Current Debates in International Trade

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15 Temmuz Mah. 148136. Sk. No: 9 Şehitkamil/Gaziantep
+90.850 260 09 97
+90.532 289 82 15
www.ozguryayınlari.com
info@ozguryayinlari.com

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Preface

Current Debates in International Trade is a comprehensive volume that addresses contemporary discussions in international trade through the lenses of digital transformation, environmental sustainability, technological innovation, and global economic dynamics. The book examines the role of environmentally friendly digital marketing practices within the context of digital transformation and sustainable development, highlighting their implications for international trade. It further explores the strategic importance of green marketing and green advertising within European Union project funds under the framework of the European Green Deal. In addition, the interrelationship between cryptocurrencies, artificial intelligence, and machine learning is analyzed to assess the impact of emerging financial technologies on the global trade system. The final section investigates the relationship between international commodity import price indices and regional economic development in G7 countries using panel data analysis. Overall, the book offers a multidimensional perspective on the evolving structure of international trade and serves as a valuable reference for academics, policymakers, and practitioners.

Contents

Chapter 1

Digital Transformation and Environmental Sustainability: Environmentally Friendly Digital Marketing Solutions

Ali Gülbaşı[1]

Abstract

This study examines the impact of digital transformation on environmental sustainability from a digital marketing perspective and explores green digital marketing solutions. Digital transformation plays a strategic role in achieving environmental sustainability goals while reshaping the business models and marketing processes of businesses. Although the relationship between digital transformation and sustainability is discussed in various dimensions in the literature, there is no holistic framework on how digital marketing can support environmental sustainability. Therefore, this study aims to fill this gap by categorizing the digital transformation process in the field of marketing from an environmental sustainability perspective. In this context, document analysis, one of the qualitative analysis techniques, was used in the study and 45 documents selected from databases such as Web of Science, Scopus, Ebsco and Google Scholar by purposive sampling method were analyzed to examine the digital transformation process in marketing from an environmental sustainability perspective and to present a holistic approach for businesses and researchers who want to develop sustainable marketing strategies.

1. Introduction

Digital transformation is the process of redesigning and developing business models, processes, and organizational structures of businesses using digital technologies. This transformation, which covers many areas from procurement to production, from customer relations to management processes, enables businesses to become more efficient, flexible and competitive (Plekhanov et al.,

1 PhD, Kütahya Dumlupınar University, Department of Information Technology, ali.gulbasi@dpu.edu.tr, ORCID ID: 0000-0003-1102-414X

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2023). Digital transformation also acts as an important catalyst in achieving the environmental sustainability goals of businesses.

One of the most important components of digital transformation is the digitization of marketing processes (Desai and Vidyapeeth, 2019: 196), which is referred to as digital marketing. Digital marketing provides businesses with a competitive advantage by focusing on analyzing consumer behavior, delivering personalized content, and increasing customer engagement. In today's world, where information and communication technologies have been transformed into disruptive innovations, businesses are trying to communicate with customers in the most efficient way (Panda & Mishra, 2022) by using websites, social media applications, and mobile platforms (Al-Azzam & Al-Mizeed, 2021) and aim to positively influence customers' purchasing decisions (Ziółkowska, 2021). Digital marketing activities also support sustainable marketing activities by minimizing the negative impact on the environment in marketing processes through the use of digital marketing tools such as digital advertising, email marketing, marketing through social media tools, search engine optimization (SEO) and search engine marketing (SEM) applications, and content marketing.

The contribution of digital transformation to sustainable marketing processes is largely driven by data-driven strategies and the effective use of digital tools. Digital marketing tools such as SEO

and SEM help businesses promote their sustainable products and services to a wider audience and increase the visibility of environmentally friendly brands. Trujillo and Perez (2022) emphasize that digital marketing plays a critical role in the transition to sustainable business models, and that businesses can more effectively fulfill their environmental responsibilities by improving their digital capabilities. In particular, social media marketing and content strategies stand out as important tools to raise consumer awareness and promote sustainable consumption habits. However, it is also noted that the impact of the competitive factor on sustainable marketing strategies has not been clearly demonstrated (Hilali et al., 2020).

It is noted that the COVID-19 pandemic has accelerated digitization processes and made sustainable marketing strategies more critical (Esses et al., 2021). During the pandemic, businesses have seized new opportunities to deliver their sustainable products and services directly to consumers through more effective use of online marketing channels. Data analytics, personalized advertising, and artificial intelligence-based marketing solutions used to increase the visibility of sustainable products, especially on e-commerce platforms, can change consumer habits and promote sustainable consumption.

Digital transformation is supporting sustainable marketing not only in manufacturing and services, but also in agriculture and retail. Smart agricultural technologies and digital supply chain management promote sustainable food production, while digital solutions such as data analytics and blockchain enable consumers to better understand the environmental impact of products (Hrustek, 2020). In addition, digital marketing practices in developing countries contribute to sustainable development and enable small businesses to offer sustainable products to global markets (Costa et al., 2022).

One of the most important contributions of digital technologies to sustainable marketing is the process of educating and guiding consumers. Social media campaigns, content marketing strategies, and effective digital advertising models that allow green products and sustainable business practices to reach a wider audience increase consumers' tendency to prefer sustainable products (Truong, 2022). In particular, the implementation of green marketing strategies through digital channels contributes to the fulfillment of businesses' environmental responsibilities and supports the growth of the sustainability-oriented market by increasing consumer awareness.

In the education sector, digital transformation can contribute to environmental sustainability through integration with sustainable marketing strategies. In particular, online education platforms are seen as a critical tool in the transition to sustainable business models (Mohamed Hashim et al., 2022). Digital education solutions and smart campus applications help to reduce environmental impacts by increasing the sustainability awareness of both businesses and individuals (Trevisan et al., 2024).

Various dimensions of the relationship between digital transformation and environmental sustainability are discussed in the literature. However, the sectoral fragmentation and the lack of a holistic approach to the theoretical framework are considered significant shortcomings of research in this area (Guandalini, 2022). The impact of digital transformation on sustainable marketing is increasingly being explored. In particular, through digital marketing strategies, it becomes possible to promote sustainable consumption behaviours and disseminate sustainable marketing practices that reduce environmental impacts (Feroz et al., 2021). In this context, this study seeks to answer the following research question in order to develop a sustainable marketing strategy by evaluating the contribution of digital transformation to sustainable marketing processes within a holistic framework and revealing the implementation components of this strategy.

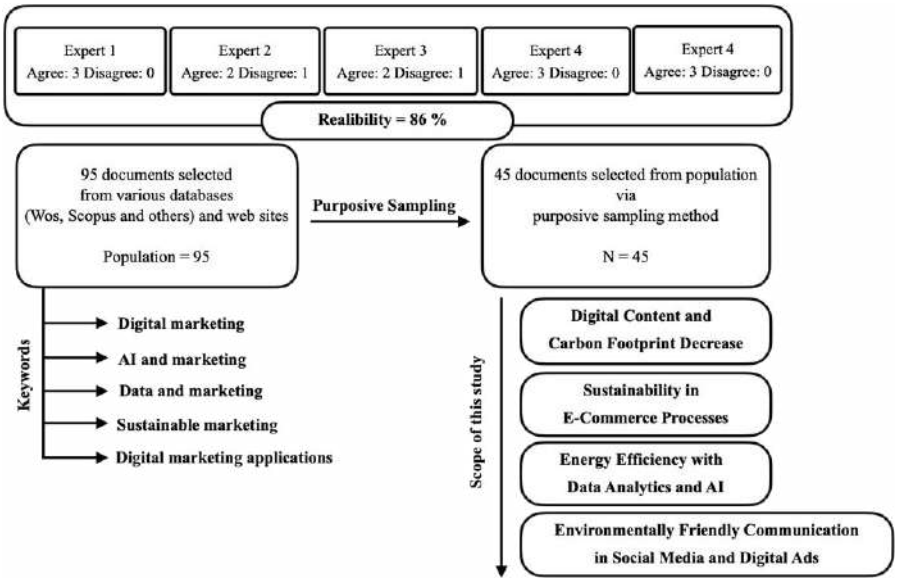
RQ1. What are the digital marketing practices that relate to digital transformation to maintain environmental sustainability? How are these practices integrated into marketing processes?

2. Methodology

Document analysis, a qualitative analysis method, was employed to address the research question of the study. This method can be utilized either as an independent analysis technique or as a complementary approach to support other methods. In this study, it was applied as an independent analysis method (Nas et al., 2021). To define the population of the study, searches were conducted on Web of Science (WoS), Scopus, and other databases (Ebsco and Google Scholar) using the keywords "digital marketing," "AI and marketing," "data and marketing," "sustainable marketing," and "digital marketing applications" from websites featuring the most current topics. A total of 95 documents relevant to the subject were identified, forming the population of the study. From this population, 45 documents, which are cited in the Results section, were selected through the purposive sampling method. These documents constituted the sample of the study. To ensure the reliability of the study, the research process and the selected samples were evaluated by five researchers who are experts in their respective fields. Three questions were posed concerning the research process, the relevance of the selected documents to the keywords, and the contribution of these documents to the study's subject matter. The evaluation yielded 13 positive and 2 negative responses. The negative feedback pertained to the need to expand the range of selected keywords. In this context, the reliability rate was calculated using the model proposed by Miles and Huberman (1994, p. 64) as follows: Reliability = Agreement / Agreement + Disagreement = 13 / (13 + 2) = 86%.

The research process of the study is illustrated in Figure 1.

Figure 1. Research Process (Authors Elaboration)



2.1. Findings

RQ1. What are the digital marketing practices that relate to digital transformation to maintain environmental sustainability? How are these practices integrated into marketing processes?

The relationship between environmental sustainability and digital marketing aims to reduce environmental impact and promote more conscious consumption habits. In this context, digital marketing practices associated with digital transformation for environmental sustainability are categorized into four distinct groups within the scope of this study.

2.2. Digital Content and Carbon Footprint Decrease

2.2.1. Usage of Green Hosting

Hosting refers to the infrastructure used for data storage. Businesses can establish their own data storage infrastructure or utilize hosting services provided by external vendors. The integration of green solutions within the hosting services used by businesses contributes to achieving sustainability goals while appealing to environmentally conscious consumers and enhancing brand loyalty. Additionally, green digital marketing strategies offer significant opportunities for gaining a competitive advantage. Green hosting solutions, known as green web hosting, are characterized as a sustainable web hosting model aimed at reducing energy consumption for IT and Internet services

by utilizing renewable resources such as solar or wind energy. This approach is part of Green IT and involves environmentally friendly operations and the use of renewable resources, with the primary objective of reducing carbon emissions. Green hosting providers minimize their energy consumption by leveraging renewable energy sources, including solar and wind power. They also engage in recycling initiatives and offset their carbon footprint through mechanisms such as carbon credits (Karyotakis & Antonopoulos, 2021; Trouwloon et al., 2023; Tokatlı et al., 2025).

2.2.2. Optimization in E-mail Marketing

Email marketing is an effective digital marketing method aimed at promoting products or services by sending commercial messages to targeted customer groups (Gedik, 2020). As a component of sustainable digital marketing, green enhancements in email marketing play a significant role (Samantaray & Pradhan, 2020). Developing a green email strategy requires minimizing unnecessary sends, targeting the appropriate audience, and utilizing personalized content. Additionally, simplifying email designs reduces both visual and data load, thereby decreasing server load and energy consumption (Pavlov et al., 2008; Wang et al., 2023). Implementing less frequent and more targeted email campaigns contributes to a reduced carbon footprint. This approach not only enhances the user experience but also supports brands in achieving their sustainability goals. Consequently, email marketing serves as an environmentally friendly and effective communication tool (Wang et al., 2023).

2.2.3. Sustainable Consumption

Sustainable consumption is an approach that emphasizes the efficient use of resources and the preference for environmentally friendly products and services. It is grounded in the principles of maintaining ecological balance and preventing waste to meet the needs of both present and future generations. Key components of sustainable consumption include practices such as energy conservation, recycling, and reuse. This approach encourages individuals and institutions to make conscious choices that minimize their ecological impact, ultimately aiming to establish an environmentally, economically, and socially balanced lifestyle over the long term (Dimitrova et al., 2022; Helvacioğlu et al., 2025).

Another aspect of sustainable consumption involves limiting the use and storage of unnecessary data. For instance, in digital marketing processes, smaller images and videos can be utilized through data compression techniques and code optimization rather than relying on high-quality visuals. This approach

is also believed to enhance visibility in search engine optimization (SEO) techniques. Additionally, such practices contribute significantly to reducing the carbon footprint, as less data translates to reduced storage space, lower computing power requirements, and decreased energy consumption (Li & Huang, 2023; Lucivero, 2020).

2.3. Environmentally Friendly Communication in Social Media and Digital Ads

2.3.1. Content Promoting Environmental Awareness

A trademark is defined by the American Marketing Association as a name, symbol, design, or combination of these elements used to identify a product and distinguish it from similar products. The World Intellectual Property Organization similarly defines a trademark as a sign used to differentiate the products of a commercial or industrial organization from those of others. Based on these definitions, a brand encompasses the totality of identity elements that enable a product to stand out in a competitive market (Kaptanoğlu et al., 2019: 249). Brands can raise social awareness about sustainability by sharing environmentally friendly content on social media platforms.

Such content can be presented in various formats, such as posts that highlight environmental issues, recycling, and tips for sustainable living. In doing so, brands not only strengthen their green image but also contribute to the spread of environmental awareness in society. Content that raises environmental awareness not only deepens the relationship between brands and consumers but also enables them to take an important step toward environmental sustainability (Jerzyk, 2016; Seelig et al., 2021).

2.3.2. Minimalist Advertising Campaigns

Digital advertising is a crucial marketing tool that enables businesses to reach consumers via the Internet. With the advancement of digital media platforms, it has largely replaced traditional advertising, providing businesses with various channels to connect with target audiences. Digital advertising includes the distribution of content and messages through various formats, such as banner ads, pre-roll and mid-roll videos, search engine advertising, online ads, and social media ads. The digital nature of these advertisements allows businesses to reach a global audience (Karakum and Ventura, 2022: 80). Minimalist advertising campaigns aim to reduce energy consumption by minimizing unnecessary clutter in digital advertisements. These campaigns focus on delivering concise content to effectively reach the target audience. The minimalist approach not only helps prevent ad fatigue among consumers

but also minimizes the negative environmental impact of digital marketing. By processing less data, minimalist ads reduce server energy consumption, thereby supporting brands' sustainability objectives (Cabañas et al., 2023).

2.3.3. Green Campaigns

Green marketing is a strategy designed to meet the needs of consumers who prioritize environmentally friendly products and services. This approach ensures that products, which are quality-driven, performance-oriented, and cost-effective, do not negatively impact the environment. Green marketing involves activities such as product modifications, alterations in production processes, development of eco-friendly advertisements, and changes in packaging (Mishra and Sharma, 2014: 79).

By showcasing the successes of environmentally friendly projects, green campaigns inspire consumers and encourage other brands to adopt a sustainable approach. Digital marketing tools enable brands to communicate their sustainability efforts to a broad audience by emphasizing environmental values. Green campaigns shared through digital platforms such as social media, blogs, and video content help raise environmental awareness and stimulate consumer demand for green products. This strategy fosters brand loyalty and trust while promoting an environmentally conscious society. In turn, it can positively influence the purchasing decisions of environmentally aware consumers (Jayasinghe, 2022; Josephine & Are, 2022).

2.3.4. Focusing on Green Consumer Trends

Green consumers are individuals who engage in consumption behaviors that promote environmental and social outcomes while enhancing consumer welfare. Green consumption is defined as a sustainable approach that benefits both current and future generations. These consumers adopt environmentally friendly habits, such as using organic products and preferring clean and renewable energy sources, to address environmental challenges. Green consumer behavior has become a critical research area for businesses in a world where demand for environmentally friendly and sustainable products and services is growing (Haba et al., 2023: 2).

The number of environmentally conscious consumers is rapidly increasing, requiring brands to adapt to these trends. Digital platforms provide powerful tools for engaging with individuals who embrace green consumer trends. Social media, in particular, has proven to be an effective platform for promoting green products. By highlighting their green products and sustainable production processes through digital content, brands can appeal to environmentally

conscious consumers. This strategy not only promotes products but also fosters a strong connection with users who embrace eco-friendly lifestyles. Platforms such as Instagram, TikTok, and YouTube can be leveraged to share educational content about the benefits and ease of use of eco-friendly products. Such content raises environmental awareness and demonstrates brands' commitment to sustainability objectives (Alagarsamy et al., 2021; Borah et al., 2024; Haba et al., 2023; Josephine & Are, 2022).

2.3.5. Influencer Partnerships

Influencer marketing is a digital marketing strategy that enables brands to communicate their messages through sponsored content by collaborating with individuals who possess significant online influence and a large following. This approach aims to promote products and services by utilizing content producers who produce valuable content on social media platforms. While influencers often share similarities with celebrities, they present a more relatable identity by engaging intimately and directly with their followers. Such interactions foster the perception of a personal relationship, making followers more responsive to the content (Vrontis et al., 2020: 617-618).

Collaborations with influencers represent a potent digital marketing strategy for promoting green products and raising environmental awareness. Partnering with influencers who have strong environmental awareness can enhance the perception of brands as environmentally friendly. These influencers can promote green products to their eco-conscious followers, encouraging their adoption. Well-executed social media campaigns can effectively reach a broad audience embracing a greener lifestyle. By leveraging influencers' reach and credibility, brands can communicate their green messages effectively. Simultaneously, collaborating with influencers helps brands meet their sustainability goals and establish trust with their target audiences (Ramdan et al., 2023; Zatwarnicka-Madura et al., 2022; Zhao et al., 2024).

2.4. Energy Efficiency with Data Analytics and AI

2.4.1. Targeted Digital Advertisements

Targeted advertising in digital marketing is an effective strategy that enables brands to reach the appropriate audience. However, the environmental impact of digital advertising should also be taken into account. By utilizing artificial intelligence-powered tools, advertisements can be personalized and tailored to align with the target audience's level of environmental awareness. Artificial intelligence (AI), which is modeled after human intelligence, allows for the development of systems capable of generating new solutions, learning, and

making decisions based on information gained from past experiences (Yoşumaz, 2024 & Yoşumaz, 2025). This approach helps avoid unnecessary ad displays and reduces excessive energy consumption. For instance, customizing ads for users interested in green products or sustainable lifestyles not only enhances advertising efficiency but also contributes to brands' sustainability goals by conveying a green message. Optimizing digital ads in this manner reduces energy consumption and bolsters the image of environmentally conscious brands (Ahmed et al., 2019; Mokoena et al., 2023; Saura et al., 2020).

2.4.2. Energy Efficiency Analytics

Data analytics is the systematic process of analyzing and drawing meaningful conclusions from an organization's data. This process involves collecting the necessary data, posing the right questions, and processing the data effectively in accordance with its speed and variability to extract the right information. Data analytics supports organizations' decision-making processes by providing valuable insights from large and variable data sets. In this way, businesses can develop strategies to maximize the value derived from data through reporting and analysis based on accurate information (Girgin, 2019: 9).

Data analytics plays a crucial role in digital marketing activities aimed at optimizing energy consumption (Saura et al., 2020). Activities such as digital advertising, content development, and website operations can be energy-intensive. In this context, energy efficiency analytics can be employed to identify marketing activities that consume excessive energy and propose more sustainable solutions (Giakomidou et al., 2022). For example, by monitoring the energy consumption of digital advertising campaigns, decisions can be made to prioritize the most efficient and environmentally friendly methods. By optimizing digital marketing strategies in this manner, brands can make more efficient use of their budgets while reducing their environmental impact. This approach is pivotal in achieving sustainability goals and helps brands build an environmentally conscious image (Groening et al., 2014).

2.5. Sustainability in E-Commerce Process

2.5.1. Sustainable Packaging

Sustainable packaging refers to packaging solutions designed and produced to minimize negative environmental impacts. These solutions promote the use of materials that are recyclable, biodegradable, and derived from renewable resources. Additionally, recycling and reusing waste materials are crucial to prevent the depletion of natural resources and raw materials. Plastic, one of the most widely used packaging materials, is made from petroleum-based polymers

that are non-biodegradable and have low recycling rates. Therefore, the use of biodegradable polymers, such as materials derived from plant sources like cellulose, starch, and chitosan, should be prioritized, and manufacturers should shift toward using 100% recyclable materials. Sustainable packaging practices include efficient raw material usage, waste reduction, and environmentally friendly production processes (Ibrahim et al., 2022: 12).

The e-commerce sector is rapidly growing, and consumer demand for environmentally friendly shopping options is also increasing. Brands can project an environmentally conscious image by using sustainable packaging solutions. Recyclable and biodegradable materials play an important role in reducing the environmental impact of e-commerce. In addition, brands can appeal to environmentally conscious consumers by emphasizing this strategy in their digital marketing campaigns. Digital platforms can educate consumers about sustainable packaging through educational content, videos, and infographics. This approach not only helps the environment but also provides long-term business benefits by building brand loyalty (Boz et al., 2020).

2.5.2. Carbon Neutral Transport Options

Carbon neutral transportation is an approach that aims to compensate for the carbon emissions generated during the transportation of products. This means achieving zero carbon emissions from the transportation process. Carbon neutral transportation can be accomplished by using environmentally friendly transportation methods or implementing carbon offset projects. For example, low-carbon transportation methods such as electric vehicles and projects like planting trees or purchasing carbon credits can help offset emissions. This strategy is not limited to e-commerce but also applies to sectors like apparel, cosmetics, and food. Carbon neutral transportation is crucial in combating climate change, reducing waste, and protecting biodiversity (Ehlig-Economides & de Guzman, 2020; Guo et al., 2022; Reddy et al., 2023).

Consumers are increasingly concerned about their environmental impact when making purchases (Alagarsamy et al., 2021). In this context, offering carbon neutral transportation options is an important way for brands to demonstrate their environmental consciousness. On e-commerce platforms, carbon neutral transportation options can be digitally promoted, allowing users to easily select them when placing orders. To achieve carbon neutrality, companies can invest in tree planting projects to offset emissions (Kronenberg & Mieszkowicz, 2011) or raise awareness about the importance of carbon credits (Yang & Xu, 2024). Highlighting this service in digital marketing

strategies can capture the attention of environmentally conscious consumers and enhance the brand's sustainability communication.

2.5.3. Digital Invoices and Documents

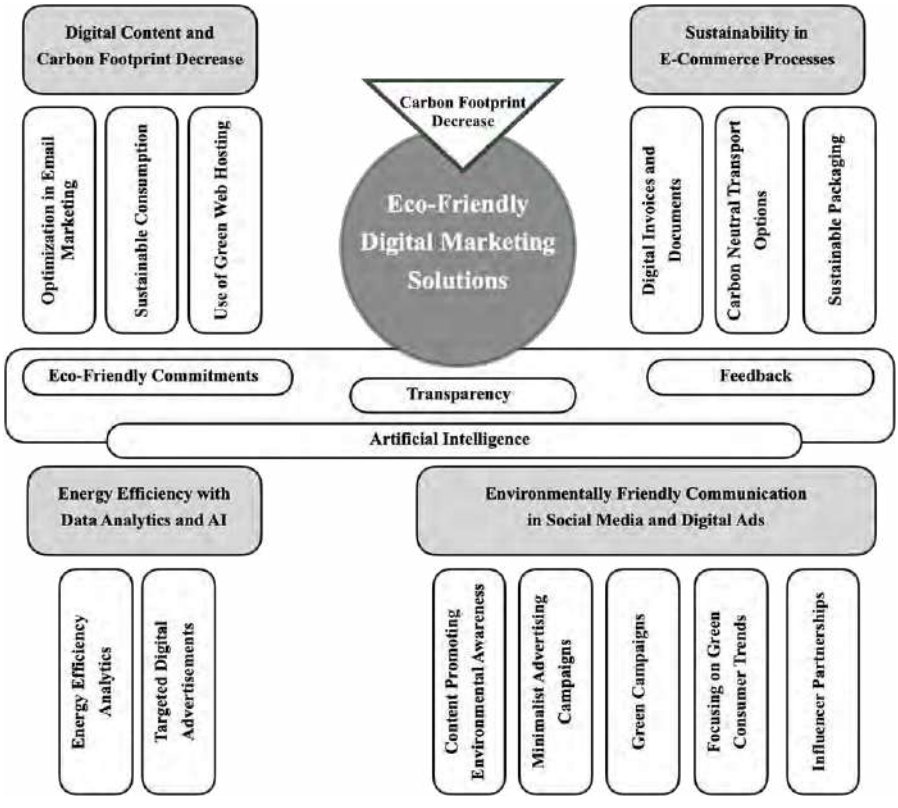
Digital invoicing and digital documents refer to the process of generating, transmitting, and storing traditional paper-based documents in a digital format. With digital transformation, invoices and documents are electronically generated and delivered to recipients via email, digital mailboxes, or other digital platforms. This process offers significant advantages in terms of speed and cost. Costs related to paper, printing, and postage are eliminated, while digital documents can be easily archived, accessed, and stored securely. Moreover, digital invoices and documents improve process efficiency through automated data processing, verification, and tracking. The use of electronic signatures and verification methods ensures secure transactions (Eke, 2023: 115-116). Digital invoices and documents are a crucial step for businesses transitioning from physical to digital data storage (Erceg & Zoranović, 2022). In doing so, they contribute to enhanced sustainability, particularly within e-commerce processes. By reducing paper consumption, the environmental footprint is minimized, while digital documents simultaneously improve the customer experience (Feroz et al., 2021).

Discussion And Conclusion

Digital transformation in marketing has a distinct dynamic compared to other business functions. The primary reason for this difference is that the audience impacted in the marketing process consists of the business's current or potential customers. In this context, digital transformation in marketing can be viewed in two main dimensions. The first dimension includes transformations implemented within the business's internal practices. Particularly, the adoption of innovative technologies such as AI enables more efficient data analysis management, which reduces the amount of data that needs to be stored, thereby lowering energy consumption. These transformations not only enhance internal business efficiencies but also contribute to environmental sustainability. Additionally, communicating these transformations to customers through advertising campaigns highlights the business's environmental commitment and has the potential to strengthen customer loyalty. The second dimension pertains to the outward-facing aspect of marketing, which involves direct interaction with customers, typically through promotional campaigns. In this dimension, digital marketing serves as a powerful tool for brands to provide transparency and effectively communicate their environmental consciousness. Today, consumers are increasingly scrutinizing the environmental impact of brands

and expect transparency regarding sustainability practices. This expectation necessitates that businesses engage with their customers in a more open and trustworthy manner. Digital platforms enable brands to communicate regularly and transparently about their sustainability practices and environmental impacts. Social media, blogs, email newsletters, and websites serve as effective channels for reporting environmental performance and announcing sustainability initiatives. Consumer feedback on brand transparency through these platforms enhances brand-consumer interaction and fosters customer loyalty. Digital marketing also presents significant opportunities for brands to effectively convey their environmental commitments. Through digital platforms, brands can share their long-term sustainability goals and build trust by presenting these goals in a transparent manner. For instance, commitments to using recyclable materials, reducing carbon footprints, or utilizing renewable energy can be communicated through social media posts, videos, and infographics. Such transparency practices not only increase consumer trust in the brand but also strengthen the brand-consumer connection. Figure 2 provides an overview of these processes.

Figure 2. Environmentally Sustainable Marketing through Digital Transformation (Authors Elaboration)



This study aims to provide green solutions by examining how digital marketing strategies can integrate sustainability into the digital transformation process. The effective use of digital marketing aligned with sustainability goals not only enhances environmental responsibility but also enables brands to gain a competitive advantage in the digital transformation journey. The practices analyzed in this study demonstrate how digital marketing can play a strategic role in minimizing environmental impact.

Practices such as digital content management, green web hosting, and data consumption optimization significantly contribute to reducing carbon footprints by enhancing energy efficiency. In particular, targeted email marketing and social media content that raises environmental awareness highlight the effectiveness of digital marketing in supporting environmental sustainability. Sustainable packaging, carbon-neutral transportation options, and digital invoices in e-commerce processes foster eco-friendly shopping experiences, raise consumer awareness, and encourage green consumption behaviors.

Moreover, digital marketing provides an effective platform for brands to communicate their sustainability commitments clearly and transparently. Collaborations with influencers and minimalist advertising campaigns play a strategic role in engaging eco-conscious consumers, while regular communication of sustainability practices through digital platforms helps build brand trust and consumer loyalty.

Theoretical Contributions

This study makes a theoretical contribution to digital marketing by addressing the relationship between digital transformation and sustainability from the perspective of digital transformation in marketing. The study theoretically explains how digital content management, email marketing, social media strategies, and e-commerce processes can be optimized in the context of sustainability. It also aims to fill the gap in the field by categorizing the digital marketing process.

This study synthesizes the literature on digital marketing and environmental sustainability to show how green digital marketing strategies can be developed.

Practical Contributions

The study's findings offer practical recommendations for businesses on how to effectively utilize digital marketing strategies to achieve sustainability objectives. Businesses can reduce their environmental impact by enhancing energy efficiency through digital content management and optimizing data consumption. Additionally, they can provide a greener shopping experience

by incorporating sustainable packaging and carbon-neutral transportation options within e-commerce processes. By leveraging influencer collaborations and social media campaigns to share content that raises environmental awareness, brands can engage environmentally conscious consumers and build trust through transparent communication of their sustainability efforts. The interactive nature of digital platforms serves as an effective tool for increasing customer loyalty, allowing consumers to quickly provide feedback on sustainability initiatives. In this context, the study offers valuable guidance to marketers and businesses seeking to align their digital marketing strategies with environmental sustainability goals. Furthermore, it provides insights for policymakers in developing public policies that promote the achievement of environmental sustainability targets.

Limitations of the Study and Future Research

This study theoretically addresses the integration of digital marketing strategies with environmental sustainability due to time and effort constraints. Future research could focus on the challenges and practical applications of this integration. In addition, sectoral uses of carbon credits and the challenges of carbon neutral practices are among the topics that can be explored.

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Chapter 2

The European Green Deal within the Scope of European Union Project Funds: The Role of Green Marketing and Green Advertising

Ali Gülbaşı[1]

İlker Manav[2]

Abstract

The deepening of climate change and environmental sustainability challenges at the global level has necessitated a rethinking of economic growth models and the development of policy frameworks aligned with environmental objectives. In this context, environmental sustainability has evolved into a multidimensional field that requires not only environmental policies but also the comprehensive transformation of production, consumption, and market dynamics. One of the most comprehensive institutional responses to this transformation is the European Green Deal, announced by the European Union in 2019. The European Green Deal presents an integrated transformation vision that encompasses multiple policy areas most notably energy, industry, transport, and finance with the objective of achieving a climate-neutral economy by 2050. To support this process, European Union funding instruments such as Horizon Europe, the LIFE Programme, and the Innovation Fund aim to promote the development of low-carbon technologies and the dissemination of sustainable production models. The extent to which these policy and financing instruments developed under the Green Deal can generate tangible outcomes at the market and societal levels largely depends on the effectiveness of green marketing and green advertising practices. In this regard, green advertising plays a critical role by enabling the transparent and verifiable communication of environmental performance, thereby increasing consumer awareness and contributing to the societal acceptance and internalization of sustainability-oriented policy objectives.

1 PhD, Kütahya Dumlupınar University, Department of Information Technology, ali.gulbasi@dpu.edu.tr, ORCID ID: 0000-0003-1102-414X

2 PhD, Agriculture and Rural Development Support Institution, ilker.manav@hotmail.com, ORCID ID: 0000-0002-9227-2606

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1. Introduction

Climate change, the rapid depletion of natural resources, and environmental degradation have positioned sustainable development at the core of the global economic and policy agenda. The sustainable development approach is based on the principle of achieving economic growth within environmental limits, conserving natural resources, and safeguarding the needs of future generations (Sargıncı & Beyazyüz, 2022). Accordingly, policies developed within this framework influence not only production and consumption processes but also marketing and advertising activities that communicate these processes to society. The growing level of environmental awareness has increased the necessity for firms to convey their sustainability-oriented production practices to consumers in a transparent and credible manner, thereby elevating green marketing and green advertising to the status of strategic instruments (Karakuş et al., 2022).

The European Union (EU) has emerged as a globally influential actor in this transformation process through its policies and financial assistance mechanisms that place environmental sustainability at the center. Financial assistance to candidate and potential candidate countries was implemented through programs such as PHARE, ISPA, and SAPARD during the 2000–2006 period; these instruments were consolidated under the Instrument for Pre-Accession Assistance (IPA) in the 2007–2013 budgetary period (Çeliktaş, 2006; Efe, 2017). The IPA was designed to support alignment with the EU acquis, strengthen institutional capacity, and promote socio-economic development in candidate countries (Yılmaz, 2015).

Over time, the structure of the IPA has evolved. During the IPA II period (2014–2020), a sector-based and performance-oriented approach was adopted, with areas such as environment, energy, and competitiveness identified as priority sectors. In this period, environmental sustainability was addressed not as a policy area limited to environmental regulation, but as a goal integrated with economic and institutional transformation (Demirhan & Ölmez, 2022). In the IPA III period (2021–2027), environmental protection, climate action, and the green agenda were elevated to core priorities, and a performance-based financing model was introduced (Onocak, 2025; Kıraç, 2025).

The most concrete manifestation of this approach was the European Green Deal, announced in 2019. The European Green Deal represents a comprehensive policy framework that envisages profound transformations across key sectors such as energy, industry, agriculture, transport, and trade, in line with the EU's objective of becoming climate-neutral by 2050 (European Commission, 2019). Within this context, IPA funds function as a complementary financial

instrument supporting the institutionalization and implementation of green transition policies in candidate countries. Projects financed under the IPA contribute not only to the diffusion of environmentally friendly production technologies but also to enhancing the visibility and societal acceptance of these investments through green marketing and green advertising practices (Mete, 2025).

This study aims to provide an overview of European Union financial assistance instruments and to examine the relationship between the European Green Deal and green marketing and green advertising practices.

2. European Union Project Funds

Within the framework of its enlargement policy, the European Union (EU) has, over time, developed a multi-layered system of pre-accession financial assistance to support candidate and potential candidate countries in their alignment with the EU acquis. Although these resources are grant-based, they are not transferred as direct cash; rather, they are disbursed through the financing of projects and programmes determined by mutual agreement between the Commission and the beneficiary country (Ubay, 2024). This financial architecture is grounded in a holistic policy approach that extends beyond the promotion of economic development to encompass the strengthening of institutional capacity, the enhancement of governance quality, the reduction of regional disparities, and the dissemination of sustainable development objectives (Ultan, 2023; Demirhan & Ölmez, 2022). Indeed, the EU's dual objective of reducing development gaps among Member States while reinforcing internal cohesion constitutes an important backdrop to its financial support mechanisms directed at third countries (Yılmaz, 2015).

In the early phase of pre-accession financial assistance, the PHARE, ISPA, and SAPARD programmes emerged as the principal instruments of the EU's support architecture for candidate countries. These programmes targeted multidimensional areas such as the development of administrative capacity, the strengthening of regional cooperation, the improvement of human resources, and the promotion of rural development. The PHARE Programme served as a key instrument for enhancing public administration capacity and supporting alignment with the EU acquis (Ultan, 2023). ISPA concentrated on financing large-scale projects aimed at bringing environmental and transport infrastructure into compliance with EU standards (Yılmaz & Tolunay, 2007). SAPARD, in turn, sought to prepare candidate countries for the Common Agricultural Policy in the fields of agriculture and rural development and attracted attention due to its decentralized implementation

design (Telli, 2023). In this context, it is emphasized that the budgets of these financial instruments were determined within the EU's annual financial framework, whereas the allocation of assistance to individual countries was decided by the European Commission (Efe, 2017).

Nevertheless, because these dispersed mechanisms implemented under different headings generated complexity, coordination difficulties, and efficiency problems in practice, the EU moved, from the 2007–2013 budgetary period onward, toward consolidating pre-accession financial assistance under a more strategic and integrated umbrella. Accordingly, the Instrument for Pre-Accession Assistance (IPA) was introduced; with Regulation No. 1085/2006, IPA was recognized as an official financial assistance instrument and replaced PHARE, ISPA, and SAPARD (Efe, 2017). This transformation also enabled the EU's financial assistance to candidate and potential candidate countries to be positioned across a broad policy domain, including structural reforms, employment, education, environment, energy, transport, human rights, and the rule of law (Yılmaz, 2015). The fact that the IPA Regulation sets out a systematic framework extending from general provisions to component-specific rules and from management and implementation processes to monitoring and reporting is considered one of the institutional foundations of this integrated approach (Yaylı & Gönültaş, 2017).

The ultimate objective of IPA is to assist candidate and potential candidate countries in aligning with the EU acquis and to support the implementation of the political and economic reforms required prior to full membership. In addition, in line with the principles of free movement defined by the Treaty of Rome, the enhancement of these countries' capacities to adapt to competitive conditions within the Union is also pursued (Ubay & Tiyar, 2020). Hence, IPA's objective is not confined to legal and institutional alignment; it also incorporates a transformation perspective aimed at raising living standards in beneficiary countries to levels comparable with those of EU Member States (Çetin, 2023).

Covering the 2007–2013 period, IPA I was designed in a component-based structure and implemented through five main components: Transition Assistance and Institution Building, Cross-Border Cooperation, Regional Development, Human Resources Development, and Rural Development (Aytuğ, 2016; Onocak, 2025). During this period, the goals of strengthening institutional capacity and accelerating alignment with the EU acquis became more pronounced, and the total budget was recorded at approximately €11.5 billion (Kıraç, 2025). In the IPA II period (2014–2020), the component-based approach was abandoned in favor of a sector-based model; democracy and

governance, rule of law, environment, energy, competitiveness, employment, education, agriculture, and regional cooperation were defined as priority sectors (Onocak, 2025). It is noted that, in this period, IPA acquired a more integrated character as a policy instrument addressing socio-economic development and political reforms simultaneously (Kıraç, 2025). Moreover, IPARD the rural development component of IPA was structured in line with the modernization of the agricultural sector and sustainable development objectives in rural areas; the scope and effectiveness of support increased during the IPARD II period (2014–2020) (Demirhan & Ölmez, 2022).

IPA III, covering the 2021–2027 period, represents a new phase in EU enlargement policy characterized by stronger policy prioritization and a performance-oriented approach. In this period, a "window approach" was adopted, and five priority areas were defined: rule of law and democracy; good governance and acquis alignment; green agenda and sustainable connectivity; competitiveness and inclusive growth; and regional and cross-border cooperation (Onocak, 2025). Under IPA III, the shift from a country-based allocation model to a performance-based pooling system was accompanied by project assessments conducted by the European Commission on the basis of "relevance" and "maturity" criteria. Relevance refers to the direct linkage of a project proposal to the EU accession process and its contribution to addressing deficiencies in acquis alignment, whereas maturity points to the capacity to launch tenders rapidly and commence implementation within a short time frame (ipa.gov.tr). The total budget allocated for IPA III was set at €14.162 billion (Kıraç, 2025).

A defining characteristic of IPA III is its strong integration with the European Green Deal. Published in 2019, the European Green Deal articulated the EU's objective of becoming a climate-neutral economy by 2050 and envisaged a comprehensive transformation across sectors such as energy, industry, agriculture, transport, and the circular economy (European Commission, 2019). Accordingly, the EU budget and financial instruments have been aligned with green transition and sustainability priorities, and pre-accession funds have increasingly been linked more directly to sustainability and green transition objectives. Indeed, within IPA III, the green agenda and sustainable connectivity have been framed through objectives such as strengthening environmental protection, combating climate change, facilitating the transition to a low-carbon and circular economy, and supporting digital and green transitions in tandem (stgm.org.tr). In this respect, IPA III is positioned as a strategic instrument accelerating candidate countries' alignment with the objectives of the European Green Deal.

Overall, EU funds and particularly IPA III stand out as strategic policy instruments that support structural transformation in candidate and potential candidate countries, strengthen institutional capacity, and promote sustainable development and green transition objectives. However, the effectiveness of these funds is not limited to the mere provision of financial resources; rather, it is closely associated with the quality of governance achieved throughout project design, implementation capacity, monitoring and evaluation mechanisms, and the dissemination of results (Demirhan & Ölmez, 2022; ipa.gov.tr). In this sense, IPA may be considered a comprehensive financial mechanism that reinforces not only the technical alignment dimension of enlargement policy but also the environmental and institutional transformation dimension underpinning a sustainable future perspective.

3. Environmental Sustainability

The concept of sustainability emerged in response to the increasing severity of environmental problems and the need to develop long-term solutions to these challenges, and over time it has evolved into a multidimensional approach. In general terms, sustainability refers to the pursuit of economic growth and social development processes without exceeding the carrying capacity of natural ecosystems and with due consideration for environmental limits. While this approach seeks to establish a balance between economic activities and environmental protection, it emphasizes long-term ecological integrity rather than short-term gains as the foundation of development (Bayraktutan & Uçak, 2011).

Environmental sustainability constitutes the environmental dimension of sustainability and is based on the fundamental principle of conserving natural resources and transferring them to future generations. In this context, environmental sustainability encompasses the balanced use of renewable and non-renewable natural resources, the preservation of ecosystems' capacity for self-regeneration, the prevention of environmental pollution, and the implementation of effective waste management practices. In addition, the conservation of biodiversity, the prevention of the destruction of natural habitats, and the fight against climate change are among the core components of environmental sustainability (Menteşe, 2017).

The environmental sustainability approach is not limited solely to technical measures aimed at protecting the environment; it also requires the restructuring of production and consumption patterns. In this regard, sustainable production models, energy efficiency, the use of clean technologies, and the promotion of environmentally friendly consumption behaviors are of critical importance

(Yoşumaz & Uzun, 2024) . Ensuring the healthy functioning of ecosystems and reducing environmental risks constitute the long-term objectives of environmental sustainability (Savaş, 2022).

4. Green Marketing

Green marketing refers to a strategic marketing approach developed by firms to position their products and services by placing environmental sustainability at the core of their activities. This approach encompasses multidimensional practices such as improvements in product design aimed at environmentally conscious consumers, environmentally compatible production methods, and sustainable packaging applications. With the growing public awareness of environmental issues, green marketing driven by increasing consumer demand for sustainable products has evolved from a limited field of application into a fundamental competitive factor and a necessary marketing strategy across many sectors (Zamanı & Tekeoğlu, 2025).

Green marketing constitutes a holistic marketing approach that involves the development of product, service, and brand strategies centered on environmental sustainability and the ethical, transparent, and reliable communication of these strategies to consumers. This perspective extends beyond the promotion of environmentally friendly products and requires the restructuring of all marketing activities from production processes and supply chains to pricing and distribution in line with sustainability principles. Particularly within the framework of the European Green Deal, green marketing has become a strategic necessity for firms, while European Union funds have enabled the development of environmentally friendly products and services and provided financial support for related marketing activities (Boran, 2023).

With the intensification of environmental problems and the strengthening of the sustainability paradigm, green marketing has become a prominent concept in the marketing literature. The concept was first introduced in 1975 at a seminar on ecological marketing organized by the American Marketing Association and was defined as the development and marketing of products that do not harm the environment, the reduction of environmental impacts in production and distribution processes, and the adoption of environmentally responsible practices by firms (Çelik et al., 2016). This definition demonstrates that green marketing is not merely a product-oriented approach, but rather a comprehensive process encompassing all stages from production to consumption.

In the literature, green marketing is addressed as a marketing approach aimed at minimizing the environmental and social negative impacts of existing

products and production systems, while encouraging the development and adoption of less harmful and environmentally friendly products and services. Accordingly, green marketing requires the reconfiguration of all elements of the marketing mix from an environmental sustainability perspective. Product design, packaging, pricing, distribution, and promotional activities are shaped by considering their environmental impacts. The green marketing approach represents a multidimensional understanding that not only encourages firms to develop environmentally responsible strategies but also aims to foster conscious consumer choices that take environmental impacts into account (Gökbaş, 2025).

Recent studies emphasize that green marketing should not be viewed solely as an approach that generates environmental benefits, but also as a strategic tool that enhances brand value, consumer trust, and firms' competitive advantage. It is highlighted that green marketing practices have positive effects on consumers' purchase intentions and brand loyalty, and that an environmentally responsible brand image supports overall business performance (Ara et al., 2020; Özcan & Özgül, 2019).

5. Green Advertising

Green advertising refers to marketing communication activities through which firms convey their products, services, or corporate practices to consumers by emphasizing environmental responsibility, ecological sustainability, and the conservation of natural resources. This type of advertising aims to increase consumer awareness by highlighting environmentally friendly attributes, encourage environmental sensitivity, and shape purchasing behaviors toward more sustainable choices. The effectiveness of green advertising is closely related to the credibility, accuracy, clarity, and perceived quality of the information conveyed in advertising messages (Zamanı & Tekeoğlu, 2025).

Green advertising is used in the marketing of products and services claimed to have relatively low environmental impact and focuses on emphasizing environmentally friendly characteristics. Through various messages, associations, and symbolic cues, this type of advertising seeks to communicate environmental claims such as a low carbon footprint, environmentally responsible production processes, or sustainability-related attributes. The core objective of green advertising is to shape consumer perceptions by foregrounding the environmental dimensions of products and, in doing so, to gain a competitive advantage in the marketplace (Santa & Drews, 2023).

In the literature, green advertising is regarded as a communication strategy that aims to influence purchasing behavior by leveraging consumers'

environmental sensitivities. Advertisements containing environmental claims enable firms to differentiate their products as lower-carbon or environmentally friendly, while also contributing to consumers' perceptions that their consumption choices reduce environmental impacts (Pinkse & Bohnsack, 2021; Sun et al., 2021). In this respect, green advertising is positioned as a tool that simultaneously increases demand-side environmental awareness and strengthens firms' market share.

However, green advertising may also lead to perceptual biases, as consumers often process information through limited attention and cognitive heuristics. Research indicates that products labeled as environmentally friendly may be perceived as having lower environmental impacts than they actually do, or that erroneous inferences may be made regarding their superior performance compared to similar alternatives (Gorissen & Weijters, 2016).

6. The Emergence of the Green Deal and Its Relationship with Green Marketing and Green Advertising

The Green Deal approach, developed with the aim of combating climate change and establishing a sustainable societal order, was conceptually introduced for the first time by Thomas Friedman in 2007. In the following years, its scope expanded under the influence of global financial, energy, and food crises, evolving into a multidimensional policy framework. This process necessitated addressing environmental problems not only from an ecological perspective but also in terms of their economic, social, and political dimensions. Ultimately, the approach gained an institutional character through the development of a comprehensive transformation strategy by the European Union (EU), placing environmental sustainability at its core. With the European Green Deal announced on 11 December 2019, the European Union put into effect an extensive policy and action plan aimed at making the Union climate-neutral by 2050. This strategy identifies the redefinition of the relationship between economic growth and environmental protection, the acceleration of the transition to renewable energy, and the promotion of sustainable development as its primary objectives (European Commission, 2019).

The European Green Deal goes beyond conventional environmental policies by offering an integrated transformation vision that encompasses a wide range of sectors, including energy, industry, agriculture, transport, and finance. Within this framework, decarbonization has been placed at the center of the economic system, and the concept of "green growth" has become one of the European Union's strategic priorities (Barbier, 2019). Rather than constituting a legally binding regulatory framework, the Green Deal represents a strong

political commitment, envisaging the transformation of existing regulations and the development of new policy instruments. Key objectives include achieving net-zero greenhouse gas emissions by 2050, decoupling economic growth from resource use, and preventing the deepening of regional and social inequalities during the green transition process. In order to attain these goals, increasing energy efficiency, expanding the use of renewable energy sources, and reducing dependence on fossil fuels are considered critical (Yolcu, 2023).

Figure 1. The European Green Deal

References: Euinasean.eu/eu-green-deal

In order to strengthen the feasibility and societal acceptance of the Green Deal, the European Union has also established a comprehensive financing and support mechanism. The Social Climate Fund aims to mitigate the potential adverse effects of the green transition on low-income households and small-scale enterprises by focusing on the fight against energy poverty and social inequalities, mobilizing more than €65 billion for this purpose (Qnbc.com.tr). Similarly, the Just Transition approach seeks to ensure that the transformation in regions dependent on carbon-intensive sectors is carried out without undermining social welfare. In this regard, the Just Transition Fund is highlighted as a key policy instrument for safeguarding employment, fostering new economic activities, and supporting regional development (Portakal et al., 2024).

In addition, the Horizon Europe Programme, which supports the knowledge and technology dimension of the European Green Deal, covers the 2021–2027 period and, with a budget of €95.5 billion, represents the European Union's most comprehensive research and innovation programme. Through its priority area on "Climate, Energy and Mobility," the programme places environmental sustainability at the center of the EU's innovation agenda, aiming to promote the development of green technologies, transform production systems, and disseminate science-based solutions in the fight against climate change. By encouraging international research and innovation cooperation, Horizon Europe also contributes to reducing regional disparities by expanding access to knowledge networks in the field of environmental innovation (Peñalosa & Castaldi, 2024).

The Horizon Europe Programme is the European Union's principal research and development framework, designed to strengthen scientific and technological capacity, enhance innovation and competitiveness, promote employment generation, and sustainably support Europe's socio-economic values. For the 2025–2027 period, the programme's priorities are structured around three main pillars. First, under the green transition, climate-neutral objectives, biodiversity protection, and the fight against pollution are strongly supported. In this context, at least 35% of the programme's budget is allocated to climate action, while 10% is dedicated to biodiversity-related activities. Second, within the framework of digital transformation, a minimum investment of EUR 13 billion is envisaged for the 2021–2027 period to support human-centred digital technologies that enhance Europe's competitiveness and strategic autonomy. Finally, in line with the objective of building a more resilient, inclusive, competitive, and democratic Europe, research activities are supported in areas such as social rights, health, security, a fair and environmentally friendly economy, and democratic participation (ipa.gov.tr).

European Union funds such as Horizon Europe, the LIFE Programme, and the Innovation Fund have been established to support the development of low-carbon technologies, promote circular economy practices, and encourage sustainable production models. However, the success of projects implemented under these funding schemes is not limited to technical outputs alone; marketing activities play a decisive role in the communication, adoption, and commercialization of project outcomes among target audiences. At this point, green marketing emerges as a key strategic instrument that enables the positioning of environmentally friendly products and services developed through EU project funding in the eyes of market actors and consumers (Peattie & Crane, 2005).

The impact of the European Green Deal on global trade and the competitive environment has elevated green marketing to a strategic position for exporting firms. Within this policy framework centered on environmental sustainability, production processes with a low carbon footprint, environmentally friendly packaging, transparent carbon reporting, and sustainable logistics practices have become decisive factors in firms' access to international markets. Green marketing thus goes beyond the promotion of environmentally sensitive products, encompassing the management of firms' environmental responsibilities across the entire value chain and the integration of this approach into marketing strategies. In this context, green marketing practices aligned with the European Green Deal provide firms with opportunities to reduce regulatory risks while gaining competitive advantages in environmentally conscious markets, thereby strengthening export performance on a sustainable basis (Bilici & Sönmezay, 2025).

The "Guideline on Advertisements Containing Environmental Claims," published by the Ministry of Trade of the Republic of Türkiye in 2022, offers a regulatory framework that clearly defines the legal and ethical boundaries of green advertising practices. The guideline emphasizes that the use of terms such as "green," "sustainable," "eco," "environmentally friendly," "carbon neutral," and "renewable," as well as similar expressions implying environmental attributes, is prohibited when used without adequate explanation or in a manner that results in ambiguity for consumers. Accordingly, environmental claims must clearly and verifiably specify which aspects of the product or service have environmental impacts, which stages of the life cycle they cover, and which measurement or assessment methods are used to determine these impacts. Furthermore, if the medium in which the advertisement is published does not allow sufficient space to provide such information, consumers must be directed to additional channels where detailed information can be accessed. In this respect, the guideline is regarded as an important regulatory instrument that moves green advertising beyond a mere marketing discourse by structuring it around the principles of transparency, verifiability, and consumer protection.

The complementary relationship between the Sustainable Development Goals and the European Green Deal, combined with the process of digitalization, has given rise to a new domain of transformation in marketing and advertising. The positioning of digital technologies as a key element in achieving environmental sustainability objectives has strengthened the role of advertising beyond that of a purely commercial communication tool, enhancing its function in raising environmental awareness and encouraging behavioral change. In this context, green advertising has emerged as a strategic communication practice that enables the transparent, responsible,

and environmentally conscious dissemination of products and services developed in line with sustainable development and Green Deal objectives to stakeholders through digital channels. The growing importance of alignment between marketing strategies and environmental actions has positioned green advertising as a complementary tool that both contributes to the Sustainable Development Goals and supports the societal adoption of the European Green Deal (Çayırağası & Sakıcı, 2021).

Within the framework of the European Green Deal, policy areas such as the transition to clean energy, sustainable transport, green industry, pollution prevention, the circular economy, a just transition, and green finance necessitate a structural transformation for businesses not only in production, supply, and logistics processes, but also in marketing and corporate communication strategies. In this context, green marketing aims to develop products and services aligned with environmental objectives, integrate sustainable practices into brand strategies, and transform environmental value propositions into sources of competitive advantage. Green advertising, in turn, emerges as a key communication tool that enables firms to convey information about their environmental performance to stakeholders in accordance with the principles of transparency, verifiability, and regulatory compliance. From this perspective, green marketing and green advertising represent not merely symbolic expressions of environmental sensitivity, but strategic instruments that enhance firms' competitiveness in international markets, strengthen corporate reputation, and reduce regulatory risks. The European Green Deal's multi-layered policy, regulatory, and financing architecture directs market actors toward sustainable production and consumption models, while simultaneously necessitating effective communication practices to ensure the societal acceptance of this transformation. Accordingly, green advertising functions as a strategic communication mechanism that increases the visibility of environmentally friendly products and services, disseminates information on sustainable production practices to the public, and supports the social legitimacy of the Green Deal's objectives. However, the effective and credible fulfillment of this role requires that green advertising practices be conducted in accordance with ethical principles and be based on measurable and verifiable environmental indicators. Otherwise, misleading environmental claims, commonly referred to as greenwashing, may undermine consumer trust and conflict with the regulatory and policy objectives of the European Green Deal. In conclusion, the European Green Deal provides a comprehensive framework that transforms green advertising from a mere marketing activity into a responsible and strategic corporate communication practice aligned with broader policy objectives.

In conclusion, the European Green Deal provides a comprehensive framework that transforms green advertising from a mere marketing activity into a responsible and strategic corporate communication practice aligned with broader policy objectives, as illustrated in Figure 2.

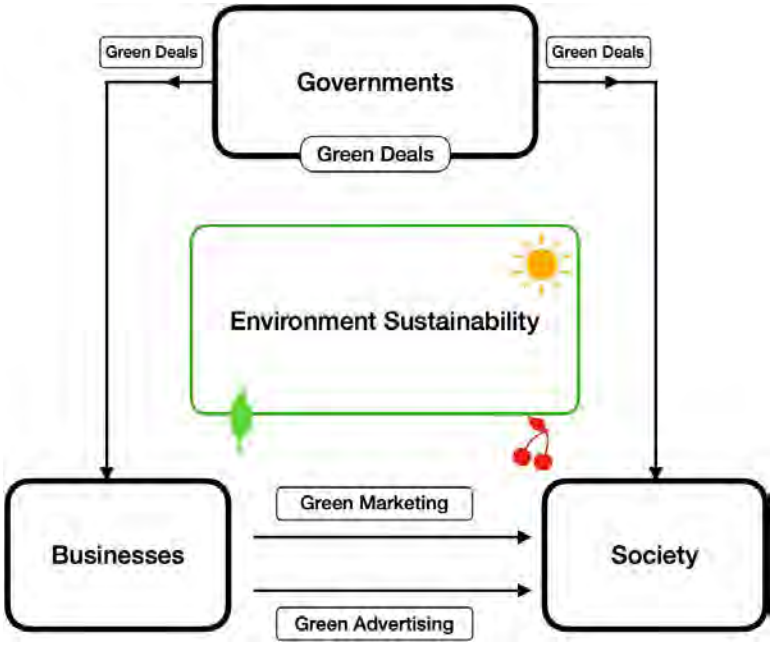

Figure 2. The Relationship Between the Green Deal and Green Marketing and Green Advertising (Authors Elaboration)

Conclusion

This study examines the global policy and economic agenda shaped around climate change and environmental sustainability within the framework of the European Union Green Deal, adopting a holistic perspective on the relationship between the financing of the green transition and green marketing particularly green advertising. The main findings indicate that sustainability-oriented policy objectives must be supported not only by technical regulations and financial support mechanisms, but also by effective marketing and communication strategies.

The findings demonstrate that European Union project funds are not merely instruments for financing the development of environmentally friendly technologies in the green transition process; rather, they also play a guiding and transformative role in promoting sustainable production and consumption

models. Funding mechanisms such as Horizon Europe, the LIFE Programme, the Innovation Fund, and similar initiatives encourage low-carbon production processes and circular economy practices. However, the ability of these processes to gain traction at both societal and market levels largely depends on the effectiveness of marketing and advertising activities. In this context, green marketing renders the environmental benefits of environmentally friendly products and services developed through funded projects tangible in consumer perception and supports demand for sustainable products.

The study further reveals that green advertising constitutes a fundamental communication mechanism facilitating the societal adoption of Green Deal objectives. Green advertising practices play a critical role in increasing environmental awareness, shaping consumer behavior toward sustainable choices, and strengthening norms of sustainable consumption. At the same time, the regulatory dimension of green advertising has become increasingly prominent, as illustrated by the "Guideline on Advertisements Containing Environmental Claims" issued by the Ministry of Trade of the Republic of Türkiye. Such regulations emphasize the necessity for green advertising to be conducted in accordance with ethical, transparent, and verifiable principles, aiming to prevent misleading image-oriented practices, protect consumers, and reduce the risk of greenwashing.

In conclusion, this study demonstrates that project funds developed within the framework of the European Union Green Deal contribute not only to establishing the financial infrastructure of the green transition, but also to strengthening its societal acceptance, market diffusion, and firms' competitive positioning through green marketing and green advertising. In particular, green advertising emerges as a strategic communication tool that enhances firms' access to international markets, supports sustainable export performance, and enables the transformation of environmental compliance into a source of competitive advantage in environmentally sensitive markets. By allowing Green Deal objectives to move beyond policy documents and find concrete expression across the entire value chain from production to consumption, green advertising plays a critical role in aligning corporate strategies with sustainability-driven trade dynamics. This holistic structure underscores the importance of addressing sustainability goals in their economic, social, and behavioral dimensions, while making the strategic role of marketing and advertising in the green transition process more visible and integral to long-term competitiveness.

Policy Recommendations

To enhance the effectiveness of the green transition process carried out within the framework of the European Green Deal, stronger and more integrated alignment between European Union project funding mechanisms and marketing and advertising policies is required. In this regard, green marketing and green advertising activities should be considered integral components of project design in initiatives supported by EU funds. Placing greater emphasis in project calls on communication and dissemination plans that clearly specify how sustainability outcomes will be conveyed to target audiences would increase the societal impact capacity of these funding mechanisms.

Moreover, ensuring credibility in green advertising practices requires that environmental claims be grounded in measurable, verifiable, and transparent indicators. The development of communication standards aligned with regulatory instruments such as the Carbon Border Adjustment Mechanism (CBAM) and similar tools would contribute to reducing the risk of greenwashing. In addition, strengthening the institutional capacities of project implementers and firms in the areas of green marketing and sustainability communication would support the more effective and durable implementation of the green transition process at both economic and societal levels.

Furthermore, the integration of green marketing and green advertising into policy design should be approached in a way that facilitates firms' access to international markets, particularly the European Union, where environmental standards are becoming increasingly stringent. It is essential that funding provided under the European Green Deal supports communication strategies that enhance the environmental compliance capacities and sustainable competitiveness of firms operating in export-oriented sectors. In this context, green advertising should be recognized as a policy instrument that strengthens export performance, enhances brand credibility, and transforms compliance with environmental regulations into a source of competitive advantage, thereby contributing to making the economic benefits of the green transition more visible.

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Chapter 3

Cryptocurrency's Interrelationship with Artificial Intelligence and Machine Learning

Ali Gülbaşı[1]

Serdar Kaya[2]

Abstract

This study examines the use of artificial intelligence and machine learning techniques in cryptocurrency price prediction through a comprehensive literature review. Cryptocurrencies, emerging as a natural consequence of the digital transformation process, are financial assets based entirely on data, and in this data-driven ecosystem, artificial intelligence algorithms have become indispensable tools for predicting future price movements.

The literature review reveals that a consensus has not yet been established in cryptocurrency price prediction modeling. There are conflicting findings regarding the superiority of different machine learning models such as LSTM, XGBoost, ANFIS, and SVR. While some research argues that LSTM is the most reliable tool in highly volatile markets, others claim that ensemble learning methods like XGBoost are more successful in practical trading optimization.

There are also serious debates regarding the data sources to be included in prediction models. Different views exist on the relative importance of social media sentiment, technical indicators, and macroeconomic variables. While some studies show that social media data is strong in short-term predictions, others emphasize the determining role of technical analysis indicators.

Model explainability and security issues have also gained importance in the literature. It is emphasized that explainable artificial intelligence techniques such as SHAP analysis are essential for model transparency, and that machine learning should be used in manipulation and anomaly detection. The study demonstrates that more empirical research and theoretical frameworks are needed in this field.

1 PhD, Kütahya Dumlupınar University, Department of Information Technology, ali.gulbasi@dpu.edu.tr, ORCID ID: 0000-0003-1102-414X

2 Graduate Student, Kütahya Dumlupınar University, Post Graduate Institute, Department of International Trade and Financing, kaya.serdar@outlook.com, ORCID ID: 0009-0004-9595-1075

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1. Introduction

Digital transformation is a fundamental change process that closely affects many segments and sectors, from businesses to societies. One of the areas affected by this transformation is crypto currencies. The digital transformation process is essentially based on the data and information cycle; in this context, crypto currencies are financial assets that emerge as a natural result of the digital transformation process. Although many financial assets have physical equivalents, crypto currencies are entirely based on data. According to Yoşumaz (2024a), the digital transformation process is not merely a technology injection; it is a comprehensive cycle that includes the acquisition, storage, analysis, and sharing of data. Within this cycle, crypto currencies have found their place in the financial system as digital assets that offer transparency and decentralization through blockchain infrastructure. On the other hand, as a result of the magnitude of this data-driven ecosystem, artificial intelligence (AI) and machine learning (ML) algorithms have become indispensable tools for making sense of big data and predicting future price movements.

There are many studies in the literature regarding the relationship between crypto currencies and AI. Kervancı and Akay (2020) stated that deep learning (DL) models are definitively superior to statistical models such as AutoRegressive Integrated Moving Average (ARIMA) in capturing nonlinear patterns; they demonstrated that DL models provide a distinct advantage particularly when working with high-frequency data. Similarly, Khedr et al. (2021) revealed that traditional statistical methods require unrealistic assumptions, whereas ML, with its "experience-based learning" capability, is the best technology in this field. However, there is a significant divergence of opinion in the literature regarding which ML model is most successful. While Boozary et al. (2025) argued that Long Short-Term Memory (LSTM) networks are the most reliable tool in highly volatile markets for Bitcoin price prediction, Adedigba et al. (2025) claimed the opposite, asserting that complex DL models do not always yield the best results, and that ensemble learning methods such as Extreme Gradient Boosting (XGBoost) and Gradient Boosting outperform deep neural networks in practical trading optimization. Korkmaz et al. (2025) also supported this finding by reporting that the XGBoost algorithm ranked highest in overall performance, while LSTM remained in second place. On the other hand, Salehi (2024) suggested that Adaptive Neuro-Fuzzy Inference System (ANFIS) models provide more robust results than singular artificial neural networks in capturing the volatile trends of the crypto market; they argued that ANFIS can better model market uncertainty by combining fuzzy logic with neural networks. In contrast, Akarsu (2024) claimed that the Support Vector Regression (SVR) model demonstrated the highest accuracy.

Ashok et al. (2025) brought a different perspective to this debate, arguing that the search for a single "best model" may be misleading; they contended that the best-performing algorithm varies from asset to asset for different crypto assets such as Bitcoin, Ethereum, and BNB.

The issue of which data sources should be included in prediction models is also an area of serious contradiction. Tanrıkulu (2021) showed that the effect of Tweet counts and Google Trend data on price is not always stable, that social media data is strong in short-term predictions but loses reliability in long-term forecasts. Gurgul et al. (2025) claimed that including social media sentiment (Twitter and Reddit) in the analysis increases profitability, and that social media data provides stronger signals than technical indicators, particularly in predicting short-term price movements. However, Korkmaz et al. (2025) argued the opposite, asserting that technical analysis indicators are decisive in model success, and that the contribution of macroeconomic and sentiment indicators remains very limited contrary to belief. Nas and Ergin Ünal (2023) also revealed the limited contribution of macroeconomic variables by stating that Bitcoin is most affected by its own past price fluctuations (intraday high and low prices), while the effects of the Fed interest rate and gold remain secondary. While Kanat (2023) argued that ML methods confirm traditional technical analysis rules such as Weighted Moving Average (WMA) and Stochastic Oscillator (STO), and that using these indicators together is the most rational strategy, Saha (2023) observed that models based solely on technical indicators fail during periods of excessive market sentiment and suggested that a combination of technical and fundamental factors is safer. Lapitskaya et al. (2025) emphasized the importance of technical indicators by stating that the combination of momentum indicators such as Moving Average Convergence Divergence (MACD), Relative Strength Index (RSI), and Commodity Channel Index (CCI) with XGBoost provides the most accurate price predictions.

Model explainability and security issues have also gained importance in the literature. Akarsu (2024) emphasized that explainable artificial intelligence (XAI) techniques such as SHapley Additive exPlanations (SHAP) analysis are essential for removing models from being "black boxes"; they suggested that it is not sufficient for prediction models to merely produce correct results, but that the decision-making process must be understandable. Wang et al. (2022) claimed that detecting informed trading with ML algorithms plays a critical role in return prediction; they showed that the trading behaviors of market makers and large investors carry important leading signals about price movements. While Shahbazi and Byun (2022) focused on the power of ML in ensuring system security through transaction tracking and anomaly

detection in the blockchain network, Alnami et al. (2025) emphasized that ML should be used in an integrated framework not only for price prediction but also for detecting abnormalities such as manipulation, wash trading, and pump-and-dump schemes in the crypto currency ecosystem. Fang et al. (2024) focused on market microstructure and claimed that analyzing limit order book dynamics with ML is key to discovering "universal" market characteristics; they drew attention to the importance of their proposed "Walkthrough Training" method to prevent model obsolescence.

The comprehensive picture emerging from this literature review clearly demonstrates that a consensus has not yet been established in crypto currency prediction modeling. The contradictions regarding model preferences (LSTM vs. XGBoost), data sources (social media vs. technical indicators), and methodological approaches (explainability vs. accuracy) indicate that more empirical research and theoretical framing are needed in this field. In this context, this study aims to contribute to the literature by revealing the relationship between AI and crypto currencies in the existing literature.

2. Conceptual Framework

Crypto currencies and the AI (especially ML) ecosystem surrounding them represent the financial and technological convergence point of digital transformation. This section consists of three parts. In the first part, information is provided on crypto currencies, and in the second part, on AI and ML. In the third part, the relationship between AI and crypto currencies is addressed.

2.1. Crypto currencies

2.1. The Definition and Historical Development of Crypto Currency

Crypto currency is an encrypted digital or virtual asset based on blockchain technology, not under the control of any central authority or government (Khedr et al., 2021; Shahbazi & Byun, 2022). While traditional monetary systems rely on hierarchical power structures such as central banks, national treasuries, and commercial banks, crypto currencies enable fund transfers over a peer-to-peer network without the need for an intermediary institution (Khedr et al., 2021; Shahbazi & Byun, 2022). This decentralized structure has formed a new structure in the financial system with the principles of transparency and immutability (Shahbazi & Byun, 2022; Poudel et al., 2023).

The concept of crypto currency entered the literature with the technical document titled "Bitcoin: A Peer-to-Peer Electronic Cash System" published

in 2008 by a person or group using the pseudonym Satoshi Nakamoto (Nakamoto, 2008; Korkmaz, Altınırmak & Karamaşa, 2025). With Bitcoin (BTC) beginning to trade for the first time in 2009, the decentralized digital currency structure effectively commenced (Boozary, Sheykhan & GhorbanTanhaei, 2025). Over time, Bitcoin was followed by thousands of altcoins and tokens, each emerging with different technological promises (Tanrıkulu, 2021; Boozary et al., 2025). For example, Ethereum (ETH), developed by Vitalik Buterin in 2015, went beyond being merely a payment instrument and offered a platform on which smart contracts and decentralized applications (dApps) could operate (Viéitez, Santos & Naranjo, 2024; Gurgul, Lessmann & Härdle, 2025).

Crypto currencies meet the modern definition of money with characteristics such as portability, durability, divisibility, and non-counterfeiting (Tanrıkulu, 2021). However, unlike traditional currencies, the essence of crypto assets is entirely composed of "data," and their values are based not on any physical asset but on the supply-demand balance and investors' psychological perceptions (Tanrıkulu, 2021; Nas & Ergin Ünal, 2023).

2.2. Blockchain Mechanism and Transaction Security

Blockchain is a distributed ledger technology that forms the fundamental infrastructure of crypto currencies, in which information is cryptographically secured and linked to each other like a chain (Tanrıkulu, 2021; Shafie-khah, 2020). This technology flawlessly implements the "data and information cycle" principle of digital transformation by enabling the secure storage, verification, and sharing of data (Yoşumaz, 2024a; Yoşumaz, 2024b).

The working principle of blockchain is based on the collection of transactions in blocks, each block containing the summary (hash) of the previous block, and the sealing of this structure with timestamps (Nakamoto, 2008; Tanrıkulu, 2021). Thanks to this connection, changing the content of a block requires changing all subsequent blocks as well, making the system extraordinarily resistant to external interventions (Nakamoto, 2008; Shahbazi & Byun, 2022). Complex cryptographic functions such as the SHA-256 algorithm used in the Bitcoin network grant each block a unique identity (Tanrıkulu, 2021; Shahbazi & Byun, 2022).

The security of the network and the production of new units are ensured through the "mining" process (Tanrıkulu, 2021; Poudel et al., 2023). Consensus algorithms such as "Proof of Work" (PoW) require participants (miners) to consume processing power (CPU/GPU) to solve complex mathematical problems (Nakamoto, 2008; Tanrıkulu, 2021). Successful miners are rewarded

with both newly produced crypto currencies and transaction fees (Nakamoto, 2008; Tanrıkulu, 2021). The storage of crypto assets is accomplished through two basic methods: "hot wallet" (internet-connected) and "cold wallet" (offline, physical device); cold wallets are considered more secure against cyber attack risk (Tanrıkulu, 2021; Shahbazi & Byun, 2022).

2.3. Crypto Currency Markets and Volatility

Crypto currency markets exhibit a structure that, unlike traditional markets, operates continuously 24/7, is globally accessible, but demonstrates an extremely volatile nature (Adedigba, Agbolade & Hasan, 2025; Boozary et al., 2025). The microstructure of these markets is shaped by elements such as liquidity conditions, order book dynamics, and informed trading (Wang et al., 2022; Fang et al., 2024).

Volatility is the most characteristic feature of crypto currency markets. Price movements react instantly to many factors such as macroeconomic news, regulatory authorities' decisions, technological updates, and social media influencers' posts (Nas & Ergin Ünal, 2023; Alnami et al., 2025). Sharp fluctuations in Bitcoin's price, in particular, have a strong domino effect on other altcoins, increasing uncertainty across the market (Korkmaz et al., 2025; Viéitez et al., 2024). Lack of liquidity and high transaction costs bring the risk of assets becoming "zombified" (Będowska-Sójka, Wójcik & Pele, 2026).

Zombie crypto assets are digital assets that, although technically existing, are not traded on exchanges, have lost their liquidity, and have trapped their investors (Będowska-Sójka et al., 2026). In the literature, this situation is associated with low trading volume, dramatic declines in market value, and prolonged price stagnation (Będowska-Sójka et al., 2026; Wang et al., 2022). According to market microstructure theory, continuous declines in trading volume lead to the widening of the bid-ask spread and ultimately the delisting of the asset from the market (Będowska-Sójka et al., 2026). Predicting these risks in advance with ML models has become a critical research area for investor security (Będowska-Sójka et al., 2026).

Crypto currency prices interact not only with internal market dynamics but also with a broad set of external indicators. In the literature, the effects of macroeconomic variables such as gold prices, crude oil prices, the S&P 500 index, the VIX volatility index, and FED interest rates on crypto markets are examined in depth (Viéitez et al., 2024; Akarsu, 2024; Nas & Ergin Ünal, 2023).

Investor sentiment is perhaps the most effective external factor in price formation in crypto markets. Unlike traditional financial assets, crypto

currencies are extremely sensitive to social media hype and public perception (Valencia, Gómez-Espinosa & Valdés-Aguirre, 2019; Gurgul et al., 2025). Data obtained from platforms such as Twitter and Reddit through Natural Language Processing (NLP) techniques are used to measure investors' fear or appetite levels (Gurgul et al., 2025; Boozary et al., 2025). For example, indicators such as the "Fear and Greed Index" are considered important inputs for increasing the prediction success of ML models (Korkmaz et al., 2025). However, some researchers argue that the effect of sentiment analysis is limited contrary to belief and that the real success is achieved with technical market data, forming a contradiction on this issue (Viéitez et al., 2024; Korkmaz et al., 2025).

In recent years, the dimension of "environmental sustainability" has also been added to the conceptual framework of crypto currencies. The high energy consumption and carbon footprint in the mining processes of assets such as Bitcoin and Ethereum have given rise to the concept of "dirty cryptocurrency" (He, 2024; Jana et al., 2022). This situation has led investors to develop new trading strategies that consider environmental risks (ESG) and has caused increased interest in sustainable financial technologies (He, 2024; Banerjee, 2024).

2.4. Analysis of Crypto Currency Markets

The methods used to make sense of crypto currency markets and predict future price movements span a wide spectrum, from traditional technical analysis tools to advanced AI algorithms.

Technical analysis aims to identify future trends by examining past price and volume movements. Indicators such as Simple Moving Average (SMA), Weighted Moving Average (WMA), MACD, RSI, and STO are the most frequently used tools by crypto currency investors (Kanat, 2023; Lapitskaya, Eratalay & Sharma, 2025). ML methods build upon these traditional technical indicators by combining them with more complex patterns and maximizing prediction accuracy (Kanat, 2023; Yaman Şahin & Ulutürk Akman, 2024).

AI and ML come into play at points where traditional statistical models such as ARIMA fall short in dealing with the volatile nature of crypto markets (Kervancı & Akay, 2020; Korkmaz et al., 2025). ML offers different paradigms including supervised (SVR and XGBoost), unsupervised (K-means clustering), and reinforcement learning (Mujlid, 2023; Ren et al., 2022). LSTM and Gated Recurrent Unit (GRU) models under the DL umbrella demonstrate superior success in capturing long-term dependencies and nonlinear relationships in time series data (Korkmaz et al., 2025; Adedigba et al., 2025). In recent years,

it has become important not only for models to make predictions but also to explain the reasons for these predictions; methods such as SHAP analysis aim to remove models from being "black boxes" (Akarsu, 2024; Alnami et al., 2025).

AI and ML are the most critical technologies that today stand at the center of data-driven decision-making processes and are considered the "workhorses" of digital transformation. These technologies not only process complex data but also possess the ability to discover hidden patterns in highly volatile markets where traditional statistical models fall short.

2.2. Artificial Intelligence

2.2.1. The Definition and Historical Development of Artificial Intelligence

AI is an evolving branch of computational algorithms designed to imitate human capabilities such as learning, reasoning, and decision-making through computer software (Yoşumaz, 2025). This technology adapts the problem-solving and reasoning processes of human intelligence to computer science as a metaphor (Yoşumaz, 2025). The origins of AI extend back to Al-Khwarizmi's work on algebra and algorithms in the 9th century and Al-Jazari's contributions to cybernetics and programmable automata in the 13th century (Yoşumaz, 2025). Conceptually, the term AI was first articulated by John McCarthy at the Dartmouth Conference in 1955, and today it has come to be recognized as the "workhorse" in the process of processing big data and transforming it into strategic information (Akarsu, 2024; Yoşumaz, 2025). The fundamental purpose of AI is to be able to recognize complex problems by learning from the environment and to offer rational solutions by making meaningful inferences from data (Akarsu, 2024).

The digital transformation process operates within a dynamic cycle that includes the acquisition, storage, and analysis of data in enterprises, and its sharing as a strategic value (Yoşumaz, 2024b; Yoşumaz, 2024a). AI and ML constitute the most critical components of this data and information cycle, establishing a technological bridge between virtual and physical worlds (Yoşumaz, 2024b). Enterprises' ability to adapt to this process depends on increasing awareness of these technologies throughout society and the establishment of a digital transformation-oriented institutional culture (Yoşumaz, 2024a). Particularly in financial markets where high-frequency data and noisy signals exist, AI systems have become strategic solution partners in forecasting tasks where traditional statistical models (ARIMA, VAR, etc.) remain limited (Khedr et al., 2021; Boozary et al., 2025).

2.2.2. Types and Working Areas of Artificial Intelligence

The AI ecosystem is classified into different categories according to technological maturity levels, the types of data it specializes in, and its working logic.

Types of AI: In the literature, AI is evaluated at three main levels according to its capacities (Yoşumaz, 2025):

a. Artificial Narrow Intelligence (ANI): These are systems with limited capabilities designed to perform a specific task (for example, playing chess or making financial price predictions) (Yoşumaz, 2025). All active applications used today fall into this class.

b. Artificial General Intelligence (AGI): This presents a type of AI where the data processing capacity becomes equal to human intelligence (Yoşumaz, 2025).

c. Artificial Superintelligence (ASI): This presents a type of AI where the data processing capacity surpasses human intelligence (Yoşumaz, 2025).

The most prominent sub-fields of AI are ML, DL, natural language processing (NLP), computer vision (CV), robotics, and artificial neural networks (ANN) (Yoşumaz, 2025). A large portion of analyses in crypto currency markets is also based on ML.

Machine Learning: ML is a subfield of AI that enables software systems to automatically improve their performance by learning from data without being explicitly programmed (Khedr et al., 2021; Mujlid, 2023). While in traditional programming computers follow every step and rule given to them, in ML the system builds its own internal rules by modeling input data (Kervancı & Akay, 2020; Tanrıkulu, 2021). This technology seeks scientific answers to the question of how to build computers that improve automatically through experience and how to enhance performance metrics (Ren et al., 2022; Mujlid, 2023). ML algorithms perform mathematical modeling by analyzing massive data sets and accomplish tasks such as classification, clustering, and prediction with high accuracy (Ren et al., 2022; Tanrıkulu, 2021).

Deep Learning and Artificial Neural Networks: DL is a subset of ML that learns complex representations and abstractions from large data sets using multilayer ANN (Akarsu, 2024; Khedr et al., 2021). These structures, which imitate the working logic of neurons in the human brain, can automatically extract hierarchical features within data (such as edges in an image or cycles in a time series) (Khedr et al., 2021; Yoşumaz, 2025). LSTM networks are considered unrivaled in financial time series predictions because they have

the capacity to remember long-term dependencies in sequential data through "memory gates" (Korkmaz et al., 2025; Wang et al., 2022).

NLP: This is the discipline that transforms human language into a form that computers can understand, analyze, and produce (Gurgul et al., 2025; Yoşumaz, 2025). In the financial world, it plays a key role in measuring investor psychology, particularly through news text and social media sentiment analysis (Gurgul et al., 2025; Mujlid, 2023).

AI learning is generally examined under four main headings (Ren et al., 2022; Mujlid, 2023):

a. Supervised Learning: This is the method where the system is given both input data and the correct results (labels) corresponding to these data (Khedr et al., 2021; Mujlid, 2023). The algorithm builds a rule that maps inputs to outputs; models such as Support Vector Machines (SVM) and Random Forest (RF) are the most powerful tools in this category (Mujlid, 2023; Tanrıkulu, 2021).

b. Unsupervised Learning: This is the model where training data is not labeled, and the system groups (clusters) data by discovering hidden patterns, similarities, and structural relationships within the data on its own (Khedr et al., 2021; Mujlid, 2023). The K-means clustering method is widely used in areas such as anomaly detection and customer segmentation (Mujlid, 2023; Tanrıkulu, 2021).

c. Semi-supervised Learning: This is a hybrid approach where learning performance is increased by using a small amount of labeled data together with a large amount of unlabeled data (Ren et al., 2022; Mujlid, 2023).

d. Reinforcement Learning: This is a process where an "agent" learns to make decisions through trial and error in order to obtain the highest reward in a specific environment (Ren et al., 2022; Mujlid, 2023). The system receives feedback (reward or penalty) from the environment after each action it takes and updates its internal state accordingly, developing the most appropriate strategy (Ren et al., 2022; Mujlid, 2023).

2.2.3. The Use of Artificial Intelligence in Financial Markets

The finance sector is one of the most ideal application areas for AI due to the large data masses it contains, high transaction frequency, and complex structural relationships (Adedigba et al., 2025; Mujlid, 2023). AI models produce more successful results than linear regression models because they can capture complex and interactive relationships among numerous variables (Khedr et al., 2021; Akarsu, 2024; Alnami et al., 2025). However, the black

box characteristic of these systems, meaning that why a prediction was made cannot always be understood, poses a challenge in terms of institutional trust (Ren et al., 2022; Akarsu, 2024). XAI techniques and SHAP analysis developed to overcome this problem make the decision-making logic of models transparent, allowing financial actors to take safer steps (Akarsu, 2024; Korkmaz et al., 2025). The use of AI in financial markets is fundamentally as follows.

a. Price and Return Prediction: AI models predict future price direction with high accuracy by analyzing past price movements, volume data, and technical indicators (Khedr et al., 2021; Mujlid, 2023). Ensemble learning models such as XGBoost and Random Forest (RF) generally demonstrate performances that surpass deep neural networks in short-term predictions and trading optimization (Adedigba et al., 2025; Korkmaz et al., 2025).

b. Sentiment Analysis: Investors' discourses on Twitter (X), Reddit, or news platforms are analyzed with NLP techniques to measure the levels of "fear" or "greed" in the market (Gurgul et al., 2025; Alnami et al., 2025). These psychological data are integrated as features into price prediction models, thereby incorporating the behavioral finance dimension of the market into the model (Gurgul et al., 2025; Korkmaz et al., 2025).

c. Algorithmic Trading and Portfolio Management: AI is used to optimize asset allocation according to risk preferences and develop dynamic strategies that maximize profit (Korkmaz et al., 2025; Ren et al., 2022). Reinforcement learning (RL) agents can evaluate market opportunities without the need for human intervention by conducting thousands of transactions within seconds (Ren et al., 2022; Adedigba et al., 2025).

d. Anomaly Detection and Security: AI is an effective control mechanism in detecting suspicious transactions, cyber attacks, and manipulation attempts such as "pump-and-dump" in financial networks (Alnami et al., 2025; Mujlid, 2023). Z-Score-based anomaly detection frameworks increase investor security by separating normal market movements from irregular ones (Alnami et al., 2025).

e. Credit Risk Assessment: ML models are used to assess credit risks by analyzing borrowers' repayment capacities through big data and to accelerate the decision processes of financial institutions (Khedr et al., 2021).

2.3. The Relationship Between Crypto Currencies, Artificial Intelligence And Machine Learning

The digital transformation process consists of a dynamic cycle that includes the acquisition, storage, and analysis of data and its transformation into strategic value (Yoşumaz, 2024b). Crypto currencies, which are the most concrete reflection of this transformation in financial markets, produce very large amounts of transparent and immutable data thanks to blockchain infrastructure (Nakamoto, 2008; Yoşumaz, 2024a). However, the extreme volatility possessed by crypto currency markets renders traditional financial analysis methods insufficient (Boozary, Sheykhan, & GhorbanTanhaei, 2025; Adedigba, Agbolade, & Hasan, 2025). At this point, AI and generally ML, which is a sub-field of AI, can discover hidden patterns within complex data masses, model nonlinear relationships, and produce rational predictions (Akarsu, 2024; Mujlid, 2023). This synergy between crypto currencies and AI points to a new economic paradigm where data is transformed into information, and information into financial advantage (Yoşumaz, 2025; Shahbazi & Byun, 2022).

2.3.1. Fundamental Use Scenarios of Artificial Intelligence in the Crypto Currency Ecosystem

The applications of AI in the crypto currency ecosystem cover a wide spectrum, from simple data analyses to complex autonomous systems. The main use scenarios that stand out in the literature can be detailed as follows:

a. Price and Volatility Prediction: The most common application area of AI is forecasting the future closing prices and market direction of assets such as BTC, ETH, and Binance Coin (BNB) (Korkmaz, Altınırmak, & Karamaşa, 2025; Adedigba et al., 2025). LSTM networks, in particular, demonstrate high accuracy rates in this field thanks to their ability to remember long-term dependencies in time series data (Boozary et al., 2025; He, 2024). On the other hand, ensemble learning models such as XGBoost and Random Forest (RF) are preferred in the optimization of trading bots due to their computational speed and success in short-term predictions (Korkmaz et al., 2025; Adedigba et al., 2025).

b. Sentiment Analysis and NLP: Crypto assets are extremely sensitive to social media news and public perception (Valencia, Gómez-Espinosa, & Valdés-Aguirre, 2019; Banerjee, 2024). Generative Artificial Intelligence (GAI) and NLP techniques measure the level of "fear" or "greed" in the market by analyzing millions of texts obtained from platforms such as Twitter (X) and Reddit (Gurgul, Lessmann, & Härdle, 2025; Poudel et al., 2023). Advanced

models such as Bidirectional and Auto-Regressive Transformers (BART) and Multi-Genre Natural Language Inference (MNLI) detect investors' bullish or bearish tendencies, integrate this data into price prediction models, and increase prediction accuracy (Gurgul et al., 2025).

c. Anomaly Detection and Security Audit: AI is a critical tool for detecting suspicious transactions and cyber attacks in the blockchain network (Alnami, Mohzary, Assiri, & Zangoti, 2025; Shahbazi & Byun, 2022). Z-Score-based anomaly detection systems warn investors against pump and dump manipulations by separating normal price movements from irregular ones (Alnami et al., 2025). Additionally, ML models play an active role in tracking "zombie" assets that have lost trading volume and illegal financial flows (Będowska-Sójka, Wójcik, & Pele, 2026; Ren et al., 2022).

d. Algorithmic Trading and Portfolio Management: Reinforcement Learning algorithms aim to maximize portfolio value by learning the most appropriate buy-sell timing according to market conditions through an "agent" (Poudel et al., 2023; Koker & Koutmos, 2020). These systems minimize human-induced emotional errors by making rational decisions in crypto exchanges that operate continuously 24/7 (Koker & Koutmos, 2020; Shahbazi & Byun, 2022).

2.3.2. Opportunities Offered by Artificial Intelligence and Crypto Currency Integration

The integration of AI and crypto currency offers important opportunities for the financial system to achieve a more efficient, democratic, and transparent structure.

a**. Reduction of Information Asymmetry:** AI makes it possible to develop rational investment strategies by analyzing big data sets that exceed the processing capacity of human intelligence (Boozary et al., 2025; Mujlid, 2023). This situation enables individual investors to have similar analytical power to professional financial actors, thereby reducing information asymmetry and contributing to the democratization of the market (Gurgul et al., 2025; Adedigba et al., 2025).

b. Financial Inclusion and Disintermediation: When the decentralized structure of crypto currencies combines with the analytical power of AI, a secure financial ecosystem is formed without the need for intermediary institutions (banks, fund managers, etc.) (Shahbazi & Byun, 2022; Poudel et al., 2023). This situation facilitates the inclusion of populations without access to banking services into the financial system, establishing economic growth opportunities at a global level (Yoşumaz, 2024a; Banerjee, 2024).

c. Strategic Decision Support Systems: AI models not only make price predictions but also offer investors a holistic decision support mechanism by identifying correlations between complex macroeconomic variables (interest rates, inflation, oil prices) and crypto assets (Nas & Ergin Ünal, 2023; Akarsu, 2024).

2.3.3. Threats and Risks Offered by Artificial Intelligence and Crypto Currency Integration

Although this technological convergence harbors great potential, the chaotic and unsupervised structure of the market also brings serious threats:

Overfitting and Generalization Problem: ML models can produce perfect results on the training set by fitting too closely to historical data, while they can fail completely in the face of new market shocks (black swan events) they have never seen (Mujlid, 2023; Korkmaz et al., 2025). This situation carries the risk of leading to major financial losses by establishing a false sense of confidence for investors (Nas & Ergin Ünal, 2023; Adedigba et al., 2025).

Sophisticated Manipulations and Bot Wars: The use of AI bots by malicious actors increases the danger of artificially manipulating prices (wash trading) with thousands of transactions within seconds in the market (Alnami et al., 2025; Gurgul et al., 2025). This situation threatens market stability by disrupting the natural supply-demand balance (Będowska-Sójka et al., 2026).

Cybersecurity and Private Key Loss: AI-based trading platforms may require access to users' private keys to perform autonomous transactions (Shahbazi & Byun, 2022; Tanrıkulu, 2021). A possible cyber attack on such platforms constitutes a major security vulnerability that could result in the theft of all user assets (Alnami et al., 2025; Shahbazi & Byun, 2022).

2.3.4. Challenges Encountered in the Crypto-AI Relationship

The biggest challenges in the integration process are related to methodological limitations and data quality:

Explainability and Black Box Problem: DL models generally cannot explain why a prediction was made in a manner understandable by humans (Akarsu, 2024; Yoşumaz, 2025). The lack of transparency weakens the trust of institutional investors and regulatory authorities (regulators) in these models (Akarsu, 2024; Alnami et al., 2025). XAI and SHAP analysis techniques developed to overcome this challenge are still in the large-scale application phase (Akarsu, 2024; Korkmaz et al., 2025).

Data Quality and Noisy Signals: Data coming from crypto exchanges can generally be noisy, incomplete, or manipulated (Poudel et al., 2023; Salehi, 2024). Models trained with incorrect or poor-quality data can misdirect investors by producing erroneous results in accordance with the "garbage in, garbage out" principle (Mujlid, 2023; Adedigba et al., 2025). Furthermore, the necessity for models to be continuously retrained with real-time data to keep pace with the 24/7 dynamism in the market requires massive computational resources and high energy consumption (He, 2024; Adedigba et al., 2025).

2.3.5. Conveniences Offered by AI and Crypto Currency Integration

a. Autonomous Market Monitoring: AI can simultaneously monitor thousands of different crypto currencies and billions of social media data 24/7, far beyond human attention span (Gurgul et al., 2025; Boozary et al., 2025). This convenience reduces investors' fear of missing out (FOMO) on market opportunities and lightens the data analysis burden (Mujlid, 2023; Yoşumaz, 2024b).

b. Dynamic Risk Management and Optimization: ML models automate risk management by dynamically updating "stop-loss" and "take-profit" levels according to sudden changes in market conditions (Adedigba et al., 2025; Koker & Koutmos, 2020). Additionally, techniques such as PCA (Principal Component Analysis) facilitate healthier portfolio diversification by enabling investors to filter out assets that show high correlation with each other (Adedigba et al., 2025; Korkmaz et al., 2025).

c. Smart Contracts and Secure Payments: AI enables smart contracts on the blockchain to be more flexible and fault-tolerant (Shahbazi & Byun, 2022; Yoşumaz, 2024b). This situation facilitates the flawless execution of financial transactions without human intervention, within predetermined conditions (Yoşumaz, 2024a; Shahbazi & Byun, 2022).

3. Discussions and Conclusion

The digital transformation process is built upon a dynamic cycle that includes the acquisition, storage, and analysis of data and its transformation into strategic value (Yoşumaz, 2024b). Crypto currencies, which are the most radical reflection of this transformation in financial markets, have emerged as a strong alternative to traditional financial systems thanks to the transparent and immutable data infrastructure offered by blockchain technology (Nakamoto, 2008). However, the extreme volatility and nonlinear complex structure possessed by crypto currency markets have made this ecosystem a difficult-

to-manage area for both investors and researchers (Adedigba, Agbolade, & Hasan, 2025; Boozary, Sheykhan, & GhorbanTanhaei, 2025). At this point, AI and ML algorithms come into play as fundamental technologies that discover hidden patterns within these massive data masses and offer rational decision support systems (Akarsu, 2024; Mujlid, 2023). This study emphasizes the importance of the strategic relationship between crypto currencies and AI.

The literature examined within the scope of the study proves that there is not universally a single best prediction model, and that success varies according to asset type and the structure of the data set (Korkmaz, Altınırmak, & Karamaşa, 2025; Hitam, & Ismail, 2018). Ensemble learning models such as XGBoost and RF demonstrate superior performance in short-term predictions and trading optimization with both their transaction efficiency in large-scale data sets and their structures that minimize overfitting risk (Adedigba et al., 2025; Korkmaz et al., 2025). The XGBoost algorithm, in particular, can rapidly learn complex data structures thanks to the gradient boosting technique and can surpass other models with its generalization capacity (Adedigba et al., 2025). On the other hand, DL models such as LSTM networks have been established as one of the most reliable tools in highly volatile assets such as Bitcoin thanks to their ability to store long-term dependencies in time series data and the effect of past price shocks through "memory gates" (Boozary et al., 2025; He, 2024). Although analyses conducted by Akarsu (2024) report that the Support Vector Regression (SVR) model reaches high accuracy rates in limited data sets, it is observed that the success of deep neural networks is consolidated as data volume increases. These findings emphasize that investors must necessarily consider the asset's liquidity, volatility, and targeted prediction horizon (minute, hourly, or daily) when making model selection (Tanrıkulu, 2021; Tekinay, 2021).

The analysis of factors affecting crypto asset prices has shown that "data quality" is more critical than algorithm selection in the success of ML models (Mujlid, 2023). Importance analyses conducted by Nas and Ergin Ünal (2023) and Korkmaz et al. (2025) revealed that crypto currency prices are most highly affected by their own past price movements (High, Low, Open) and technical analysis indicators. Indicators such as RSI, MACD, and Stochastic %K, in particular, are the technical signals that provide the most significant contribution to the predictive power of models (Korkmaz et al., 2025; Lapitskaya, Eratalay, & Sharma, 2025). In contrast, the effect of macroeconomic indicators such as interest rates, inflation, and exchange rates on crypto markets continues to remain controversial in the literature (Basher & Sadorsky, 2022; Korkmaz et al., 2025). While some studies emphasize the suppressive effect of these variables on Bitcoin (Akarsu, 2024), some research

asserts that crypto assets move independently with their own internal dynamics and market microstructure (Wang et al., 2022). Sentiment analysis has become an integral part of models with the development of NLP techniques (Gurgul, Lessmann, & Härdle, 2025). Data obtained from social media (X, Reddit) and news feeds significantly increase the accuracy of prediction models, particularly during sudden market reversals, by reflecting the level of "fear" or "greed" in the market (Banerjee, 2024; Gurgul et al., 2025).

The most fundamental obstacle in applying AI and ML models to crypto markets is that complex models are seen as black boxes (Akarsu, 2024). This situation weakens the trust of institutional investors and regulators in models. At this point, the use of XAI techniques such as SHAP analysis consolidates the reliability of strategic decision support systems by making transparent which variable contributes in what direction to the prediction (Akarsu, 2024; Korkmaz et al., 2025).

Consequently, the synergy between crypto currency markets and AI is one of the most powerful driving forces shaping the future of the digital economy. The crypto currency world is like a decentralized and massive digital data library in which new pages are continuously being added in thousands of languages. AI, in turn, assumes an important role in data research in this library. Within the scope of future research, examining the power struggle between countries around the world and investigating the effects of these struggles on crypto currencies could be valuable for understanding volatility in crypto currency markets.

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Chapter 4

International Commodity Import Price Index and Regional Economic Development: Panel Data Analysis for G7 Countries

Ali Gülbaşı[1]

İbrahim Metehan Koca[2]

Abstract

The relationship between commodity prices and economic growth is being investigated with increasing interest in economic literature. Various international price indices related to this topic are calculated and published. With the rise of large volumes in global trade, the impact of commodity prices on national economies is also increasing. This study examines the relationship between commodity import prices and economic development for G7 countries. The analysis covers the period between 1962 and 2024. Cross-sectional dependence, homogeneity, unit root, and cointegration tests were used. The AMG approach was preferred as the estimation model. According to the results of the study, commodity import prices do not affect economic growth in the US, UK, and Canada, while they negatively affect it in Japan, Italy, Germany, and France. In addition, common commodity price shocks experienced on a global scale have a strong impact on the development dynamics of G7 economies.

1. Introduction

The relationship between commodity prices and economic growth has been extensively studied in economic literature, particularly since the 1980s. This interest stems particularly from the extreme sensitivity of commodity-dependent countries (CDCs), whose income largely comes from primary commodity exports to the volatility and uncertainty of these incomes. In contrast to the resource blessing hypothesis, which argues that natural resources

1 PhD, Kütahya Dumlupınar University, Department of Information Technology, ali.gulbasi@dpu.edu.tr, ORCID ID: 0000-0003-1102-414X

2 Science Expert, metekoca3444@gmail.com, ORCID ID: 0009-0002-5562-3347

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act as a motor for economic development, many empirical studies have put forward the resource curse hypothesis, showing that resource-rich countries grow more slowly than resource-poor countries. The fundamental economic and political mechanisms behind the resource curse are listed as: the "Dutch Disease," which causes the manufacturing sector to lose competitiveness; uncertainty resulting from high volatility in commodity prices, declining levels of education (human capital) and institutional weaknesses such as rent seeking and corruption. Current empirical studies highlight that the impact of commodity price shocks on growth varies significantly depending on the time horizon, commodity type, and the quality of institutional development in countries. For example, in countries with weak corporate governance, it has been seen that booms in non-agricultural commodities, particularly energy and metals, have negative long-term effects on growth and overshadow initial short-term income gains. On the other hand, long-term historical perspectives from the 17th century to the present provide empirical evidence supporting the Prebisch-Singer hypothesis, which argues that primary commodity prices tend to fall in real terms compared to manufactured goods. Theoretical models argue that long-term economic growth rates are independent of permanent changes in commodity prices (super-neutrality), suggesting that price movements only affect growth through short-term transmission dynamics and aggregate factor productivity. Furthermore, China's rapid industrialization and urbanization since the beginning of the 21st century have deepened the financialization of commodity markets and taken the growth-price relationship to a new dimension. In the post-financialization era, the link between economic growth and commodity prices has been found to have at least tripled, making developing countries more vulnerable to global shocks. Finally, it was concluded that the impact of positive and negative shocks in commodity prices on growth is asymmetric, and that growth is primarily negatively affected by negative price shocks in the short term, while price increases have a positive effect on GDP in the long term.

This study examines the impact of international commodity import prices on economic development in different regions. For the G7 countries, analyses were conducted considering the specific characteristics of each country, yielding country-specific results which are then reported.

2. Literature Review

A review of past literature on the subject reveals that while some studies argue that increases in commodity prices and abundant natural resources support economic growth, others suggest that this effectuates a "natural resource curse" that negatively affects growth in the long term. More recent

studies emphasize that the effect depends on countries' institutional structure, level of economic diversification, and the direction of commodity price shocks. Studies arguing for the positive effects of natural resources and commodity prices on economic growth suggest that commodity revenues can stimulate growth through investment, government spending, and infrastructure financing. Sala-i-Martin, Doppelhofer, and Miller (2004), in their study analyzing the determinants of long-term growth, show that natural resources do not have a direct negative impact on growth. Similarly, Brunnschweiler and Bulte (2008) and Alexeev and Conrad (2009) prove that abundance of natural resources can be compatible with economic growth under proper macroeconomic policies and institutional structures. Raddatz (2007) found that commodity price shocks in low-income countries have a positive short-term effect on economic growth. Enilov M. (2024) showed that commodity prices generally have a strong ability to predict future economic growth, but this dependence has increased at least threefold with the financialization of commodity markets and developing countries have become more dependent on commodity prices than developed countries in this process.

In contrast, the literature supporting the natural resource curse hypothesis argues that increases in commodity prices slow economic growth in the long run. Sachs and Warner (2001) and Gylfason, Herbertsson, and Zoega (1999) prove that dependence on natural resources is associated with poor growth performance. The main economic channels of this negative relationship include the Dutch disease, high volatility in commodity prices, and a decline in human capital investment. According to Sachs and Warner (2001), increases in commodity prices lead to an appreciation of the real exchange rate, weakening the competitiveness of the manufacturing sector and limiting economic diversification. Gylfason (2001) argues that natural resource revenues reduce investments in education and human capital.

Volatility in commodity prices is also seen as a significant source of negative impacts on growth. Deaton (1999) states that fluctuations in commodity prices increase income uncertainty and lead to macroeconomic instability, particularly in African economies. Van der Ploeg and Poelhekke (2009) show that commodity price volatility negatively affects investment decisions and puts pressure on growth. Similarly, Venables (2016) emphasizes that the economic development process can be disrupted if natural resource revenues are not managed effectively.

Studies arguing that the impact of commodity prices on growth is decided by institutional structure also hold a significant place in literature. Mehlum, Moene, and Torvik (2006) show that in countries with strong institutions,

natural resource revenues support economic growth, while in countries with weak institutions, they negatively affect growth due to rent-seeking and inefficient public spending. Tornell and Lane (1999) argue that natural resource revenues suppress economic growth through the "voracity effect" by increasing the struggle for distribution among political elites. Collier and Goderis (2012) show that commodity price shocks can support growth in the short term, but this effect can reverse in the long term.

In recent years, literature has focused on the asymmetric effects of commodity price shocks. Dehn (2000) argued that negative commodity price shocks have lasting and strong negative effects on economic growth, while positive shocks have no significant long-term effect. Deaton and Miller (1995) also show that commodity price increases boost incomes in the short term, but this effect is not sustainable. Addison, Ghoshray, and Stamatogiannis (2016) found that the effects of agricultural commodity price shocks on growth in Sub-Saharan Africa were weak and asymmetric. Tahar et al. (2021) found that in commodity-dependent countries, commodity prices have an asymmetric effect on economic growth. In the long run, price increases boost GDP more strongly than price decreases, while in the short run, growth is only negatively affected by negative shocks.

A limited number of studies that examine the commodity-growth relationship from the opposite perspective argue that economic growth can affect commodity prices. Elekdag et al. (2008) and Cheung and Morin (2007) show that global economic growth and especially increased demand in emerging Asian economies are decisive factors in deciding oil and metal prices. Arbatli and Vasishtha (2012) and Roache (2012) prove that economic activity shocks in the US and China lead to significant fluctuations in global commodity prices. Ferraro and Peretto (2018) show that long-term economic growth is independent of changes in commodity prices (super-neutrality), and that prices only affect growth through short-term transmission dynamics.

In summary, the relationship between commodity prices and economic growth has not reached a clear consensus in literature. The direction and size of the effect vary depending on the type of commodity, the direction of price shocks, the institutional structure of the country, and the econometric method used. In this context, it is believed that studies examining the effects of commodity prices on economic growth using advanced and flexible methods will make significant contributions to literature and the policy-making process.

3. Methodology

This study examines the long-term relationship between economic growth and commodity import prices in G7 countries using annual panel data from 1962–2024. Economic growth is represented by the logarithm of real gross domestic product and commodity prices are represented by the logarithm of the Commodity Import Price Index (lncıpı). The Commodity Import Price Index data, calculated by the World Bank, was taken from the IMF database, while the economic growth data was taken from the World Bank database. Given the prominent level of economic and trade integration among G7 countries, cross-sectional dependence and country-specific dynamics have been given consideration in the analysis. First, cross-sectional dependence in the panel was examined using the CD, CDw, CDw+, and CD* tests developed by Pesaran (2015, 2021), Juodis and Reese (2021), Fan et al. (2015), and Pesaran and Xie (2021). After finding the presence of cross-sectional dependence, the stationarity properties of the variables were analyzed using the CİPS unit root test developed by Pesaran (2007). The CIPS test allows for the determination of the degree of integration of the series in the panel, taking cross-sectional dependence into account. The existence of a long-term relationship between variables was investigated using the Westerlund (2007) panel cointegration test, which allows for heterogeneity and cross-sectional dependence. Furthermore, the homogeneity of slope coefficients was assessed through tests developed by Pesaran and Yamagata (2008) and Blomquist and Westerlund (2013). Based on the findings, the AMG (Augmented Mean Group) estimator developed by Bond and Eberhardt (2009) and Eberhardt and Teal (2010), which considers cross-sectional dependence through common dynamic factors and allows the estimation of country specific long-term coefficients, was preferred. The AMG equation analyzed is as follows:

$$lngdp_{it} = a_i + \beta_i lncıpı_{it} + \gamma_i t + \lambda_i \hat{f}_t + \varepsilon_{it} \quad (1)$$

Where:

i denotes countries and t denotes time.

$lngdp_{it}$: represents the natural logarithm of real gross domestic product, serving as a proxy for economic growth in country i at time t.

$lncıpı_{it}$: denotes the natural logarithm of the Commodity Import Price Index, capturing international commodity price movements faced by country i.

a_i : is the country specific intercept, reflecting unobserved heterogeneity across countries.

β_i : represents the country specific long-run elasticity of economic growth with respect to commodity import prices.

t : is a deterministic time trend accounting for long-term structural changes.

$\hat{f}_t$: denotes the unobserved common dynamic factor obtained from the first stage AMG estimation, capturing cross-sectional dependence arising from global shocks.

λ_i : is the factor loading associated with the common dynamic process, allowing the impact of global shocks to vary across countries.

ε_{it} : is the idiosyncratic error term.

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. dev.	Min	Max
lngdp	441	28.409	.8464642	26.44785	30.74757
lncıpı	441	27.02174	.3909442	26.25491	27.83419

Source: Author' calculations.

Table 1 presents descriptive statistics for the panel dataset covering the period 1962–2024 for G7 countries. There are 441 observations for both variables. The logarithm of real GDP (lngdp) has a mean of 28.41, and a standard deviation of 0.85 shows relatively limited variability between countries and time. The meaning of the lncipi variable is 27.02, and its standard deviation is 0.39; this suggests that commodity import prices have followed a more stable trend over the long term. The difference between the minimum and maximum values of both variables reveals that there are no extreme observations in the panel and that the data exhibits a suitable distribution for long-term analyses.

4. Results

In panel data analysis, finding cross-sectional dependence is crucial as a starting point. Deciding cross-sectional dependence is then a decisive factor in selecting later tests.

Table 2. Testing for Weak Cross-Sectional Dependence

Variables	CD	CDw	CDw+	CD*
lngdp	35.53	15.43	178.23	-104.40
	(0.000)	(0.000)	(0.000)	(0.000)
lncıpı	36.14	15.48	181.10	4.27
	(0.000)	(0.000)	(0.000)	(0.000)

Note: CD, CDw, CDw+, and CD* refer to the cross-sectional dependence tests proposed by Pesaran (2015, 2021), Juodis and Reese (2021), Fan et al. (2015), and Pesaran and Xie (2021), respectively. Source: Author' calculations.

The cross-sectional dependence test results in the table show that the null hypothesis of cross-sectional independence for the variables lngdp and lncıpı is statistically strongly rejected under all tests (CD, CDw, CDw+, and CD*) ($p<0.01$). This finding reveals that economic growth and commodity import prices among G7 countries are interdependent due to common global shocks and cross-country spillover effects. Therefore, second-generation unit root tests that take cross-sectional dependence into account should be used in the analyses. The Pesaran (2007) CİPS test was used to determine the stationarity of the series.

Table 3. Pesaran Panel Unit Root Test

		Level			
Variables	Model	CV %10	CV %5	CV %1	CİPS
lngdp	constant	-2.21	-2.33	-2.54	-1.687
	cons+trend	-2.72	-2.83	-3.04	-2.580
lncıpı	constant	-2.21	-2.33	-2.54	-2.053
	cons+trend	-2.72	-2.83	-3.04	-2.358
		First Difference			
lngdp	constant	-2.21	-2.33	-2.54	-5.550***
	cons+trend	-2.72	-2.83	-3.04	-5.794***
lncıpı	constant	-2.21	-2.33	-2.54	-6.190***
	cons+trend	-2.72	-2.83	-3.04	-6.420***

Note: *** indicates stationarity at the 1% significance level. **Source:** ***Author' calculations.***

Pesaran (2007) CİPS test shows that the variables are stationary in the first difference I (1) for constant and constant+trend models. Subsequently

Pesaran and Yamagata (2008) and Blomquist Westerlund (2013) tests were applied to decide the homogeneity of the slope coefficients in the panel.

Table 4. Testing for Slope Heterogeneity

Pesaran and Yamagata (2008)	Test Statistic	p-value
$\tilde{\Delta}$	[-0.729]	0.466
$\tilde{\Delta}_{adj.}$	[-0.747]	0.455
Blomquist and Westerlund (2013)		
$\tilde{\Delta}$	[-0.501]	0.616
$\tilde{\Delta}_{ajd.}$	[-0.514]	0.607

Source: Author' calculations.

The table results show that the null hypothesis that the slope coefficients are homogeneous cannot be rejected in terms of both homogeneity tests. The p-values of the test statistics for the Pesaran and Yamagata (2008) test are 0.466 and 0.455, respectively, and are statistically insignificant. Similarly, the p-values corresponding to the test statistics obtained in the Blomquist and Westerlund (2013) test are 0.616 and 0.607. These findings show that the slope coefficients do not differ significantly among the countries including the panel and that the relationship between the variables shows a statistically homogeneous structure. After this stage, the existence of a cointegration relationship between the variables was analyzed using the ECM (Error Connection Test) panel cointegration test developed by Westerlund (2007).

Table 5. Cointegration tests

Statistic	Value	Z-value	P-value
Gt	-2.638	-2.533	0.006
Ga	-3.763	1.642	0.950
Pt	-6.987	-3.176	0.001
Pa	-3.518	0.424	0.664

Source: Author' calculations.

The Gt statistics based on the group mean ($p = 0.006$) and the Pt statistic based on the panel mean ($p = 0.001$) are statistically significant and show the presence of cointegration. In contrast, the Ga ($p = 0.950$) and Pa ($p = 0.664$) statistics are insignificant and do not support the cointegration hypothesis. In the Westerlund (2007) approach, the significance of the Gt and Pt tests indicates that a long-term equilibrium relationship exists in at least some

cross-sectional units. Consequently, evidence of cointegration was found for at least some cross-sectional units. Therefore, it is necessary to obtain and interpret separate results for each country. Due to cross-sectional dependence, the AMG (Augmented Mean Group) estimator developed by Bond and Eberhardt (2009) and Eberhardt and Teal (2010) were preferred for deciding the long-term relationship between variables on a country-specific basis.

Table 6. Augmented Mean Group Results

Dependent Variable (lngdp)	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]
			United States		
lncıpı	-.0350388	.0272351	-1.29	0.198	-.0884187 .0183411
CDF[1]	1.141175	.0274678	41.55	0.000	1.087339 1.195011
constant	29.72203	.7124728	41.72	0.000	28.32561 31.11845
			United Kingdom		
lncıpı	.0029086	.0330029	0.09	0.930	-.0617759 .0675932
CDF	.8851554	.024064	36.78	0.000	.8379909 .9323199
constant	27.2433	.8796353	30.97	0.000	25.51925 28.96735
			Canada		
lncıpı	.0269986	.0153161	1.76	0.078	-.0030203 .0570176
CDF	1.070216	.0122913	87.07	0.000	1.046125 1.094306
constant	25.68831	.4060747	63.26	0.000	24.89242 26.4842
			Japan		
lncıpı	-.2542343	.0414933	-6.13	0.000	-.3355596 -.172909
CDF	1.238811	.0357752	34.63	0.000	1.168693 1.308929
constant	34.27396	1.095802	31.28	0.000	32.12623 36.42169
			Italy		
lncıpı	-.1698839	.0324507	-5.24	0.000	-.2334862 -.1062817
CDF	.8661099	.0239133	36.22	0.000	.8192406 .9129791

1 CDF: Common Dynamic Factor refers to the AMG augmentation term capturing unobserved common shocks.

constant	31.67625	.8630331	36.70	0.000	29.98473 33.36776
			Germany		
lncıpı	-.0682722	.009544	-7.15	0.000	-.0869782 -.0495662
CDF	.857503	.0079882	107.35	0.000	.8418464 .8731596
constant	29.42656	.2523563	116.61	0.000	28.93195 29.92117
			France		
lncıpı	-.0328056	.0078846	-4.16	0.000	-.0482591 -.017352
CDF	.9556687	.0067388	141.82	0.000	.9424609 .9688765
constant	27.98663	.2083594	134.32	0.000	27.57825 28.395

Source: Author' calculations.

The AMG results presented in Table 6 show that the long-term impact of commodity import prices on economic growth in G7 countries differs among countries. The lncıpı coefficients are statistically insignificant for the US, UK, and Canada. This shows that commodity import prices do not play a decisive role in regional economic development in the long term in these countries. In contrast, the lncıpı coefficients are negative and statistically significant for Japan, Italy, Germany, and France, showing that increases in commodity import prices suppress long-term economic development in these countries. The Common Dynamic Factor (CDF) coefficient is positive and highly significant across all countries, proving that common global shocks have a strong and shared impact on the development dynamics of G7 economies. These findings reveal that the effects of commodity price shocks on growth differ depending on country-specific economic structure and external trade dependency.

5. Conclusion

This study examines the long-term impact of commodity import prices on economic growth in G7 countries during the period 1962–2024 using the Augmented Mean Group (AMG) method, which considers cross-sectional dependence and inter-country heterogeneity. The findings reveal that the effects of commodity import prices on economic growth differ significantly among countries. According to AMG's forecast results, commodity import prices have a negative and statistically significant impact on economic growth

for Japan, Italy, Germany, and France. This show increases in commodity import costs in these countries, in the long- run, increase production costs and limit growth performance. In contrast, the lncıpı coefficients are statistically insignificant for the US, the UK, and Canada. Therefore, it is accepted that commodity import prices do not play a decisive role in long-term growth in these countries. Japan is a heavily reliant economy on imports for energy and raw materials, and increases in commodity import prices raise production costs, negatively affecting growth. In Italy, the high demand for intermediate goods and energy inputs in industrial production means that import commodity price shocks put pressure on economic activity. Germany has a production structure heavily reliant on commodity and energy inputs, particularly in sectors such as automotive, machinery, and chemicals. Therefore, increases in commodity import prices raise production costs, negatively affecting industrial production and so economic growth. Similarly, in France, the production structure's reliance on industrial and energy inputs means that increases in imported commodity prices put pressure on growth through the cost channel. Furthermore, since both countries are dominated by export-oriented growth models, increasing input costs weaken international competitiveness and limit growth performance.

The fact that the Common Dynamics Factor (CDF) is positive and significant for all countries shows that common shocks in global commodity markets and international economic conditions have a significant impact on the growth dynamics of G7 countries. In this context, the findings suggest that policy responses to increases in commodity import prices should be designed on a country-by-country basis, considering the economic structures and levels of external dependence of each country. Especially in countries more dependent on commodities, diversifying supply, increasing domestic intermediate input production, and strengthening protective mechanisms against commodity price volatility appear critical for long-term growth.

Future studies could broaden the scope of research countries, for example, including G20 or developing countries, to examine how the long-term effects of commodity import prices on economic growth vary at distinct levels of economic development. Furthermore, sector-specific analyses, such as those for industry, agriculture, and services, could reveal the impact of commodity price shocks on different sectors of the economy. While the impact of short-term fluctuations and transient shocks can be assessed using models such as VAR or VECM, the inclusion of other macroeconomic variables, such as exchange rates or trade volumes, could provide a more comprehensive understanding of the impact of commodity prices on growth.

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