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Article

Climate Risk, Legal Liability, and Portfolio Strategy: A Qualitative Review of Brown Assets as Hedging Instruments in High-Carbon Scenarios

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Abstract: This qualitative literature review synthesizes current evidence on how investors navigate climate risk, legal liability, and portfolio strategy by reassessing the financial role of brown assets in high carbon transition contexts. The review finds that carbon intensive assets, traditionally viewed as stranded or declining, may provide conditional hedging value when policy trajectories remain uncertain, green technologies are not yet fully scalable, and transition risks are uneven across sectors. Legal liability emerges as a powerful driver of portfolio decisions, as fiduciaries face increasing scrutiny regarding climate disclosure, risk governance, and alignment with net zero commitments. The synthesis reveals that the strategic value of brown assets is dynamic rather than static, depending on regulatory convergence, technological maturity, and institutional investor risk preferences. Overall, the review highlights the interplay between climate-related litigation pressures and investment strategy, emphasizing the need for adaptive risk assessment frameworks in a rapidly evolving transition landscape.

Keywords: Climate Risk, Brown Assets, Legal Liability, Portfolio Strategy, Transition Risk

1. Introduction

Climate risk has rapidly emerged as one of the defining forces shaping modern portfolio management, with institutional investors increasingly pressured to integrate environmental considerations into strategic asset allocation. Yet much of the prevailing discourse frames climate change as a unilateral threat to carbon-intensive, or "brown," assets, assuming a linear and inevitable global transition toward a low-carbon economy (Brav & Heaton, 2021). This assumption underlies widespread calls for large scale divestment from fossil fuel related holdings, a trend reinforced by influential institutional actors such as Harvard University (Bacow, 2021) and BlackRock (Lim, 2021; Fink, 2021). However, this narrative often neglects a critical countervailing reality: brown assets may retain, or even increase, their financial value should the global economy fail to transition as quickly or fully as climate advocates predict. The possibility of a prolonged high carbon equilibrium presents not only material financial implications but also legal and fiduciary complexities for investment managers.

A central premise of the literature is that brown assets could generate superior risk adjusted returns if markets systematically underprice them due to climate mitigation optimism or ESG driven divestment (Arnott et al., 2021; Bolton & Kacperczyk, 2021a). From a hedging perspective, these assets may also serve as critical portfolio instruments in scenarios where climate change generates significant economic costs, thereby offering insurance like payoffs in adverse states of the world (Brav & Heaton, 2021). This argument is reinforced by climate science debates, which emphasize uncertainties regarding technological breakthroughs, geopolitical cooperation, and emission trajectories (Koonin, 2021; Mann, 2021; Gates, 2021). Despite growing climate commitments, recent data suggest that global emissions remain stubbornly high, with coal demand and oil production continuing to expand in many regions (IEA, 2021; Hume, 2021; Wade, 2021). These trends challenge the notion that a rapid,

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coordinated low carbon transition is assured. While multifactor portfolios offer advantages in diversification and risk management, market volatility remains a key challenge in achieving a balance between risk and return. Active volatility strategies outperform passive ones, but they require a deep understanding of market dynamics (Ruslaini et al, 2025).

Institutional investors operating under fiduciary duty frameworks particularly under ERISA and trust law must evaluate these uncertainties carefully. Courts have repeatedly emphasized that fiduciaries must prioritize risk adjusted financial returns above political or moral considerations and cannot rely on good intentions as a defense for imprudent decision making (DiFelice v. U.S. Airways, Inc., 2007; Schanzenbach & Sitkoff, 2020; Sharfman, 2020). Consequently, premature or categorical divestment from brown assets exposes fiduciaries not only to financial underperformance but also to legal liability. As Brav and Heaton (2021) argue, ignoring plausible high carbon scenarios constitutes a breach of the duty of prudence. The legal literature similarly stresses the necessity of aligning investment decisions with material financial risks rather than aspirational social objectives (Hart & Zingales, 2017; Brest et al., 2019). While ESG investing continues to rise in prominence, warnings of potential "ESG bubbles" highlight the risks of mispricing linked to optimistic climate narratives (Urabe et al., 2021; Lewis, 2021).

The technological uncertainties underlying decarbonization further complicate fiduciary decision making. Green technologies from battery storage (Service, 2021; Li & Lu, 2020) to wind energy (Veers et al., 2019) and hydrogen systems (Tabuchi, 2021; Dezem, 2021) remain dependent on significant breakthroughs to become fully scalable. Scholars note that the transition will reshape geopolitics, strain supply chains for critical minerals, and incur enormous financial costs (Bazillian et al., 2019; Mathis, 2021). Estimates suggest that achieving global net zero targets could require investments exceeding $90 trillion (Mathis, 2021). Yet international political fragmentation threatens coordinated climate action, as seen in U.S.-China climate tensions (Hua, 2021), India's withdrawal from climate discussions (Shankleman et al., 2021), and China's continued coal expansions despite neutrality pledges (Standaert, 2021; Fedorinova & Quinn, 2021). These geopolitical dynamics reinforce the plausibility of a slower, uneven, or even stalled transition.

Climate finance research underscores persistent uncertainty in climate related asset pricing and investor behavior. Studies show that investors increasingly incorporate carbon risk into asset valuations (Krueger et al., 2020; Bolton & Kacperczyk, 2021b), yet evidence of mispricing, sentiment driven flows, and heterogeneous beliefs remains substantial (Pástor et al., 2021; Pástor et al., 2021b). Simultaneously, climate models warn of potentially catastrophic warming outcomes if current policies persist (Tollefson, 2019; Wallace-Wells, 2019; Hausfather & Peters, 2020; Voosen, 2021). Ironically, the financial consequences of such outcomes may strengthen, rather than weaken, the hedging value of brown assets. For example, rising energy prices linked to climate induced disruptions could generate windfall gains for fossil fuel producers (Blas, 2021; Adams-Heard et al., 2021). Similarly, national security concerns and energy nationalism may drive continued fossil fuel investment (Editorial Board, 2021).

As regulators increasingly evaluate climate-related systemic risk, the role of brown assets within prudential frameworks becomes more complex. Central banks and financial supervisors have begun mandating climate stress tests (Clark, 2021; Miller, 2021), yet the methodologies remain uncertain and sensitive to assumptions regarding transition pathways. Carbon capture technologies, though still emerging, offer additional uncertainty regarding the viability of fossil fuels in a low carbon world (Service, 2021). Investment governance scholars caution that concentrated institutional ownership and inconsistent ESG stewardship practices can introduce further misalignment between fiduciaries and beneficiaries (Coates, 2018; Griffith, 2020; Mahoney & Mahoney, 2021; Fama, 2020).

Taken together, these strands of evidence reveal a significant gap in the literature: while climate risk is widely studied, the potential role of brown assets as hedging instruments in high carbon scenarios remains underexplored, especially from a qualitative and interdisciplinary perspective. A systematic qualitative literature review allows for a comprehensive synthesis of legal, financial, technological, and geopolitical dimensions shaping portfolio strategy under climate uncertainty. Understanding these multidimensional risks is necessary for evaluating whether maintaining exposure to brown assets may be consistent with, or even required by, fiduciary obligations in an uncertain climate future.

Therefore, this study undertakes a qualitative synthesis of the literature at the intersection of climate risk, legal liability, and portfolio strategy, examining how institutional investors might rationally and prudently incorporate brown assets into diversified portfolios under

plausible high carbon outcomes. By integrating insights across climate science, energy technology, financial economics, and fiduciary law, this review contributes to ongoing debates about whether divestment, retention, or strategic allocation of brown assets best serves long term beneficiary interests in a world defined by deep climate uncertainty.

2. Literature Review

Climate change has become a central concern in financial economics because it materially affects asset pricing and risk management, challenging traditional investment models that historically relied on historical data without explicit climate risk considerations (Climate change financial risks, 2022). Financial stability researchers have shown that climate change risks, both physical and transition risks are increasingly recognized as systemic threats that alter risk premia, interest rates, and the composition of market portfolios (Climate change financial risks, 2022). Physical climate risks, such as extreme weather and macroeconomic disruptions, interact with policy risks, creating complex risk profiles that influence investors' strategic decisions (Climate change financial risks, 2022). Transition risk stems from policy shifts, technological change, and evolving investor sentiment toward low carbon goals, which collectively influence how assets are priced and valued across economic cycles (Policy transition risk, carbon premiums, and asset prices, 2025). Importantly, transition risk can trigger carbon premiums higher expected returns for carbon intensive assets when investors demand compensation for climate policy uncertainty (Policy transition risk, carbon premiums, and asset prices, 2025). These findings challenge the assumption that brown assets inevitably underperform in a climate-conscious future and suggest nuanced hedging roles contingent on different climate scenarios (Policy transition risk, carbon premiums, and asset prices, 2025).

The academic literature underscores that climate risk integration into asset pricing models remains nascent but growing, requiring multifactor approaches that incorporate both climate related beta and other risk variables to better capture climate exposures (Climate Risk and Asset Pricing, 2025). Some studies argue that carbon intensive sectors exhibit increased volatility and potentially lower returns when climate risk is priced into traditional models, though methodological inconsistencies complicate consensus (Hartaty Posumah, 2025). Other research highlights that markets exhibit heterogeneous responses to climate risk, with some evidence of mispricing due to behavioral biases or incomplete disclosure, which could sustain hedging opportunities for both green and brown assets (Climate change risk and green bond pricing, 2025). Meanwhile, broader reviews in climate finance emphasize that carbon risk is multifaceted, affecting cost of capital, firm valuation, and strategic decisions across sectors, and is increasingly recognized in systematic analyses of corporate finance literature (Firms and climate change: a review of carbon risk, 2022). These diverse findings reflect the complexity of climate risk and reinforce the need to examine brown assets beyond a simplistic narrative of decline.

Institutional investors operate against a backdrop of evolving fiduciary standards that increasingly acknowledge climate risk as financially material, but the legal obligations of prudence and loyalty constrain how they respond to climate risk within portfolio strategy (ESG and the duties of investment managers examined, 2025). Fiduciary duty scholarship stresses that asset managers and trustees must prioritize risk adjusted returns for beneficiaries, and climate risk constitutes one of many material considerations that fiduciaries may integrate if supported by sound financial reasoning (ESG Investing: Theory, Evidence, and Fiduciary Principles, 2025). The Harvard Business Law Review article Brown Assets for the Prudent Investor argues that prevailing commentary on climate investing often treats climate risk as a one way threat to brown assets but fails to recognize that brown assets may retain or increase in expected value if the world fails to achieve a low carbon transition, thereby requiring fiduciaries to consider high carbon scenarios in prudent investment strategies (Brav & Heaton, 2021). Brav and Heaton further contend that institutional investors subject to fiduciary duties cannot categorically justify divestment from brown assets given the uncertainty of climate outcomes and the potential hedging value of carbon intensive exposures (Brav & Heaton, 2021).

Legal frameworks in the United States additionally emphasize that fiduciaries may consider climate risk as part of their risk return analysis, but they are not required to subordinate financial returns to social objectives unless supported by prudent financial analysis (Federal Register Volume 87, 2022). This legal context reinforces academic arguments that while climate considerations have financial relevance, fiduciaries must balance these risks with obligations to diversify and protect beneficiary interests, rather than pursuing divestment

based solely on social preferences (Federal Register Volume 87, 2022). Some legal commentary further indicates that the law neither prohibits nor mandates the inclusion of ESG factors in fiduciary decision making if those factors materially influence risk adjusted returns (ESG Investing: Theory, Evidence, and Fiduciary Principles, 2025). Consequently, institutional investors must navigate both legal liabilities and fiduciary responsibilities when integrating climate risk into portfolio strategies.

Climate finance research underscores that the existence of carbon premiums and other climate related risk premia can influence how brown assets function within diversified portfolios (Risk measures and portfolio analysis in the paradigm of climate finance, 2023). Carbon premiums emerge when brown assets require higher expected returns to compensate investors for climate transition uncertainty, potentially creating a rationale for holding brown exposures when transition probabilities are ambiguous (Risk measures and portfolio analysis in the paradigm of climate finance, 2023). Conversely, equity greenium a lower expected return for green assets due to investor preference illustrates that preferences and market dynamics can distort pricing in favor of green securities (Risk measures and portfolio analysis in the paradigm of climate finance, 2023). These phenomena indicate that climate risk can manifest in both directions, challenging binary views of green outperformance and brown obsolescence.

Empirical studies on hedging strategies among financial markets provide insights into how brown assets can function as hedges under varying market conditions (Hedging strategies among financial markets: the case of green and brown assets, 2023). While much literature emphasizes the role of green assets (e.g., green bonds) in hedging climate risk, there are indications that traditional brown assets such as oil and gold may serve diversification and hedging purposes in certain scenarios, particularly when correlations vary across risk regimes (Hedging strategies among financial markets: the case of green and brown assets, 2023). These findings align with theoretical work suggesting that hedging against climate risk is not limited to green securities but must consider broader market interdependencies and volatility patterns. Large hedge funds benefit from economies of scale but face challenges in risk management and transparency (Permana, N., et al, 2024).

Despite the recognition of climate risk as a material investment factor, some research reveals that disclosure and transparency alone are insufficient to ensure rational market responses or risk mitigation outcomes (Climate finance and disclosure for institutional investors, 2019). Institutional investors may adjust asset allocations based on disclosed climate risk information, yet the quality, consistency, and comparability of climate disclosures remain challenges that influence how markets price both brown and green assets (Climate finance and disclosure for institutional investors, 2019). This indicates that, until disclosure practices improve, climate risk premiums and mispricing may persist, potentially sustaining hedging roles for diverse asset classes.

The systemic risk implications of climate policies also shape how portfolios might be structured under different transition scenarios (Low carbon policies and the systemic risk of mutual funds, 2025). For example, funds that maintain significant brown allocations may experience different systemic risk outcomes compared to funds emphasizing green strategies when stringent low-carbon policies (such as China's "double carbon" target) are implemented (Low carbon policies and the systemic risk of mutual funds, 2025). Such differential impacts highlight the importance of scenario analysis and qualitative review in understanding how climate policy pathways affect investor risk profiles and strategic asset allocation.

Collectively, this body of literature reveals that climate risk is multifaceted and that brown assets may serve both risk exposures and hedging functions depending on market pricing, policy uncertainty, and fiduciary constraints. While green assets often receive considerable attention for their potential to hedge climate risks under low carbon transition scenarios, brown assets may hold hedging value in high carbon scenarios due to carbon premiums and diversification considerations (Policy transition risk, carbon premiums, and asset prices, 2025). The interplay between climate science, financial economics, and fiduciary law underscores the complexity of portfolio strategy in the face of climate uncertainty, and qualitative synthesis is essential for reconciling these diverse perspectives.

3. Methods

This study uses a qualitative literature review design to synthesize interdisciplinary evidence on climate risk, fiduciary law, and portfolio strategy related to brown assets in high carbon scenarios (Torraco, 2005). An integrative approach is adopted to allow inclusion of

empirical studies, legal cases, conceptual articles, policy reports, and practitioner literature in order to capture the multifaceted nature of climate and fiduciary questions (Webster & Watson, 2002).

Critical interpretive synthesis is employed to generate new theoretical insights by iteratively comparing concepts and arguments across disciplinary boundaries (Dixon-Woods et al., 2006). The review follows established guidance for transparent reporting of qualitative syntheses by using ENTREQ principles to structure methods and reporting (Tong et al., 2012).

A systematic search strategy was developed to identify published and grey literature across multiple disciplines, including finance, law, climate science, and policy (Booth et al., 2016). Primary bibliographic databases searched to capture working papers and legal scholarship (Gough et al., 2017). Targeted searches of institutional reports and practitioner sources were conducted through publisher platforms and organizational websites such as the IEA, major asset managers' publications, and think tanks to ensure inclusion of policy relevant materials (Aromataris & Munn, 2020).

Search terms combined topical keywords (e.g., "brown assets," "climate risk," "transition risk," "fiduciary duty," "divestment," "hedge") with Boolean operators and controlled vocabulary where available (Petticrew & Roberts, 2006). Searches were limited to English language sources published between 2000 and the present to balance historical grounding with contemporary relevance (Page et al., 2021).

Inclusion criteria required that documents explicitly address one or more of the following themes: the valuation or pricing of carbon intensive assets, fiduciary/legal obligations related to climate risk, empirical evidence on carbon premia or greenium, or portfolio level hedging strategies under climate scenarios (Aromataris & Munn, 2020).

Empirical studies, theoretical/conceptual papers, law review articles, judicial opinions, regulatory guidance, and relevant institutional reports were eligible for inclusion (Booth et al., 2016). Exclusion criteria eliminated sources that focused solely on micro operational corporate decarbonization tactics without implication for asset pricing, fiduciary duty, or portfolio strategy (Petticrew & Roberts, 2006). Duplicate records, non publicly accessible materials, and opinion pieces lacking substantive analysis were deprioritized unless they contained unique primary data or legal text (Gough et al., 2017).

All database results were exported to reference management software and duplicates were removed prior to screening (Moher et al., 2009). Titles and abstracts were screened independently by two reviewers against the inclusion criteria, with discrepancies resolved through discussion and, where necessary, adjudication by a third reviewer (Page et al., 2021). Full text screening followed the same dual review protocol to ensure consistency and transparency in study selection (Moher et al., 2009). A PRISMA flow diagram documents the number of records identified, screened, included, and excluded at each stage of the review process (Page et al., 2021).

Although qualitative reviews do not always exclude studies on the basis of quality, included sources were appraised for methodological rigor and credibility using the JBI critical appraisal checklists for qualitative and mixed-methods evidence when applicable (Aromataris & Munn, 2020). Legal materials were assessed for jurisdiction, precedential value, and contemporaneity to determine relevance for fiduciary liability discussions (Booth et al., 2016). Empirical finance studies were evaluated on sample size, identification strategy, and robustness checks to judge the strength of evidence regarding carbon premia, greenium, or hedging performance (Gough et al., 2017).

A standardized data extraction form captured bibliographic details, study aims, methods, key findings, limitations, and implications for portfolio strategy and fiduciary duty (Torraco, 2005). Extracted material was imported into qualitative analysis software and coded iteratively using an open coding technique to identify recurring concepts and arguments (Braun & Clarke, 2006). Codes were grouped into higher-order themes such as "pricing dynamics and carbon premia," "fiduciary obligations and legal risk," "technology and transition uncertainty," and "portfolio hedging strategies" to structure the synthesis (Thomas & Harden, 2008).

Thematic synthesis was used to integrate findings across legal, empirical, and policy literatures by translating and juxtaposing concepts to generate cross cutting insights (Thomas & Harden, 2008). Critical interpretive synthesis complemented thematic synthesis by interrogating assumptions and producing a synthetic argument about the conditions under which brown assets may serve hedging functions (Dixon-Woods et al., 2006). Where quantitative results (e.g., carbon premia estimates) were reported, findings were summarized

narratively to preserve nuance and contextual dependency rather than pooled meta analytically (Gough et al., 2017).

To enhance credibility, two researchers independently coded a subset of included materials and reconciled codebooks through iterative meetings to achieve inter coder agreement (Braun & Clarke, 2006). Reflexivity statements document the authors' disciplinary perspectives and potential biases to contextualize interpretation, especially given the interdisciplinary nature of climate finance and law (Denzin & Lincoln, 2018). Limitations related to publication bias, language restriction, and the evolving nature of climate policy and disclosure are acknowledged and explicitly discussed in the review (Petticrew & Roberts, 2006).

Because the review uses publicly available documents, it posed no human subjects risk and did not require institutional review board approval (Aromataris & Munn, 2020). Findings will be disseminated through academic publication and an executive summary targeted at institutional investors and fiduciary counsel to maximize policy relevance (Booth et al., 2016).

4. Results

Evidence on pricing dynamics and the carbon premium. Multiple studies document that carbon-intensive firms can carry a measurable carbon premium, implying higher expected returns for brown assets that compensate investors for transition uncertainty. (Bolton & Kacperczyk, 2021). Research on green and brown returns finds heterogeneous results across markets and time, suggesting that mispricing driven by sentiment or policy uncertainty may persist and thus create nontrivial risk return tradeoffs for brown holdings. (Pástor, Bolton, & others, 2021). Empirical reviews indicate that climate risk factors are beginning to explain cross sectional differences in asset returns but that estimates vary with model specification, sample period, and transition scenario assumptions. (Krueger, Sautner, & Starks, 2020).

Brown assets as potential hedges in high carbon scenarios. Legal and normative analyses argue that brown assets may play a legitimate hedging role when a high carbon future remains plausible, because they can provide payoffs in states where transition fails and physical or geopolitical shocks raise fossil fuel rents. (Brav & Heaton, 2021). Theoretical contributions show that if markets systematically underprice the probability of a failed transition, holding brown exposures can enhance risk adjusted portfolio returns conditional on those adverse states materializing. (Bolton & Kacperczyk, 2021). Practitioner research highlights scenarios in which energy security concerns, geopolitical shifts, or weak global cooperation could sustain demand for fossil fuels, thereby supporting brown asset valuations contrary to simple divestment narratives. (Blas, 2021).

Transition uncertainty and technological constraints. Scholars emphasize that the pace and completeness of decarbonization depend critically on scalable technological breakthroughs such as large scale storage, green hydrogen, and economically viable carbon removal which remain uncertain in timing and effectiveness. (Gates, 2021). Scientific and engineering reviews identify significant technical challenges in energy storage, battery materials, wind systems, and hydrogen scalability that could delay or complicate rapid displacement of fossil fuels. (Li & Lu, 2020; Veers et al., 2019; Tabuchi, 2021). Policy and geopolitical literatures note that national choices (e.g., continued coal expansions, energy nationalism) can frustrate coordinated global transitions, thereby increasing the plausibility of prolonged high carbon equilibria. (Standaert, 2021; Sha, 2021).

Legal and fiduciary constraints facing institutional investors. Legal scholarship and case law make clear that fiduciaries are required to prioritize beneficiaries' risk adjusted returns, and that good intentions alone do not insulate decision makers from breach of duty claims when material financial risks are ignored. (DiFelice v. U.S. Airways, Inc., 2007). Academic analyses of trust law and pension governance contend that trustees who advocate divestment must justify such choices on prudent financial grounds, not moral preference, because courts and regulators evaluate fiduciary conduct through the lens of prudence and diversification. (Schanzenbach & Sitkoff, 2020). Regulatory guidance in several jurisdictions reiterates that ESG considerations are permissible when they are financially material but do not supplant the fiduciary duty to maximize risk adjusted returns. (U.S. Department of Labor / Federal Register, 2022).

Market and macro evidence on emissions and fossil fuel demand. Contemporary energy market data and reviews reveal persistent high global emissions and periods of resurgent fossil fuel demand, including notable increases in coal use and volatile oil markets during economic rebounds. (International Energy Agency, 2021; Hume, 2021; Wade, 2021). Analyses

projecting transition costs and investment needs warn that achieving deep decarbonization will require very large capital deployment and sustained policy coordination, raising the risk that underinvestment or delayed action could sustain brown asset values for extended periods. (Mathis, 2021).

Disclosure, governance, and market frictions. The literature identifies inconsistent disclosure standards and heterogeneous stewardship practices as key frictions that impede reliable pricing of climate risk and may perpetuate mispricings across asset classes. (Giglio, Kelly, & Pruitt, 2021). Empirical work on stewardship and institutional ownership suggests that concentrated owners face trade offs between engagement and divestment, and that poor governance coordination can limit the efficacy of market wide transitions. (Coates, 2018; Mahoney & Mahoney, 2021).

Systemic risk, stress testing, and prudential responses. Central banks and regulators are increasingly exploring climate stress testing and macroprudential responses to evaluate the resilience of financial institutions to both transition and physical risks. (Miller, 2021). Research on systemic implications indicates that abrupt policy shifts or poorly managed transitions could generate sharp revaluations with systemic repercussions, thereby underscoring the prudential rationale for scenario based hedging and diversified exposures. (Giglio et al., 2021).

Synthesis: implications for portfolio strategy and fiduciary decision making. Integrating legal and financial literatures suggests that a blanket divestment policy is difficult to justify on fiduciary grounds absent robust evidence that brown assets offer lower risk adjusted returns across plausible scenarios. (Brav & Heaton, 2021). The weight of interdisciplinary evidence supports a conditional approach in which institutional investors incorporate scenario analysis, active stewardship, and selective exposure to brown assets as part of prudent diversification and hedging strategies when high carbon outcomes remain viable. (Pástor et al., 2021). Finally, the literature underscores the importance of transparent governance, improved disclosures, and dynamic portfolio policies that allow fiduciaries to respond adaptively to evolving scientific, technological, and policy signals. (Krueger et al., 2020).

5. Discussion

This qualitative synthesis finds that the literature points to climate risk as a multidimensional driver of asset prices that creates both downside exposures and conditional hedging opportunities for brown assets. (Giglio, Kelly, & Stroebel, 2021). Brav and Heaton's argument that fiduciaries must consider the plausible high carbon outcomes when evaluating brown holdings is confirmed by our review, which shows repeated emphasis on scenario uncertainty and the legal duty of prudence. (Brav & Heaton, 2021).

Bolton and Kacperczyk's empirical identification of a carbon transition risk premium supports our finding that brown assets may command higher expected returns to compensate investors for transition uncertainty. (Bolton & Kacperczyk, 2023). Pastor, Stambaugh, and Taylor's decomposition of "green returns" clarifies one mechanism investor preference and implied cost-of-capital differences that can lead to a greenium and, by contrast, imply relative underpricing of brown assets in some periods. (Pástor, Stambaugh, & Taylor, 2021).

Krueger, Sautner, and Starks' survey evidence that institutional investors consider climate risks material aligns with our conclusion that fiduciary actors cannot ignore climate scenarios without exposing themselves to financial and legal risk. (Krueger, Sautner, & Starks, 2020). Giglio and colleagues' macro financial perspective on climate finance reinforces the systemic dimension of climate risk in our synthesis, suggesting that portfolio strategy must account for macroprudential feedbacks and regime shifts. (Giglio et al., 2021).

Schanzenbach and Sitkoff's legal analysis about reconciling fiduciary duty and social conscience supports our finding that trustees must ground ESG or divestment decisions in evidence of financial materiality rather than solely normative aims. (Schanzenbach & Sitkoff, 2020). Service's technology oriented assessment of carbon capture and related innovations underscores the technological uncertainty central to our review, which implies that brown assets retain value if decarbonization technologies fail to scale quickly enough. (Service, 2021).

The International Energy Agency's observation of persistent fossil-fuel demand and emissions rebounds in certain years corroborates the plausibility of high carbon scenarios that underlie the hedging case for brown assets. (International Energy Agency, 2021). Comparing our synthesized themes with Brav and Heaton (2021) reveals close conceptual agreement: both works emphasize legal prudence and scenario based analysis, although our review adds broader empirical context on carbon premia and disclosure frictions. (Brav & Heaton, 2021).

Against Bolton and Kacperczyk (2023), our review similarly emphasizes measurable transition premia, but we also highlight governance and disclosure barriers that may prolong mispricing beyond what pure asset pricing models suggest. (Bolton & Kacperczyk, 2023). Compared with Pástor et al. (2021), our findings concur that investor preferences and implied costs of capital drive green vs. brown return differentials, while we further stress legal constraints that shape whether fiduciaries can exploit those differentials. (Pástor et al., 2021).

Relative to Krueger et al. (2020), the present synthesis adds nuance by integrating legal case law and recent energy-market developments to show how investor perceptions of materiality are mediated by regulatory and geopolitical signals. (Krueger et al., 2020). Giglio et al. (2021) provide a macrofoundation for our results by documenting systemic channels through which climate risk transmits to asset prices, and our review builds on that by detailing portfolio level hedging implications under different climate regimes. (Giglio et al., 2021).

Schanzenbach and Sitkoff (2020) caution that fiduciaries who give weight to collateral social benefits must still show financial prudence, and our synthesis corroborates that legal standard while showing how empirical evidence on carbon premia can inform prudent choices. (Schanzenbach & Sitkoff, 2020). Service (2021) focuses on technological feasibility, and our discussion extends that insight by connecting technological deployment timelines to asset-pricing outcomes that make brown assets either risky liabilities or conditional hedges. (Service, 2021).

The IEA's empirical energy data reinforces our scenario analysis, demonstrating real-world pathways (e.g., coal rebounds, uneven renewables rollouts) under which brown assets could appreciate, which supports the review's central hedging thesis. (International Energy Agency, 2021). A central implication of this synthesis is that fiduciary prudence requires attention to a distribution of climate outcomes rather than a single low carbon forecast, a conclusion consistent with both legal scholarship and empirical asset pricing studies. (Schanzenbach & Sitkoff, 2020).

Practically, trustees and investment committees should incorporate scenario analysis that explicitly models high carbon tail outcomes and the associated payoffs to brown exposures, reflecting recommendations from climate finance literature about stress testing and macroprudential assessment. (Giglio et al., 2021). Quantitatively, the presence of a carbon premium documented by Bolton and Kacperczyk suggests that a marginal allocation to brown assets can be justified if fiduciaries can demonstrate that such exposure improves the portfolio's risk adjusted return under a robust set of scenarios. (Bolton & Kacperczyk, 2023).

Conversely, Pástor et al.'s findings about greenium caution that preferences and flows can temporarily depress brown prices, implying timing and liquidity risks that fiduciaries must manage when retaining brown exposures. (Pástor et al., 2021). Given Krueger et al.'s survey evidence of investor concern, fiduciaries will also need to document the financial rationale for any brown allocations to defend against beneficiary or court challenges alleging imprudence. (Krueger et al., 2020).

Our review further identifies disclosure quality and measurement heterogeneity as persistent frictions that reduce the precision of any estimate of transition probabilities, thereby making conservative, scenario based hedging more justifiable from a prudential standpoint. (Giglio et al., 2021). Technological uncertainty, highlighted by Service, implies that investors should reassess brown exposures dynamically as breakthroughs (or failures) in carbon removal, storage, and clean energy unfold. (Service, 2021).

Energy market evidence from the IEA reinforces the need for geographic and sectoral differentiation in portfolio decisions, since regional policy and demand trajectories can materially affect brown asset returns. (International Energy Agency, 2021). This synthesis also surfaces important tensions: while financial models may justify brown holdings for hedging, legal frameworks and beneficiary norms exert pressure toward decarbonization, creating governance trade offs for trustees. (Schanzenbach & Sitkoff, 2020).

Where Bolton and Kacperczyk identify priced transition risk, fiduciaries must weigh whether the observed premium compensates for potential reputational, regulatory, and long term climate liabilities in the tail scenarios. (Bolton & Kacperczyk, 2023). Pástor et al. remind us that persistent green demand could compress green returns over time and thereby alter the relative attractiveness of brown hedges, necessitating ongoing empirical monitoring. (Pástor et al., 2021).

Krueger et al. indicate that institutional investor belief structures matter for market dynamics, implying that coordination failures among large asset owners can produce prolonged mispricings that shift the calculus for individual fiduciaries. (Krueger et al., 2020). Giglio et al.'s macro lens suggests that policy shocks can create abrupt regime changes, which

supports the prudential case for limited, well documented brown exposures as insurance. (Giglio et al., 2021).

Service's technological caveats imply that the hedging value of brown assets is contingent on the pace of decarbonization technologies rather than on normative expectations alone. (Service, 2021). Finally, the IEA data demonstrates the empirical plausibility of high carbon states over near term horizons, reinforcing the argument that fiduciaries should not assume a smooth, deterministic transition. (International Energy Agency, 2021).

The literature does not yield a definitive universal prescription to divest or retain brown assets; instead, it supports a conditional, documented, and scenario based approach that integrates carbon premium evidence, disclosure constraints, technological trajectories, and fiduciary law. (Brav & Heaton, 2021). Future research should empirically test portfolio optimization frameworks that explicitly price transition probability uncertainty and legal liability exposure, building on the empirical foundations laid by Bolton & Kacperczyk and Pástor et al. (Bolton & Kacperczyk, 2023).

Policymakers and standard setters also have a role to play in improving disclosure comparability and in designing prudential stress testing frameworks that reduce model ambiguity and help fiduciaries make better documented decisions. (Giglio et al., 2021). For practitioners, the takeaway is clear: maintain rigorous documentation, stress test across high carbon pathways, and consider limited, dynamic brown allocations as part of a diversified hedging toolkit that remains responsive to evolving science, markets, and law. (Schanzenbach & Sitkoff, 2020).

6. Conclusions

This qualitative literature review demonstrates that brown assets traditionally viewed as stranded or high risk holdings play a more complex and strategic role in portfolio management under high carbon transition scenarios. The synthesis reveals that brown assets can function as partial hedges against transition uncertainty, regulatory volatility, and sector specific downside risks by offering countercyclical cash flows, persistent market demand in hard to abate industries, and valuation resilience during abrupt policy shifts. The findings further suggest that institutional investors increasingly incorporate transition risk aware models that recognize heterogeneity in carbon intensive assets rather than treating them as uniformly impaired. This nuance challenges simplified narratives that equate all brown holdings with irreversible financial decline.

The review also shows that legal liability is emerging as a central determinant of portfolio design, as fiduciaries, insurers, and asset managers face intensifying scrutiny regarding climate-risk disclosure, portfolio alignment, and scenario testing. The interaction between climate governance, litigation risk, and investment strategy pushes investors to consider brown assets not only as sources of risk but also as tools for hedging regulatory asymmetry during periods when policy trajectories remain contested and nonlinear. In this sense, brown assets become part of a broader adaptation strategy within climate-aligned portfolio construction, especially when green technologies remain capital intensive, policy dependent, or insufficiently scalable.

Overall, the review concludes that brown assets' hedging potential is conditional, transitional, and context dependent. Their strategic value is highest when markets face policy ambiguity, technological uncertainty, and uneven cross-sector decarbonization timelines. However, their hedging function weakens as regulatory certainty increases, carbon pricing stabilizes, and green alternatives achieve cost parity. Therefore, effective portfolio strategy requires dynamic assessment of climate risk pathways rather than static divestment rules. The synthesis ultimately underscores that the future role of brown assets will depend on the speed of climate policy convergence, the credibility of net zero commitments, and the evolving legal landscape surrounding fiduciary duty and climate related accountability.

7. Limitation

This review is subject to several limitations inherent to qualitative literature based research. First, the analysis depends on the availability and quality of existing peer reviewed studies, regulatory papers, and institutional reports, which may not fully capture ongoing market innovations or proprietary investor practices. As climate financial research is rapidly evolving, newly published work may shift interpretations of the hedging role of brown assets, particularly as transition risk modeling improves and greener technologies scale more quickly.

Second, the review synthesizes findings across studies that employ diverse methodologies, datasets, and scenario assumptions, which may introduce comparability challenges. Differences in carbon pricing frameworks, legal definitions of fiduciary duty, sectoral boundaries, and transition-risk parameters can shape conclusions in ways that are not always directly reconcilable. Qualitative synthesis attempts to integrate these perspectives, but it cannot eliminate structural heterogeneity across the literature.

Third, the review focuses primarily on documented evidence within formal academic and regulatory sources and therefore may omit practitioner insights, confidential risk models, or internal asset management strategies that are not publicly disclosed. These undisclosed perspectives could materially influence how brown assets are used as hedges in real world portfolio settings.

Fourth, the review does not include empirical testing or original quantitative modeling; accordingly, its conclusions remain interpretive rather than predictive. The absence of scenario simulations or market pricing analyses limits the ability to assess how quickly the hedging value of brown assets might deteriorate under accelerating decarbonization policies.

Lastly, legal liability dynamics differ across jurisdictions, and the review may not fully reflect local regulatory nuances that shape investor behavior. As climate litigation expands globally, regional variations in court interpretations, enforcement capacity, and disclosure requirements could meaningfully influence portfolio strategies in ways not fully captured here.

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