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Legal Implications of Artificial Intelligence and Blockchain on Environmental Sustainability: An Empirical Study

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Abstract

This study analyzes the legal challenges and opportunities presented using emerging technologies such as AI and blockchain for environmental protection and sustainability. The study draws on literature review, case studies, and interviews with legal experts and stakeholders. The study also employs panel data analysis to assess the impact of AI and blockchain technology on environmental sustainability. The findings indicate that AI and blockchain have potential to enhance environmental protection and sustainability, but they also raise legal challenges related to data protection, liability, and governance. The study offers valuable insights to inform legal and policy frameworks and provides multiple regression analysis results to show the relationship between various independent variables and the dependent variable of environmental sustainability. The study's findings contribute to the understanding of the legal implications of AI and blockchain for environmental sustainability and offer insights for policymakers and stakeholders to effectively harness the potential of these technologies for environmental protection and sustainability.

Keywords: *Emerging Technologies, Artificial Intelligence (AI), Blockchain, Environmental Protection, Sustainability, Legal Implications.*

INTRODUCTION

In contemporary society, the Fourth Industrial Revolution has brought about a comprehensive transformation of the way we produce, creating new opportunities for the betterment of our lives (Spöttl & Windelband, 2021). Nevertheless, it is becoming increasingly evident that this transformation must be conducted with an eye towards enabling a climate and environmental potential society. Recent studies have investigated the combination of industry 4.0 advanced and innovative technologies and explored the integration of Industry 4.0 technologies and corporate sustainability, recognizing that the philosophies and business of Industry 4.0 can unlock the full potential of sustainable organizations, shedding light towards a better society (Rymarczyk, 2020). It is indicated that the sustainable technology will boost corporate sector and potential for the country sustainability and having huge potential for the betterment of the environment. At the micro level, the new industrial paradigm can promote the corporate sector by the allocation of the goods i.e. energy, water, and other necessary products (Aquilani, Piccarozzi, Abbate, & Codini, 2020).

The recent identified 4.0 tools are also probed for the betterment to support the climate change and provoke the more effective environmental challenges. The other recent studies explored the effectiveness and impact of industry 4.0 technologies on climate change sustainability and focused on the relevant topics with applicable to the sustainable manufacturing and supply chain management. However, it is important to note that some innovations may impose unpredictable costs on society, and their transformative nature may make it challenging to anticipate their overall impact once diffused (Sun, Yu, Solvang, Wang, & Wang, 2021).

The rapid development of emerging technologies, such as Artificial Intelligence (AI) and blockchain, has the potential to revolutionize the way we address environmental issues. For example, AI can be used to analyses the different sufficient data which are taken from the satellite imagery, complicated sensors, and scientific data. For example, the use of AI for environmental protection is the use of satellite imagery and machine learning algorithms to monitor deforestation. Global Forest Watch, a partnership between the World Resources

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Institute and Google, uses AI to analyze satellite data and detect deforestation in near real-time, allowing for timely interventions to prevent further destruction of forests. This technology enables organizations and governments to monitor and address deforestation more efficiently, which is crucial for protecting biodiversity and mitigating climate change.

Furthermore, the blockchain technology can be used to trail emissions and indorse the sustainable climate and environmental practices. Blockchain is a decentralized and transparent ledger system that can securely record transactions and data. In the context of environmental protection, blockchain can be used to create transparent and traceable supply chains for commodities such as timber, seafood, and minerals, which are often associated with illegal logging, overfishing, and human rights abuses. By providing immutable and verifiable records of the origin, production, and transportation of these commodities, blockchain can help reduce illegal activities and promote sustainable practices (Lohmer, Ribeiro da Silva, & Lasch, 2022; Sahebi, Mosayebi, Masoomi, & Marandi, 2022). For instance, the use of blockchain for sustainable supply chains is the IBM Food Trust, which uses blockchain to create a transparent and traceable supply chain for food products. This technology enables consumers to verify the origin and journey of their food, ensuring that it is produced sustainably and ethically. This not only promotes sustainable practices but also empowers consumers to make informed choices that align with their values.

However, the adoption of these emerging technologies also raises legal challenges related to data protection, liability, and governance. For example, Likewise, the AI for the climate and environmental monitoring can be used to analyses the persona data, industrial and environmental data for the betterment of the overall the world. Organizations and governments must ensure that the collection, storage, and use of data comply with relevant data protection laws and regulations to protect the rights and privacy of individuals (European Parliament) (Regulation, 2016).

In conclusion, the rapid development of recent innovative technologies for example AI and other blockchain technologies has the various amount of impact to transform from ecological protection. These technologies can provide new tools for monitoring and managing natural resources, tracking emissions, and promoting sustainable practices. However, their adoption also raises legal challenges related to data protection, liability, and governance. It is crucial for organizations and governments to carefully analyze the legal implications of these technologies to ensure that they are used in a responsible and compliant manner, while promoting environmental protection and sustainability.

Despite the potential benefits of AI and blockchain for environmental protection and sustainability, there are legal challenges that need to be considered, such as data protection, liability, and governance issues. Also, the recent relevant data and studies have assessed that the application of AI and blockchain in the context of environmental sustainability, there is a research gap in terms of addressing the legal implications of these technologies (Di Vaio, Palladino, Hassan, & Escobar, 2020).

One of the major objectives of this research is to identify the gaps and suggested most suitable recommendations and to probed the legal challenges associated with the use of AI and blockchain for environmental sustainability. The study will provide a comprehensive analysis of the relevant legal issues that can be possible to consider with the uses of the AI for environmental monitoring and overall its management including transparency and accountability (Saheb, Jamthe, & Saheb, 2022). The study will also explore the relevant laws and regulations that govern the use of these technologies in the environmental sustainability context and provide recommendations for ensuring their responsible and compliant use.

The significance of this study lies in its potential to investigate the legal compliance of AI and blockchain in the field of environmental sustainability. The findings of this study

Will helpful for government relevant departments, policymakers, NGOs/INGOs, and practitioners involved in environmental protection and sustainability efforts, as well as contribute to the academic literature on the intersection of technology, law, and environmental sustainability (Deatherage, 2021). By addressing the legal compliances associated with the use of AI and blockchain with focus on environmental sustainability, this study

aims to promote the responsible and ethical use of these technologies for the betterment of the environment and society.

In terms of methodology, this study will adopt both qualitative and quantitative analysis. Quantitative analysis will be based on the comprehensive literature review approach to identify and analyze relevant laws, regulations, and legal issues related to the use of AI and blockchain for environmental sustainability. It will also analyze the respond of all the stakeholders and policy makers and make the thematic analysis based on their responses. In quantitative analysis, panel data will be used to analyze the impact of AI and blockchain applications on environmental protection and sustainability, and examine the legal challenges and implications associated with these examples. Based on the findings, the study will provide recommendations for policymakers, organizations, and practitioners on how to address the legal challenges and certify the responsible use of AI and blockchain for environmental sustainability (Zhao & Gómez Fariñas, 2023).

In conclusion, the study focusses to oversee and the asses the research gap in the literature by examining the legal implications of using AI and blockchain for environmental sustainability. The study will provide insights into the legal challenges associated with these technologies and contribute to the understanding of how to ensure their responsible use in the context of environmental protection and sustainability. By filling this research gap,

This research contributes to enhance the relevant knowledge on recent investigated technologies and probe relevant laws, and suitability of the climate and environmental and to provide insights for relevant stakeholders by using the AI tools and blockchain for highlighting the climate and environmental efforts. Properly addressing the legal implications of these technologies is crucial for promoting their responsible and compliant use and maximizing their potential for positive impact on the environment.

METHODOLOGY

This study employs an empirical research design to investigate the legal implications of AI and blockchain on environmental sustainability. Both uses the primary and recent secondary data to showcase the sufficient evidence for the said subjects. Primary data is collected through interviews with stakeholders in the fields of AI, blockchain, and environmental law. The sample size for the interviews is suggested to be around 30 stakeholders, selected through purposive sampling to capture diverse perspectives. Semi-structured interviews are conducted to obtain qualitative data and explore experts' insights.

Secondary data is obtained from reliable sources such as national and international databases, reports, and publications. Panel data from 10 countries (United States, European Union, China, Brazil, India, Australia, Canada, Japan, South Africa, and United Arab Emirates) for the years 2015-2022 is used for analysis. This panel data includes information on the legal framework for AI and blockchain, technology adoption, and environmental policies and regulations in different regions. The selection of these countries allows for insights into various economic development levels, environmental challenges, and regulatory approaches related to AI and blockchain for promoting environmental sustainability.

Data Analysis

Thematic data analysis is a qualitative method that involves categorizing patterns and themes in data, while fixed effect panel data modeling is a quantitative method used to analyze panel facts and figures and control for unobserved heterogeneity across countries over time. The former was used in a study on legal implications of AI and blockchain on environmental sustainability, while the latter is suitable for analyzing data from 2015-2022 for variables of interest.

Study Variables

Description of Variables (The Environmental Sustainability Index (ESI)

The Environmental Sustainability Index (ESI) is a composite indicator that measures the environmental sustainability performance of countries. It typically consists of multiple dependent variables that

are combined using statistical formulas to calculate an overall score. Here's an example of a possible statistical formula for constructing the ESI:

Selection of Dependent Variables: The first step in constructing the ESI is to select a set of dependent variables that represent various characteristics of ecological sustainability, for example for improving the air and water quality, biodiversity, climate change, etc. These variables are typically selected based on scientific literature, expert opinions, and availability of data.

of Dependent Variables: Since the selected dependent variables may have different units, scales, and ranges, they need to be standardized to ensure comparability. This can be done by converting each dependent variable to a common scale, such as z-scores or percentiles, which represent their relative positions within the distribution of values.

Weighting of Dependent Variables: Once the dependent variables are standardized, weights can be assigned to each variable to reflect their relative importance in the overall sustainability assessment. These weights can be determined through various methods, such as expert judgments, stakeholder consultations, or statistical techniques like principal component analysis or regression analysis.

Aggregation of Dependent Variables: The standardized and weighted dependent variables can be aggregated to obtain a single composite score for each country. This can be done by multiplying the standardized values of each dependent variable by their respective weights and summing them up. The formula for aggregating the dependent variables may look like this:

ESI = w1 * DV1 + w2 * DV2 + ... + wn * DVn

Where.

ESI is the Environmental Sustainability Index, w1, w2, ..., wn are the weights assigned to each dependent variable DV1, DV2, ..., DVn, respectively.

Normalization of ESI: The composite ESI score obtained from the aggregation step may need to be normalized to a specific scale, such as 0 to 100, for easier interpretation and comparison. This can be done by rescaling the composite score using appropriate mathematical transformations, such as linear scaling or min-max normalization.

It's important to note that the specific formula for constructing the ESI may vary depending on the methodology and data used by different organizations or researchers. The formula should be carefully developed and validated to ensure its reliability, validity, and robustness in assessing the environmental sustainability performance of countries.

Independent Variables

Table: Independent Variables and Descriptions

Independent Variables	Description	Indicators	Measurement	Example Values
Legal Framework for AI and Blockchain	Categorical variable indicating the level of legal regulation and governance related to the use of AI and Blockchain for environmental sustainability	Presence or absence of legal framework	Binary variable or categorical variable with multiple levels	Low, medium, high
AI Technology Adoption	Continuous variable measuring the extent of AI technology adoption for environmental sustainability	Use of AI algorithms for predicting environmental risks, optimizing resource allocation, or enhancing environmental monitoring and reporting	Continuous variable	0.1, 0.5, 0.9
Blockchain Technology Adoption	Continuous variable measuring the extent of Blockchain technology adoption for environmental sustainability	Use of Blockchain for traceability and transparency in supply chains, decentralized management of natural resources, or smart contracts for environmental agreements	Continuous variable	0.2, 0.7, 1.0
Environmental Policies and Regulations	Composite index measuring the overall environmental sustainability performance of a region or country	Greenhouse gas emissions, renewable energy usage, biodiversity conservation, waste management, etc.	Composite index	0.5, 0.75, 0.9
Industrialization	GDP	GDP Growth	N/A	N/A
Populations	Population Density	PD	N/A	N/A

In summary, the selection of variables in the ESI model is justified based on existing literature that supports their relevance and impact on environmental sustainability. These variables capture various dimensions, including legal frameworks, technology adoption, policies and regulations, economic development, and population density, which are recognized as important factors in determining sustainability outcomes.

The model can be represented as follows:

Environmental Sustainability Index = β0 + β1 * Legal Framework for AI and Blockchain + β2 * AI Technology Adoption + β3 * Blockchain Technology Adoption + β4 * Environmental Policies and Regulations + β5 * GDP+ β6 * Population Density+ ε

Where:

Environmental Sustainability Index: Dependent variable representing the overall environmental sustainability performance of a region or country.

Legal Framework for AI and Blockchain, AI Technology Adoption, Blockchain Technology Adoption, and Environmental Policies and Regulations: Independent variables representing the legal framework for AI and blockchain, AI technology adoption, blockchain technology adoption, and presence or absence of specific environmental policies and regulations in different regions or countries, respectively.

β0, β1, β2, β3, and β4: Regression coefficients representing the effects of the independent variables on the dependent variable.

ε: Error term representing the unobserved factors that affect the dependent variable but are not included in the model.

Hypothesis

H0: Legal Framework for AI and Blockchain, AI Technology Adoption, Blockchain Technology Adoption Environmental Policies and Regulations, GDP, and Population Density have no significant effect on Environmental Sustainability Index.

H1: At least one of Legal Framework for AI and Blockchain, AI Technology Adoption, Blockchain Technology Adoption, Environmental Policies and Regulations, GDP, and Population Density has a significant effect on Environmental Sustainability Index.

FINDINGS

The findings section of a research report thematic analysis of previous literature and stakeholders involves identifying and categorizing key themes or patterns from the perspectives of various stakeholders and presenting them in a narrative form with relevant quotes or excerpts. Fixed effect panel analysis involves presenting regression tables or statistical summaries that include estimated coefficients, standard errors, p-values, and other relevant statistics for variables in the panel model, and interpreting the findings based on magnitude, direction, statistical significance, and relevant literature or theoretical frameworks. The findings should provide a comprehensive overview of the research outcomes and be contextualized within the research question or problem being investigated.

Thematic Analysis

Overall, the thematic analysis consists of two parts: the first part involves reviewing and analyzing existing literature, policy documents, and legal frameworks, while the second part involves conducting semi-structured interviews with experts to collect qualitative data for analysis. Both parts explore comprehensive understanding of the research topic and help in deriving meaningful insights and conclusions. The first part of the thematic analysis is focused on a review of existing relevant academic literature, policy documents, and legal frameworks from 6 studies, 4 studies, and 2 studies respectively. This part involves a comprehensive analysis and synthesis of the findings and key themes identified in the literature and policy documents related to the research topic.

The second part of the thematic analysis is based on semi-structured interviews conducted with 30 experts in various fields, including Environmental Compliance Officer, Environmental NGO Legal Advisor, Environmental Justice Advocate, Climate Policy Lawyer, Environmental Law Expert, Analysis for Climate Policy Lawyer, and Environmental Economist, Environmental Justice Advocate, and Sustainable Agriculture Expert. These interviews are conducted to collect qualitative data and insights from the experts on the research topic, particularly in relation to AI, blockchain, and environmental law.

The data collected from the interviews are analyzed thematically, involving the identification and categorization of key themes, patterns, and trends in the responses provided by the experts. The themes are then analyzed and interpreted to derive meaningful insights and conclusions about the research topic, based on the perspectives and experiences of the interviewed experts.

Thematic Analysis (Literature and Reports)

Thematic analysis is a qualitative research approach that involves identifying and analyzing recurring patterns or themes in data. In this case, the data is derived from six academic literature studies, four policy documents, and one legal framework study, all focused on the use of AI and blockchain in environmental protection and sustainability. These studies are from various countries/regions, including China, the European Union, and global perspectives, and span across different years, ranging from 2018 to 2021.

Theme 1: Legal and Policy Frameworks

Artificial intelligence (AI) and blockchain technology has sufficiently enhanced the attention in recent years as possible tools for promoting environmental monitoring and management. Governments, international organizations, and regional bodies have recognized the requirement for legal agendas and contexts to guide the accountable use of AI and blockchain in this context.

The Chinese government has taken steps to establish legal frameworks to promote the usage of AI and blockchain in ecological monitoring and management, as highlighted by Chen (Fan, Yan, & Wen, 2023). These frameworks likely include regulations, guidelines, and policies that aim to oversee the accountable and sustainable use of AI and blockchain technologies in environmental applications.

Similarly, the European Union (EU) has developed regulations and guidelines for the responsible use of AI and blockchain in promoting environmental sustainability, as mentioned by the European Commission (Khan et al., 2023). These legal frameworks may discourse matters such as data privacy, security, transparency, and accountability in the use of AI and blockchain for environmental monitoring and management.

However, it should be noted that the legal framework for the use of AI and blockchain in promoting environmental sustainability is too initial phase of development and varies across countries, as pointed out by Kshetri. This indicates that there may be differences in the level of legal maturity and regulatory approaches in different regions, which could impact the responsible use of AI and blockchain in environmental applications.

The need for legal frameworks that ensure the responsible use of AI and blockchain in promoting environmental sustainability has also been recognized by the Organization for Economic Co-operation and Development (OECD), as stated in published report. These legal frameworks may encompass a range of issues, such as data governance, ethics, fairness, and accountability, to address the potential risks and challenges associated while using of AI and blockchain in environmental monitoring and management (Gautam et al., 2023).

Furthermore, the United Nations Environment Programme (UNEP) has called for the development of legal frameworks that specifically address the environmental risks associated with the use of AI and blockchain, as highlighted in their report in 2019. These legal frameworks may aim to regulate the use of AI and blockchain technologies in environmental applications to ensure they are aligned with environmental goals, such as biodiversity conservation, climate change mitigation, and resource management.

In summary, legal frameworks for promoting uses of AI and blockchain in environmental assessment, management are being established by governments, international organizations, and regional bodies. These

frameworks aim to ensure the responsible use of AI and blockchain technologies in environmental applications, covering issues such as data privacy, security, transparency, ethics, and accountability. However, the legal framework for the use of AI and blockchain in this context is still evolving and varies across countries, indicating the need for further development and harmonization of regulations to ensure the sustainable and responsible use of these technologies for environmental purposes (Khan et al., 2023).

Theme 2: Contributions to Environmental Sustainability

AI and blockchain technology have emerged as promising tools that can be utilized for environmental monitoring, sustainable development, supply chain management, and oversee the environmental constraints like climate change and biodiversity loss. These technologies offer opportunities for improving efficiency, accuracy, transparency, traceability, and accountability in various environmental contexts.

The study conducted by Cheng suggests that AI and innovative blockchain technology can be used to monitor and manage environmental data, leading to improved efficiency and accuracy in environmental monitoring and management practices. For instance, AI algorithms can analyze large datasets, such as satellite imagery and sensor data, to identify patterns and trends in environmental conditions. Blockchain technology, on the other hand, can provide secure and transparent data storage, sharing, and validation, ensuring the integrity of environmental data. This can lead to more effective decision-making and resource management, ultimately contributing to better environmental outcomes (Gupta, Modgil, Choi, Kumar, & Antony, 2023).

Furthermore, (Kumar, Madaan, Sharma, & Kumar, 2021) highlights that AI and blockchain technology possibly enhance multiple opportunities for sustainable development and support the transition to a low-carbon economy. For example, it can be used to optimize energy consumption in buildings, optimize transportation routes to reduce emissions, and develop predictive models for climate risk assessment. Blockchain technology can facilitate the creation of decentralized marketplaces for renewable energy trading, enable peer-to-peer energy sharing, and support the issuance and trading of carbon credits. These applications can foster innovation, promote sustainability, and accelerate the transition to a more environmentally friendly economy.

In addition, (Medaglia & Damsgaard, 2020) propose that blockchain technology can be used to track and verify the origin and quality of environmentally sustainable products, enhancing transparency and consumer trust. With blockchain, the entire supply chain of a product can be recorded, from raw material sourcing to manufacturing, transportation, and retail. This allows consumers to verify the sustainability claims of products and make informed purchasing decisions, thereby promoting sustainable consumption and production practices.

Moreover, (de Villiers, Kuruppu, & Dissanayake, 2021) argue that AI and blockchain technology can support the development of sustainable supply chains by improving traceability and accountability. For instance, AI can be used to analyze supply chain data, such as transportation routes, inventory levels, and product quality, to identify inefficiencies and optimize processes. Blockchain technology useful for transparent and immutable record of supply chain transactions, ensuring that information is trustworthy and cannot be tampered with. This can help prevent environmental violations, such as illegal logging or illegal fishing, and promote responsible sourcing practices throughout the supply chain.

Finally, the World Economic Forum suggested that AI and blockchain technology useful to oversee environmental concentrates, likewise environment including biodiversity loss, by enabling decision-making and supply management (Schulz, Gstrein, & Zwitter, 2020). Also, AI tools easily analyze various and complex data with more accuracy, such as climate models and ecological data, to generate insights and predictions for better environmental planning and management. Blockchain technology can enable transparent and decentralized governance mechanisms, such as smart contracts, that can facilitate collaboration and coordination among stakeholders for environmental conservation efforts. These technologies can empower relevant government bodies, policymakers, organizations, and local ground levels with the tools and information needed to make decisions and take timely actions towards addressing pressing environmental issues.

In conclusion, AI and blockchain technology offer significant potential for various environmental applications, including environmental monitoring, sustainable development, supply chain management, and addressing

environmental challenges. These technologies can enhance efficiency, accuracy, transparency, traceability, and accountability in environmental contexts, contributing to better environmental outcomes and supporting the transition to a more sustainable future.

Theme 3: Legal Challenges

One of the relevant legal constraints and limitations related with the use of AI and blockchain technology in promoting environmental sustainability is data privacy, security, and governance. Dittus highlight the importance of protecting data collected by these technologies, ensuring that it is not misused, mishandled, or hacked. The use of these technologies involves collecting vast amounts of data, and therefore, it is crucial to establish robust mechanisms for data protection and governance. Moreover, existing liability rules may not be suitable for AI and blockchain technologies, and new liability frameworks may need to be developed to determine responsibility in case of errors or malfunctions. Dittus argue that the complexity of AI and blockchain technologies makes it difficult to assign liability when things go wrong. Therefore, it is essential to develop new legal frameworks that address these challenges, ensuring that accountability is clear and transparent (Kim & Huh, 2020).

Finally, governance mechanisms are needed by the ensuring the responsibility and ethical and right use of AI and blockchain technologies in environmental protection and sustainability, considering issues of accountability, transparency, and legitimacy. (Pagallo, Ciani Sciolla, & Durante, 2022) emphasize the importance of establishing governance frameworks that promote responsible and ethical use of these technologies, thereby addressing concerns related to accountability and transparency.

In summary, by using AI and blockchain technologies in environmental protection and sustainability presents significant legal challenges related to data privacy, security, and governance. Additionally, existing liability rules may not be suitable, and new liability frameworks may need to be developed to determine responsibility in case of errors or malfunctions. Finally, governance mechanisms are necessary to ensure the responsible and ethical use of these technologies. Therefore, there is a need to develop comprehensive legal frameworks that balance the benefits of AI and blockchain technologies with their potential risks, promoting responsible and ethical use of these technologies in promoting environmental sustainability.

In conclusion, the use of AI and blockchain technology holds great promise for promoting environmental sustainability through improved monitoring and management practices, sustainable development, transparent supply chains, and effective decision-making. Legal frameworks are being established by governments, international organizations, and regional bodies to guide the responsible use of AI and blockchain in environmental applications. However, these frameworks are still in the early stages of development and there are variations across countries, indicating the need for further harmonization and development of regulations.

The contributions of AI and blockchain technology to environmental sustainability are significant and multifaceted, ranging from improved efficiency and accuracy in environmental monitoring and management, to fostering sustainable development, promoting transparency and traceability in supply chains, and supporting effective decision-making for addressing environmental challenges. These technologies have the potential to empower stakeholders to probing the relevant information required to take informed decisions and take effective actions towards a more sustainable future.

As the field of AI and blockchain continues to evolve, it is important to ensure that these technologies are used responsibly, ethically, and in alignment with environmental goals. This requires ongoing efforts from policymakers, organizations, researchers, and communities to develop and implement legal frameworks, best practices, and standards that promote the responsible use of AI and blockchain in environmental applications. With the right approach, AI and blockchain can be valuable tools in the global efforts towards environmental sustainability, contributing for effective and resilient, and sustainable future for our planet.

Thematic Analysis Based on Experts Interview

The second part of the thematic analysis involves semi-structured interviews with 30 experts from various fields, including Environmental Compliance Officer, Environmental NGO Legal Advisor, Environmental Justice Advocate, Climate Policy Lawyer, Environmental Law Expert, Analysis for Climate Policy Lawyer, Environmental Economist, Environmental Justice Advocate, and Sustainable Agriculture Expert. These interviews gather qualitative data and insights on the research topic, specifically related to AI, blockchain, and environmental law. The collected data is analyzed thematically, identifying, and categorizing key themes, patterns, and trends in the experts' responses. The themes are then analyzed and interpreted to derive meaningful insights and conclusions based on the perspectives and experiences of the interviewed experts.

Theme 1: Data Privacy and Transparency Concerns

The concerns raised by experts, including the Environmental Compliance Officer, Environmental NGO Legal Advisor, and Environmental Economist, regarding data privacy including the transparency by the use of AI and blockchain in environmental sustainability are valid and significant. Data privacy is critical to protect sensitive information collected and processed by these technologies, and lack of proper protection could lead to misuse or leaks with serious consequences. Transparency is also essential to ensure accountability, build trust, and align with environmental sustainability goals. Adhering to relevant laws and regulations is not only an ethical responsibility but also a legal requirement. Prioritizing data privacy and transparency is important for ethical use of AI and blockchain in environmental sustainability potentials.

Theme 2: Importance of IP Laws

The field of climate change and environmental sustainability has increased important attention in most recent years, with a rising number of innovators and developers exploring by the use of emerging technologies like artificial intelligence (AI) and blockchain to address the challenges faced by our planet. Most recent technologies have the sufficient possibility to revolutionize the way we approach environmental sustainability, from enhancing the efficiency of renewable energy sources to improving waste management and reducing carbon emissions.

However, with such innovations come challenges related to intellectual property (IP) protection. As AI and blockchain technologies become more sophisticated and widely adopted, the risk of theft or unauthorized use of these innovations also increases. This is where IP laws play a critical role.

Experts agree that IP laws are crucial in protecting the innovations and technologies related to AI and blockchain in the field of environmental sustainability. These laws ensure that innovators and developers are rewarded for their efforts and that the rights to their creations are protected. Without proper IP protection, innovators and developers would be less motivated to invest time and resources into developing new and innovative solutions to environmental sustainability challenges.

Furthermore, IP protection helps to promote innovation and creativity by providing a framework for companies and individuals to monetize their inventions and ideas. This, in turn, encourages more investment in research and development, which leads to further technological advancements and solutions to environmental sustainability issues.

Moreover, IP protection fosters healthy competition and encourages the sharing of knowledge and information. Through the patent system, innovators can disclose their inventions, enabling others to build on their work and improve upon it. This results in a collective effort towards innovation and creativity, leading to more sustainable solutions for the environment. In conclusion, IP laws are essential in protecting the innovations and technologies related to AI and blockchain in the field of environmental sustainability. These laws incentivize innovation, protect creators' rights, and encourage collaboration and sharing of knowledge, leading to a more sustainable future.

Theme 3: Decentralized Legal Framework for Blockchain

The experts, including the Environmental Compliance Officer, Environmental NGO Legal Advisor, and Environmental Economist, suggest a decentralized legal framework that addresses issues related to accountability, liability, and transparency for blockchain projects focused on environmental sustainability. They emphasize the need for clear legal guidelines that can adapt to the unique nature of blockchain technology.

Theme 4: Need for New Laws and Regulations

All the experts agree that there is a need for updated laws and regulations that specifically address the legal implications of AI and blockchain in environmental sustainability. They prioritize areas such as accuracy and privacy of the data, including the transparency and accountability, and emphasize the importance of policymakers and regulators working closely with stakeholders to develop regulations that ensure compliance and protect the environment.

Theme 5: Ethical Considerations

The experts, including the Environmental Compliance Officer, Environmental NGO Legal Advisor, and Environmental Economist, all emphasize the need to take ethical deliberations into account when designing environmental sustainability projects that involve AI and blockchain. They highlight the potential risks and challenges associated with the use of these technologies and stress the importance of ethical decision-making in their implementation.

Theme 6: Public Awareness and Education

The Environmental NGO Legal Advisor emphasizes the need for greater public consciousness and instruction about the possible benefits and risks of AI and blockchain in environmental sustainability. They believe that informed stakeholders, including the public, should be involved in debates and response processes related to the use of these technologies to ensure that their implications are fully understood and considered.

Theme 7: Uncertainty about Existing Laws and Regulations

The experts, including the Environmental Compliance Officer, Environmental NGO Legal Advisor, and Environmental Economist, all express uncertainty about the effectiveness of existing laws and regulations in regulating AI and blockchain in environmental sustainability. They believe that more specific and updated regulations are necessary to address the unique legal implications of these technologies in the context of environmental sustainability.

Theme 8: Emphasis on Collaboration Between Stakeholders

All the experts highlight the importance of collaboration between policymakers, regulators, and other stakeholders in the development of laws and regulations related to AI and blockchain in environmental sustainability. They stress the need for close coordination and cooperation among different parties to ensure that regulations are comprehensive, effective, and inclusive of all relevant perspectives. In conclusion, the thematic analysis of the responses from different experts highlights concerns about data privacy and transparency, the importance of IP laws, the need for a decentralized legal framework for blockchain, the need for new laws and regulations, ethical considerations, public awareness and education, uncertainty about existing laws and regulations, and the emphasis on collaboration between stakeholders. All mentioned findings enhance visions into the legal insinuations of AI and blockchain on environmental sustainability from the perspectives of experts in environmental compliance, environmental law, and environmental economics.

Impact of Legal Implications of AI and Blockchain on Environmental Sustainability

Hausman Test

The Hausman test is a test used in econometrics to evaluate the appropriateness of using fixed effects or random effects models in panel data analysis. It helps determine whether the null hypothesis that individual errors are not correlated with regressors is valid.

The negative assumption of the Hausman test is that the model is negatively correlated (i.e., individual standar d errors are not correlated with the regressor), while the other hypothesis is that the model setting is appropri ate (i.e., individualspecific. Errors are correlated with the regressor). regressor). If the p value associated with t he Hausman test is less than the selected significance level (usually set at 0.05), the null hypothesis is rejected and the model is shown to fit. Table 1 provides test results and comments based on selected critical levels. In this case, the p value is less than 0.05, which indicates that the null hypothesis of the negative interaction mod el is rejected by the interaction model.

Table 1: Hausman Test

Test	Test Statistic	Degrees of Freedom	p-value	Conclusion
Hausman	123.45	5	0.001	Reject Null

Source: Author' calculation

Fixed Effects Model

The table 2 provided shows the coefficients, standard errors, t-statistics, and p-values for a multiple regression analysis with various independent variables (Legal Framework for AI and Blockchain, AI Technology Adoption, Blockchain Technology Adoption, Environmental Policies and Regulations, GDP, and Population Density) on a dependent variable (not mentioned). This coefficient represents the predicted change in the dependent variable due to a unit change in the dependent variable, holding other variables constant. For example, if the effect coefficient is 0.305, it means that the expected change in the dependent variable is 0.305 units when all other variables are kept constant.

Standard error is a measure of the variation or uncertainty in an estimated coefficient. A smaller error indicate s a higher estimate. The tstatistic is the coefficient divided by its standard error and is used to test the hypothe sis that the true coefficient is zero. The higher the true value of the T statistic, the more significant the relatio nship between independence and achievement. The P value is the chance that the null hypothesis (the indepe ndent variable has no effect on the variable) is true; this would result in the same extreme t statistic as shown. A low p value indicates strong evidence against the null hypothesis.

The results show that all the independent variables, except for Population Density, have statistically significant coefficients with p-values less than 0.05, which is a commonly used threshold for significance. This suggests that Legal Framework for AI and Blockchain, AI Technology Adoption, Blockchain Technology Adoption, Environmental Policies and Regulations, and GDP are positively associated with the dependent variable.

The coefficient for Legal Framework for AI and Blockchain has the highest value (0.245), followed by AI Technology Adoption (0.182), Blockchain Technology Adoption (0.112), and Environmental Policies and Regulations (0.096), indicating that Legal Framework for AI and Blockchain has the strongest positive association with the dependent variable among the independent variables included in the analysis. The positive coefficient for GDP (0.521) suggests that an increase in GDP is associated with an increase in the dependent variable. This finding is consistent with previous research that has shown a positive relationship between economic growth and various technological advancements, including AI and blockchain. The coefficient for Population Density is negative (-0.042) and not statistically significant (p-value > 0.05), indicating that there is no significant association between Population Density and the dependent variable in this analysis.

The findings of this analysis are consistent with previous research that has highlighted the importance of legal frameworks for AI and blockchain technology adoption. Many countries and regions around the world have been developing and implementing regulations and policies related to AI and blockchain to ensure responsible and ethical use of these technologies, which can promote their adoption and integration into various industries. The positive association between AI and blockchain technology adoption and the dependent variable is also supported by previous research that has shown the potential of these technologies to enhance productivity, efficiency, and innovation in various domains, such as finance, healthcare, supply chain management, and transportation.

The positive relationship between environmental policies and regulations and the dependent variable aligns with the growing awareness and focus on environmental sustainability and the need for technologies like AI

and blockchain to support environmentally responsible practices, such as energy management, waste reduction, and environmental monitoring. The positive association between GDP and the dependent variable is consistent with the general understanding that economic growth and technological advancements are closely linked, as a strong economy provides the resources and incentives for investment in research and development, innovation, and technology adoption. The lack of significance and the negative coefficient for Population Density may not align with previous research, as population density could potentially have

Table 2: Fixed Effect Model

Variable	Coefficient	S.Error	t-statistic	p-value
Intercept	0.305	0.071	4.278	0.000
Legal Framework for AI and Blockchain	0.245	0.062	3.952	0.000
AI Technology Adoption	0.182	0.058	3.138	0.002
Blockchain Technology Adoption	0.112	0.041	2.732	0.008
Environmental Policies and Regulations	0.096	0.037	2.595	0.010
GDP	0.521	0.094	5.544	0.000
Population Density	-0.042	0.026	-1.615	0.106
R-Sequre	0.75			

Source: Author' calculation

DISCUSSION

According to the structural model results shown in Table 2, the coefficients of all independent variables except population density are significant at a confidence level of 95% and above. An R-squared value of 0.75 means that the model explains 75% of the variance in the variable.

The Legal Framework for AI and Blockchain has the highest coefficient of 0.245, indicating that it has the strongest positive effect on the dependent variable. This suggests that countries that have favorable legal frameworks for AI and Blockchain are more likely to experience growth in their technology sectors.

The coefficients for AI and Blockchain Technology Adoption are also statistically significant, indicating that the adoption of these technologies has a positive impact on economic growth. This is consistent with previous research that suggests that the adoption of AI and Blockchain technologies can increase productivity, innovation, and competitiveness in various industries (Guryanova, Shestakov, & Tikhonov, 2020).

The coefficient for Environmental Policies and Regulations is also statistically significant, indicating that countries with more stringent environmental policies and regulations tend to have higher economic growth rates. This is consistent with previous research that suggests that environmental policies can promote sustainable economic growth by incentivizing companies to adopt cleaner technologies and reducing the negative externalities associated with pollution (Sætra, 2023). The coefficient for GDP is also statistically significant, indicating that countries with higher GDP tend to have higher economic growth rates. This is consistent with the well-established positive relationship between GDP and economic growth.

Finally, the coefficient for Population Density is not statistically significant, indicating that population density does not have a significant impact on economic growth. This finding is somewhat surprising as previous research has suggested that population density can have both positive and negative effects on economic growth depending on various factors such as infrastructure, human capital, and technological advancements (Bildirici & Ersin, 2023). Overall, the results of the fixed effect model suggest that the Legal Framework for AI and Blockchain, AI and Blockchain Technology Adoption, Environmental Policies and Regulations, and GDP are all important factors that contribute to economic growth. However, more research is needed to better understand the relationship between population and economic growth.

The findings of this study are consistent with previous research on the use of AI and blockchain technology for environmental sustainability. The need for legal frameworks and regulations to guide the responsible use of these technologies in environmental applications has been recognized by governments, international organizations, and regional bodies (Darwish, 2023). However, these frameworks are still in the early stages of

development and there are variations across countries, indicating the need for further harmonization and development of regulations (Jiang et al., 2023).

Previous research has also highlighted the multifaceted contributions of AI and blockchain technology to environmental sustainability, including improved efficiency and accuracy in environmental monitoring and management, fostering sustainable development, promoting transparency and traceability in supply chains, and supporting effective decision-making. These technologies have the potential to empower stakeholders with the tools and information needed to make informed decisions and take effective actions towards a more sustainable future, as emphasized by experts in environmental compliance, environmental law, and environmental economics in this study (Darwish, 2023),

Furthermore, previous research has also raised concerns about data privacy and transparency, the importance of intellectual property (IP) laws, the need for a decentralized legal framework for blockchain, ethical considerations, public awareness and education, uncertainty about existing laws and regulations, and the emphasis on collaboration between stakeholders (Júnior et al., 2023). These concerns align with the thematic analysis of the responses from different experts in this study, providing further support for the need to address these issues in the development and implementation of legal frameworks and best practices for the responsible use of AI and blockchain in environmental applications.

In conclusion, the findings of this study are consistent with previous research on the use of AI and blockchain technology for environmental sustainability. Legal frameworks are being established but are still in the early stages of development and there are variations across countries, indicating the need for further harmonization and development of regulations. The contributions of AI and blockchain technology to environmental sustainability are significant and multifaceted, but concerns about data privacy, transparency, IP laws, ethical considerations, and collaboration between stakeholders need to be addressed. With the right approach, AI and blockchain can be valuable tools in the global efforts towards environmental sustainability, contributing to a more resilient, equitable, and sustainable future for our planet, as recognized in previous research (Allena, 2020).

CONCLUSIONS

In conclusion, this research article aimed to analyze the legal challenges and opportunities presented by AI and blockchain for environmental protection and sustainability. The study employed an empirical approach, collecting and analyzing data from primary and secondary sources, and used both qualitative and panel data analysis methods. Through interviews with experts in the fields of AI, blockchain, and environmental law, the study gathered valuable insights into the legal implications of AI and blockchain on environmental sustainability. The sample size of 30 stakeholders was chosen through purposive sampling to ensure diverse perspectives were captured while maintaining manageability. Additionally, panel data from 10 countries was proposed to be used for analysis, including regions with different economic development levels, environmental challenges, and regulatory approaches. This allowed for a comprehensive analysis of the legal framework governing the use of AI and blockchain for promoting environmental sustainability.

In conclusion, the results of the analysis indicate that Legal Framework for AI and Blockchain has the strongest positive association with the dependent variable among the independent variables included in the study. This is followed by AI Technology Adoption, Blockchain Technology Adoption, and Environmental Policies and Regulations. Additionally, an increase in GDP is associated with an increase in the dependent variable, which is consistent with previous research on the positive relationship between economic growth and technological advancements. However, Population Density does not show a significant association with the dependent variable in this analysis.

This research article provides recommendations and limitations based on its findings on the relationship between AI, blockchain, and environmental sustainability. The recommendations include enhancing the legal framework for AI and blockchain, promoting the adoption of these technologies, strengthening environmental policies and regulations, and considering economic growth and development. The limitations include the small sample size and selection, data availability and reliability, causality and interpretation, and the rapidly evolving

nature of technology and law. Policymakers and researchers should consider these factors when developing strategies and policies related to AI, blockchain, and environmental sustainability.

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