliminate the inefficiency caused by market failure. However, government interventions are not always effectively implemented to resolve market failures. An alternative solution to this is private interventions where the parties involved in the externality reach mutual agreements. To achieve this, it is suggested that economic units of sufficient scale be designed, focusing not on individual behaviors but on the collective actions of groups (Stiglitz & Rosengard, 2000: 139).

For example, in a case of positive externality between two producers — a fruit grower and a beekeeper who pollinates the grower's flowers — the parties involved may not initiate a licensing action to purchase the positive externality. This results in the disregard of a beneficial situation, leading to inefficiency. However, if these two producers merge to form a single firm, their private and social costs will also merge. This will encourage them to take the externality into account and act to increase their efficiency. This process, where the affected parties merge to control the externality, is called internalization (Hindriks & Myles, 2013: 242).

The internalization theory suggests that internalizing externalities is more beneficial when the cost of using market processes and contractual agreements is higher than organizing the situation within a firm.[11] Consequently, the theory of internalization should demonstrate why markets are

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[10] While listing the environmental policy instruments, Oates and Baumol placed taxes and subsidies as 2 items under price incentives. In the footnotes, Baumol & Oates even suggested that auction of pollution rights could be added to this ranking (Baumol & Oates, 1975: 97). Alan Randall, on the other hand, has listed this order as 1) Negotiated market solutions 2) Systems of taxes, fees, fines and subsidies per unit 3) They are standard systems enforced by the threat of fines or imprisonment. He said that the three systems range from greater reliance on market forces to less reliance, with the first based on private negotiation and the second and third on government intervention (Randall, 1972: 175)

[11] Since the internalization theory is defined in its own terms, the market mechanism, which involves the negotiation of the parties, is put on the back burner. However, internalization theory has two aspects; the first is that the government intervenes with taxes or subsidies when market mechanisms are insufficient. Thus, the externality will be internalized. The second - and the main one - is the 'internalization of externalities' that occurs when the market itself recognizes property rights and allows the parties to come to an agreement. In conclusion, it is important to

more costly than internal organization in managing external changes. Otherwise, it will fail to justify its validity, leaving no reason to prefer internalization for regulating external changes. The internalization theory justifies itself over market regulations based on the following three arguments (Hennart, 1986: 791):

- Firms are more efficient in external markets not because they use market processes better, but because they utilize internal hierarchical methods.
- Firms sometimes achieve this not by avoiding markets, but by changing the interface with a series of market regulations into a single employment contract.
- Market failures arise from high transaction costs in acquiring intermediate goods, while firm failures stem from the cost of contracting for factor services. In other words, the high transaction costs used to explain market failures are also used to explain why firms fail.

The internalization theory also claims that the hierarchical method within firms solves the information problem discussed earlier under topics like taxation and licensing rights. In a perfect market (where there are no transaction costs), prices convey information about everyone's actions, and decisions are made optimally based on individuals' participation. However, in the real world, markets rarely achieve perfect efficiency, and prices fail to adequately limit social welfare. Against this, internalization theory proposes that a firm can manage its internal operations by organizing its employees hierarchically through employment contracts. In a hierarchical structure, employees submit to the employer and relinquish the right to allocate their resources (such as labor, time, and effort), leaving these decisions to the employer. As a result, employees under hierarchy agree to perform their tasks within certain constraints, leaving resource allocation decisions to a centralized party (the employer). Otherwise, in the process of resource allocation through market prices, employees would be paid based on the outcome of their own production efforts, and none would want their production and effort to be directed by someone else. In other words, workers would remain indifferent to resource allocation within the firm, and detailed management decisions would be carried out by administrative orders (Hennart, 1986: 793-794). This situation suggests that the maximization objective within the market mechanism can be corrected by firm-level arrangements organized hierarchically. Additionally, the hierarchy will limit the decision-making power of each agent in the market mechanism, transferring authority to the employer. Individuals, rewarded based on administrative directives rather than market-determined outputs, will remain indifferent to resource allocation.

Bithas argues that in order to prevent environmental pollution, the monetary payment of environmental costs, hence 'environmental taxes', however small, are necessary and that the problem of externalities can only be solved by internalizing externalities (Bithas, 2006: 159-161). In the context of the relationship between the internalization of environmental externalities and sustainability, he emphasizes the importance of internalization. In a situation of externalities where perpetrators steal environmental welfare from victims, institutions will fail to protect individual rights, and an irreparable loss of welfare will occur, leading to environmental degradation. In conditions of environmental externalities where welfare is stolen, socio-economic welfare cannot be maximized, and the solution to this problem lies in the internalization of environmental externalities. Bithas also notes that all mainstream economic policy tools proposed for the environment aim to internalize environmental externalities (Bithas, 2011: 1705-1706).

Coase Approach

When externalities are in question, the process in which the involved parties come together to internalize the externality and make agreements is called the Coase Approach. For example, if there are smokers and non-smokers in the same room, and if the loss to non-smokers exceeds the

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recognize that this chapter should be perceived as a transition and that it includes both interventions - government and market.

gain of smokers, the smokers should come together and pay compensation. Additionally, it can be said that smokers can gain ownership of the property by making payments. Thus, property rights give the owner control over the assets (in the example, smoking) and the right to receive fees for its use (in the example, the benefit of smoking) (Stiglitz & Rosengard, 2000: 134). The Coase Approach argues that people will continue negotiating until they reach Pareto efficiency, assuming that effective bargaining is not hindered by anything. However, this statement is tautological, as people can also negotiate the path to efficiency or productivity (Farrell, 1987: 113).

In his 1960 article *The Problem of Social Cost*, Coase proposed "bargaining" as an alternative to government intervention in the sixth section, but he also frankly acknowledged that the problem incurs costs from both government regulations and market solutions. Although he considered the option of "doing nothing" about the externality issue, he ultimately argued that appropriate social regulation should be chosen to deal with the "harmful effects" problem. While emphasizing that every solution has its costs, Coase stated that there is no reason to rely solely on government regulation instead of the market or the firm. He also noted that economists and policymakers often overestimate the advantages of government regulations. The choice between the options — market or government regulations — should be based on a detailed investigation of how the market, the firm, and the government handle the issue of harmful effects (Coase, 1960: 18-19).

Coase mentioned that the government may perform certain tasks at a lower cost than a private enterprise, but he also noted that the government's administrative mechanism is not cost-free. Moreover, he emphasized that an administration that operates without competition and is subject to political pressure may not always introduce efficiency-enhancing regulations. He argued that an ordinary firm can carry out the same activities at a lower cost due to competition from other firms, and that the availability of the market as an alternative to its own activities ensures that control remains in the hands of the firm.[12] In such a case, measures would also be taken against internal organization within the firm. The solution would be adopted "in cases where the firm's administrative costs are lower than market transaction costs, and where the gains from rearranging activities exceed the firm's organizational costs"[13] (Coase, 1960: 16-17).

Coase found the foundation of most analyses related to the problem of harmful effects in Pigou's book *The Economics of Welfare*, where Pigou explained the basic finding as the difference between social and private products. The solution to this difference was to impose a tax on pollution-producing firms based on the amount of pollution or to relocate the factory away from the area. In the traditional approach, when Person A harms Person B, the solution is to restrict Person A (from causing harm). However, Coase argued that this approach is flawed, as the real problem is deciding whether A should restrict B or B should restrict A. In other words, the problem turns into one of avoiding harm. For example, if cattle roam freely without fences and damage the crops of the neighboring farm, we are forced to choose between meat and crops. In this case, the decision must be made based on the value of what is obtained and what is sacrificed (Coase, 1960: 2).

In the third section of his article[14] Coase addressed the issue of conflict between a cattle rancher and a farmer with an example. When cattle roam freely, they damage the crops in proportion to the number of cattle.[15] In such a case, an agreement will be made between the cattle breeder and

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[12] Coase argued that in the presence of externalities, there should be an 'administrative management' that would enable firms to deal with each other. This eliminates individual bargaining between the various factors of production, and the reorganization of production takes place without the need for bargaining between factor owners.

[13] Market transactions involve discovering who one wants to deal with, finding out on what terms people want to deal, and conducting negotiations that lead to a bargain. These transactions are extremely costly. According to Coase, in this case, output increases only when these costs are higher. In the opposite case, the compensation obligation - the agreement between the parties - will not kick in.

[14] ''The Pricing System With Liability For Damage''

[15] If there is 1 cattle, the annual crop lost is 1. When the number of cattle is 2, the total annual loss is 3, while the additional loss per cattle is 2.

the farmer, and the party causing the externality will incur an additional cost. For example, if the rancher increases the number of cattle, the profit from the additional meat would depend on whether it exceeds the additional costs (the annual crop value paid by the rancher to the farmer). If the additional profit is less, the rancher will not increase the size of the herd. The critical point to emphasize here is that when externalities are involved, the farmer's yield will not increase but will instead decrease to a certain point. For instance, in a situation where the farmer earns 12 units from the land with a cost of 10, the farmer's net income would be 2 units. Assuming the cattle damage the crops by 1 unit, the farmer now earns 11 units from the market and 1 unit from the rancher. If the cattle breeder increases the number of cattle to 3[16] the rancher will have to pay an additional 2 units for the damage. However, the farmer's net income remains at 2 units. In this case, the farmer would be willing to abandon farming if offered a payment of more than 2 units. So, a satisfactory negotiation regarding the cessation of farming may occur. Therefore, the decrease in the value of the crop depends on the cost of increasing the herd. The type of payment made to the farmer in reality would depend on the bargaining skills of the farmer and the rancher. But the payment made by the rancher to the farmer would not be high enough to cause the rancher to abandon the agreement[17] so the agreement would not affect resource allocation but would only influence the distribution of income and wealth between the rancher and the farmer. As a result, there is a procedure that allows for compensation of the crop damage without the possibility of halting farming. This is not a process in which the government supports the farmer (through subsidies, for example) when it is unprofitable for the farmer to sell crops in the market. Whether the procedure involves paying the rancher not to cultivate the land or renting the land for a price slightly higher than what the farmer would pay, the outcome will maximize the production value. However, when the problem is left to market transactions instead of agreements between individuals, if the damage to the crops exceeds the land rent, things will go awry, and a long-term solution to the externalities will not be achieved (Coase, 1960: 2-6).

Viewed from the Pigouvian perspective, in the example of the cattle rancher and the farmer, the party causing the harm would be forced to pay compensation equal to the difference between private and social costs. Coase, on the other hand, argues that when property rights are transferred, and as long as the parties can negotiate, the question of who is responsible becomes irrelevant. The bilateral agreement removes the need to consider who originally held the right and aims to minimize the potential harm (Boundreaux, 2019: 12). Based on the example above, if there is an externality between two parties, the party causing the externality will not stop creating it.[18] This is because the rancher does not bear the cost of the externality he creates. If a bilateral agreement is reached between the farmer and the rancher, the farmer will offer to pay more than the cost of fencing the cattle. The critical point here is that if the rancher still rejects the payment, the "foregone payments" will be internalized to the rancher. This means that the cost created by the farmer due to the damage to his crops will be internalized — invisibly —[19] by the rancher. The

[16] If each additional meat production is greater than the cost incurred, the cattle breeder will increase the number of cattle.

[17] Çünkü çiftçi her zaman araziyi işlenmeden bırakmaya yetecek kadar bir ödeme almak isteyecektir. Fakat çiftçi, hiçbir zaman ne bu araziyi çitle çevirmenin maliyetinden daha yüksek ne de sığır yetiştiricisinin komşu mülkü kullanmaktan vazgeçmesine neden olacak kadar yüksek bir ödeme alamaz.

[18] The basic assumption here is that the cattle breeder has the right of ownership.

[19] Because when the cattle breeder, acting with the freedom that the property grants him, harms the farmer, he will not receive any additional payment and this will be felt as an invisible loss. The invisible loss is the amount to be paid by the farmer to the cattle breeder.

internalization of this cost and its manifestation as an invisible loss will lead the rancher to take precautions[20] regarding his cattle (Boundreaux, 2019: 13-16).[21]

Kaldor-Hicks Approach

Pareto efficiency is defined as the optimal point where one person's situation cannot be improved without worsening another person's situation. According to Pareto, the total welfare principle suggests that at least one change must result in a net increase in welfare without worsening anyone's situation — even if the amount of improvement in welfare cannot be measured. To demonstrate that Pareto efficiency has been achieved, it must be shown that all parties affected by the change have consented to it. For example, if person A sells a tomato to person B for $2, it can be said that the benefit of $2 to person A exceeds the benefit that the tomato provides to person B. However, this explanation can only be made in the absence of third-party effects. When a free-market system involving multiple individuals is in place, setting prices according to everyone's preferences or obtaining everyone's consent becomes difficult.[22] In other words, under conditions without externalities, a company can close a factory in Town A and move it to Town B, causing property values to drop in Town A and rise in Town B. According to Pareto efficiency, which excludes third parties, there would be no action taken to eliminate inefficiency. Therefore, the goals of maximizing wealth and preserving autonomy would begin to conflict (Posner, 1980a: 488-490).

The Kaldor-Hicks approach, in contrast to Pareto efficiency, starts by aiming for wealth maximization. Unlike Pareto efficiency, which is concerned with ensuring that no one is made worse off, the Kaldor-Hicks approach allows for compensation for the losses incurred from value increases. According to this approach, in production activities where external economies are present, the firm causing the external cost should compensate the affected firm for the amount of the external benefit generated by the production activity (Taytak & Meçik, 2009: 84). For example, in the case where property values decrease in Town A and increase in Town B, the property owners in Town A should be compensated by those in Town B. Thus, when there is a 100-unit welfare loss due to the decline in property value in Town A and an 80-unit welfare gain from the increase in property value in Town B, the Kaldor-Hicks approach would follow the "compensation criterion" to address the value loss. However, according to the Pareto criterion, it cannot be determined whether the welfare gain of the property owners in Town B is greater than the welfare loss of the property owners in Town A. Similarly, Pareto efficiency cannot provide a criterion in the case of monetary externalities. Even if wealth maximization is achieved by compensating third parties, the harm experienced by those negatively affected by the change may exceed the benefit gained by the winners (Posner, 1980a: 491).

Following these explanations, the difference between the wealth maximization goal of the Kaldor-Hicks approach and the utility maximization goal of Pareto efficiency should be highlighted. Wealth maximization is achieved when goods and other resources are in the hands of those who value them the most, and a person who is willing to pay more for a good and can do so values it more (Dworkin, 1980: 191). The logic of utilitarianism, on the other hand, argues for expanding the boundaries as much as possible and making the ethical goal the maximization of total happiness or satisfaction in the universe (Posner, 1979: 113). Therefore, the difference

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[20] The assumption is that, since the ownership right is vested in the cattle breeder, it is likely that the farmer will be required to pay until the cattle are completely removed. Thus, in the opposite way to the one given in the previous paragraph, the process may continue to the point of abandonment of cattle breeding. But the outcome would not be different when the ownership right passes to the farmer, and the cattle breeder would pay compensation for the damage caused. The cattle farmer would probably fence the cattle, choosing the lower-cost situation.

[21] In the article, the example of landowners being harmed by the sparks caused by the railroads is given. However, in order not to disrupt the flow between the cattle breeder and the farmer given in the text, the logical inference of the example given in the article is applied to the example here.

[22] We come across a situation where the interpersonal Pareto efficiency is determined through the free tomato market. In other words, the Pareto system that determines the efficiency between the two parties enters a process that is free of third party effects, as it cannot be met by the price regulations emphasized in the transition to a free market.

between wealth and utility lies in wanting something badly but not being able to obtain it due to ownership or competing claims. In the wealth maximization system, a person cannot claim rights over a good, while in the utility maximization system, this is possible (Posner, 1980b: 243-244). Thus, wealth maximization is not purely driven by desire but by the ability to pay, backed by skill. Accordingly, the Kaldor-Hicks approach will be efficient when monetary wealth is maximized, and it will not measure utility or happiness but only the payment in monetary terms. That is, the approach leaves aside the idea that the benefits (or harms) of externalities can be measured or compared. In general, the requirement for sustaining this analysis is to determine people's willingness to pay for different outcomes (Stringham, 2001: 42).

Although the Kaldor-Hicks approach is offered as an alternative to Pareto efficiency, which excludes third parties, it faces several criticisms. One of the main criticisms is that wealth maximization, as an ethical criterion, produces results that conflict with moral intuitions. Posner summarizes this conflict in two points. First, the economist insists on freedom of contract in cases where fraud, externalities, inefficiencies, monopolies, or other market failures are absent. For example, from the perspective of wealth maximization, if Person A sells themselves into slavery to Person B to support their family, or if Person D borrows money from Person C under a contract that allows C to break D's legs, there is no economic basis to reject these practices. There is no basis to criticize such behavior, as it is purely wealth maximization. The second point is that wealth maximization is indifferent to egalitarian values. In general, wealthier people are more productive, work harder, are more intelligent, or possess higher marginal products for whatever reason. Thus, there is no need for wealth maximization to result in a fair distribution (Posner, 1979: 134-135).

Other criticisms relate to the changing, diverse, and fluctuating nature of market volatility and preferences. The fact that the world is constantly changing, and the assumption that people will behave in the future as they have in the past, leads to invalid prices and an expanding market, posing a significant obstacle to this approach. The approach assumes a fixed scale of preferences and does not account for dynamic preference analysis. A second criticism is that this approach relies on the observation of a third-party economist, government official, judge, or politician rather than on agreements between individuals. However, this requires the observer to carefully examine both parties' preferences and willingness to pay. Considering the effects on all people for all possible outcomes makes the situation even more complex. Additionally, given that the judge making the decision is human and not omniscient, the question of how the observer will make such a decision remains unclear. Similarly, the self-serving roles of biased observers in determining individuals' preferences also render this approach ineffective. Even if it is assumed that the parties involved in the loss and gain are better positioned to observe and analyze the situation more closely, the affected parties must be able to fully monitor the performance of their companies and make consistent decisions to maximize the firm's value for the approach to be effective (Stringham, 2001: 43-46)

Scitovsky Approach

Tibor Scitovsky began his analysis by categorizing the approaches of previous (Classical paradigm) economists toward externalities. Before making these categorizations, he mentioned that the concept of 'external economies' is one of the most difficult terms in economic literature, and that the definitions provided are insufficient. The first insufficiency stems from the general definition of external economies as "services provided by one producer to another free of charge" which Scitovsky found inadequate because it fails to specify the nature, form, or reasons why these services are free. The second insufficiency, according to Scitovsky, is that while the concept of external economies is based on the difference between profit and welfare, and the inability of perfect competition to reach an optimum state, it is unclear in many cases under what circumstances it falls within the realm of "external economies." Additionally, Scitovsky believed that some view the concept of ‘’'external economies’’ as exceptional and unnecessary, and that explaining this may require ideological approaches (Scitovsky, 1954: 143).

The difficulty in defining the concept of external economies led Scitovsky to create certain categorizations. One of these is "Equilibrium Theory" and the other is the "Industrialization Theory" in underdeveloped countries. Equilibrium Theory has two characteristics: first, it assumes perfect competition on both sides of the market (involving the externality), and second, it assumes the perfect divisibility of all resources and products. This approach, within the framework of the classical paradigm, does not directly involve interdependence and is a static theory that aims for the Paretian optimum, where economic effects such as welfare and profit are only transmitted through market prices. Scitovsky responded to the principles that emerged around Equilibrium Theory with four types of objections, primarily because it did not involve direct interdependence. First, he argued that an individual's satisfaction depends not only on the goods and services they consume but also on the satisfaction of others. Second, he stated that an individual's satisfaction is not just influenced by the goods and services they demand from producers but also by external effects such as smoke, noise, and environmental damage caused by producers. Third, he noted that producers' output could be influenced by the actions of individuals and the demand they place on the products produced by the firm. Finally, he argued that a producer's output depends not only on their own resources but also on the activities of other firms. In this last point, Scitovsky emphasized the interdependence between producers, in addition to the interdependence among consumers (Scitovsky, 1954: 143).

Industrialization theory, another area where the concept of external economies is used, involves the allocation of savings among alternative investment opportunities. Scitovsky, after defining alternative investment opportunities, i.e. private profitability of investment, as a situation that everyone desires, said that there may be many exceptions to this situation for underdeveloped countries. Accordingly, he did not find a definition of the concept of 'external economy' within underdeveloped countries. However, he said that if we proceed from the definition of a profit function that 'shows that the firm's profit depends not only on its own output and factor inputs, but also on other factor inputs' then we can define the external economies of less developed countries. That is, contrary to the equilibrium theory, the external economies of underdeveloped countries involve interdependence between producers and consumers (Scitovsky, 1954: 144-146).

After explaining both approaches, Scivotsky explains the reason why 'Equilibrium Theory' cannot be applied to the practical problem of investment in three ways. The first is that perfect divisibility of products cannot always be fulfilled. This is because, according to the theory, the economic optimum must fulfill marginal conditions. The indivisibility of goods prevents this situation.[23] Second, while equilibrium theory is static, investment funds are not. Finally, the difference between national and international perspectives in investment policy debates is often manifested in the difference between social utility and private profit. Indeed, while social benefit is identified with national benefit, private profit affects the social welfare of the whole world, taking into account external economies. In other words, although equilibrium theory does not include 'interdependence', profit calculations cannot be made solely within national utility and include foreign economies in the profit criterion (Scitovsky, 1954: 147-151).

When Scitovsky's approach to welfare economics[24] is considered, he raises objections to the explanations of the Classical Economists covering all welfare propositions. This objection comes to what the Classics called 'allocative efficiency', the ability to optimally allocate a given amount of used resources among their various uses in consumption and production (Scitovsky, 1941: 77). Taking into account the 'Equilibrium Theory' discussed in the previous paragraphs, it is said that

[23] The divisibility of goods refers to goods that are capable of satisfying needs even after they have been divided into parts.

[24] According to him, the aim of welfare economics is to test the efficiency of economic institutions in the utilization of the productive resources of a society. At this point, the main distinction is between the constancy and variability of the resources employed (Scitovsky, 1941: 77) (Also, for Scitovsky's explanations on welfare economics: Scitovsky, Papers on Welfare and Growth, 2003).

this approach involves perfect competition and that the best allocation of resources between different uses is only possible if the rates of substitution are equal.[25] Because only in such a case can one person's satisfaction increase without decreasing the satisfaction of another. Hence, Classical allocative efficiency involves people allocating goods and services among themselves according to the contract curve, independently of initial conditions. Such allocative efficiency would exclude consumption, export and import taxes from the model (Scitovsky, 1941: 78). Moreover, ignoring initial conditions would not have an equal impact on the welfare of all at the point of allocation of resources and would favor some people. Against this dominant paradigm, Scitovsky argued that welfare propositions cannot be considered independently of interpersonal utility comparisons (Scitovsky, 1941: 79).

Scitovsky, who tries to introduce new welfare principles in opposition to the classical 'allocative efficiency' thinks that we should first ask whether it is possible to make everyone better off in the new situation after resource allocation than in the initial situation.[26] Second, starting from the initial situation, we should examine whether income redistribution can lead us back to a position superior to the new situation. If the former is possible and the latter is impossible, we would say that the new state is better, and vice versa that the new state is worse. That is, allocative efficiency should be optimal both before and after resource allocation (Scitovsky, 1941: 86-87).

As a result, it can be said that Scitovsky's thinking on the external economy is based on the reciprocal relationship between producers and consumers and that Classical thinkers, acting with static equilibrium models, ignored and oversimplified this situation. Therefore, within the framework of 'dependency', as an alternative to the Kaldor-Hicks approach[27] two economic units should engage in bargaining in order to limit their activities on each other (Yıldırım, 1992: 22). According to this approach, if one economic unit incurs an external cost as a result of the production or consumption activity of the other economic unit, the party incurring the external cost should engage in bargaining to limit the activity of the economic unit causing it. Thus, the equilibrium level will be equalized for both parties and social welfare will be optimized (Aktan & Tosuner, 1986: 149).

Conclusion

Externalities and environmental issues, as defined under market failures, present one of the greatest challenges faced by modern economies. Market mechanisms fail to achieve their objectives when they cannot reach the 'first-best' resource allocation and maximum efficiency. In this context, government interventions have become indispensable to fill the gaps created by market mechanisms. However, the fact that government interventions also encounter certain problems results in government failure in achieving their objectives. Therefore, as an alternative, market-based solutions have been presented as an essential tool to fill the gap left by government interventions.

The primary issue with government interventions is that, although they may be successful in theory, they often have no practical application. In other words, their validity can only be

[25] Scitovsky argued that the simplest solution to a problem for the purpose of welfare economics was that of the Classics, and that this approach was analytical and fixed.

[26] The first approach is said by Scitovsky to be similar to the Kaldor-Hicks approach. Indeed, the Kaldor-Hicks approach tries to predict whether the gainers will have a compensatory effect on the losers after the allocation of available resources. However, Scitovsky objected to the use of this approach in isolation, arguing that it is asymmetric and overemphasizes the situation before the allocation of resources. Indeed, according to Kaldor's conception of welfare, the government, which distributes welfare, has a special attachment to the state prior to the redistribution of resources and carries out the distribution based on this single reference (Scitovsky, 1941: 88)

[27] In the Kaldor-Hicks approach, which is based on the principle of compensation, when a policy that takes society from state A to state B is considered, if those who gain in state B are better off even though they compensate the losers, they will be in a more preferable situation than in state A. But the 'Scitovsky Paradox' says that the increased welfare from state A to state B can be achieved in the opposite way from state B to state A. We therefore need to eliminate this contradiction. Scitovsky's solution to the paradox, the 'Scitovsky Double Criterion', will increase welfare or produce a desirable outcome in the transition from state A to state B, but will not improve the criteria in the transition from state B to state A.

demonstrated theoretically. As a result, they become an idealistic form of intervention that operates on supposed theories but does not appear in real life. The second fundamental problem is the issue of information. The inability of governments or policymakers to have complete information due to the variability of economic activities can also complicate the determination of the Pigouvian tax to be implemented. Additionally, the lack of information can make it difficult to calculate consumer and producer preference information. Along with these two main problems, more specific issues include licenses allowing individuals to act freely within the framework of "pollution permits" subsidies creating a situation akin to robbery, and the high costs associated with direct controls, all pointing to the failure of a centralized intervention method. Moreover, regulatory authorities' biased political interventions and their immunity from pressure may lead to privileged behavior in favor of certain interests.

In contrast, market-based solutions offered as alternatives to government intervention tools have a more flexible and dynamic structure. While market-based solutions may face similar problems to government interventions, such as 'imperfect information' and 'transaction costs' they seek more realistic solutions by surpassing theoretical and idealistic approaches. Thus, they measure problems in monetary terms rather than in terms of utility and happiness. On the other hand, they establish environments where parties can freely contract and determine property rights. By placing humans at the center of decisions and choices, they overcome the limitations of centralized control and allow affected parties to participate more actively in the resolution processes. That is, they minimize the influence of third parties and open the door to bilateral agreements within the framework of free movement. In conclusion, they create a space where the limitations on actions are broadened, and free choices are established.

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ANALİZANDO LOS PARÁMETROS PARA DEFİNİR EL KİLÓMETRO 0: UN ESTUDİO DE LA LİTERATURA CİENTÍFİCA Y LA COMUNİDAD NORMATİVA

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Resumen

El concepto de "Kilómetro 0" en productos agrícolas tiene un impacto significativo en varios beneficios, entre ellos la reducción del impacto ambiental, la economía local y la garantía de frescura y calidad de los productos. Este estudio se basa en la definición y caracterización objetiva del concepto de "Kilómetro 0" que media en el análisis de investigaciones y estándares académicos de la Unión Europea (UE), y en particular de la Política Agrícola Común (PAC) y el Reglamento (UE).) 2018/848 sobre producción y etiquetado ecológico. Además, el estudio relaciona estos parámetros con los Objetivos de Desarrollo Sostenible (ODS) de la Agenda 2030, proporciónando un marco integral para su implementación y promoción. El análisis identifica estos parámetros clave: proximidad geográfica, impacto ambiental, frescura y calidad, apoyo a la economía local, certificación y trazabilidad, apoyo de políticas y número de intermediarios. Los hallazgos indican que la implementación efectiva del "Kilómetro 0" puede contribuir significativamente a la sostenibilidad ambiental y al desarrollo económico rural, alineándose con varios ODS, incluyendo la acción climática, la producción y el consumo sostenibles y el crecimiento económico.

Palabras clave: Kilómetro 0; Política Agrícola Común (PAC); Objetivos de Desarrollo Sostenible (ODS); Trazabilidad alimentaria; Economía rural.

Marco Teorico

El concepto de "Kilómetro 0" en productos agrícolas tiene relevancia por los múltiples beneficios que incluyen la reducción del impacto ambiental, el impacto en las economías locales y la garantía de frescura y calidad de los productos. Este Marco Teórico busca definir y caracterizar este concepto a través del análisis de investigaciones académicas, normativas europeas actuales y su alineación con la Agenda 2030 para el Desarrollo Sostenible. La popularidad del "Kilómetro 0" se basa en su capacidad de contribuir al rápido desarrollo, como es el caso de Brunori (2019).

La proximidad geográfica es fundamental para el concepto de "Kilómetro 0". Una primera aproximación a la definición de cadena corta que se encuentra en la normativa de la comunidad que define la PAC, y que se establece que los productos han demostrado tener un radio máximo de 100 kilómetros de distancia de la zona de producción. Hay una distancia entre los dos puntos de la población o la misma como radio acción del producto,

Esta garantía no sólo contribuye a la reducción de las emisiones de CO2, sino que también se aplica a los agricultores locales para facilitar la venta directa de nuestros productos. Estudios han demostrado que la optimización de la ubicación de los centros de distribución y el diseño eficiente de la red logística pueden minimizar las distancias de transporte y, por ende, las emisiones de carbono (Hasanzade et al. 2022). Se puede evaluar la necesidad de determinar la posición de reducción de distancia en las zonas agrícolas más importantes y también determinar la distancia desde la parte trasera de la radio.

El impacto ambiental de las prácticas y distribución agrícola son otros de los componentes esenciales del "Kilómetro 0". La Política Agrícola Común (PAC) de la Unión Europea y el Reglamento (UE) 2018/848 sobre producción ecológica y etiquetado promueven prácticas que

minimizan la huella de carbono y fomentan la sostenibilidad (Comisión Europea, 2012). Estas normativas incentivan el uso de equipos tecnificados agrícolas y la reducción de emisiones de carbono asociadas al transporte de productos, alineándose con los principios del "Kilómetro 0". Además, la Agenda 2030 para el Desarrollo Sostenible, específicamente el Objetivo de Desarrollo Sostenible (ODS) 13, promueve la acción por el clima, incentivando prácticas que mitiguen el cambio climático (Gómez Isa, 2022).

La proximidad de la geográfica permite un mayor control de la cadena de aire fresco, lo que es crucial para mantener la frescura y calidad de los productos perecederos como frutas, verduras y productos lactosos. Las investigaciones destacan la importancia de las cadenas de frío eficientes para garantizar que los productos lleguen frescos al consumidor final, reduciendo el tiempo entre la cosecha y el consumo (Zhu et al., 2023).

Está alineado con el ODS 12 de la Agenda 2030, que garantiza las modalidades de consumo y producción sostenible (Denver et al., 2019)

El apoyo a la economía local es un pilar fundamental, para la economía de las zonas rurales y de las explotaciones agrarias. Promover la producción y el consumo local también ayuda a fortalecer las economías rurales, producir ingredientes sostenibles y hacer que el desarrollo sea sostenible. La PAC y los programas de desarrollo rural de la UE están diseñados para mejorar la viabilidad económica de las zonas rurales, promoviendo mercados locales y cadenas de suministro cortas (Comisión Europea, 2021). Estas iniciativas no solo benefician a los agricultores locales, sino que también contribuyen a la cohesión social y económica de las regionales rurales, en línea con el ODS 8 que promueve el crecimiento económico inclusivo y sostenible (Gamazo Chillón, 2023).

Debido a que los productos están etiquetados como "Kilómetro 0", es fundamental establecer sistemas de certificación y seguridad. Estos sistemas aseguran que los productos cumplan con los estándares establecidos y que el mar original sea verificable. Las normativas de la UE sobre etiquetado y trazabilidad son fundamentales para garantizar la autenticidad y la transparencia en la producción y distribución de estos productos (Comisión Europea, 2012). Esto también se aplica al ODS 12, que garantiza el mecenazgo del consumo y la producción (Cruz Maceín & Benito Barba, 2018).

Las políticas y subsidios del gobierno juegan un papel vital en la promoción del "Kilómetro 0". Las iniciativas de política tienen como objetivo proporcionar incentivos apropiados para la adopción de prácticas agrícolas prácticas y el financiamiento de la infraestructura necesaria para el mantenimiento de cadenas de suministro eficientes y sostenibles. Los estudios muestran cómo los subsidios gubernamentales pueden más significativamente la logística de la cadena de frío, haciendo que el transporte de productos frescos sea más eficiente y sostenible (Zhu et al., 2023). Estas acciones están en consonancia con el ODS 2, que busca poner fin al hambre, lograr la seguridad alimentaria y promover la agricultura sostenible (Collantes, 2019).

Reducir el número de intermediarios entre el productor y el consumidor es clave para gestionar la integración del "Kilómetro 0". Los menos intermediarios implican pequeños costes y mayor transparencia, permitiendo una conexión más directa entre productos y consumidores. Estudios han demostrado una cadena de suministro más corta puede mejorar la eficiencia y reducir costos, beneficiando tanto a los productosores como a los consumidores finales (Abatekassa & Peterson, 2011). Está alineado con el ODS 12, que promueve la eficiencia en el uso de los recursos (Zhong, 2023).

Atendiendo a estas cuestiones, especialmente en la dispersión documental y detección bibliográfica, decidimos analizar las categorías que definen el concepto de kilómetro 0 en una definición lógica y aplicable, como es el caso, el presente estudio se centra en la definición y caracterización de el concepto "Kilómetro 0" en productos agrícolas.

Este concepto, ampliamente promovido en la actualidad, busca fomentar el consumo de los productos locales para reducir el impacto ambiental, apoyar las economías locales y garantizar la frescura y calidad de los alimentos alineándose con la Agenda 2030.

Las preguntas de investigación que han guiado el estudio han sido las siguientes:

1. ¿Cuál es la distancia máxima que se debe considerar para un producto agrícola del mar etiquetado como "Kilómetro 0", y esta proximidad geográfica contribuye a la reducción de emisiones de CO2 y a los agricultores locales?
2. ¿El concepto de “Kilómetro 0” incide en la minimización de la huella de carbono y la adopción de prácticas agrícolas prácticas?
3. ¿Cuál es la cercanía del área geográfica y las cadenas frutícolas contribuyen eficientemente a garantizar la calidad y calidad de los productos procesados como frutas, verduras y lactosa?
4. ¿ Esta es la forma? ¿La etiqueta "Kilómetro 0" se aplica a la economía local y contribuye al desarrollo económico y social de las comunidades rurales?

5. ¿Qué sistemas de certificación y seguimiento se requieren para garantizar la autenticidad y transparencia de los productos etiquetados como "Kilómetro 0"?
6. ¿Qué papel tienen las políticas y subsidios del gobierno en forma de cadenas de suministro cortas y sostenibles para productos "Kilómetro 0"?
7. ¿La reducción del número de intermediarios entre el producto y el consumidor mejora la eficiencia, reduce el coste y aumenta la transparencia en la cadena de suministro de productos "Kilómetro 0"?

Y se concretan en los siguientes objetivos específicos:

1. **Definir la Proximidad Geográfica** : Establecer el parámetro de distancia máxima entre el lugar de producción y el punto de venta para considerar un producto como "Kilómetro 0". Evaluar esta contribución aproximada a la reducción de emisiones y el apoyo a los agricultores locales, en línea con el ODS 11 (Ciudades y comunidades sostenibles) y el ODS 13 (Acción por el clima).
2. **Análisis del Impacto Ambiental** : Evaluar la importancia de minimizar la cantidad de medios de carbono en la reducción de las emisiones de CO2 equivalente asociadas al transporte y adoptar prácticas agrícolas que sean estables y energéticamente eficientes. Este objeto está alineado con los directivos de la PAC y el Reglamento (UE) 2018/848, al igual que con el ODS 12 (Producción y consumo responsables) y el ODS 13 (Acción por el clima).
3. **Garantizar la Frescura y Calidad** : Investigar cómo la proximidad geográfica y las cadenas de frío eficientes contribuyen a mantener la frescura y calidad de los productos, especialmente en productos perecederos como frutas, verduras y lácteos. Este objeto está relacionado con el ODS 3 (Salud y Bienestar) y el ODS 12 (Producción y consumo responsables).
4. **Fomentar el Apoyo a la Economía Local** : Explorar las formatos en que el concepto "Kilómetro 0" apoya a los agricultores y productos locales, promoviendo la sostenibilidad económica y social en las comunidades rurales, en línea con los programas de desarrollo rural y fondos de La UE, y contribuir al ODS 8 (Trabajo decente y crecimiento económico) y ODS 11 (Ciudades y comunidades sostenibles).
5. **Implementación de Sistemas de Certificación y Trazabilidad** : Diseñar y evaluar sistemas de certificación y seguimiento que aseguren la autenticidad y transparencia del origen local de los productos "Kilómetro 0", conforme a los estándares de etiqueta de la UE. Este objeto está alineado con el ODS 12 (Producción y consumo responsables).
6. **Evaluar el Apoyo de Políticas Públicas** : Analizar el papel de las políticas gubernamentales y subsidios en el fomento de cadenas de suministro cortas y sostenibles. Evaluar esta política incentivando la adopción de prácticas ecológicas y proporcionando apoyo financiero para la infraestructura necesaria, contribuyendo a los ODS 2 (Hambre cero) y ODS 13 (Acción por el clima).
7. **Reducir el número de intermediarios** : Consideremos que la reducción del número de intermediarios entre el productor y el consumidor puede aumentar la eficiencia, reducir el coste y aumentar la transparencia y conexión directa, beneficiando tanto a los productos como a los consumidores finales. Este objetivo está relacionado con el ODS 8 (trabajo decente y desarrollo económico) y el ODS 12 (producción y consumo responsable).

Método

Diseño de estudio

Dada la dispersión documental detectada y el déficit de investigaciones concretas sobre este tema (O'Dowd y Werner, 2024), el presente estudio se deseñó como un análisis de contenido cualitativo (Vallés, 1999) que integra fuentes académicas y marcos normativos relevantes para definir. Los parámetros del “Kilómetro 0” en productos agrícolas. La selección del contenido analítico para interpretar y categorizar los datos cualitativos recopilados a través de los documentos consultados

implica la identificación de patrones temáticos, conceptos recurrentes y significados subyacentes del concepto de kilómetro cero.

El análisis inductivo realizado permite que los temas surjan de forma natural a partir de los datos. La codificación y categorización de la información verbal se realizan para capturar la esencia de las percepciones, opiniones y experiencias. El objeto de uso está diseñado para requerir una comprensión integral y profunda del concepto de agricultura de proximidad.

En este sentido, la investigación se centra en la revisión de literatura científica y documentos normativos de la Unión Europea, así como en la relación con los Objetivos de Desarrollo Sostenible (ODS) de la Agenda 2030, para identificar y sintetizar los parámetros clave que caracterizan este es el concepto.

Fuentes de información

Para realizar el análisis, consultamos a los equipos académicos de investigación en las normas de la Unión Europea, particularmente la Política Agrícola Comunitaria (PAC) y el Reglamento (UE) 2018/848 sobre producción ecológica y etiquetado. Además, el estudio relaciona estos parámetros con los Objetivos de Desarrollo Sostenible (ODS) de la Agenda 2030, proporciónando a un marco integral para su implementación y promoción. Los principales usos del fuego:

1. Artículos científicos de revistas académicas, obtenidos a través de buscadores como: Scopus, Medline, Google académico.
2. Documentos normativos de la Unión Europea disponibles en EUR-Lex, incluyendo la Política Agrícola Común (PAC) y el Reglamento (UE) 2018/848 sobre producción ecológica y etiquetado.
3. Documentos e informes de la Agenda 2030 y Objetivos de Desarrollo Sostenible (ODS).

Criterios de selección de estudios.

Seleccionaron estudios y documentos que cumplieran con los siguientes criterios de inclusión (Ruiz Olabuenaga, 2012):

1. Publicación reciente (últimos 10 años) para asegurar la actualidad de la información.
2. Relevancia directa al concepto de “Kilómetro 0” en productos agrícolas, incluyendo aspectos como sostenibilidad, logística, transporte y calidad, apoyo económico local, certificación y durabilidad.
3. Disponibilidad de datos empíricos normativos que puedan ser analizados cualitativamente.
4. Relación con los Objetivos de Desarrollo Sostenible de la Agenda 2030, específicamente aquellos que promueven la sostenibilidad ambiental, el desarrollo económico local y la reducción de emisiones de carbono.

Proceso de análisis

El análisis de contenido se realiza en varias fases:

1. Identificación de Parámetros Clave: Se revisaron y extrajeron los parámetros mencionados en los artículos científicos y documentos normativos. Los parámetros identificados incluyen distancia, impacto ambiental, frescura y calidad, apoyo a la economía local, certificación y trazabilidad, apoyo de políticas y número de intermediarios.
2. Codificación de la Información: Se codificaron los textos de los artículos y documentos para identificar y categorizar información relevante según los parámetros definidos.
3. Síntesis de Información: Integra la información codificada en una narrativa cohesiva que describe cómo cada parámetro contribuye a la definición del "Kilómetro 0" en productos agrarios.
4. Validación de resultados: Comparar los distintivos con los estándares y políticas de la

Unión Europea para garantizar la coherencia y relevancia de los parámetros identificados.

5. Validación de resultados: Comparar los distintivos con los estándares y políticas de la Unión Europea para garantizar la coherencia y relevancia de los parámetros identificados.

Los resultados del análisis de las organizaciones y rotación de los siete parámetros clave identificados. Cada sección del análisis de contenido presenta una síntesis de la literatura y normativas relevantes, destacando la interrelación entre los parámetros y su importancia para la definición y promoción del "Kilómetro 0" en productos agrícolas y su contribución al cumplimiento de las ODS.

Resultados: Parámetros que definen el “Kilómetro 0” en productos agrícolas

Este análisis sintetiza la investigación actual y los marcos normativos para definir los parámetros del "Kilómetro 0" en productos agrícolas, centrándose en la distancia, el impacto ambiental, la frescura y calidad, el apoyo a la economía local, la certificación y trazabilidad, el apoyo de políticas y el número de intermediarios. Los hallazgos integran perspectivas de múltiples estudios y directrices reglamentarias, particularmente la Política Agrícola Común (PAC) de la Unión Europea y las regulaciones sobre producción y etiquetado ecológico. Además, se consideran los Objetivos de Desarrollo Sostenible (ODS) de la Agenda 2030 para contextualizar la relevancia de estos parámetros.

El concepto de "Kilómetro 0" promueve el consumo de productos alimenticios locales para reducir el impacto ambiental, apoyar las economías locales y asegurar la frescura de los productos. Este análisis identifica y discute estos parámetros claves fundamentales para definir el "Kilómetro 0" en productos agrícolas: distancia, impacto ambiental, frecuencia y calidad, apoyo en la economía local, certificación e impacto, apoyo de políticas y número de intermediarios.

Distancia

El criterio principal para los productos "Kilómetro 0" es la cercanía al punto de consumo. Esto reducirá las emisiones del transporte y apoya la agricultura localmente. Estudios enfatizan la optimización de los centros de distribución para minimizar las distancias de transporte, alineándose con este parámetro. Esto se basa en ODS 11 (Ciudades y comunidades sostenibles) y ODS 13 (Acción por el clima) (Wang et al., 2022; Zhu et al., 2023).

Impacto Ambiental

Minimizar el contenido de carbono es esencial, lo que implica la reducción de las emisiones de CO2 del transporte y la adopción de prácticas agrícolas prácticas. El centro de distribución máximo puede reducir significativamente las emisiones de carbono y al mismo tiempo minimizar las distancias de transporte. La eficiencia energética y los aspectos prácticos en la cadena de refrigeración son cruciales para reducir las emisiones durante el almacenamiento y el transporte.El PAC fomenta prácticas agrícolas beneficiosas para el clima y el ambiente mediocre, promoviendo la modernización y competitividad de las explotaciones agrícolas. El Reglamento (UE) 2018/848 sobre producción ecológica y etiquetado incentiva la producción local y sostenible, alineándose con los principios del "Kilómetro 0". Estas acciones están alineadas con los ODS 12 (Producción y consumo responsables) y ODS 13 (Acción por el clima) (Wang et al., 2022; Zhu et al., 2023; Unión Europea, 2018, 2021).

Fresca y Calidad

La proximidad permite garantizar la frescura y la calidad de los productos, reduciendo el tiempo entre la cosecha y el consumo. Las cadenas de frío eficientes son vitales para mantener la calidad de los productos perecederos durante el transporte y almacenamiento. Un gesto de la cadena de frío es muy significativo en la frecuencia y calidad de los productos frescos. También está vinculado a ODS 3 (Salud y Bienestar) y ODS 12 (Producción y consumo responsables) (Zhu et al., 2023; Wang et al., 2022; Graeub et al., 2016).

Apoyo a la Economía Local

El concepto de “Kilómetro 0” está dirigido a los agricultores y a los productos locales, promoviendo la mayor estabilidad económica y social. El desarrollo de cadenas de suministro locales beneficia a los consumidores y fortalece las economías rurales, proporcionando ingresos estables y oportunidades de empleo a los agricultores locales. Los programas de desarrollo rural y bases estructurales de la UE incluyen la promoción de mercados locales y cadenas de suministro cortas para aumentar la viabilidad económica de las zonas rurales y reducir la dependencia de las importaciones de lejanas. Está en línea con el ODS 8 (Trabajo decente y crecimiento económico) y el ODS 11 (Ciudades y comunidades sostenibles) (Unión Europea, 2021).

Certificación y Trazabilidad

Los sistemas establecidos de certificación y rendimiento son fundamentales para asegurar que los productos sean etiquetados como "Kilómetro 0" cumplan con los estándares establecidos. Los estándares de confiabilidad y etiqueta garantizan que los consumidores puedan identificar el origen de los productos y las decisiones tomadas para que sean consumidos, por lo que es fundamental para la versión "Kilómetro 0". Esta es una línea con el ODS 12 (Producción y consumo responsables) (Unión Europea, 2018).

Apoyo de Políticas

Las políticas y subsidios del gobierno deben centrarse en la cadena de suministro cortas mediante incentivos para prácticas prácticas y apoyo financiero para la infraestructura necesaria. Los subsidios gubernamentales pueden mayor la logística de la cadena de frío, haciendo que el transporte de productos frescos sea más eficiente y sostenible. Las políticas públicas de protección y promoción de los productos locales son fundamentales para el fin del "Kilómetro 0". Estas acciones están en consonancia con los ODS 2 (Hambre cero) y ODS 13 (Acción por el clima) (Zhu et al., 2023).

Número de intermediarios

Reducir el número de intermediarios entre el productor y el consumidor es clave para mantener la integración del concepto "Kilómetro 0". Los menos intermediarios implican pequeños costes, mayor transparencia y una conexión más directa entre productos y consumidores. Una cadena de suministro más corta puede mayor la eficiencia y menores costos, además de aumentar los beneficios para los agricultores locales y mayor calidad del producto para el consumidor final. El PAC y las iniciativas de desarrollo rural también promueven cadenas de suministro cortas, apoyando la venta directa y los mercados locales para reducir la intermediación. Está en línea con el ODS 8 (Trabajo decente y crecimiento económico) y el ODS 12 (Producción y consumo responsables) (Graeub et al., 2016; Kireeva & O'Connor, 2010; Unión Europea, 2021).

En resumen, integrar los hallazgos de investigación y los marcos normativos de la UE proporciona una definición integral del "Kilómetro 0" en productos agrícolas. Los siete parámetros discutidos —distancia, impacto ambiental, frescura y calidad, apoyo a la economía local, certificación y trazabilidad, apoyo de políticas y número de intermediarios— son esenciales para promover una agricultura local y sostenible que beneficie tanto a los consumidores como a los productores. La investigación y el análisis de políticas futuras continúan afinando estos parámetros para mejorar la efectividad de la iniciativa "Kilómetro 0".

El "Kilómetro 0" y los Objetivos de Desarrollo Sostenible

En concordancia con el "Kilómetro 0", se va una introducción al concepto de sostenibilidad, el cual es un término que hace referencia a "la capacidad de satisfacer las necesidades actuales de la sociedad con los recursos naturales disponibles, pero sin comprometer las oportunidades de las futuras generaciones para satisfacer las suyas" (Saavedra Robledo, 2010).

Es importante, no sólo para la protección del medio ambiente, sino también en relación con los aspectos económicos y sociales, lo que requiere un compromiso conjunto para conseguir un mundo más justo para todo.

Para poder lograrla, se han de llevar a cabo prácticas sostenibles, teniendo como referencia siempre a los Objetivos de Desarrollo Sostenible (ODS), establecidos en 2015 por la Asamblea General de las Naciones Unidas y que se pretende que sean alcanzados en el año 2030. Se trata de un concepto transversal, puesto que, de una manera directa o indirecta, se relaciona con los 17 ODS existentes en la Agenda 2030 sobre desarrollo sostenible en los aspectos económicos, sociales y ambientales (ONU).

Concepto de "Kilómetro 0"

identificados en la categoría "Kilómetro 0" en los productos agrícolas están definidos en el

concepto sable:

El "Kilómetro 0" en productos agroalimentarios es una categoría derivada de un sistema de producción y consumo local que se utiliza para definir los productos que proporcionan una radio de acción del producto local en base a su cercanía a núcleos de población o centros de venta. . Esta certificación garantiza a los consumidores que el producto agroalimentario consumido reduce el impacto ambiental y el número de intermediarios, garantiza la frescura, calidad y trazabilidad de los alimentos, y fortalece las economías locales y las explotaciones familiares. Desde una perspectiva socioeconómica, dicha categoría se apoya en políticas públicas que facilitan las prácticas agrícolas sostenibles y las cadenas de suministro cortas, alineándose con los Objetivos de Desarrollo Sostenible de la Agenda 2030.

Discusión

El concepto de "Kilómetro 0" en productos agrícolas presenta una serie significativa de ventanas que siguen siendo relevantes en el contexto actual de sostenibilidad y desarrollo rural. Los hallazgos de este estudio confirman que la proximidad geográfica es esencial no solo para reducir las emisiones de CO2, sino también para fortalecer las economías locales. La literatura existe respalda esta conclusión, destacando que la proximidad geográfica en los sistemas alimentarios locales es clave para reducir las emisiones de carbonoo y promover la sostenibilidad ambiental (Hasanzade et al., 2022).

Además, la eficaz gestión de la cadena de frío es crucial para mantener la frescura y calidad de los productos perecederos. La investigación subraya que una cadena de frío bien gestionada es esencial para reducir el desperdicio alimentario y garantizar la satisfacción del consumidor, aspectos fundamentales en la promoción de prácticas de consumo sostenibles (Gregorio et al, 2022).

El apoyo a la economía local es otro aspecto crítico del "Kilómetro 0". Promover la producción y el consumo local fortalece las economías rurales, proporcionando ingresos estables y fomentando el desarrollo sostenible. La importancia de las cadenas cortas de suministro para el desarrollo económico rural ha sido ampliamente documentada, subrayando su papel en la revitalización de las comunidades rurales (Cruz Maceín & Benito Barba, 2018).

La implementación de sistemas de certificación y confiabilidad es fundamental para garantizar la autenticidad y transparencia de los productos "Kilómetro 0". Estos sistemas permiten a los consumidores tomar decisiones informadas, las cuales son cruciales para gestionar la confianza en los productos locales y asegurar que el cumplan se base en los estándares de calidad (Armesto López & Gómez Martín, 2016).

Las políticas y subsidios del gobierno han creado un papel vital de cara al "Kilómetro 0". Las iniciativas políticas, como los subsidios, son esenciales para mejorar la infraestructura y la efficiencia de la cadena de frío, haciendo que la agricultura local sea más sostenible y resiliente (Collantes, 2019).

Reducir el número de intermediarios entre el productor y el consumidor es clave para gestionar la integración del "Kilómetro 0". Una cadena de suministro más corta no solo reduce costos, sino que también mejora la eficiencia, beneficiando tanto a productores como a consumidores, lo que refuerza la sostenibilidad económica y social (Renting et al., 2003).

En resumen, el concepto de "Kilómetro 0" no sólo es relevante para el medio ambiente y el desarrollo rural, sino que también se alinea con diversos objetivos de la Agenda 2030, entre ellos la acción climática, la producción y el consumo responsable, la salud del abeja, y el crecimiento económico incluido. La implementación efectiva de este concepto puede contribuir significativamente a la consecución de estos objetos, promoviendo una agricultura local y asegurando que el beneficio sea tanto para los consumidores como para los productos. La investigación y el desarrollo de políticas futuras continúan afinando estos parámetros para mejorar la efectividad de las iniciativas del “Kilómetro 0” (Gómez Isa, 2022).

Conclusiones

El presente estudio tiene una comprensión integral del concepto "Kilómetro 0" en productos agrícolas, integrando la investigación académica a los estándares de la Unión Europea y los Objetivos de Desarrollo Sostenible (ODS) de la Agenda 2030. Los resultados del análisis han sido identificado Discutir estos parámetros clave: distancia, impacto ambiental, frescura y calidad, apoyo a la economía local, certificación y trazabilidad, apoyo de políticas y número de intermediarios.

La proximidad geográfica es fundamental para reducir las emisiones de CO2 y apoyar a los agricultores locales. Optimizar la distribución de los centros de distribución y diseñar sistemas logísticos eficientes, minimizando las distancias de transporte, en línea y dosis con este parámetro y contribuyendo a los ODS 11 (Ciudades y comunidades sostenibles) y 13 (Acción por el clima). Es crucial minimizar el contenido de carbono reduciendo las emisiones de CO2 del transporte y adoptando prácticas agrícolas prácticas. Las normativas de la PAC y el Reglamento (UE) 2018/848 incentivan estas prácticas, promoviendo la sostenibilidad en la producción y distribución de productos agrarios. Esto está basado en ODS 12 (Producción y consumo responsables) y 13 (Acción por el clima).

La proximidad de la geográfica permite un mayor gesto de la cadena de frío, fundamental para mantener la frescura y calidad de los productos perecederos. Estudios han demostrado que las cadenas de frío eficientes son vitales para asegurar que los productos lleguen frescos al consumidor final, reduciendo el tiempo entre la cosecha y el consumo. Este es un lineado con los ODS 3 (Salud y bee star) y 12 (Producción y consumo responsables).

Promover la producción y el consumo local fortalece las economías rurales, proporcionando ingresos estables y fomentando el desarrollo sostenible. La PAC y los programas de desarrollo rural de la UE están diseñados para mejorar la viabilidad económica de las zonas rurales, promover los mercados locales y las cadenas de suministro. Esto está en línea con los ODS 8 (Trabajo decente y crecimiento económico) y 11 (Ciudades y comunidades sostenibles).

Establecer sistemas de certificación y confiabilidad es fundamental para asegurar la autenticidad y transparencia de los productos "Kilómetro 0". Las normas de la UE tienen tal etiquetado y

garantía de que los consumidores puedan identificar el origen de los productos y tomar decisiones informadas por el consumidor. Esta es una línea con el ODS 12 (Producción y consumo responsables).

Las políticas gubernamentales y las ayudas son vitales para fomentar las cadenas de suministro cortas y sostenibles. Las iniciativas políticas proporcionarán incentivos adecuados para la adopción de prácticas agrícolas sostenibles y la financiación de la infraestructura necesaria. Los subsidios gubernamentales pueden significativamente significativamente la logística de la cadena de frío, haciendo que el transporte de productos frescos sea más eficiente y sostenible. Está en consonancia con los ODS 2 (Hambre cero) y 13 (Acción por el clima).

Reducir el número de intermediarios entre el productor y el consumidor es clave para mantener la integración del concepto "Kilómetro 0". Los menos intermediarios implican pequeños costes, mayor transparencia y una conexión más directa entre productos y consumidores. Una cadena de suministro más corta puede conseguir mayor eficiencia y costes reducidos, beneficiando tanto a los productos como a los consumidores finales. Pretende alcanzar la eficiencia económica y se sitúa en la línea con los ODS 8 (trabajo decente y desarrollo económico) y 12 (producción y consumo responsable).

Al fin y al cabo, se puede aplicar una definición concreta de la etiqueta “Kilómetro 0” a los productos agrícolas, en función de la distancia considerada en el valle, pero es importante que el apoyo de las políticas públicas garantice la reducción de la el impacto ambiental, el número de intermediarios en la cadena de producción, la frescura, calidad y trazabilidad de los alimentos, de modo que a través de dicha calificación se favorecen la economía local y las explotaciones familiares.

La investigación y el análisis de políticas futuras continúan afinando estos parámetros para mejorar la efectividad de la iniciativa "Kilómetro 0", que garantiza un impacto positivo a largo plazo en la sociedad y el medio ambiente.

Es interesante analizar el impacto de la cultura en la producción agrícola, de modo que los alimentos con identidad territorial tinerfeña tienen una fuerte influencia en la calidad de la tierra y los factores culturales que se relacionan con las tradiciones. Este es el análisis del concepto de “Kilómetro 0) en América Latina y Asia.

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AN EVALUATION ON CORPORATE SUSTAINABILITY OF COMPANIES

Recep DURUL

In traditional company management, the fundamental element is ensuring the longevity of the company while maintaining a strong financial position and profitability. In recent years, due to the rapid increase in production and consumption, corporate sustainability has come into focus within the business world. This shift is driven by factors like the climate crisis caused by greenhouse gas emissions, irreversible environmental pollution, and the existential threat to the planet in the coming years.

Companies are now being evaluated not only based on their financial performance and profitability but also on how effectively they internalize sustainability principles. This approach, termed *corporate sustainability*, prioritizes establishing performance criteria under environmental, social, and governance (ESG) categories. It is defined as a model that promotes responsible production practices focused on environmental protection, alongside investments, financial management, and organizational structures that align with sustainability goals.

In other words, corporate sustainability implies that companies can achieve their investment, growth, development, and profitability goals while minimizing environmental harm and contributing to a more livable environment in the future. It also encompasses activities like efficiency, awareness of environmentally respectful behavior, and value creation within the framework of core sustainability goals. Beyond these primary objectives, companies may also engage in social responsibility projects, adhere to business ethics, emphasize governance and transparency, establish sustainable supply chains, support innovative activities for producing and trading eco-friendly products, prioritize green financing, and foster strong collaboration with internal and external stakeholders. These strategies facilitate the transition to a sustainable corporate structure.

This study aims to provide theoretical and conceptual explanations of corporate sustainability, followed by an analysis of corporate sustainability practices and performance evaluations of companies in Turkey, using national data. The final section will offer some policy recommendations.

Keywords: Corporate sustainability, company sustainability, the environment

INTRODUCTION

Concerns about climate change, irreversible environmental degradation, and the ability of the current generation to leave behind a livable planet for future generations have made sustainability a central issue in recent years. The United Nations (UN, 1987) defines sustainability as meeting the needs of the present without compromising the ability of future generations to meet their own needs. Viederman (1994) describes sustainability as the ethical use of natural resources and human capital. In societies where human and natural resources are used prudently, ensuring their availability for future generations, social, economic, technical, and environmental sustainability can be achieved. The integrity of the ecological system must be maintained, and the environment must be handed over to future generations in the same state it was inherited from the previous ones.

The fundamental characteristics of sustainability are outlined as follows (Viederman, 1994):

- Sustainability is primarily based on social foundations. For the concept to be actively accepted in economic and social life, it must be supported by laws both locally and globally.
- Sustainability encompasses all social and environmental practices implemented today for an envisioned future.
- Sustainability efforts may have a starting point but never an end. It evolves and adapts to changing circumstances.
- Sustainability is not merely about halting environmental degradation. It represents a comprehensive improvement that elevates the quality of life for all living beings, along with economic, social, and cultural advancements.
- Effective integration of sustainability into systems facilitates clear measures against short, medium-, and long-term risks.

The World Economic Forum's *Global Risk Report* (2024) details the short- and long-term risks, as summarized in Table-1.

Table-1. Expected Risks in the Next 2 and 10 Years

	Expected Risks in 2 Years		**Expected Risks in 10 Years**
1	Misinformation or Disinformation	1	Extreme weather events and related disasters
2	Extreme weather events and related disasters	2	Unexpected dramatic changes in the global system
3	Social polarization	3	Loss of biodiversity and ecosystem collapse
4	Cybersecurity issues	4	Natural resource scarcity
5	Armed conflicts between countries	5	Misinformation or Disinformation
6	Lack of economic opportunities	6	Unanticipated and undesirable side effects of AI technologies
7	Inflation	7	Forced migration
8	Forced migration	8	Cybersecurity issues
9	Economic crises	9	Social polarization
10	Air, water, and soil pollution	10	Air, water, and soil pollution

Source: World Economic Forum (2024). Green: Represents Environmental Risks; Blue: Represents; Economic Risks; Yellow: Represents Geopolitical Risks; Orange: Represents Social Risks; Purple: Represents Technological Risks

According to Table-1, the second most significant risk expected within the next 2 years is disasters linked to unexpected environmental events, such as storms and floods caused by excessive rainfall. These are among the most prominent short-term risks. In the 10-year projection, environmental risks dominate the top four positions, highlighting issues like increasing natural resource scarcity, global system changes, and biodiversity loss. These challenges signal severe problems that could become intractable in the coming years. In the short term, economic challenges and migration concerns are the most significant risks affecting all countries. The table clearly illustrates the critical importance of social, economic, and environmental sustainability.

Consequently, topics such as environmental issues, social responsibility, and sustainable economic activities have become fundamental concerns in today's business world. A study by the United States Environmental Protection Agency (EPA) analyzing corporate responsibilities shows that 80% of Fortune 500 and S&P 500 companies issue corporate social responsibility (CSR) reports. Similarly, many small, medium, and large enterprises in the U.S. have started regularly publishing

reports on environmental, social, and economic sustainability. Corporate sustainability is gaining more value not only in EU countries but also in many developing nations, including Turkey.
Strengthening the integration of sustainability in corporate processes, identifying weaknesses, developing alternative policies, and enhancing production and service quality all contribute to effective corporate sustainability. Achieving sustainability requires the establishment of principles that guide new strategies within the sector. It adopts a multi-layered, holistic approach, considering long-term environmental, social, and economic sustainability in the company's short- and medium-term plans. Unlike traditional models focusing solely on profit maximization, a broader perspective is taken, emphasizing the external impact of company operations. This approach aims to minimize negative external impacts while fostering positive social development and sustainable corporate growth. In essence, corporate sustainability means that businesses not only fulfill their financial responsibilities but also integrate social, economic, and environmental duties into their operations.
Based on these explanations, the most significant benefits of corporate sustainability for companies are (Kuşat, 2012):

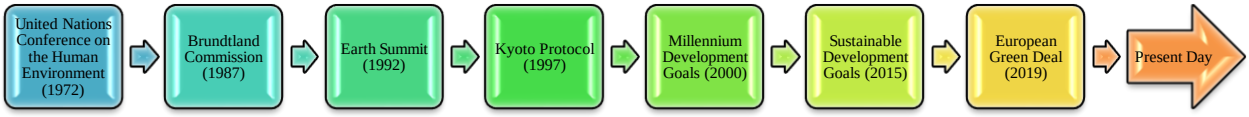
- Contributing to sustainable development goals: It provides insights into areas where companies should focus.
- Enabling collaboration with internal and external stakeholders toward a common goal, thereby enhancing synergy and effectiveness.

The study aims to further explain corporate sustainability, its importance for companies, and its implications for the economy and society they operate in. The final section will discuss ongoing challenges in corporate sustainability and propose alternative policy solutions.

Historical Background of Sustainability

The Industrial Revolution drove economic actors into fierce competition to maximize production levels. As cities like London and other industrial centers saw a rapid increase in both workforce and factories, the natural environment began to deteriorate rapidly. From the early industrial period until the late 20th century, pollution of land, air, and water was often seen as an unavoidable cost of economic growth and development, leading to neglect. However, over the past 50 years, the environmental damage caused by industrial activities has highlighted the potential for irreversible climate and environmental problems if the current production levels continue.
In response, international organizations, particularly the United Nations (UN), have launched efforts to raise global awareness, setting conferences, meetings, and targets to address these issues. *Figure-1* provides a chronological overview of global initiatives for environmental conservation and sustainability. The 1972 *UN Conference on the Human Environment* in Stockholm underscored that sustainability must play a crucial role not only in environmental protection but also in economic activities, growth, and social justice. The *Stockholm Declaration and Action Plan*, with 26 guiding principles, prioritized key environmental concerns and sought to enhance dialogue between industrialized and developing nations. The action plan was structured into three main components: a) Global Environmental Assessment Program (monitoring plan); (b) Environmental management activities; (c) National and international environmental management plans. These three components were divided into 109 sub-categories with recommended actions. The most significant outcome of the Stockholm Conference was the establishment of the *UN Environment Program (UNEP)*.

Figure-1. Historical Progression of Global Sustainability Efforts



Source: HIB (2024:3)

The concept of sustainable development first appeared in the *Brundtland Report* prepared by the World Commission on Environment and Development in 1987, defining it as meeting the needs of the present without compromising the ability of future generations to meet their own needs. Since then, sustainability has become the primary goal across all sectors and fields.

On December 11, 1997, the *Kyoto Protocol* was signed in Kyoto, Japan, and came into force on February 16, 2005. It covered the United Nations' efforts on climate change, aiming to limit greenhouse gas emissions by both industrialized and developing countries based on agreed targets. It encouraged local and global implementation of policies, measures, and regulations to control climate change. In its initial phase (2008-2012), the protocol set a target to reduce carbon emissions to 5% below 1990 levels. Its flexible market-based model included emission allowances. The protocol's strategy to reduce emissions led to eco-friendly investments in developing countries, replacing outdated, polluting technologies with cleaner and more economical infrastructure. In the second phase, a reduction plan for 2013-2020 was established in Doha on December 8, 2012, with 144 additional measures introduced on October 28, 2020.

On September 27, 2015, the *2030 Agenda for Sustainable Development Goals (SDGs)* was launched in New York, comprising 17 main goals and 169 sub-goals. These goals were designed to create an alternative global development model focusing on sustainable cities, climate change, disaster and drought mitigation, and biodiversity conservation. Some of the SDGs include:

- **SDG 3**: Ensure healthy lives and promote well-being for all ages.
- **SDG 6**: Ensure sustainable water management.
- **SDG 7**: Ensure access to affordable, sustainable, and modern energy.
- **SDG 8**: Promote sustainable economic growth and prosperity.
- **SDG 9**: Support inclusive and sustainable industrialization and infrastructure.
- **SDG 11**: Ensure safe and sustainable cities.
- **SDG 12**: Promote responsible consumption and production.
- **SDG 13**: Take urgent action to combat climate change and its impacts.
- **SDG 14**: Conserve and sustainably use oceans and other water bodies.
- **SDG 15**: Protect and sustainably manage terrestrial ecosystems, control soil degradation, and prevent biodiversity loss.
- **SDG 16**: Establish accountable and inclusive institutions for sustainable performance.

On December 11, 2019, the European Commission announced the European Green Deal. According to the deal, the aim is to achieve net-zero greenhouse gas emissions by 2050, setting growth targets to make Europe the world's first climate-neutral continent. The Green Deal envisions transforming Europe into a resource-efficient, competitive, and modern economy, with €1 trillion allocated for sustainable investments in the first 10 years. Turkey, which has a Customs Union agreement with the EU, has also been included in the adaptation plans outlined in the European Green Deal. The action plan includes 32 targets and 81 action items under the following headings: (a) regulations on limiting carbon emissions, (b) establishment of a circular economy, (c) environmentally friendly and uninterrupted energy supply, (d) sustainable agriculture, (e) sustainable transportation systems, (f) combating greenhouse gases and climate change, (g) inter-country diplomacy to minimize climate change, and (h) European Green Deal awareness activities (Republic of Turkey Ministry of Foreign Affairs Directorate for EU Affairs, 2024).

What is Corporate Sustainability for Firms?

Corporate sustainability or sustainable growth in firms is achieved through the efficiency, equity, and limitation of harm to people, nature, and business activities. While carrying out their operations, firms may face social and biophysical constraints. These constraints often include challenges in sourcing the necessary resources for production, supply chain issues, and insufficient services needed at various stages of operations. Firms manage these constraints by planning their production and commercial activities accordingly. Reducing these constraints to ensure a seamless production, distribution, and sales process is among the primary goals of firms.

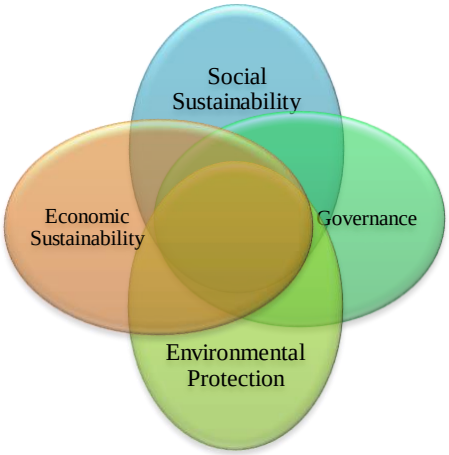
Globally, the increase in production and consumption to meet the growing population's demands has led to faster depletion of natural resources and increased environmental pollution during production. Additionally, the efforts of developing countries to achieve more economic activity than developed nations, in an attempt to reduce economic inequality, have intensified pollution levels in these regions. The concept of sustainable growth aims to reduce this inequality to some extent by promoting the equal sharing of benefits and costs, the fair distribution of resources, and the accessibility of markets to everyone.

In the traditional capitalist management model, wealth tends to be redistributed from the poor to the rich and from the future to the present. This approach does not align with sustainable growth dynamics. In this context, sustainable growth in firms seeks to address the negative aspects of the current system by focusing on ethical values. Achieving optimal use of the ecological structure, limiting adverse impacts, and ensuring fair distribution of resources and wealth not only shapes a firm's future prospects but also contributes to the broader societal goals.

Efforts to equalize income distribution between the rich and the poor, efficient use of resources, and redistribution of wealth in favor of the poor aim to realize sustainable development dynamics rather than merely economic growth. Firms shift from the rush for higher production volumes and sales toward setting quality goals. Higher-quality production models that meet customer needs optimally will lead to longer product lifecycles, less waste, and reduced resource consumption, indirectly contributing to environmental protection. This lays the foundation for building a sustainable corporate structure (Gladwin, Kennelly, and Krause, 1995:896-897).

To achieve optimal corporate sustainability, firms need to make progress in four key areas: economic, environmental, social, and managerial. These areas are detailed in Figure 2 and explained below.

Figure 2. Areas of Corporate Sustainability



Source: Tokgöz & Öncü (2009)

Environmental Sustainability

Focuses on the firm's ecological impact on the planet. The primary goals are to reduce the consumption of resources required for production and to minimize waste generation. In this context, firms typically incorporate eco-friendly practices into their production processes, aim to reduce water consumption, and establish a sustainable management model within the supply chain.

Social Sustainability

Represents the firm's responsibility to make a positive impact on society. This includes ensuring that employees from diverse social groups can find a place within the firm, promoting fair distribution of labor and responsibilities to enhance workforce efficiency, supporting local communities, and creating a work environment that respects human rights.

Economic Sustainability

Involves conducting economic activities not with the aim of short-term profit maximization, but rather with the goal of stable economic growth in the long term.

Governance

Goes beyond merely achieving high profit margins to satisfy top management; it emphasizes increasing the firm's long-term economic value. Governance aims to create optimal benefits for employees, customers, suppliers, and both internal and external stakeholders without neglecting their rights and interests. It includes responsible financial management, sound investment decisions, and maintaining profitability at a stable level through an ethical business model. Furthermore, when developing future plans, the firm takes into account not only top management's views but also the suggestions of employees and internal and external stakeholders within the framework of the sustainability strategy.

Table-2 illustrates the differences between traditional management models and firms operating under a corporate sustainability strategy.

Table-2. Differences Between Traditional Companies and Companies with a Corporate Sustainability Strategy

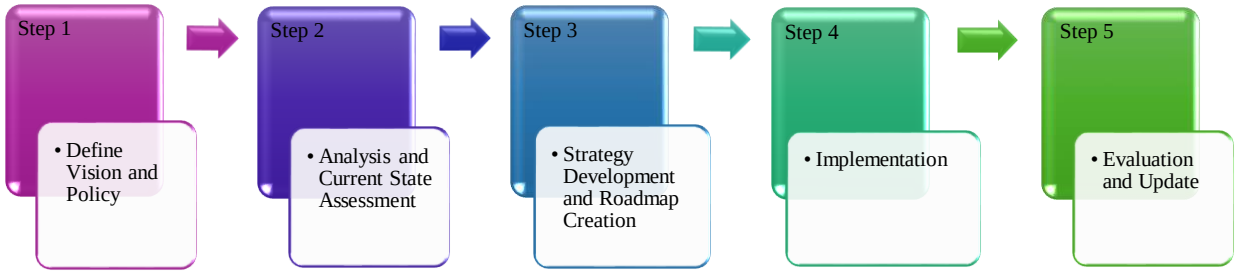
Area	Traditional Companies	Companies with a Corporate Sustainability Strategy
Goals	Rapid improvement of financial structure, economic growth, maximizing shareholder profit	Sustainable and high-quality living, enhancing the welfare of shareholders

Values	Centralized patriarchal management, obedience to traditional decisions, rapid achievement of profit-driven goals	Emphasis on biological and environmental awareness, collaboration, and shared values beyond patriarchal management
Organizational Structure	Hierarchical structure, top-down decision-making, centralized management, significant pay disparities	Minimal hierarchy, participatory decision-making, decentralized governance model, minimal pay disparities
Environment	Considers the environment only as a resource provider, externalizes pollution and waste during production	Integrates with the environment, recognizes finite resources, aims to minimize harm through technical and biological measures, promotes recycling and reuse
Production	Focuses on profit maximization and efficiency, externalizes environmental damage as a non-essential factor	Internalizes environmental impact, adheres to circular economy principles, minimizes waste, and implements responsible production
Production Process	High energy and resource consumption, uses cost-reducing technology suitable for mass production	Uses renewable or eco-friendly energy sources, aims for optimal output with minimal energy and resource consumption, improves cost-effectiveness
Product	Focuses on trends, style, and aesthetics, often resulting in excessive packaging and waste to attract customers	Produces products that meet needs using eco-friendly production methods
Demand/Consumption	Encourages excessive consumption as a growth model, sees increased demand as a sign of more profit	Emphasizes responsible consumption, aligns production with sustainable demand to minimize environmental harm, aims for long-term sustainable economic activity
Risk	Focuses on changes in production market, supply chain, and consumer preferences, as well as financial risks	Considers traditional risks along with technological innovations, waste management, environmental impact, societal influence, and public opinion
Individual	Treats individuals as consumers, aims to maximize profit by influencing consumer choices, often disregards environmental impact	Encourages individuals to minimize environmental damage, promotes responsible production and consumption, focuses on recycling and reuse

Source: Shrivastava (1995) and the Author's Own Evaluations

To Initiate Corporate Sustainability Efforts, Companies Should Follow the Steps Outlined in Figure-3 (Seçen, 2023):

Figure-3. Steps for Corporate Sustainability in Companies



Based on this process, the five steps for implementing corporate sustainability can be detailed as follows:

Step 1: Define Vision and Policy

The company begins by defining a vision that centers on sustainability. During this phase, input

from internal and external stakeholders, including employees, is gathered to ensure the vision is widely accepted. The aim is to establish a new set of goals that reflects a sustainability-focused approach.

Step 2: Analysis and Current State Assessment

In this step, the company assesses its current alignment with the sustainability model. The analysis identifies the company's gaps, core activities, and the inputs and outputs of production processes, along with their impacts. Each area is evaluated for its position in the sustainability framework, highlighting weaknesses and areas needing improvement. Risks, opportunities, and constraints related to sustainability are also identified.

Step 3: Strategy Development and Roadmap Creation

The strategy focuses on high-impact sustainability elements that can produce quick results and add significant value. The organizational structure is reviewed to ensure it aligns with sustainability principles, and a comprehensive roadmap is created to guide the company's actions.

Step 4: Implementation

The sustainability strategy is integrated into the company's operations. Efforts focus on project implementation, operational alignment, and meeting stakeholder expectations and needs. Establishing continuous communication with stakeholders helps build sustainable mechanisms.

Step 5: Evaluation and Update

The final step involves evaluating the outcomes of sustainability efforts to determine how well they meet expectations. Weaknesses and gaps are addressed, while successful areas are strengthened. Follow-ups and regular monitoring ensure that the system operates systematically with a sustainable approach.

Sustainability of the Supply Chain in Firms

Uninterrupted, stable, and predictable supply of resources is crucial for firms to maintain seamless production and fulfill their commitments. Before globalization, all firms sought to secure uninterrupted resource supply by sourcing raw materials and intermediate goods from the closest sources. However, with the increasing impact of globalization worldwide, the possibility of procuring the cheapest goods and resources in the easiest way paved the way for obtaining materials not from the nearest regions but from locations that are most financially and logistically suitable for the firm.

Before the pandemic, China was the world's most crucial link in the supply chain, providing the cheapest and most continuous supply. However, with the onset of the pandemic, China, one of its origins, significantly lost this role on a global scale. Firms, similar to the pre-globalization period, began sourcing raw materials and intermediate goods from the nearest and most appropriate locations, despite higher costs. In this new situation, the prices of sourced raw materials and intermediate goods have risen well above the prices offered by China before the pandemic, leading to a significant increase in production costs for firms globally.

More challenging is that the necessary raw materials and intermediate goods can no longer be obtained in the required quantity or at the desired time, which has significantly impacted the continuity of the production process. The necessity of sourcing needed resources from different locations at varying prices each time has also disrupted stability in production costs, forcing firms to take risks when pricing goods for future sales. The importance of supply chain sustainability has become clear, especially in the post-pandemic period. Considering the link between stable

resource supply and the environment and social life, supply chain sustainability can be discussed in a contemporary sense.

In this context, supply chain sustainability can be defined as considering, protecting, and enhancing economic, environmental, and social values for all stakeholders involved in the process of delivering products and services to the end user. To ensure sustainability in the supply chain, it is essential to establish sustainable business ethics and production behaviors, set rules to be followed by laws and regulations, and create global standards that are accepted worldwide.

Firms, while conducting production and service activities by considering environmental and social factors alongside their financial expectations, must comply with these international standards to protect both the firm's interests and those of its internal and external stakeholders and to align with global standards. This forms the key to a globally sustainable supply chain (United Nations Global Compact, 2019:5).

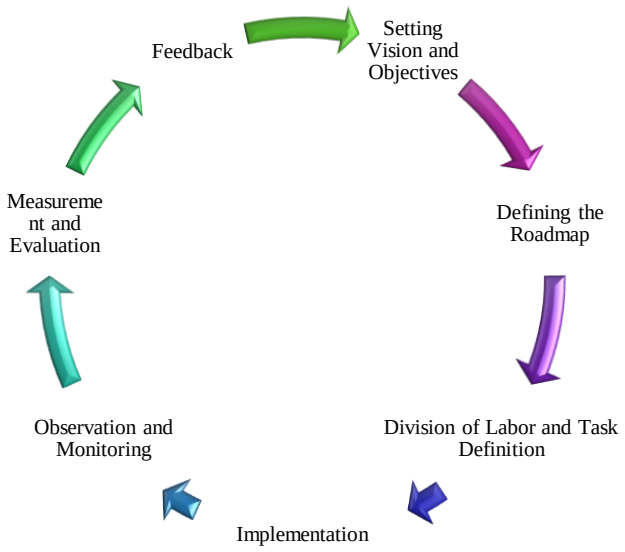
The steps firms should follow to establish a sustainable supply chain are explained in Figure 4. According to Figure 4, the process begins with defining the vision and objectives. In this step, expectations regarding supply chain sustainability are clarified, and the initial steps are taken to form an accurate strategy by considering internal and external conditions. The second step is determining the roadmap, where the necessary paths, methods, and efforts are defined according to the established vision.

The next step is the division of labor and task definition, where suitable personnel are assigned to the processes defined in the previous step, along with clear job descriptions. The implementation phase begins when all preparations are completed and put into action. In the observation and monitoring step, the implemented practices are regularly followed up. It is checked whether the process progresses within the initially defined rules, and interventions are made in problematic areas to prevent deviations from the rules.

In the measurement and evaluation step, the implemented practices are assessed, successful and problematic areas are identified, and efforts are made to reinforce good practices and revise problematic ones. The reporting process represents the feedback stage, where the findings are shared with the top management and relevant internal and external stakeholders to establish a sustainable structure in the supply chain permanently.

All these steps should be prepared in line with the Management Model, which indicates the strategies and practices mentioned in the Global Compact Principles (United Nations Global Compact, 2019:5).

Figure 4. Steps Firms Should Follow to Establish a Sustainable Supply Chain



Source: United Nations Global Compact (2019:5)

Expected Impacts of Corporate Sustainability

The positive developments expected from firms that achieve corporate sustainability are outlined below (CASEM, 2023; Vanderbilt University, 2023; Seçen, 2023):

1. **Increased Reputation and High Valuation:** Alongside being an intangible asset, a firm's improved reputation will attract more loyal customers and investors.

2. **Lower Cost of Capital:** Enhanced credibility leads to lower borrowing costs from banks, which provides significant advantages. Lower credit costs enable easier and cheaper access to funds, allowing firms to make larger investments at lower costs, resulting in increased business volume, bulk sales, and reduced production costs from bulk raw material purchases. This leads to higher sales rates and profits.

3. **Cost Advantage:** Energy and resource efficiency, waste management, and eco-friendly practices help firms reduce costs in the long term, indirectly increasing profit margins. Cost advantages also facilitate stronger entry into new markets and competitiveness.

4. **Reduced Risk:** Proactive measures in sustainability can reduce operational risks, creating opportunities for stable corporate growth and more cost-effective production chains. Risks such as supply chain disruptions and reputation loss can also be minimized.

5. **Innovation and Novelty:** The effort to operate according to sustainability principles drives firms to innovate by developing new products and services, offering a competitive edge in the market.

6. **Competitive Advantage:** Beyond cost benefits, corporate sustainability fosters high production-low-cost opportunities through innovation and advanced technology utilization.

7. **Improved Stakeholder Relationships:** Corporate sustainability helps build trust-based relationships with customers, employees, investors, and communities, fostering long-term, strong relationships with internal and external stakeholders.
8. **Increased Employee Loyalty and Productivity:** Considering employee input in decision-making enhances their commitment and loyalty. When employees sense their workplace aligns with ethical and sustainable values, they are more motivated in their work, often as much as financial incentives.
9. **Environmental Benefits:** Minimizing negative environmental impacts during production, protecting biodiversity, and reducing climate change threats are integral measures at the firm level.
10. **New Financial Opportunities:** Sustainability attracts interest from investors and financial institutions, expanding financing and investment opportunities.
11. **Increased Brand Value:** Operating with sustainability principles enhances a firm's reputation and brand value. Consumers tend to prefer products from ethically driven firms.
12. **Increased Customer Base:** A stable and ethically aligned firm profile boosts customer satisfaction, contributing to a broader customer portfolio.
13. **Social Engagement:** Through sustainability efforts, firms can contribute to local communities, supporting their development and improving societal well-being.
14. **Advantage in International Trade and Long-Term Viability:** Sustainable firms adapt more easily to changing market conditions and global economic fluctuations, ensuring long-term survival.

Despite increasing global interest, achieving a sustainable corporate structure also presents implementation challenges. The most notable challenge is the lack of consensus on prioritizing Environmental, Social, and Governance (ESG) performance within organizations. The absence of a global standard definition for ESG reporting and inadequate regulations often result in voluntary, inconsistent, and vague reporting that lacks tangible evaluation criteria. Uncertainty about which data to include in reports and the lack of comparability of this data create significant ambiguity for both company managers and investors.

To address this uncertainty, the International Sustainability Standards Board (ISSB), established by the International Accounting Standards Board (IFRS), issued two standards (S1 and S2) in June 2023. Similarly, the European Financial Reporting Advisory Group (EFRAG) introduced the "Corporate Sustainability Reporting Directive (CSRD)" in the same year, setting out EU sustainability reporting standards. These standards mandate that firms meeting certain criteria, including SMEs, must share their sustainability activities with stakeholders. However, a concrete global standardization has not yet been achieved.

Moreover, firms in the process of sustainable corporate development also face significant uncertainties in the transition to a "net-zero" economy. Sustainable financing supports the adoption of future eco-friendly technologies while also driving the decarbonization of high-carbon-emitting

firms today. The lack of a concrete global roadmap to achieve "net-zero," insufficient understanding of climate risks, and the urgent need for decisive actions combine to create significant risks (Akbank, 2024).

Additional Issues and Proposed Solutions for Sustainable Corporate Structures (Vanderbilt University, 2023; author's own evaluations):

1. Prioritization of Profit Over Sustainability: While many firm managers understand sustainability principles, financial investments often prioritize profit maximization at the expense of these principles. This choice negatively impacts the firm's ability to achieve long-term sustainability strategies.

2. Conflict Between Business Opportunities and Sustainability Principles: The lack of established global, binding principles often puts firms in a dilemma when faced with profitable but environmentally conflicting opportunities. In the absence of strict regulations, firms may ignore environmental and social responsibilities to avoid missing profitable ventures.

3. Managerial Differences in Vision: Decision-makers may favor short-term and inadequate strategies over sustainability goals. While top management may unanimously pursue profit-maximizing policies, differences of opinion among managers can also arise, making it harder to implement and achieve long-term strategic goals.

4. Harmonization of Supply Chain Management: Establishing a stable, cost-effective sustainability model requires addressing issues such as insufficient transparency, control, and oversight mechanisms.

5. Regulatory Constraints: Government regulations that do not consider long-term sustainability goals can pose challenges to achieving shared targets.

6. Resource Limitations: Small businesses may struggle with resource allocation compared to larger enterprises, making it harder for them to achieve sustainability goals.

The following policy recommendations can be proposed as solutions to these challenges.

1. Establish clear internal goals aligned with the organization's core mission and values.

2. Create a collaborative environment that involves the board, internal, and external stakeholders in the process, clearly defining the roles and responsibilities of each group in the process.

3. Strengthen collaboration on sustainability with employees, customers, internal and external stakeholders, suppliers, and local communities, considering different perspectives.

4. Operate regular monitoring and reporting mechanisms, publish statistical reports consistently, and ensure transparent observation to track whether sustainability processes align with the objectives. This evaluation should cover short-term, then medium- and long-term assessments.

5. Integrate eco-friendly resources into production processes and develop strategies to minimize waste and optimize resource use.

6. Focus on financial sustainability and green financing.

7. Collaborate with suppliers and partner firms within the principles of sustainable corporate governance, preferring sustainable firms when selecting partners.

8. Define ethical principles suitable for a sustainable corporate structure, ensuring compliance through regular monitoring and reporting.
9. Stay informed about current government regulations to maintain a competitive position within the sector.

10. Seek support from independent external auditing firms to ensure objective evaluation of sustainability efforts.

11. Educate employees on the importance of sustainability strategies, encouraging them to view sustainability practices not merely as tasks, but as integral parts of their work and personal lives.

The above policy recommendations can be implemented at the firm and national levels. However, it is crucial to remember that many of these firms operate internationally. Therefore, in addition to local regulations in each country, universally applicable global laws should be established, with clearly defined rules that firms must follow, facilitating effective corporate sustainability globally. Improvements in the environment and social life expected from corporate sustainability can only be achieved through global consensus and shared practices.

Conclusion

Climate change and environmental degradation highlight the need for sustainability principles across all sectors, including the corporate level. This study provides insights into corporate sustainability in firms. Findings indicate that corporate sustainability prioritizes long-term benefits and permanence over short- or medium-term gains, considering the needs of the broader ecosystem. Unlike traditional models, sustainable corporate strategies emphasize a governance model based on multi-stakeholder participation and collaboration.

However, the absence of local and global standardization leads to uncertainty, limiting the effectiveness and efficiency of sustainability initiatives. Ensuring a sustainable environment for future generations requires a global collective effort and responsible production and consumption strategies.

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MAPPING THE LANDSCAPE OF INNOVATION AND SUSTAINABILITY IN THE TRANSPORTATION SECTOR: A BIBLIOMETRIC ANALYSIS

Seyfettin ERDOGAN

Recep ULUCAK

Abstract

The transportation sector faces increasing pressure to adopt sustainable and innovative practices to mitigate its significant environmental impact. This study presents a comprehensive bibliometric analysis of 3,264 academic papers from the Web of Science database, focusing on the intersection of innovation, sustainability, and transportation. The analysis identifies key trends, influential works, leading contributors, and collaboration patterns within this rapidly evolving field. Results show a sharp increase in research output after 2015, with China and the United States emerging as the top contributors. Thematic analysis reveals a shift from early foundational topics, such as innovation management, to more specialized themes like system performance, life-cycle assessments, CO2 emissions, and advanced technologies such as nanoparticles. This research provides a detailed understanding of how the field has evolved and offers insights into emerging trends and future research directions. By identifying key areas of focus, such as performance optimization, emissions reduction, and energy storage, the study aims to guide ongoing efforts to promote sustainable transportation solutions globally. The findings serve as a resource for both academic research and policy development, helping to address critical challenges in achieving sustainable transportation systems.

Keywords: Bibliometric analysis, transportation, innovation, sustainability

Introduction

The transportation sector is one of the largest contributors to global environmental challenges, including greenhouse gas emissions, air pollution, and excessive energy consumption (Van Fan et al., 2018). As urbanization continues and global mobility increases, the need for sustainable transportation solutions has become more urgent than ever (Shah et al., 2021). This growing demand has sparked a surge in research focusing on the intersection of innovation, sustainability, and transportation, aiming to develop new technologies, policies, and systems that can reduce the sector's environmental footprint while ensuring efficiency and accessibility (Jelti et al., 2023). Sustainable transportation plays a crucial role in achieving global climate goals, such as those outlined in the Paris Agreement and the United Nations Sustainable Development Goals (SDGs) (Avotra & Nawaz 2023).

Recent advancements in transportation systems—from electric and autonomous vehicles to smart city infrastructure—illustrate the potential of technological innovations to drive sustainable practices (Elasy et al., 2024). At the same time, researchers are exploring policy frameworks, behavioral changes, and infrastructure development strategies to encourage widespread adoption of these innovations (Pan & Ryan 2024; Jaiswal et al., 2024; Zarbakhshnia & Ma 2024; Singh et al., 2023). Understanding the breadth and impact of this research is essential to guiding further developments in the field and ensuring that emerging technologies align with broader sustainability goals. This is where bibliometric analysis becomes an essential tool. By systematically mapping existing studies, bibliometric analysis not only provides a comprehensive overview of the field but also helps researchers and policymakers identify patterns, trends, and key

contributors in the evolving discourse of transportation innovation and sustainability (Mishra et al., 2024; Cobo et al. 2011, Rejeb et al., 2022).

One of the main reasons bibliometric analysis is critical in this field is that it enables researchers to understand the emerging trends and focal areas of research (Ulhaq et al., 2024, Passas 2024). This understanding allows scholars to focus their efforts on high-impact areas and identify gaps that may have been overlooked. Furthermore, bibliometric analysis can uncover interdisciplinary connections, showing how transportation sustainability intersects with fields like urban planning, energy economics, and environmental science, thus fostering cross-disciplinary collaborations (Purwanto 2024). Bibliometric analysis also serves as a tool for assessing the impact and productivity of various stakeholders involved in the research (Baber & Fanea-Ivanovici 2024). It provides quantitative insights into the most influential publications, authors, and institutions contributing to innovation and sustainability in transportation (Wu & Tsai 2024; Joshipura et al., 2024).

This study presents a comprehensive bibliometric analysis aimed at mapping the evolving research landscape related to innovation and sustainability in transportation. By examining 3,264 academic papers from the Web of Science database, this research delves into key trends, thematic developments, influential works, and collaboration patterns that have shaped this field over the past several decades. The goal is to provide a clear understanding of how research in this domain has evolved, what areas are gaining momentum, and which contributors—whether they be authors, institutions, or countries—are leading the charge in advancing sustainable transportation.

Through the use of bibliometric techniques such as citation analysis, keyword co-occurrence mapping, and co-authorship networks, this study will identify the most significant areas of research, emerging topics, and major collaborations within the global research community. This research aims to serve not only as a reflection of the past and present state of sustainable transportation research but also as a strategic tool for shaping future research and policy directions. As the transportation sector continues to grapple with its environmental impacts, the findings of this study will help highlight critical gaps in the literature, emerging areas of opportunity, and the collaborations necessary to achieve sustainable, innovative solutions on a global scale.

Data

To conduct a comprehensive bibliometric analysis of innovation and sustainability in the transportation sector, a dataset of academic documents was retrieved from the Web of Science (WoS) database. The search was designed to capture a wide range of literature that addresses the intersection of “transportation”, “sustainability”, and “innovation” in titles, abstracts and keywords. This syntax ensured the inclusion of documents that used variations of "transport," "sustainability," and "innovation" in their key terms, titles, and abstracts. As a result, the search yielded a total of 3,264 papers published across various journals, representing a broad spectrum of research related to the sustainability and innovation of transportation systems. This dataset serves as the foundation for the subsequent bibliometric analysis, aimed at mapping key trends, influential works, and leading contributors in this research area.

Using the keywords sustainable transportation and innovation, we filtered 3264 documents on web science, which the oldest publication date is 1995 although there was no restriction for the period. Figure 1 represents the annual scientific production of articles related to innovation and sustainability in transportation. It demonstrates a significant increase in the number of articles published over time, particularly after 2015. From 1995 to around 2010, the number of published articles remained relatively low and stable, with only a gradual increase. However, starting around 2013, there is a notable upward trend in scientific output, which sharply accelerates after 2018. By

2023, production reaches its peak with over 600 articles published in that year alone. This sharp increase in publications indicates growing interest and research activity in the field, likely driven by the increasing global focus on sustainable transportation solutions, technological advancements, and policy developments aimed at addressing environmental and climate-related challenges. The acceleration after 2018 may also reflect the growing urgency of sustainable development goals (SDGs) and the incorporation of innovative technologies in the transportation sector.

Figure 2 represents the average number of citations per article in the field of innovation and sustainability in transportation. The trend is highly variable, indicating fluctuations in how frequently articles are cited over time. During this period, the citation count per article remained relatively low, with a gradual increase observed after 2000. A sharp spike is seen around 2007, where articles from this period received a significantly higher number of citations on average. This spike could be attributed to seminal works or major publications that influenced subsequent research in the field.

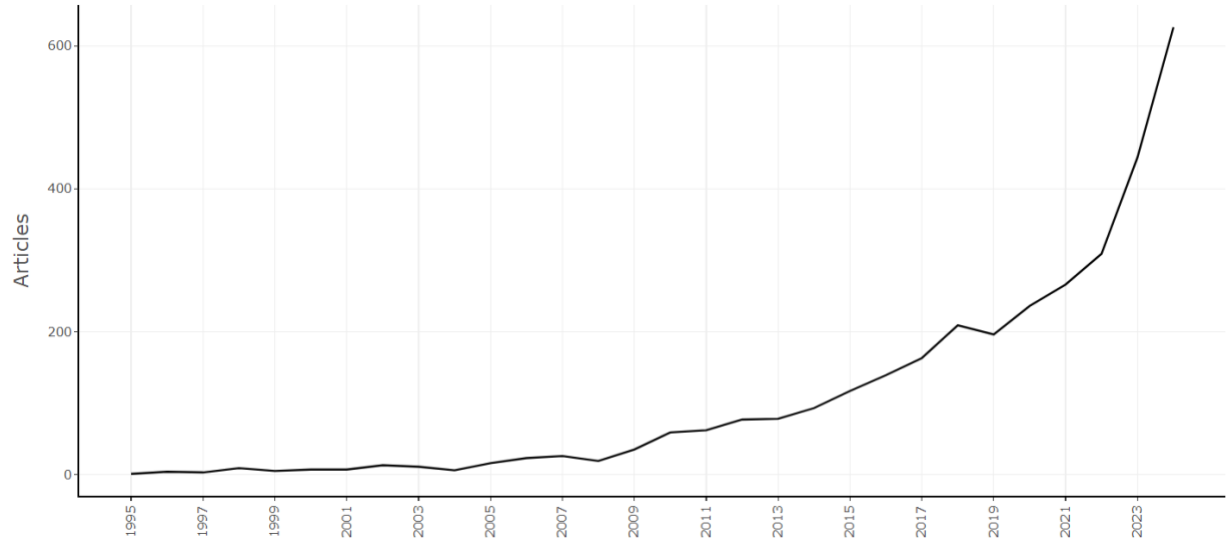

Figure 1: Annual Scientific Production

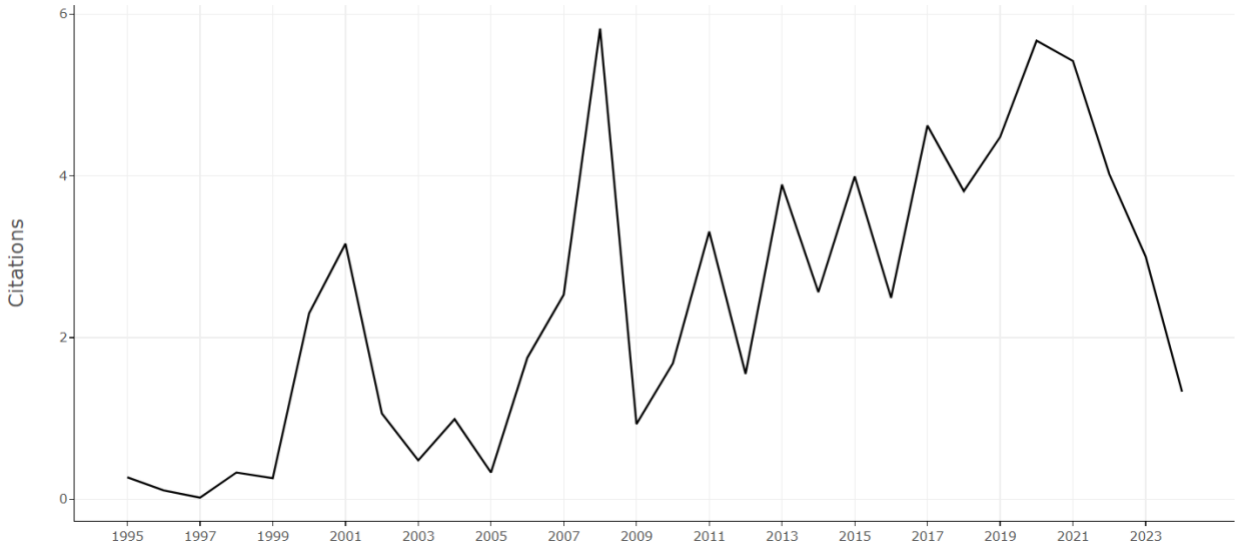

Figure 2: Average Citations Per Year

Post-2007, the citation rate declines sharply but then begin to stabilize from 2011 onwards. After 2013, the graph shows a somewhat consistent pattern of citation rates, although there is still noticeable variability from year to year. The highest average citations per article appear between 2019 and 2021, reflecting the impact of recent research during this period, which may have been heavily referenced due to the rise in global discussions around sustainability and innovative transportation solutions. However, after 2021, the average number of citations per article shows a steep decline. This decrease may be due to the time it takes for newly published articles (in 2022 and 2023) to accumulate citations, as citation patterns often lag behind publication dates.

Figure 3: Top Leading Authors by number of papers

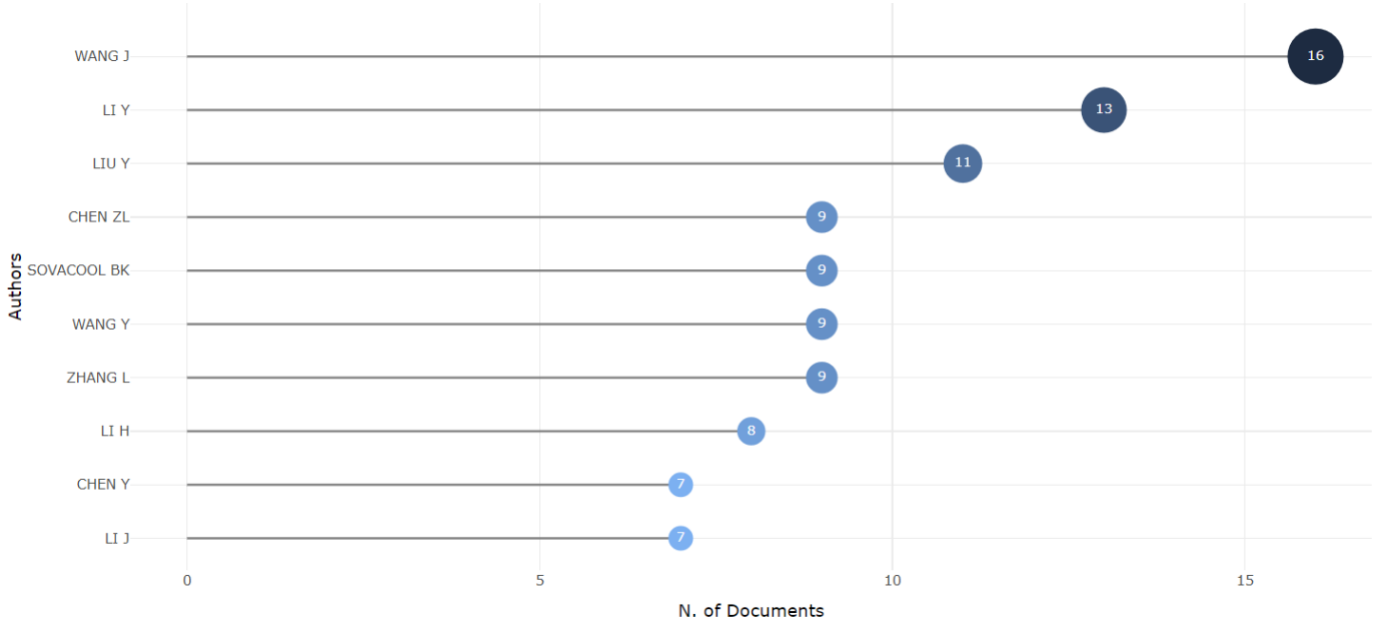

Figure 3 displays the top contributing authors in the field of innovation and sustainability in transportation, ranked by the number of documents they have published. The horizontal bars represent the number of documents attributed to each author. Wang J is the most prolific author, with 16 published documents, making a significant contribution to the field. Li Y follows closely, with 13 documents, and Liu Y comes next with 11 documents. Chen ZL, Sovacool BK, Wang Y, and Zhang L each have 9 documents, indicating their strong research activity in this domain. Li H has 8 published documents, while Chen Y and Li J each have 7.

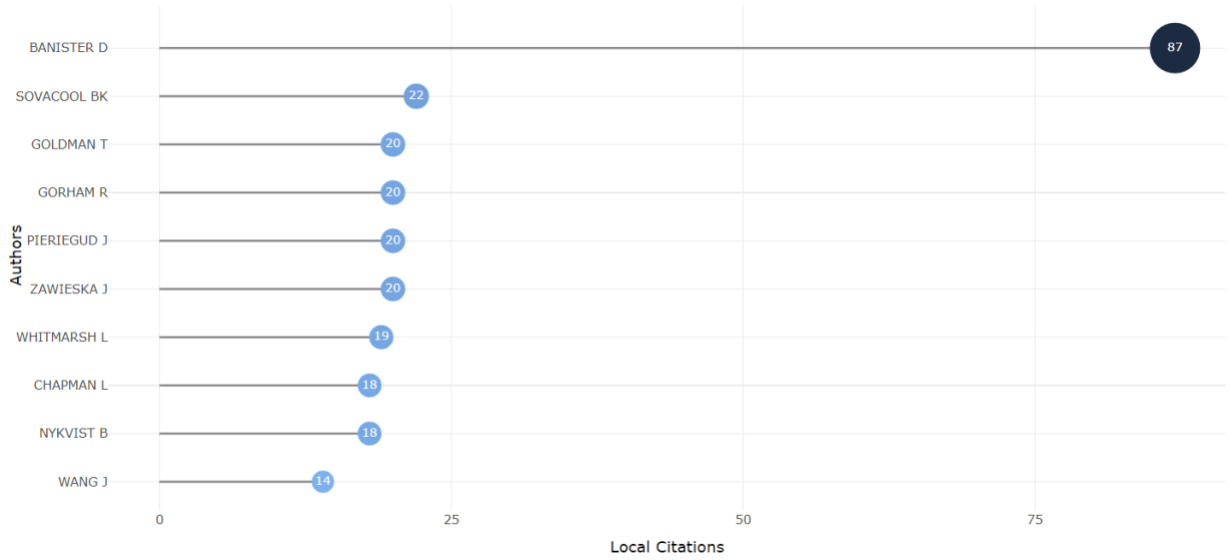

Figure 4: Top Leading Authors by number of citations

Figure 4 represents the top authors in the field of innovation and sustainability in transportation, ranked by the number of local citations they have received. The horizontal bars indicate the total number of citations for each author within the local dataset. A local citation refers to the number of times a document or an author has been cited within a specific dataset or collection of documents being analyzed, as opposed to global citations, which refer to the number of times a work has been cited in the entire academic database or literature. Banister D is the most highly cited author with a significant 87 local citations, indicating a major influence on the field. Sovacool BK comes next with 22 local citations, followed by Goldman T, Gorham R, Pereigud J, and Zawieska J, each receiving 20 citations. Whitmarsh L has 19 citations, while Chapman L and Nykvist B are both at 18 citations. Wang J rounds out the list with 14 local citations. The high number of citations for Banister D suggests that this author's work is foundational or has been particularly impactful in shaping ongoing research within the field. The other authors, while cited less frequently, also show significant influence, contributing to important discussions and developments in innovation and sustainability in transportation.

Results

The results of this bibliometric analysis provide a detailed overview of the research landscape related to innovation and sustainability in the transportation sector. By analyzing a dataset of 3,264 papers retrieved from the Web of Science database, we examine the key trends, influential works, leading authors, and major contributors shaping this field. The results are presented through various metrics and visualizations, including keyword occurrences, leading papers, countries and journals, and thematic evolution.

This section highlights the most active areas of research, identifies central themes, and reveals important collaboration patterns that have emerged over time. Through the analysis of these bibliometric indicators, we gain a clearer understanding of how research on transportation innovation and sustainability has evolved, which areas are receiving the most attention, and where future research efforts might be directed to address pressing global challenges in sustainable transportation.

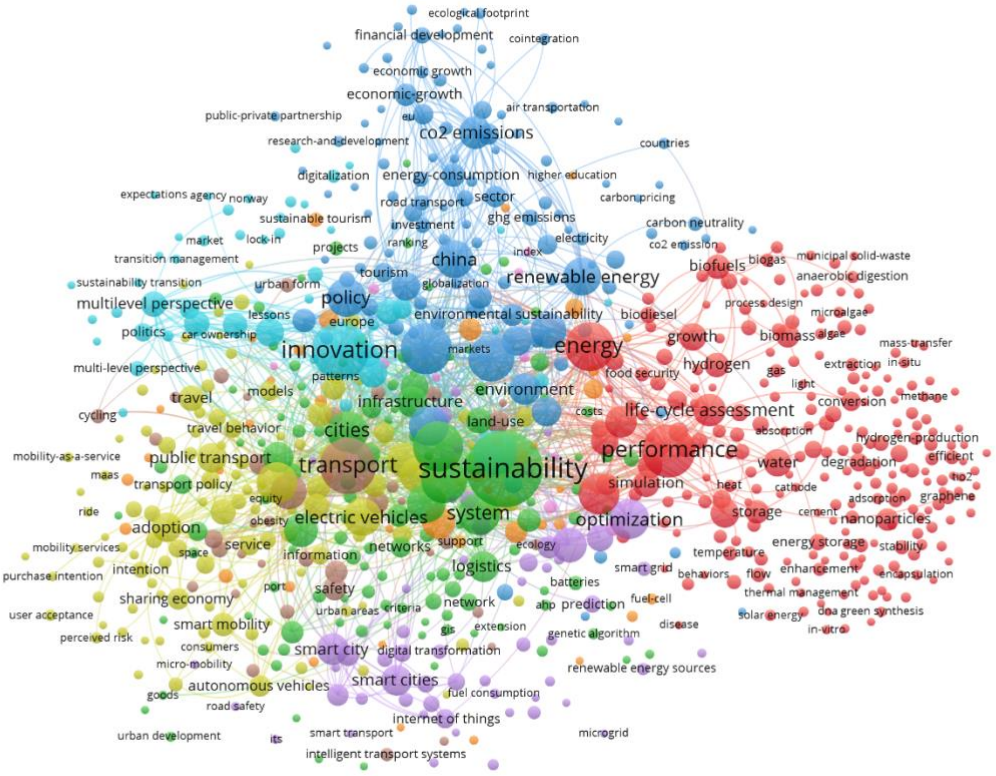

Figure 5: Keyword occurrence in the field of innovation, transportation and sustainability

Figure 5 reveals that research on transportation innovation and sustainability is multifaceted, covering technological advancements, environmental impacts, policy development, and urban planning. The main thematic areas—ranging from electric vehicles and smart mobility to lifecycle assessments and renewable energy—are interconnected, reflecting the complexity of achieving sustainable transportation solutions. These clusters guide us toward understanding where current research is concentrated and how various aspects of transportation innovation are contributing to sustainability efforts globally. Keywords like innovation and sustainability appear centrally on the map, connecting different clusters. This indicates that innovation, whether in the form of technology adoption, policy implementation, or infrastructure development, is closely tied to achieving sustainability in transportation.

Green Cluster has the transport and sustainability focus covering keywords transport, sustainability, electric vehicles, public transport, infrastructure, cities, adoption, smart mobility. This cluster revolves around transportation modes, sustainability in urban areas, and the adoption of new technologies like electric vehicles and smart mobility solutions. It highlights research focused on sustainable transportation infrastructure, city planning, and the transition to green transportation methods. Topics such as public transport policy and the infrastructure needed to support sustainable urban mobility also appear prominently here.

Yellow Cluster has a focus innovation and technology adoption by covering keywords innovation, adoption, sharing economy, smart cities, autonomous vehicles, mobility services, intention. This cluster emphasizes the role of technological innovation in transportation, with a particular focus

on the adoption of new mobility services like autonomous vehicles and shared economies. The keywords in this cluster suggest an interest in how individuals and societies adopt these innovations, as well as the factors influencing these decisions, such as user acceptance and perceived risk.

Blue Cluster has a focus energy and environmental Impact with the keywords CO2 emissions, renewable energy, energy consumption, environmental sustainability, policy, carbon neutrality, China, economic growth. This cluster focuses on the environmental and energy-related aspects of sustainability in transportation. The emphasis on CO2 emissions, renewable energy, and carbon neutrality reflects global concerns about reducing the environmental impact of transportation. Policy discussions, particularly in China and Europe, suggest a regional focus on how different governments are tackling the intersection of transportation and energy consumption to mitigate climate change.

Red Cluster has a theme of performance and lifecycle assessment by covering keywords performance, life-cycle assessment, optimization, biomass, hydrogen, energy storage, biofuels, nanotechnology. This cluster focuses on assessing the performance and environmental impact of various transportation-related technologies and materials. Research in this area looks at optimizing the use of biofuels, hydrogen, and other energy storage solutions. There is a strong link to lifecycle assessments, which evaluate the long-term environmental impact of these technologies. This cluster suggests an interest in more technical research related to the materials and energy sources for sustainable transportation. The blue and red clusters (related to energy, CO2 emissions, and lifecycle assessment) are heavily interconnected, underscoring the importance of evaluating energy consumption and emissions in both technological development and policy discussions.

Purple Cluster underlines smart cities and digital transformation, intelligent transport systems, Internet of Things (IoT), safety, urban development. This cluster highlights the integration of smart city concepts and digital technologies into transportation systems. Topics such as intelligent transport systems and IoT suggest a focus on using digital tools to enhance urban mobility, improve safety, and optimize traffic management. The research in this area tends to examine how technology can be leveraged to create more efficient and sustainable transportation systems within urban environments.

Figure 6 represents a network of leading documents in the field of transportation innovation and sustainability, with each bubble corresponding to a specific document. The size of the bubble reflects the number of citations that the document has received, indicating its influence in the field. Larger bubbles signify documents that have been widely cited, suggesting they are foundational or highly impactful works. For example, Banister (2008) is the most prominent, with the largest bubble, suggesting it is one of the most cited and influential papers in this domain. Other highly cited documents include Chapman (2007) and Govindan (2014), as indicated by their larger bubbles. These works likely serve as key references for research on transportation sustainability, innovation, and environmental impact. The lines connecting the bubbles represent citation links between these documents, showing how they build on or reference each other. For instance, Banister (2008) is highly connected to other papers, suggesting it has been referenced in a wide range of subsequent studies. Other significant connections can be observed between Chapman (2007) and Govindan (2014), showing a network of scholarly influence where these key works cite or are cited by one another. Overall, the figure visualizes how certain documents have shaped the research landscape by being frequently cited, and it highlights the interconnectedness of leading papers in the field of innovation and sustainability in transportation.

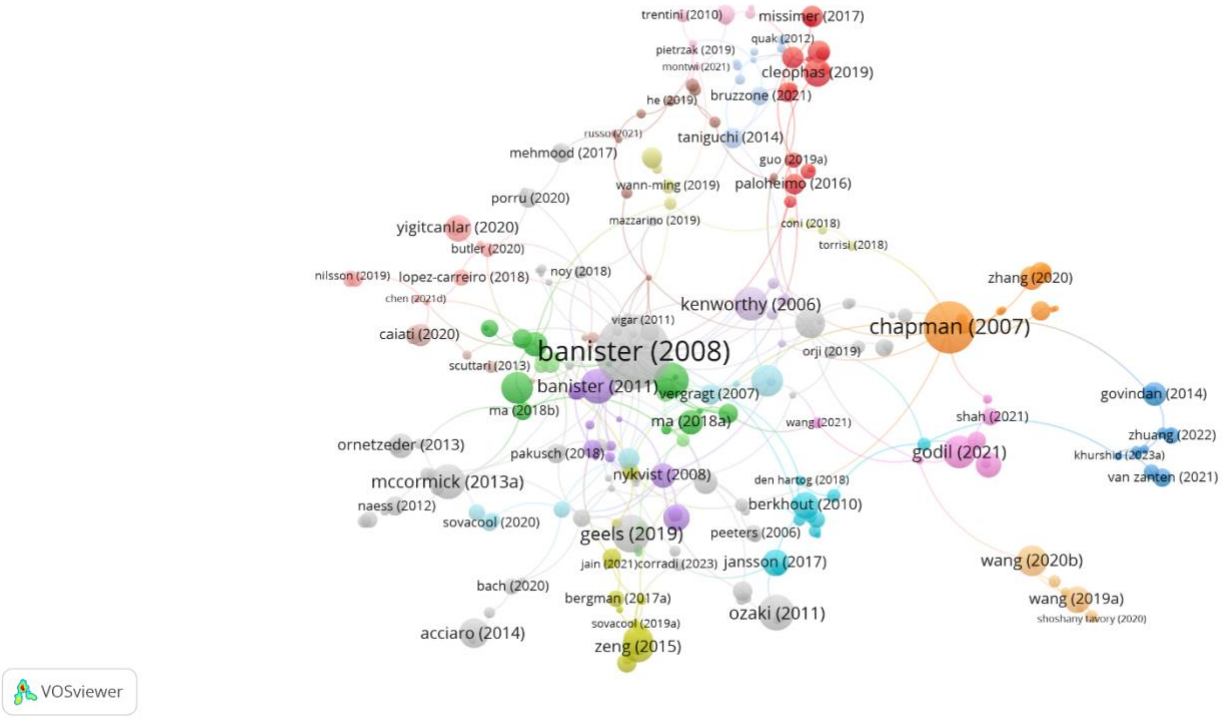

Figure 6: Leading papers in the field of innovation, transportation and sustainability

Figure 7 illustrates the leading journals in the field of transportation innovation and sustainability. The size of each bubble represents the number of papers published by that journal, with larger bubbles indicating a higher volume of publications. The lines connecting the bubbles represent citation links between journals, showing how frequently they reference each other's work.

Sustainability and the Journal of Cleaner Production are two of the most prominent journals, as indicated by their large bubble sizes. These journals publish a significant amount of research in the areas of sustainability, clean production processes, and environmental management, making them central sources in this field. They are also highly interconnected with other key journals, suggesting that they serve as common references across a wide range of studies related to sustainable transportation.

Other important journals include Applied Energy, Energy Policy, Renewable & Sustainable Energy, and Transportation Research Record. These journals cover diverse topics ranging from energy efficiency and policy implications to transportation system innovations. The connections between these journals highlight interdisciplinary research, where studies in transportation often cross-reference energy, environmental management, and sustainability solutions.

Journals such as Sustainable Cities and Society, Transport Policy, and IEEE Access also appear frequently, contributing to discussions about urban infrastructure, smart cities, and technology's role in shaping sustainable transport solutions. The close citation relationships between these journals demonstrate the integrative nature of research on sustainability, urban planning, and innovation in the transportation sector.

This figure highlights the leading publications driving research in this domain and showcases the interconnectedness of sustainability, energy, and transportation-focused journals through frequent cross-citation.

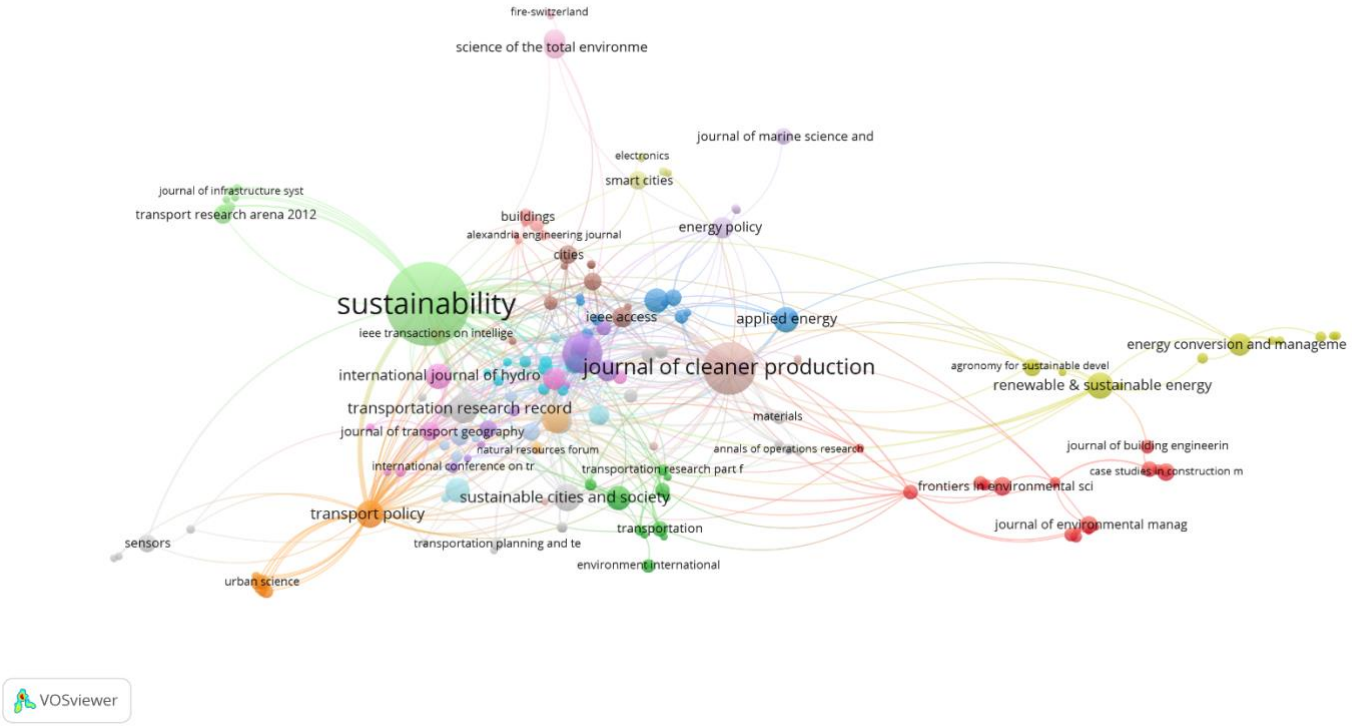

Figure 7: Leading journals in the field of innovation, transportation and sustainability

Figure 8 represents leading countries in transportation innovation and sustainability research, with the size of each bubble indicating the number of papers published by authors from each country. The lines between the bubbles represent collaborative connections between authors from different countries. China and the USA stand out as the most prominent countries, indicated by their large bubbles. This suggests that researchers from these countries contribute significantly to the body of literature in the field. They are also well-connected with other countries, reflecting extensive international collaboration. China, in particular, is linked to many countries across different regions, underscoring its active role in global research networks.

Countries such as Italy, England, Germany, and Spain also appear frequently, indicating their strong contributions to the field. These countries show considerable connections to both each other and other regions, reflecting their involvement in cross-national research collaborations.

Other countries, including India, Canada, and Australia, also show moderate activity, contributing important research while maintaining significant collaborative ties with other nations. Regions such as Pakistan, Turkey, and Nigeria show growing participation, with connections to leading countries like China and the USA.

This visualization highlights the global nature of research in transportation innovation and sustainability, with major contributions coming from both developed and developing countries. The interconnectedness of these countries, particularly between China, the USA, and European nations, suggests a highly collaborative field that benefits from diverse international insights and expertise.

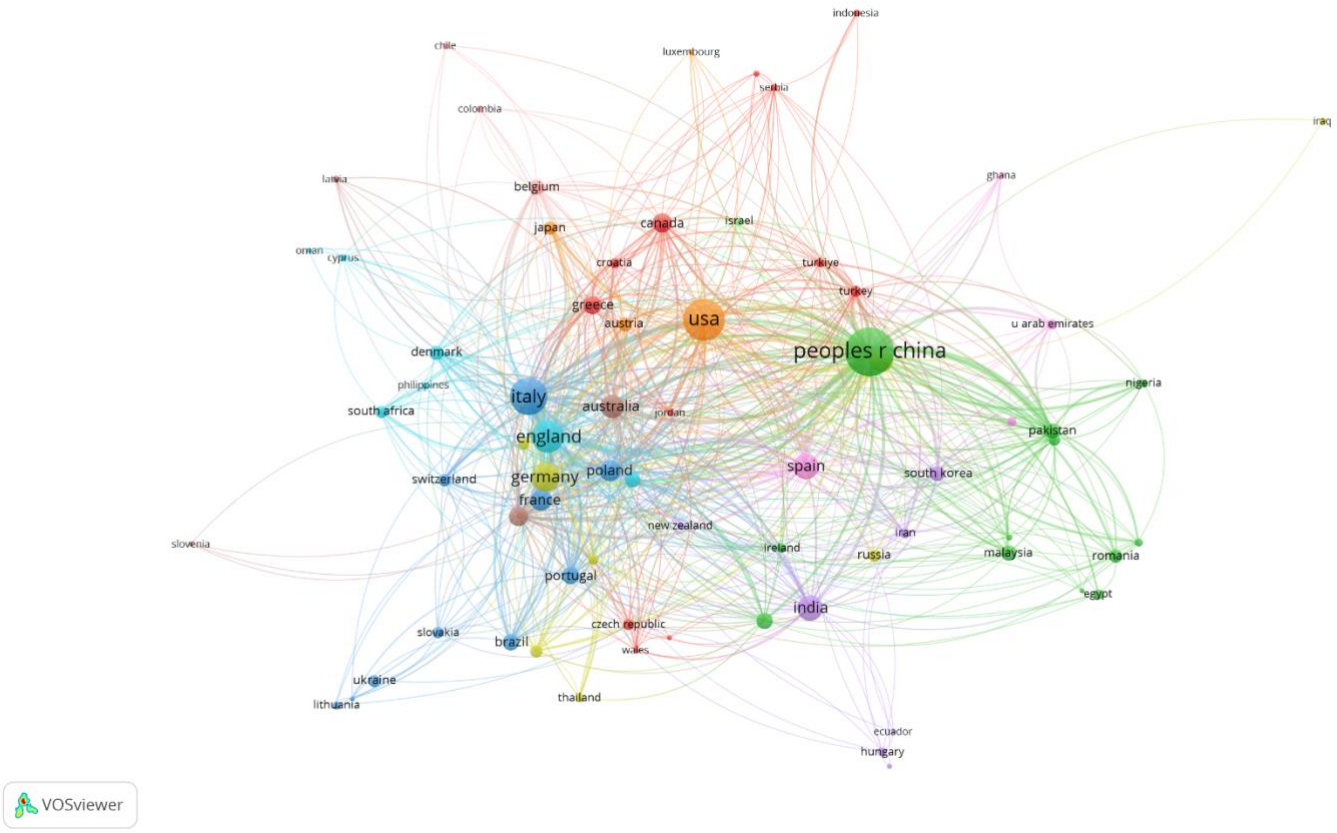

Figure 8: Leading countries in the field of innovation, transportation and sustainability

Figure 9 illustrates the annual scientific production of articles related to transportation innovation and sustainability for five leading countries: China, Germany, Italy, United Kingdom, and USA. The number of articles from each country has increased significantly since the mid-2000s, with a particularly sharp rise after 2015, reflecting growing global attention to sustainable transportation solutions. China exhibits the most dramatic increase in scientific output, especially after 2017, surpassing all other countries by 2023 with close to 1,500 articles. This growth suggests a robust focus on innovation and sustainability in the transportation sector in China. The USA also shows substantial growth, maintaining a steady upward trend throughout the timeline and producing a significant volume of articles, though slightly behind China by 2023. The United Kingdom and Germany follow similar trajectories, with both countries showing a marked increase in publications, especially post-2015, reflecting their strong academic presence in this field. Italy exhibits a slower but steady growth in output, lagging slightly behind the other countries but still contributing considerably to the literature on sustainable transportation. This figure underscores

the global research momentum surrounding transportation innovation and sustainability, with China emerging as the dominant contributor in recent years.

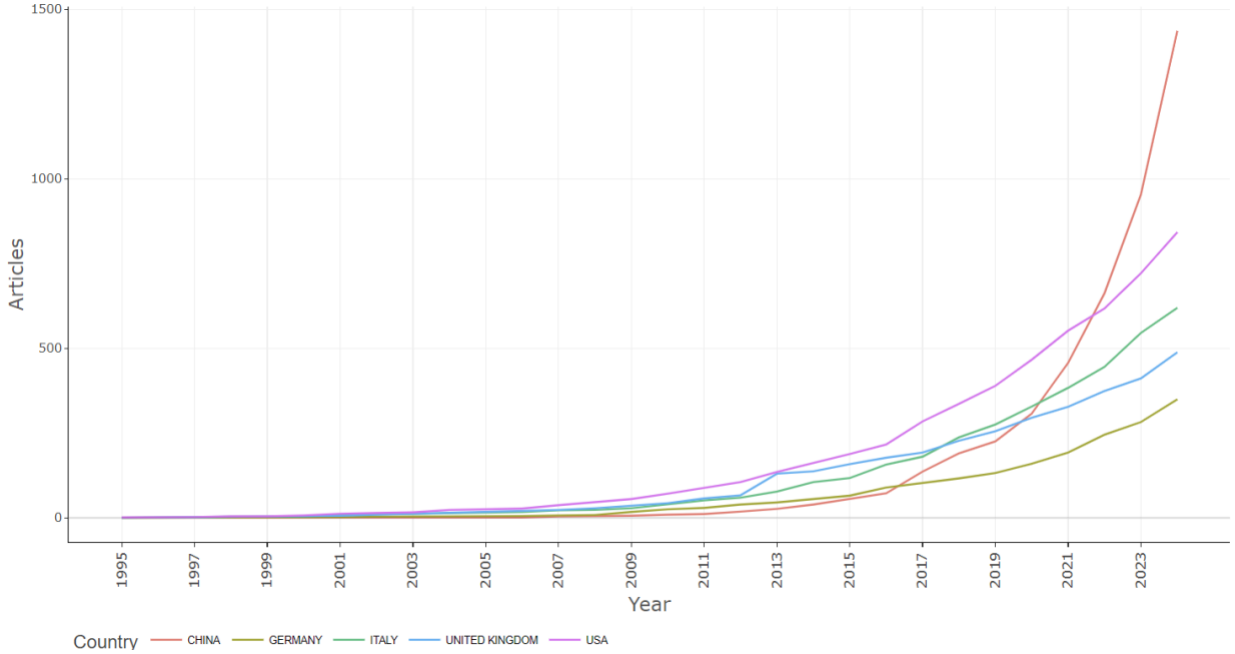

Figure 9: Number of publications for top countries over years

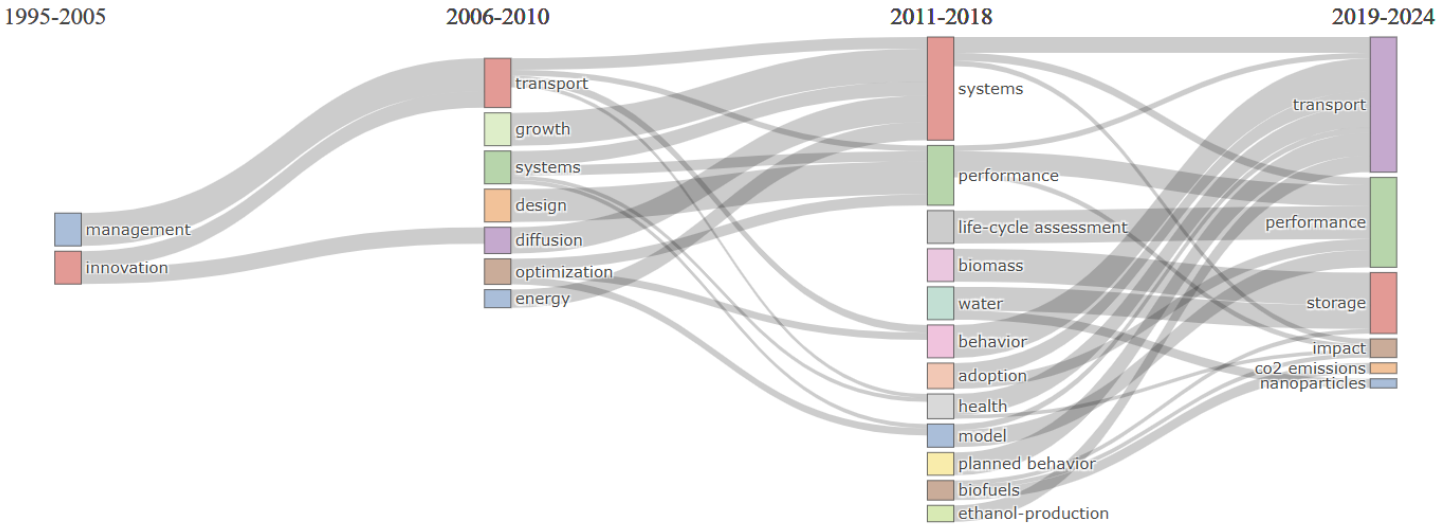

Figure 10: Thematic Evolution

The thematic evolution of research in transportation innovation and sustainability shows a clear progression in focus areas over time. Early research concentrated on foundational topics such as innovation and management, which laid the groundwork for understanding how to implement sustainable practices in transportation systems. As the field advanced, the focus shifted towards more applied themes, including the optimization of transport systems, energy use, and the diffusion of new technologies. Research increasingly emphasized performance, systems design, and life-

cycle assessments, reflecting a growing interest in measuring and improving the environmental impact of transportation innovations. Themes like behavior and adoption also became important, highlighting the role of user engagement and societal uptake in achieving sustainability goals. More recently, there has been an increased focus on specific environmental issues, such as CO2 emissions, impact assessments, and new materials like nanoparticles, which further indicates the field's evolution towards addressing the global climate crisis and finding advanced technological solutions for sustainable transportation.

Conclusion

The analysis of innovation and sustainability in transportation reveals a field that has experienced substantial growth, both in terms of research output and thematic depth. The bibliometric analysis of 3,264 papers from the Web of Science demonstrates that research in this area has surged dramatically, particularly after 2015, with China and the United States emerging as leading contributors. This growing global research momentum is likely driven by the urgent need to address climate change, enhance energy efficiency, and promote sustainable transportation solutions.

The visualization of keyword occurrences and thematic evolution shows a clear shift in focus from early topics centered on management and innovation to more technical and environmental concerns, such as system performance, life-cycle assessments, energy use, and CO2 emissions. This progression underscores how the research landscape has matured, moving from foundational concepts of sustainability to more specific and advanced topics, including the optimization of transport systems and the adoption of new, environmentally friendly technologies. The introduction of new themes like nanoparticles and storage solutions reflects the increasing role of technological innovation in addressing sustainability challenges.

An analysis of leading documents and journals highlights the significant contributions of a few key papers and publications. The most highly cited authors, such as Banister and Sovacool, have produced work that continues to shape the direction of research, as evidenced by their strong local citation counts. Journals like the Journal of Cleaner Production and Sustainability are at the forefront of disseminating these critical findings, further driving forward the discourse on sustainable transportation practices.

The collaboration networks between countries illustrate the interconnected nature of this research field. China and the United States lead in terms of output, but there is also significant cross-national collaboration, particularly between Europe, North America, and Asia. This global cooperation is essential for addressing transportation sustainability challenges, as solutions require a coordinated international effort across regions with varying transportation infrastructures and environmental policies.

In summary, the field of transportation innovation and sustainability is rapidly evolving, with an ever-increasing body of research that is becoming more specialized and technologically advanced. The trends identified in this analysis suggest that the focus will continue to shift towards quantifying environmental impacts, improving energy efficiency, and exploring advanced materials and technologies. The insights gained from this bibliometric analysis can help guide future research efforts, ensuring they align with the most critical challenges and opportunities for achieving sustainable transportation on a global scale.

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