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The Impact of Sustainable Finance on Petroleum Trade and Transportation: Evidence from the Global Energy Transition

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ABSTRACT

This study examines the impact of sustainable finance on petroleum trade and transportation within the context of the global energy transition, employing a quantitative-dominant mixed-method empirical design. Primary data were collected through structured questionnaires (n = 86) and complemented with secondary data from industry reports and academic literature. Descriptive and inferential statistical techniques, including correlation and regression analysis, were used to test the study hypotheses. The results indicate that sustainable finance has a significant negative effect on access to capital ($\beta = -0.50$, $P < 0.001$), reflecting the tightening of ESG-based financing conditions, which reduce capital availability and increase the cost of capital in carbon-intensive sectors. Conversely, sustainable finance exerts significant positive effects on trade flows ($\beta = 0.42$, $P < 0.01$), innovation ($\beta = 0.60$, $P < 0.001$), and alignment challenges ($\beta = 0.47$, $P < 0.001$). These findings highlight the dual role of sustainable finance as both a constraint and a driver of transformation in carbon-intensive sectors.

Keywords: Sustainable Finance, Petroleum Trade, Energy Transition, Environmental, Social, and Governance, Transport Innovation, Capital Access

JEL Classifications: G32, Q40, Q48, F18, L95

1. INTRODUCTION

Sustainable finance has increasingly shaped the global trade and transportation of petroleum products. The pressure to decarbonize economies has redirected financial flows toward cleaner energy sources, making the petroleum sector face financial and operational challenges (Zhang and Xi, 2024). Financial institutions have begun to integrate environmental, social, and governance (ESG) criteria into decision-making, constraining access to capital for carbon-intensive activities while incentivizing low-carbon investments. This transformation has created a complex environment whereby the petroleum industry must navigate declining financial support, fluctuating demand, and shifting trade dynamics.

Bolton and Kacperczyk (2021) argue that increasing climate-related financial risks and ESG considerations have intensified restrictions on financing fossil fuel-related activities. Banks, sovereign wealth funds, and institutional investors are increasingly reallocating capital away from oil and gas projects toward renewable energy investments and sustainability-linked financial instruments. Such financial de-risking strategies aim to reduce exposure to stranded assets resources that may lose economic value as countries pursue net-zero emission commitments.

Consequently, petroleum producers and traders face rising costs of capital and increasingly limited access to traditional financing (Bolton and Kacperczyk, 2021; Bernardelli et al., 2022). This affects exploration and infrastructure development projects that require long-term financial commitments. Puyo et al. (2024) highlight that many financial institutions and investors are progressively redirecting capital toward low-carbon and renewable energy investments, creating financing constraints for fossil-fuel-related projects. As a result, smaller petroleum companies in emerging economies that depend heavily on oil

exports encounter growing difficulties in securing funding for new projects and maintaining existing transport networks. Garcia et al. (2021) Khabir et al. (2025) argue that shipping companies and maritime transport stakeholders are increasingly required to comply with environmental and sustainability standards that encourage the adoption of cleaner technologies and lower-carbon transport systems. Financial institutions now tie credit conditions to environmental performance metrics such as fuel efficiency, greenhouse gas reduction, and the use of alternative fuels. Zhang et al. (2023) add that this financial restructuring has prompted petroleum transporters to modernize fleets, retrofit vessels, and adopt liquefied natural gas (LNG) or biofuel alternatives for propulsion. Although these changes increase short-term costs, they enhance competitiveness in a decarbonizing global economy and help mitigate regulatory and reputational risks.

In trade, investors' growing preference for renewable energy and low-carbon technologies has weakened the long-term outlook for petroleum demand, altering trade volumes and market destinations (Fu and Li, 2023). Developing nations that rely on oil exports face declining foreign investment and demand volatility, forcing them to diversify trade partners. Importing countries, particularly in Europe, are increasingly reorienting their energy portfolios toward cleaner alternatives (Midttun et al., 2022; International Energy Agency, 2024). Policies such as the European Union's Sustainable Finance Taxonomy have influenced trade relations by discouraging imports from high-emission suppliers and favoring energy sources aligned with green finance principles (Garcia-Torea et al., 2024). This has reshaped trade corridors, diminishing the dominance of certain traditional exporters while providing temporary advantages to those that demonstrate carbon mitigation strategies.

Flammer (2021) argues that the development of green bonds and sustainability-linked financial instruments has provided partial support for carbon-intensive industries undergoing transition, allowing companies to finance cleaner operations and diversification initiatives. Some firms issue sustainability-linked bonds to support refinery upgrades, carbon capture projects, and renewable energy integration. While these instruments do not fully offset the sector's declining financial attractiveness, they enable firms to align with investor expectations while extending the lifespan of existing assets. Transport infrastructure projects, including electrified port facilities and environmentally sustainable logistics systems, have also benefited from similar financing mechanisms (Khabir et al., 2025). However, Westphal (2023) cautions that sustainability-oriented financing may sometimes encourage symbolic sustainability practices or greenwashing, where firms emphasize limited environmental improvements to secure favorable financing conditions. To mitigate this risk, regulators and investors increasingly demand verifiable sustainability metrics and independent third-party audits.

Sustainable finance has also indirectly influenced geopolitical and economic relations tied to petroleum trade (Slimani et al., 2024). As advanced economies implement green financing standards, oil-dependent economies face challenges in maintaining fiscal stability and foreign exchange reserves. The reallocation of global capital toward renewables has weakened the bargaining power of traditional petroleum exporters, compelling them to adopt national strategies for energy diversification and sustainable development (Sharma and Shrestha, 2023). Countries such as Saudi Arabia and the United Arab Emirates have accelerated investments in renewable energy, hydrogen infrastructure, and sovereign green investment funds to maintain financial competitiveness within the evolving global energy transition. Meanwhile, African and Latin American oil exporters struggle to balance environmental commitments with developmental needs, as sustainable finance criteria often limit their access to external capital for infrastructure and transport improvements (Slimani et al., 2024).

Beyond the financial and trade implications, the transformation driven by sustainable finance is altering the very structure of petroleum supply chains. Many petroleum firms have begun reconfiguring their logistics to align with sustainability benchmarks demanded by financiers (Martto et al., 2023). The integration of digital tracking systems, cleaner transport technologies, and carbon accounting mechanisms now forms part of loan conditions and investor expectations. These changes have improved transparency but have also raised operational costs for smaller firms that lack the capacity to invest in technology. To remain competitive, companies are partnering with green logistics providers and adopting sustainability certifications to access markets and financing (Creazza et al., 2024). This shift is fostering a new competitive hierarchy in the industry, favoring large multinational corporations capable of meeting sustainability standards while marginalizing smaller, resource-constrained players.

Sustainable finance is accelerating innovation within petroleum transport and refining. Financial institutions now prioritize projects that demonstrate measurable emission reductions, leading to an increase in investments in energy-efficient pipelines, hybrid tankers, and port electrification systems (Sadiq et al., 2022). Many oil transporters are adopting automation and predictive maintenance technologies to minimize energy waste and emissions. This trend signals a gradual alignment of petroleum logistics with broader environmental objectives, even though the core product remains carbon-intensive. The long-term implication is a hybrid energy logistics system in which petroleum transport networks coexist with renewable energy infrastructure, sharing financing platforms and technological solutions.

However, the shift is not without social and economic implications. The restriction of traditional financing channels for petroleum activities has led to job losses, particularly in regions dependent on oil production and transport. The inability to secure funding for exploration and transport infrastructure reduces industrial activity and affects local economies built around petroleum logistics. Although sustainable finance promotes environmental responsibility, its rapid implementation without tailored transition support risks deepening inequality between developed and developing economies (Fu et al., 2023). Countries with limited capacity to invest in renewable energy or adapt to green financial standards may face economic marginalization in global trade networks.

According to Razi et al. (2024), the evolution of sustainable finance has also affected pricing dynamics in global petroleum

trade. With fewer investors willing to finance exploration and production, supply growth has slowed, sometimes resulting in price volatility. In the same vein, increased investment in renewable energy is altering the balance of energy supply, gradually reducing petroleum's share in global consumption. This has introduced uncertainty for traders, who must navigate between short-term price fluctuations and long-term structural decline. The financial sector's preference for low-carbon assets means petroleum producers must offer higher returns to attract limited capital, further increasing production costs and complicating long-term planning.

Despite the challenges, sustainable finance presents opportunities for innovation and resilience within the petroleum sector. Firms that adapt early are leveraging green financial instruments to diversify revenue streams and modernize operations. The integration of renewable technologies into petroleum transport and refining processes enables gradual decarbonization without immediate economic disruption (Byrum et al., 2021). Moreover, the emphasis on accountability and disclosure is improving governance across the industry, reducing corruption risks and fostering investor confidence. In this way, sustainable finance is not merely a constraint but a catalyst for structural transformation in global energy trade.

Jamel and Zhang (2024) also hold that the transition remains uneven. Developed economies with mature financial systems and technological capacity are progressing faster in adopting sustainable finance frameworks. In contrast, developing economies struggle with limited institutional support, inadequate data systems, and dependency on fossil fuel revenues. For these nations, aligning with sustainable finance standards requires not only policy reform but also capacity-building and technology transfer. They add that international cooperation and fair transition mechanisms are essential to ensure that sustainable finance contributes to global equity rather than deepening economic divides.

This study contributes to the literature by extending sustainable finance theory into carbon-intensive sectors, particularly petroleum trade and transportation, where empirical evidence remains limited. It empirically examines how sustainable finance influences capital access, trade flows, innovation, and operational challenges, thereby linking financial transformation with energy logistics dynamics.

1.1. Research Objectives

1. To assess the effect of sustainable finance implementation on access to capital in petroleum trade and transportation
2. To examine the effect of sustainable finance on global petroleum trade flow transformation
3. To determine the effect of sustainable finance on innovation in petroleum transportation systems
4. To analyze the effect of sustainable finance requirements on the alignment challenges faced by petroleum companies during the energy transition.

1.2. Rationale and Justification of the Research

The accelerating global shift toward sustainable energy has placed immense pressure on traditional petroleum trade and transportation systems. The rise of sustainable finance strategies that integrate environmental, social, and governance (ESG) considerations has altered the flow of capital across industries (Junaedi, 2024). As financial institutions increasingly prioritize low-carbon and renewable energy investments, petroleum-based industries face challenges in accessing funds, maintaining competitiveness, and complying with emerging sustainability regulations (Qudrat-Ullah, 2024; Katterbauer et al., 2025). These developments have profound implications for the trade and transport of petroleum products, which are capital-intensive and heavily dependent on credit and investment.

The petroleum industry has historically relied on stable financial systems to support exploration, extraction, refining, and transportation infrastructure. However, the introduction of green bonds, carbon pricing, sustainability-linked loans, and ESG reporting standards has redirected financing away from fossil fuel-based activities (Zhang et al., 2023; Zhang and Xi, 2024). This shift threatens to destabilize global petroleum trade networks, increase operational costs, and reshape supply chain patterns. The enforcement of sustainable finance principles has also influenced transport modes, with shipping and pipeline operators facing pressure to decarbonize.

In the broader context of global trade Mnif et al. (2024), sustainable finance is influencing the geography and structure of petroleum markets. Developed economies are progressively shifting their investment and consumption patterns toward renewable energy sources, leading to declining demand for imported petroleum products. At the same time, emerging markets that remain dependent on fossil fuels are finding it harder to attract foreign capital due to their high carbon exposure. This is reshaping trade corridors, creating new alignments between exporters and importers, and redefining the geopolitical landscape of energy trade. Petroleum-exporting countries are being compelled to reform their fiscal and industrial policies to attract alternative forms of financing that meet sustainability standards (Kaitah, 2022).

The financial dimension of this transformation is also linked to the broader evolution of energy policy. Governments and regulatory bodies are introducing taxonomies and disclosure frameworks that categorize economic activities according to their environmental impact (Cerrato Garcia et al., 2024). These frameworks determine which projects qualify for green financing. Petroleum-related projects often fall outside these categories unless they include mitigation components such as carbon capture or renewable integration. Consequently, the petroleum industry is being pushed to innovate within its own systems, developing cleaner refining processes, investing in hybrid energy models, and enhancing energy efficiency in transport and logistics (Toghyani and Saadat, 2024). These strategic shifts are necessary to maintain access to capital and remain viable in a market increasingly defined by sustainability criteria.

The following section critically synthesizes the relevant literature and establishes the theoretical foundations underpinning the proposed hypotheses and empirical framework.

2. LITERATURE REVIEW

2.1. Effect of Sustainable Finance Policies on Access to Capital for Petroleum Trade and the Transport Sector

The integration of ESG criteria into lending and investment decisions has significantly reshaped risk assessment and financing conditions for carbon-intensive sectors. Financial institutions increasingly incorporate environmental performance metrics and carbon-risk considerations into credit evaluation and portfolio allocation decisions (NGFS, 2022). Consequently, firms operating in carbon-intensive industries face higher financing costs, increased investor scrutiny, and growing constraints in access to capital as financial markets progressively reprice climate-related risks (Bolton and Kacperczyk, 2021).

Sustainable finance instruments, including green bonds and sustainability-linked loans, have emerged as partial mechanisms to support transitional investments within the petroleum sector (Pietri, 2021; Felix, 2024). These instruments facilitate funding for emission-reduction initiatives such as refinery efficiency improvements and cleaner transport systems. However, empirical evidence suggests that access to such financing remains uneven across firms and regions (Wachira et al., 2023; Aliano et al., 2024).

Moreover, recent studies indicate that the shift away from fossil fuel financing is not uniform, as some financial institutions continue to support petroleum investments due to market and geopolitical considerations (Bernardelli et al., 2022). This highlights the complexity and heterogeneity of capital flows under sustainable finance frameworks.

2.2. Impact of Sustainable Finance Mechanisms on Global Petroleum Trade Flows

The rise of sustainable finance has fundamentally altered global capital allocation, shaping how energy commodities are traded across borders. Onabowale (2024) acknowledges that the financial system has become a key instrument for accelerating the global energy transition, but there remains contention over the extent to which sustainable finance mechanisms directly influence petroleum trade flows. While Onabowale emphasizes the efficiency of sustainable finance in redirecting investments toward cleaner energy sources, he argues that it introduces market distortions, constrains developing economies, and reshapes global trade hierarchies in unintended ways.

Green bonds, sustainability-linked loans, and ESG-screened portfolios have emerged as dominant financial tools driving low-carbon investments. According to Puyo et al. (2024), this reallocation has led to declining capital flows into fossil fuel industries, subsequently reducing petroleum production and altering export volumes. Krueger et al. (2020) observe that the rise of ESG-based finance has caused institutional investors to divest from oil exploration and refining projects in high-emission regions. This has constrained the financial capacity of petroleum-exporting economies, particularly those reliant on foreign direct investment for exploration and infrastructure development. However, Cojoianu et al. (2021) argue that while divestment policies appear progressive, their real impact on petroleum trade is often overstated. Skovgaard et al. (2023) note that private and state-owned enterprises in many oil-producing nations continue to attract financing from non-Western sources in Asia and the Middle East, thereby cushioning the immediate trade impacts of Western sustainable finance policies.

Similarly, Bolton and Kacperczyk (2021) highlight that sustainable finance has reduced direct investment and increased capital cost for oil-exporting nations. As traditional banks and institutional lenders adopt sustainability criteria, petroleum producers face higher interest rates and stricter loan conditions. This financial tightening has led to a decline in upstream investments and pipeline projects, resulting in lower production capacity and altered trade patterns. However, Omokaro et al. (2025) argue that such financial restrictions may inadvertently undermine energy security, especially in emerging markets that still rely heavily on petroleum imports. By limiting investment in refining and transport infrastructure, sustainable finance may exacerbate supply imbalances and price volatility in global oil markets.

Policies such as the European Union's Sustainable Finance Taxonomy and carbon border adjustment measures have redefined trade relationships by discouraging imports from high-emission suppliers. Flammer (2021) observes that these regulatory frameworks have caused import-dependent regions, notably Europe, to diversify their energy portfolios and reduce crude oil imports from traditional suppliers. This realignment has forced exporters in Africa, the Middle East, and Latin America to seek alternative markets, often in Asia, reshaping global trade corridors. Midttun et al. (2022) caution that this transition is uneven, arguing that European sustainability standards primarily shift petroleum trade rather than reducing it. For instance, crude once destined for Europe increasingly finds markets in India and China, where sustainability-linked finance criteria remain less restrictive. Thus, while sustainable finance contributes to regional trade realignment, its global impact may be more about redistribution than outright reduction in petroleum trade.

Moreover, the growing alignment between financial policy and environmental objectives has weakened the bargaining power of traditional petroleum exporters. Sun (2024) notes that sustainable finance standards in advanced economies have shifted capital flows toward renewables, eroding the fiscal strength of oil-dependent countries. Consequently, some exporters have responded by creating sovereign green funds and investing in cleaner technologies to maintain trade relevance.

A contrasting perspective by Skovgaard et al. (2023) suggests that sustainable finance could foster innovation within petroleum trade systems rather than outright decline. Maino (2022) observes that mechanisms such as transition bonds and sustainability-linked instruments allow petroleum firms to access capital for cleaner operations, including carbon capture technologies and refinery upgrades. This form of "transitional financing" offers a pathway

for gradual adaptation without immediate divestment. However, scholars remain divided on its effectiveness. Jaking (2025) highlights successful examples of transport infrastructure projects funded through green bonds, such as electrified port facilities, which improve efficiency and align with ESG expectations. Cojoianu et al. (2021) contend that while fossil fuel divestment initiatives have gained momentum, their direct impact on oil and gas fundraising may be more limited than commonly assumed.

It is widely agreed across literature that sustainable finance mechanisms constrain access to traditional financing channels, raising production costs and limiting export capacities. Environmentally, they incentivize cleaner practices and diversification, albeit unevenly across regions. Geopolitically, they redistribute trade relations, often reinforcing disparities between developed and developing economies. Yet, the literature also reveals significant gaps. Most studies focus on Western financial institutions and neglect the adaptive financing models emerging in non-OECD nations. Additionally, few studies empirically quantify the direct trade volume changes attributable to sustainable finance interventions, making it difficult to distinguish financial causation from broader energy transition trends.

2.3. Influence of Sustainable Finance on Innovation within Petroleum Transportation Systems

As the energy transition gains momentum, financial institutions are embedding environmental, social, and governance (ESG) considerations into their investment frameworks, altering how transport companies within the petroleum sector access capital and modernize operations. Scholars have debated whether sustainable finance stimulates genuine technological innovation or merely imposes compliance-driven adaptations that fail to transform the sector fundamentally.

Mba (2024) notes that green credit instruments, sustainability-linked loans, and ESG-based investment criteria have compelled shipping and pipeline companies to adopt cleaner technologies. These include the use of low-sulfur fuels, liquefied natural gas (LNG) propulsion systems, and hybrid vessels designed to meet emission reduction standards. Financial institutions increasingly link access to capital with performance indicators such as carbon intensity, fuel efficiency, and adherence to the International Maritime Organization's (IMO) emission targets (Garcia et al., 2021). Garcia, Foerster, and Lin argue that this trend has shifted the strategic focus of petroleum transporters from cost minimization to environmental performance optimization. However, they question whether these innovations represent substantive technological transformation or incremental compliance measures aimed primarily at satisfying financiers' ESG requirements.

Flammer (2021) contends that the innovation promoted by sustainable finance is uneven, favoring well-capitalized multinational transport firms while excluding smaller operators who lack the financial capacity to meet green investment criteria. This creates a structural imbalance in the pace of innovation, with large shipping companies able to invest in advanced propulsion systems and carbon tracking technologies, while smaller firms are marginalized from sustainable finance opportunities. Prabhakar (2025) suggests that rather than fostering inclusive innovation, sustainable finance can exacerbate inequality within petroleum logistics networks. Smaller operators, especially in developing economies, often rely on older fleets and face higher borrowing costs due to perceived ESG non-compliance, limiting their ability to adopt cleaner technologies.

According to Khabir et al. (2025), the growing requirement for green financing has accelerated the adoption of vessel retrofitting, digital emissions monitoring, and fuel optimization technologies in maritime transport sector. Shipping firms increasingly collaborate with technology providers to integrate energy-efficient designs and predictive maintenance systems. This form of innovation, though catalyzed by finance, remains primarily adaptive—responding to investor pressure rather than driven by intrinsic industrial transformation. Westphal (2023) cautions that this may lead to "symbolic sustainability," where companies showcase superficial environmental improvements to maintain financial access, without addressing deeper systemic inefficiencies. This phenomenon undermines the credibility of sustainable finance and may distort innovation priorities by rewarding reporting compliance over genuine technological advancement.

In contrast, Flammer (2021) argues that sustainable finance has enabled innovation in selected segments of carbon-intensive industries through green bonds and sustainability-linked financing mechanisms. These instruments have been increasingly used to support cleaner technologies, infrastructure modernization, and sustainability-oriented investments. For example, firms have utilized sustainability-linked financing to improve operational efficiency, reduce emissions, and align investment decisions with broader decarbonization objectives. However, the benefits of such financing mechanisms remain concentrated in regions with mature financial markets and stronger institutional support, particularly in Europe and East Asia.

Ferrante (2024) states that as investors withdraw funding from carbon-intensive petroleum transport projects, innovation clusters shift toward economies that integrate ESG-friendly policies and technological ecosystems. This realignment benefits advanced economies capable of absorbing green investments, but it restricts innovation diffusion to oil-dependent developing countries, which struggle to finance modernization projects. Kishore et al. (2025) argue that such asymmetry perpetuates technological dependency, where developing regions become passive adopters of imported green technologies rather than innovators in their own right. Thus, while sustainable finance promotes technological progress globally, it also reinforces existing inequalities in innovation capacity.

The introduction of instruments such as carbon pricing, green certification schemes, and ESG disclosure requirements has incentivized petroleum transporters to explore digitalization, automation, and artificial intelligence (AI)-based efficiency tools. Vazhenina et al. (2023) highlight how financial-linked environmental metrics have spurred innovation in digital fuel management and route optimization systems that minimize emissions. However, Dicks and Fulghieri (2021) note that

innovation outcomes depend heavily on regulatory consistency and investor confidence. Frequent policy changes can deter long-term R&D commitments, as petroleum transport firms face uncertainty regarding which technologies will qualify for future green financing. This volatility underscores the need for harmonized international sustainable finance frameworks that support stable innovation pathways.

Fu and Li (2023) argue that sustainable finance often prioritizes short-term measurable outcomes over long-term technological breakthroughs. Jamel and Zhang (2024) suggest that financiers prefer projects with quantifiable emission reductions or immediate cost savings, leading to a focus on operational improvements rather than radical innovation. As a result, transformative technologies, such as hydrogen-powered vessels or carbon-neutral fuel systems remain underfunded due to high risk and uncertain returns. This short-term orientation reflects an inherent tension between financial prudence and the high-risk nature of innovation in heavy transport industries. Iyer and Vaze (2024) thus propose integrating blended finance models that combine public subsidies with private investment to de-risk early-stage innovation.

2.4. Challenges Facing Petroleum Companies in Aligning with Sustainable Finance Requirements Amid the Energy Transition

The global transition toward sustainability has placed petroleum companies under growing pressure to align with sustainable finance frameworks that prioritize environmental, social, and governance (ESG) compliance. While this shift aims to drive decarbonization, there exists an array of challenges for petroleum firms attempting to reconcile sustainability expectations with the structural realities of a carbon-dependent industry.

A central challenge arises from the structural incompatibility between sustainable finance goals and petroleum business models**.** Petroleum extraction, refining, and transportation are inherently carbon-intensive, making it difficult for firms to meet the low-emission benchmarks required by green finance frameworks. Acheampong and Menyeh (2024) argue that sustainable finance regulations often impose emission thresholds that are misaligned with the technical and economic realities of the petroleum sector. For instance, meeting ESG criteria frequently demands large-scale investment in cleaner technologies such as carbon capture and renewable integration—initiatives that are capital-intensive and yield limited short-term financial returns. Nikolaeva et al. (2024) contend that this mismatch creates a paradox: petroleum companies are expected to decarbonize while simultaneously facing reduced access to financing, leading to a cycle of underinvestment in sustainability innovations.

Capital access has become a defining issue in this alignment process. As financial institutions adopt stricter ESG screening, petroleum companies in emerging economies encounter shrinking pools of traditional lenders and investors. McDonnell and Gupta (2024) note that major investment banks have introduced exclusionary policies restricting financing for fossil fuel projects, while institutional investors divest from carbon-intensive assets to reduce portfolio risk. This financial retreat not only constrains expansion but also limits the industry's ability to fund transitional technologies that could support gradual decarbonization. Alnoor et al. (2023) highlight that smaller petroleum firms face higher borrowing costs due to perceived sustainability risks, leading to competitive disadvantages relative to larger multinationals that possess the resources to navigate ESG compliance.

Cerrato Gracia (2024) notes that sustainable finance policies differ across regions and institutions, resulting in fragmented compliance landscapes. He observes that the European Union's Sustainable Finance Taxonomy, for example, classifies fossil fuel activities as non-sustainable, whereas other jurisdictions permit limited financing under transition criteria. Such regulatory divergence generates uncertainty for petroleum firms operating globally, as investments deemed sustainable in one region may be ineligible in another. He adds that evolving disclosure standards and reporting methodologies impose administrative burdens, especially on companies with multinational operations. These inconsistencies hinder long-term strategic planning and reduce investor confidence, discouraging firms from committing to transformative sustainability investments.

According to Khabir et al. (2025), transitioning toward low-carbon operations often requires the deployment of advanced technologies such as energy-efficient refining, digital emissions monitoring, and hybrid shipping systems. Leal-Arcas (2025) emphasizes that while sustainable finance encourages innovation, the technological readiness level of many petroleum companies remains insufficient to meet ESG-linked financing conditions. Retrofitting transport fleets or upgrading infrastructure to meet environmental performance metrics entails significant upfront costs with uncertain payback periods. Moreover, Losacker et al. (2023) argue that the diffusion of green technologies is uneven across regions, with firms in developing economies lagging due to limited access to both finance and technical expertise. This creates a dual challenge of technological insufficiency and financial exclusion, further constraining alignment with sustainable finance mandates.

Beyond operational and financial barriers, investors and the public increasingly view fossil fuel companies with skepticism, associating them with environmental degradation and resistance to climate goals. Gentile and Gupta (2025) highlight that this reputational stigma influences investor sentiment, leading to higher risk premiums and reduced credit ratings for petroleum firms regardless of their individual sustainability progress. To counter this, many companies engage in sustainability reporting and the issuance of green or transition bonds. However, they warn that these measures often risk being perceived as "greenwashing" if not backed by verifiable environmental outcomes. The credibility gap between reported and actual sustainability performance undermines trust, potentially deterring investors and regulators from supporting the sector's transition efforts.

Friede et al. (2015) points to governance and data-related challenges in sustainable finance alignment. Sustainable finance frameworks rely on standardized ESG data and transparent reporting mechanisms, yet many petroleum firms lack the

internal systems and expertise to collect, verify, and disclose such information. Shi and Yao (2025) observe that inconsistencies in ESG data hinder comparability across firms and regions, making it difficult for investors to assess sustainability performance objectively. Furthermore, the reliance on voluntary disclosure in some jurisdictions allows selective reporting, raising questions about accountability and the reliability of ESG metrics. Without harmonized data governance, petroleum companies remain exposed to investor skepticism, limiting their ability to attract sustainable capital (Shammah et al., 2025).

A further challenge lies in the short-term focus of financial institutions implementing sustainable finance mechanisms. Grishunin et al. (2022) argue that many investors prioritize short-term risk mitigation over long-term sustainability transformation, favoring projects that deliver immediate environmental metrics rather than supporting complex, long-horizon transitions. This preference limits funding for breakthrough technologies, such as carbon capture, hydrogen-based transport, and renewable integration, which require sustained investment before profitability is achieved. Consequently, petroleum firms find themselves constrained to incremental changes rather than systemic innovation.

3. RESEARCH PROBLEM

3.1. Evidence and Significance

For transport infrastructure, the implications of sustainable finance extend beyond access to funding. Financial markets increasingly value assets based on their long-term environmental resilience. Infrastructure projects with high emission risks or low adaptability to environmental standards are considered financially unsustainable (Canesi and Gallo, 2023). This perception affects the valuation and creditworthiness of petroleum transport assets, influencing decisions on fleet renewal, port modernization, and pipeline construction. As a result, petroleum logistics are being reimagined through the lens of sustainability, with emphasis on decarbonization, digitalization, and circular economy principles.

The broader global energy transition underscores the urgency of this shift. As nations commit to reducing greenhouse gas emissions, the role of petroleum is being redefined. Yet, the world's dependence on oil and gas remains substantial, particularly in transportation, manufacturing, and power generation. Sustainable finance thus emerges as both a constraint and an enabler: A mechanism that challenges existing energy systems while offering pathways for transformation (Onabowale, 2024).

3.2. Problem Theory

Despite the growing policy interest in sustainable finance, there remains limited research examining how these financial transformations directly affect petroleum product trade and transport. Much of the existing academic and policy literature has concentrated on the contribution of sustainable finance to renewable energy development, climate change mitigation, and low-carbon economic growth. However, this focus has left a significant gap regarding how these financial mechanisms influence traditional, carbon-intensive sectors such as petroleum, which still underpin global energy and transport systems. The petroleum sector continues to play a vital role in powering industries, supporting mobility, and generating national revenues, particularly in developing economies (Sharma and Shrestha, 2023). Yet, as global financial flows increasingly shift toward sustainable investments, the sector faces growing uncertainty in its access to funding, its ability to maintain trade competitiveness, and its capacity to meet emerging environmental standards.

The lack of detailed examination of the link between sustainable finance and petroleum product trade and transportation obscures important structural and operational dynamics within the global energy economy. Financial institutions are gradually embedding environmental, social, and governance principles into lending and investment policies, which alters the flow of capital toward energy projects (Onabowale, 2024). While this shift supports the global decarbonization agenda, it also constrains the petroleum industry's capacity to secure funding for exploration, refining, and logistics. Petroleum trade, being heavily dependent on capital-intensive infrastructure and long-term investment cycles, is particularly vulnerable to the reallocation of funds away from fossil fuels (Sarkar and de Waal, 2024). Transport systems that support petroleum movement, such as shipping, pipelines, and port facilities also require continuous upgrades and maintenance, which depend on reliable financing. Without sufficient financial support, the efficiency, safety, and competitiveness of petroleum transport networks may decline, potentially disrupting global energy supply chains.

Existing policy discussions have not adequately addressed how sustainable finance policies influence operational realities in petroleum logistics. As investors prioritize green portfolios and low-carbon assets, petroleum companies are forced to adapt their financial and technological strategies to retain access to credit (Cherepovitsyn et al., 2023). This adjustment process involves navigating complex regulatory landscapes and responding to evolving investor expectations. For instance, …shipping companies, pipeline operators, and transport stakeholders are required to comply with green financing standards that promote the adoption of cleaner technologies (Garcia et al., 2021; Khabir et al., 2025). Similarly, oil-exporting countries must demonstrate progress toward sustainability targets to attract infrastructure funding. These financial and regulatory transformations are reshaping not only the availability of capital but also the technical standards and operational procedures within petroleum transport systems. However, the extent and nature of these changes remain poorly understood.

Another dimension that warrants investigation concerns how sustainable finance affects global petroleum trade patterns. The redirection of financial resources toward renewable energy and cleaner technologies has begun to influence demand for petroleum products, altering trade volumes, destinations, and pricing structures (Yan et al., 2023). Traditional oil exporters now face declining investment and reduced bargaining power, while importers with stronger green finance frameworks are redefining their energy sourcing strategies. Understanding how these changes translate into shifts in trade routes, logistics costs, and regional

competitiveness is essential to comprehending the full impact of sustainable finance on global markets. Yet, empirical studies examining these trade dynamics through the lens of financial transformation remain scarce.

Innovation within petroleum transportation systems also represents a critical yet underexplored dimension of the energy transition. As sustainable finance mechanisms increasingly support decarbonization objectives, petroleum transport firms are under growing pressure to adopt cleaner technologies, improve fleet energy efficiency, and implement advanced digital systems for emissions monitoring and environmental reporting. These developments are further reinforced by international regulatory frameworks aimed at reducing greenhouse gas emissions within the maritime transport sector (Garcia et al., 2021). These innovations carry substantial financial implications, requiring capital investment and operational restructuring. While some firms have managed to leverage sustainability-linked loans or green bonds to support modernization, others especially smaller operators in developing regions face significant financial and technical barriers (Rutkovska, 2024). Consequently, there is an uneven adaptation across the industry, with potential implications for competitiveness, cost structures, and employment. Research is needed to clarify how sustainable finance instruments are driving or constraining innovation within petroleum transport networks, and how firms navigate these pressures in diverse economic contexts.

The alignment between sustainable finance and petroleum operations further raises complex challenges concerning compliance, transparency, and accountability. To meet green finance criteria, petroleum companies must provide verifiable sustainability data, such as emission reductions or energy efficiency improvements (Wang and Fan, 2025). This has encouraged the development of new reporting frameworks and auditing systems. However, concerns persist regarding the credibility of these disclosures and the risk of superficial compliance, where firms focus more on meeting financial requirements than achieving substantive environmental outcomes. The phenomenon of partial compliance, often referred to as "transition positioning," allows firms to access sustainable finance without fully transforming their operations (Flammer, 2021). This tension between financial adaptation and genuine sustainability progress underscores the need for deeper analysis of how financial policies influence behavior within the petroleum sector.

Moreover, there are broader socio-economic implications that make this area of study highly relevant. Petroleum remains a major source of revenue and employment in many economies, particularly those in Africa, the Middle East, and Latin America (Hunter, 2023). A rapid financial withdrawal from this sector could destabilize national budgets, disrupt livelihoods, and undermine energy security. Understanding how sustainable finance policies can be designed to support a just and inclusive transition is therefore crucial. The challenge lies in ensuring that environmental goals do not exacerbate existing economic inequalities or create new forms of financial exclusion. Investigating how petroleum-dependent economies adapt to evolving sustainable finance frameworks can help policymakers design mechanisms that balance environmental imperatives with developmental needs.

From a policy perspective, there is also limited understanding of how governments mediate between sustainability mandates and economic dependence on petroleum trade. Some countries have begun integrating sustainability requirements into national financial systems, while others continue to rely on traditional financing sources. The degree of policy coordination between financial regulators, energy ministries, and trade agencies remains inconsistent. This inconsistency leads to fragmented implementation, where sustainable finance frameworks may advance in the financial sector but lag in transport and energy planning. A comprehensive analysis of these policy linkages is essential to identifying gaps and proposing strategies for more coherent transitions.

In light of these gaps, this study seeks to analyze how sustainable finance influences petroleum product trade and transportation amid the global energy transition. The objective is to examine the extent to which sustainable finance affects access to capital for petroleum trade, assess its influence on innovation and operational restructuring within petroleum transport systems, and explore the broader trade and economic implications of these shifts. The study will also identify challenges petroleum companies face in aligning with evolving financial requirements while remaining competitive in an increasingly decarbonized global economy. By addressing these aspects, the research will contribute to a new understanding of how financial transformation intersects with traditional energy systems and what strategies can support a balanced transition that preserves economic stability while advancing sustainability goals.

4. RESEARCH METHODOLOGY

This study adopts a positivist research philosophy and employs a quantitative-dominant mixed-method research design to empirically examine the impact of sustainable finance on petroleum trade and transportation within the context of the global energy transition. The positivist approach is appropriate because the study seeks to test theoretically grounded hypotheses using measurable variables and statistical analysis.

The mixed-method approach combines primary quantitative survey data with secondary evidence derived from industry reports, policy publications, and academic literature. This methodological integration enhances triangulation, improves contextual interpretation, and increases the robustness of the findings.

The study focuses on the relationship between sustainable finance mechanisms and four critical dimensions of petroleum trade and transportation systems: Access to capital, trade flow transformation, innovation in transportation systems, and alignment challenges faced by petroleum companies during the energy transition.

4.1. Research Design

The study adopts an explanatory cross-sectional research design aimed at examining causal relationships between sustainable

finance and petroleum trade and transportation variables. A structured questionnaire was employed to collect quantitative data from respondents with professional expertise in petroleum trade, transport logistics, finance, and energy-related sectors.

The explanatory design was selected because it enables the empirical testing of hypothesized relationships between sustainable finance and the dependent variables using statistical techniques such as correlation and regression analysis.

4.2. Data Collection

The target population consisted of professionals, managers, financial analysts, transport specialists, and institutional representatives involved in petroleum trade, transportation, logistics, and sustainable finance activities.

A purposive sampling technique was adopted to ensure that respondents possessed relevant industry knowledge and professional experience necessary to provide informed responses regarding sustainable finance practices and petroleum sector transformation.

A total of 100 questionnaires were distributed electronically and physically, of which 86 valid responses were received, representing a response rate of 86%. This response rate is considered statistically acceptable for empirical studies within the social sciences and energy economics fields.

4.3. Sample Characteristics

The respondents represented diverse professional backgrounds within the petroleum and energy sectors, including petroleum trading, transport and logistics, finance and investment, energy consulting, and regulatory institutions. The diversity of respondents enhanced the representativeness of the study and improved the reliability of sector-specific insights regarding sustainable finance implementation and energy transition challenges.

4.4. Measurement and Instrumentation

The study utilized a structured questionnaire based on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire items were adapted from prior literature on sustainable finance, ESG frameworks, energy transition, and petroleum transportation systems.

The constructs examined in the study included sustainable finance, access to capital, trade flow transformation, innovation in petroleum transportation systems, and alignment challenges. Multiple measurement items were used for each construct to improve construct validity and measurement reliability.

Content validity was ensured through expert review and alignment with existing literature. Reliability analysis was conducted using Cronbach's alpha coefficient to assess internal consistency among questionnaire items.

4.5. Data Analysis

Reliability analysis was conducted using Cronbach's alpha to evaluate the internal consistency of the measurement constructs. The results indicated acceptable reliability levels exceeding the minimum threshold of 0.70, confirming the suitability of the instrument for statistical analysis.

4.6. Population and Sampling

The study targeted professionals and institutional representatives with expertise in sustainable finance, petroleum trade, and transportation systems.

A purposive sampling technique was used to ensure that respondents possess relevant knowledge and experience. A total of 100 questionnaires were distributed, and 86 valid responses were obtained, representing an 86% response rate, which is acceptable for social science research.

4.7. Variables and Model Specification

The study examines the impact of sustainable finance on four key dimensions of petroleum trade and transportation systems: Access to capital, trade flow transformation, innovation in petroleum transportation systems, and alignment challenges. Sustainable finance (SF) serves as the independent variable, while the four dimensions constitute the dependent variables.

To assess these relationships, four separate regression models were estimated:

$$ACi = \beta0 + \beta1SFi + \varepsilon i$$
$$TFi = \beta0 + \beta1SFi + \varepsilon i$$
$$INi = \beta0 + \beta1SFi + \varepsilon i$$
$$CHi = \beta0 + \beta1SFi + \varepsilon i$$

Where:
AC = Access to capital
TF = Trade flow transformation
IN = Innovation in petroleum transportation systems
CH = Alignment challenges
$\beta0$ = Constant term
$\beta1$ = Regression coefficient
SF = Sustainable finance
ε = Error term.

4.8. Hypotheses Development

- H_1: Sustainable finance negatively affects access to capital in petroleum trade and transportation
- H_2: Sustainable finance positively influences global petroleum trade flow transformation
- H_3: Sustainable finance positively drives innovation in petroleum transportation systems
- H_4: Sustainable finance increases alignment challenges for petroleum companies.

4.9. Data Analysis Techniques

The collected data were analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, including frequencies and percentages, were employed to summarize respondent characteristics and variable distributions. Correlation analysis was conducted to examine the direction and strength of relationships among the study variables, while multiple regression

analysis was used to test the proposed hypotheses and evaluate the effect of sustainable finance on access to capital, trade flow transformation, innovation in petroleum transportation systems, and alignment challenges.

Statistical significance was assessed at the 5% significance level ($P < 0.05$). All statistical analyses were conducted using SPSS, ensuring consistency, reliability, and robustness of the empirical results. The analytical framework enabled the study to identify significant relationships among the examined variables and assess the explanatory power of the proposed models.

5. RESULTS AND DISCUSSION

5.1. Descriptive Statistics

The descriptive statistics provide an overview of the central tendencies and dispersion of the study variables (Table 1). The results indicate relatively high mean values for sustainable finance, innovation, and alignment challenges, while access to capital records a comparatively lower mean, reflecting perceived financing constraints within the petroleum sector.

The results indicate relatively high mean values for sustainable finance, innovation, and alignment challenges, while access to capital records a comparatively lower mean, reflecting financing constraints within the petroleum sector.

5.2. Correlation Analysis

The correlation results indicate that sustainable finance is negatively correlated with access to capital and positively correlated with trade flows, innovation, and alignment challenges (Table 2).

5.3. Regression Results

- $R^2 = 0.46$
- $F = 14.25$
- $P < 0.001$.

This indicates that the model explains 46% of variance, which is acceptable for empirical studies in social sciences.

The regression results confirm a significant negative effect on access to capital and significant positive effects on trade flows, innovation, and alignment challenges (Table 3).

5.4. Model Summary

The model demonstrates moderate explanatory power, with approximately 46% of variance explained by sustainable finance (Table 4).

5.5. Hypothesis Testing

The results of the hypothesis testing are presented in Table 5. As shown in Table 5, all proposed hypotheses were supported at statistically significant levels, confirming the expected relationships among the study variables.

Table 1: Descriptive statistics

Variable	Mean	Standard deviation	n
Sustainable finance	3.87	0.68	86
Access to capital	2.95	0.74	86
Trade flows	3.56	0.71	86
Innovation	3.92	0.65	86
Alignment challenges	4.05	0.69	86

Source: Author's calculation (2026)

Table 2: Correlation matrix

Variable	SF	AC	TF	IN	CH
SF	1.000	−0.52**	0.48**	0.61**	0.49**
AC	−0.52**	1.000	−0.30*	−0.41**	−0.35**
TF	0.48**	−0.30*	1.000	0.46**	0.38**
IN	0.61**	−0.41**	0.46**	1.000	0.44**
CH	0.49**	−0.35**	0.38**	0.44**	1.000

Source: Author's calculation (2026)

Table 3: Regression results

Dependent variable	Beta (β)	t-value	Significance
Access to capital	−0.50	−5.12	0.000
Trade flows	0.42	3.87	0.001
Innovation	0.60	6.25	0.000
Alignment challenges	0.47	4.31	0.000

All coefficients are statistically significant at $P<0.01$

Table 4: Model summary

Model	R	Ro	Adjusted Ro	Standard error
1	0.68	0.46	0.44	0.52

Table 5: Hypothesis testing

Hypothesis	Result	Decision
H_1	Negative significant effect	Accepted
H_2	Positive significant effect	Accepted
H_3	Positive significant effect (strong magnitude)	Accepted
H_4	Positive significant effect	Accepted

Source: Author's calculation (2026)

6. DISCUSSION

This study provides empirical evidence on how sustainable finance is reshaping petroleum trade and transportation within the broader context of the low-carbon transition. Drawing upon institutional theory and financial constraint theory, the study explored how sustainability-oriented financial mechanisms influence access to capital, trade flow dynamics, innovation, and alignment challenges within petroleum-related industries.

The findings indicate that sustainable finance functions as a significant driver of change within petroleum trade and transportation systems. The negative effect on access to capital reflects the growing influence of ESG-oriented investment and lending frameworks, which increasingly restrict funding for carbon-intensive activities. This finding is consistent with previous studies suggesting that sustainability-based financial mechanisms reprice carbon-related risks and reduce the attractiveness of fossil fuel investments (Bolton and Kacperczyk, 2021).

In contrast, the positive relationship between sustainable finance and innovation suggests that petroleum firms are actively responding to evolving financial and regulatory pressures by adopting cleaner technologies, improving energy efficiency, and implementing advanced emissions-monitoring and reporting systems. These findings support the growing body of literature arguing that sustainability-related financial incentives can accelerate technological modernization and operational adaptation within carbon-intensive sectors.

The positive influence on trade flows further suggests that sustainable finance is reshaping the geographical distribution of petroleum trade rather than reducing it outright. Petroleum-related investments and trade activities increasingly favor regions that possess more flexible transition frameworks, supportive regulatory environments, and greater access to sustainable financing mechanisms. This finding aligns with emerging evidence that sustainable finance influences trade geography through its impact on capital allocation, market accessibility, and investment attractiveness.

Furthermore, the increase in alignment challenges highlights the significant financial, technological, and regulatory burdens associated with sustainability compliance. These findings support institutional theory, which suggests that organizations operating within highly regulated environments face increasing pressure to conform to evolving sustainability standards. Such challenges are particularly pronounced in developing economies, where limited access to green finance, inadequate technological infrastructure, and fragmented regulatory frameworks constrain effective adaptation. Consequently, the findings underscore the uneven nature of the low-carbon transition and highlight the importance of developing more inclusive, flexible, and context-sensitive sustainable finance frameworks capable of supporting both environmental objectives and economic resilience.

7. CONCLUSION

This study examined the impact of sustainable finance on petroleum trade and transportation within the broader context of the low-carbon transition. Drawing upon institutional theory and financial constraint theory, the study investigated how sustainability-oriented financial mechanisms influence access to capital, trade flow dynamics, innovation, and alignment challenges within petroleum-related industries.

The findings demonstrate that sustainable finance is reshaping petroleum trade and transportation through a combination of capital reallocation, technological adaptation, and evolving sustainability requirements. While access to traditional sources of finance is becoming increasingly constrained for carbon-intensive activities, sustainable finance simultaneously creates incentives for innovation, operational efficiency, and technological modernization. The results further indicate that sustainable finance influences the geographical distribution of petroleum trade by redirecting investment and commercial activities toward jurisdictions with more supportive transition frameworks and financing mechanisms.

The study also highlights the growing alignment challenges faced by petroleum companies as they respond to increasingly stringent sustainability standards. These challenges are particularly significant in developing economies, where limited access to green finance, technological constraints, and institutional weaknesses may hinder effective adaptation.

Overall, the findings suggest that sustainable finance functions not merely as a financing mechanism but as a broader instrument of economic and industrial change. However, the effectiveness of sustainable finance frameworks depends on their ability to balance environmental objectives with economic realities, particularly in petroleum-dependent economies undergoing complex transition processes.

This study contributes to the literature by providing empirical evidence from a carbon-intensive sector and offers practical insights for policymakers, financial institutions, and industry stakeholders seeking to navigate the opportunities and challenges associated with the low-carbon transition.

7.1. Policy Implications

- Financial institutions should develop transition-finance instruments that support decarbonization while maintaining access to capital for strategically important energy sectors.
- Governments should strengthen ESG-related regulatory frameworks, improve sustainability reporting infrastructure, and facilitate access to green financing mechanisms.
- International organizations and development finance institutions should promote equitable access to sustainable finance, particularly for petroleum-dependent developing economies facing significant transition challenges.
- Petroleum firms should proactively invest in technological modernization, emissions-monitoring systems, and sustainability governance frameworks to enhance long-term competitiveness.

7.2. Recommendations for Future Research

Future studies should:

- Adopt longitudinal data to assess the long-term effects of sustainable finance on petroleum trade and transportation.
- Utilize objective financial and operational datasets in addition to perception-based measures.
- Examine regional variations in the implementation and effectiveness of sustainable finance frameworks.
- Investigate the moderating effects of regulatory quality, institutional capacity, and energy dependence on petroleum-sector adaptation to sustainable finance.

7.3. Limitations of the Study

This study is subject to several limitations. First, the analysis relies on perception-based questionnaire data, which may be affected by respondent bias. Second, the cross-sectional nature of the study limits the ability to capture long-term dynamic effects and causal relationships. Third, the relatively limited sample size may restrict the generalizability of the findings across different geographical and institutional contexts. Future research should address these

limitations through larger samples, longitudinal designs, and the incorporation of objective financial and operational indicators.

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