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Abstract:

The looming climate crisis calls for the development of novel forms of response, but so far, climate change action does not meet its ambitions to tackle the issue. Voluntary Carbon Markets (VCMs) are one proposed solution to bridge the gap. However, VCMs are criticized for not providing real climate benefits and exacerbating inequality. This paper critically assesses VCMs, focusing on their regulatory, ecological, and social dysfunctions through an ecological economics lens. It identifies key issues such as inadequate transparency, compromised environmental integrity due to issues of additionality, permanence, double counting, carbon leakage, rebound effects, and adverse social impacts. By analyzing these dysfunctions and the underlying theoretical assumptions, the paper highlights how power relations, fundamental uncertainties, information asymmetries, and the commodification of nature contribute to the observed problems in VCMs. Through a qualitative literature analysis, this research provides a comprehensive evaluation of VCMs' role in global climate policy, emphasizing the need for robust regulatory frameworks, transparency, and inclusive decision-making processes to enhance their efficacy. The findings suggest that while VCMs have potential, addressing their inherent limitations is crucial for their legitimacy and effectiveness in combating climate change.

JEL code: F64, Q50, Q54, Q57, Q58

Key words: Voluntary carbon markets, carbon offsetting, regulatory frameworks, ecological economics, environmental integrity

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1. Introduction

The pressing climate crisis requires innovative solutions to mitigate its far-reaching impacts, and Voluntary Carbon Markets (VCMs) have emerged as a prominent mechanism in this endeavor (Stoddard et al., 2021, p. 665). In VCMs, carbon credits are traded, allowing companies and individuals to voluntarily offset their emissions. These markets differ from compliance carbon markets, which are regulated by mandatory frameworks like the European Union Emissions Trading System (EU ETS). Despite their potential, VCMs are subject to significant scrutiny and criticism. Scholars highlight several dysfunctions, including regulatory, ecological, and social challenges, which question the efficacy and integrity of these markets (Cames et al., 2016).

Current literature extensively examines the functioning of VCMs, its potential benefits, and challenges within the broader context of carbon offsetting (Bumpus & Liverman, 2008; Chen et al., 2021). Scholars highlighted various issues within these markets, including inadequate transparency (Ahonen et al., 2022; Root & Krause, 2023), questionable additionality and permanence of carbon offsets (Badgley et al., 2022; West et al., 2023), and potential adverse impacts on local communities (Bayrak & Marafa, 2016). While some studies suggest improvements and propose solutions (Broekhoff et al., 2019; Cornillie et al., 2021), the critique from an ecological economics perspective remains underdeveloped.

This paper aims to critically assess the regulatory, ecological, and social dysfunctions of VCMs from an ecological economics perspective by analyzing the underlying assumptions and operational mechanisms of VCMs. The rationale for this research lies in addressing the gap in existing literature and contributing to the ongoing debate on the legitimacy and efficacy of VCMs as tools for combating climate change. Understanding these dysfunctions is crucial for developing more effective and equitable mechanisms.

In an effort to contribute to the ongoing discussion, this paper proposes the following research questions: What regulatory, ecological, and social dysfunctions do voluntary carbon markets face, and how can they be analyzed from an ecological economics perspective?

This paper employs a qualitative literature analysis, focusing on peer-reviewed articles and significant non-peer-reviewed sources, including studies, books, official reports, and blog entries to present a holistic evaluation. The literature was accessed between early December 2023 and July 2024 through multiple databases, including Google Scholar, ResearchGate and ScienceDirect. The search strategy employed a snowballing technique based on Wohlin's (2014) guidelines, whereby initial literature results were used to identify additional relevant sources, prompting further data inquiries.

The paper is organized as follows: First, a literature review categorizes existing research on VCMs into regulatory, ecological, and social dimensions. Next, a descriptive section explains the functioning of VCMs and introduces key stakeholders. This is followed by an analysis of the dysfunctions within VCMs. Subsequently, the theoretical foundations of these markets are examined, leading to a critique from an ecological economics perspective. Finally, the paper concludes by discussing implications, proposing potential solutions, and suggesting directions for future research.

2. Literature Review

VCMs have been extensively discussed in academic and grey literature. The literature examines the functioning of carbon pricing (Haites, 2018; Sturm & Vogt, 2011; Wiesmeth, 2003) and VCMs in particular (Bumpus & Liverman, 2008; Chen et al., 2021). Research on VCMs typically falls into three main categories: studies that emphasize the innovative potential of VCMs (Farber, 2023; Warburg et al., 2021), those that acknowledge market failures but propose improvements (Broekhoff et al., 2019; Cornillie et al., 2021; Donofrio & Calderon, 2023; Edmonds et al., 2019), and those that critically assess VCMs' regulatory, ecological, and social dysfunctions. This literature review focuses on the third category, presenting key research findings and methodologies relevant to the dysfunctions of VCMs.

Scholars have extensively examined the lack of governance within VCMs, highlighting issues such as inadequate regulatory frameworks and oversight (Bumpus et al., 2010; Bumpus & Liverman, 2008; Chen et al., 2021; Nelson, 2013; Ziegler, 2023). Another significant regulatory issue is the lack of transparency, which has been explored by various scholars underscoring the need for more robust governance and clearer transparency mechanisms (Kreibich & Hermwille, 2021; Root & Krause, 2023; Wyburd, 2024).

A critical area of research is the environmental integrity of VCMs (Battocletti et al., 2023; Calvin et al., 2015; Filewod & McCarney, 2023; Michaelowa et al., 2019; Parker et al., 2022;

Reimers et al., 2021; Schneider & La Hoz Theuer, 2019). Scholars have conducted comprehensive assessments to determine the likelihood of additionality of carbon offset projects. Quantitative assessments provide insights into the overall efficacy of these projects (Calel, 2013; Cames et al., 2016). Specific studies on certain projects advanced methodologies, such as synthetic control methods (West et al., 2020, 2023) and standardized evaluation approaches using pixel matching (Guizar-Coutiño et al., 2022).

The social impacts of VCMs have also been a significant focus of academic inquiry. Research by Bayrak and Marafa (2016) and Dunne and Quiroz (2023) examines the adverse social effects of carbon offset projects on indigenous communities and local populations. Battocletti et al. (2023) contribute to the understanding of dependencies within these markets, while Lohmann (2009a) provides a comprehensive examination of corporate influence and corruption. Another strand of literature questions the purpose of emission trading, as it represents an ecologically ineffective and socially unjust instrument (Lohmann, 2006, pp. 219–329, 2011; Pearse & Böhm, 2014; Stoddard et al., 2021). This strand is closely connected to scholars critiquing the valuation and commodification of nature (Castree, 2008; Gómez-Baggethun, 2017; Kill, 2015; Spash, 2017).

The current body of literature extensively examines dysfunctions within VCMs; however, it lacks a comprehensive integration of recent empirical studies and theoretical analyses from an ecological-economics standpoint. This paper aims to fill this gap by categorizing dysfunctions into regulatory, environmental, and social categories, establishing a framework, and linking it to concepts within ecological economics.

3. Voluntary Carbon Markets

This section provides an overview of the functioning of VCMs and details the key phases in the carbon credits process from creation to intermediation and retirement. This approach aims to clarify each stakeholder's role and their interactions within the VCMs ecosystem.

3.1. Overview of Voluntary Carbon Markets

To avert extreme climate hazards, various mitigation instruments have been developed, with carbon pricing being a cornerstone solution (Stoddard et al., 2021, p. 665). This approach internalizes environmental costs into production and consumption decisions by assigning a monetary value to carbon emissions, thereby promoting cost-effective emission reductions. Carbon pricing can be implemented through emissions trading, which can take place in compliance carbon markets or VCMs. In VCMs, companies and individuals voluntarily purchase carbon offsets[1] (Haites, 2018, p. 955). VCMs are platforms where individuals and organizations create, issue, buy, and sell carbon credits outside of regulated carbon pricing mechanisms (Ahonen et al., 2022, p. 241). A carbon credit is a scheme through which one party compensates another for actions that reduce, avoid, or remove carbon (Battocletti et al., 2023, p. 2)

Carbon credits can be categorized into three main types (Hong et al., 2023, pp. 10–12):

(1) Carbon avoidance credits (approximately 75% of certified credits): These prevent activities that would emit carbon, such as avoided deforestation.
(2) Carbon reduction credits (roughly 22% of certified credits): These lower GHG emissions compared to previous levels, including initiatives like improving fuel efficiency or mitigating methane emissions from waste processes.
(3) Carbon removal credits (approximately 3% of certified credits): These involve extracting CO_2 from the atmosphere and sequestering it for extended periods through nature-based solutions like reforestation or engineered solutions such as direct air capture and storage.

Each credit represents the verified avoidance, reduction or removal of one tonne of CO_2 equivalent (CO_2e), which is a unit translating the global warming potential of any GHG into the equivalent impact of CO_2 (Pearse & Böhm, 2014, p. 326). A hypothetical baseline scenario is calculated to substantiate the avoidance, reduction or removal, projecting what would have occurred without the activity (Cornillie et al., 2021, p. 3).

Building upon the previously discussed types of carbon credits, it is crucial to analyze the different actors involved in VCMs and their role in the generation and purchase of carbon credits. The primary demand for carbon credits comes from multinational corporations using VCMs as a cost-effective means to achieve their climate neutrality targets (Allen et al., 2022, p. 875; Lou et al., 2023, p. 3). Private individuals also participate within VCMs reducing their personal carbon footprints. The supply of credits is generated by project funders, developers, and owners (Chen et al., 2021, p. 3). Standards-setting bodies play a crucial role by acting as

[1] In this paper, the terms “carbon offsets” and “carbon credits” are used synonymously.

referees and ensuring trust through independent oversight of additionality and other methodological questions (Cornillie et al., 2021, p. 3). These roles and interactions within the ecosystem are elaborated in the next section.

The unregulated nature of VCMs allows for a broader range of projects compared to the more regulated compliance markets (Chen et al., 2021, p. 8). This flexibility fosters "technological innovation, providing a testing ground for new approaches … [and enables] direct investment to local communities and technologies that go beyond what policy can directly stimulate" (Verra, 2021b). Furthermore, VCM activities increasingly qualify for co-benefits, meaning that alongside the creation of carbon credits, additional Sustainable Development Goals (SDGs) are met (Fearnehough et al., 2020, p. 38).

The broader range of projects and various other factors influence the prices of carbon credits. These prices fluctuate due to external demand, market risk, and overall trust in the market and its commodities. Additionally, the quality of the carbon credits influences their price. Qualities affecting the price include project economics, project type, vintage or issuance year of the credit, and geographic location (Bravo et al., 2023, pp. 36, 58–59; Ecosystem Marketplace, 2024, pp. 10–21). For instance, a carbon credit from a high-input-cost carbon removal project using the latest methodologies, originating from a European country with sustainable development co-benefits, will command a higher price than a credit from an older project to avoid deforestation in Latin America. In 2023, average prices varied significantly between the individual project types, ranging from 4.76 USD to 12.01 USD (Ecosystem Marketplace, 2024, p. 14).

Despite the growing importance of VCMs, in comparison to global emissions, which amounted to 37.4 billion tCO_2e in 2023 (IEA, 2024, p. 4), VCMs account for a relatively small segment of 160 $MtCO_2e$ reduced emissions[2] that were purchased by end-buyers in 2023. Exxon Mobil Corporation's emissions alone accounted for 638 $MtCO_2e$ (Exxon Mobil Corporation, 2023, pp. 77–81). If Exxon Mobil had chosen to offset these emissions through carbon offsets, the estimated cost would have been approximately 4.2 billion USD, which would be almost 6 times the size of the VCMs.[3] As organizations commit to achieving net-zero emissions and

[2] To simplify, the term 'reduced emissions' is used below instead of 'avoided, reduced or removed emissions'.
[3] This calculation is based on data for transaction volumes, which according to Ecosystem Marketplace (2024, p. 4) totaled 723 million USD in 2023 and the average prices for one tonne of CO_2e in VCMs in 2023 (Ecosystem Marketplace, 2024, p. 4).

increasingly depend on carbon offsetting (Battocletti et al., 2023, p. 1), various market analysts forecast a significant future surge in demand (Blaufelder et al., 2021, p. 2; Ecosystem Marketplace, 2024, p. 21; Edmonds et al., 2019, p. 4). For instance, Blaufelder et al. (2021, p. 2) forecast up to a hundredfold increase in demand by 2050, resulting in VCMs being worth over 50 billion USD by 2030.

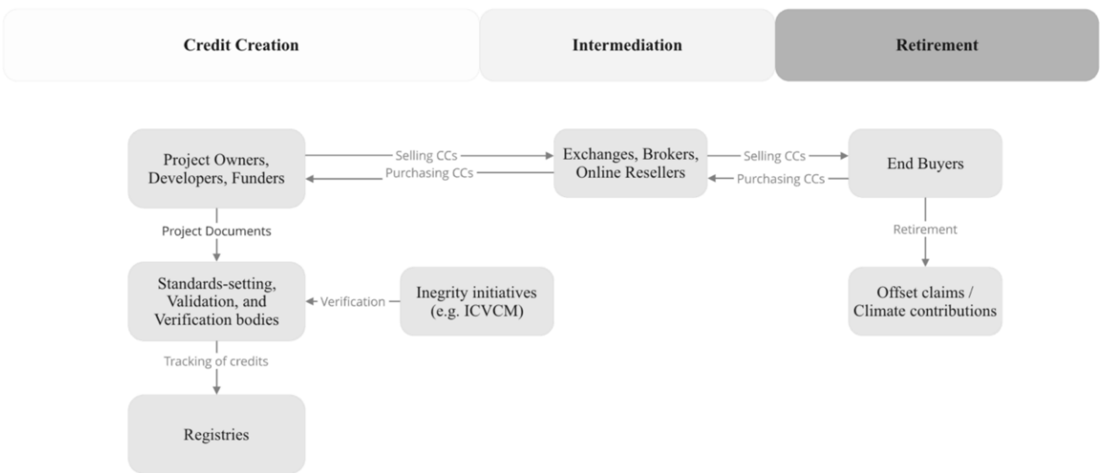
In summary, VCMs offer a versatile and expanding platform for carbon offsetting, involving a diverse range of projects and stakeholders, which are described in more detail in the following sections.

3.2. Key Phases in the Carbon Credits Process

The implementation of voluntary carbon offset projects involves various parties, stakeholders, and authorities. While the specific entities involved may vary across projects, certain categories of market participants remain constant, often serving multiple functions. Stakeholders can be categorized into three phases of the process: credit creation, intermediation, and credit retirement (Root & Krause, 2023). This entire process typically takes between 18 months and six years (Battocletti et al., 2023, p. 8). Additionally, there are rather passive but impacted stakeholders who are influenced by these activities. Figure 1 illustrates the market agents involved in this process.

Figure 1

Overview of market agents involved in creation, intermediation and retirement of Carbon Credits



Source: Authors' illustration based on Chen et al. (2021, pp. 3–5), Root & Krause (2023, pp. 19–50), Ziegler (2023, p. 50)

3.2.1. Credit Creation

The creation of a carbon credit begins with identifying a potential project and securing funding (Root & Krause, 2023, pp. 20–21). The project owners oversee and control the implementation and assets associated with the project. Depending on the project type, they may consist of land or renewable energy installers or organizations engaged in cookstove projects in emerging markets. Their primary focus is project management, rather than generating carbon credits. Consequently, they collaborate with developers to assess their potential for carbon emission reduction or carbon removal and to navigate the registration, validation, and verification processes (Root & Krause, 2023, p. 22).

Building upon this, project developers, whether for-profit or non-profit, engage in various stages of the project. At minimum, they design the Project Design Document (PDD), which includes the anticipated emission reductions or removal, project scope, plans for quantification and monitoring, and other social and environmental benefits associated with the initiative (Root & Krause, 2023, p. 14). The project developer market is significantly influenced by major developers. Bettaclotti et al. (2023, p. 16) indicate that the five largest developers contribute nearly 20 percent of the total volume.

Subsequently, a draft of the PDD is submitted to a standards-setting body, responsible for ensuring credibility, transparency, and integrity by overseeing additionality and other methodological questions (Cornillie et al., 2021, p. 3). Competing private standards emerged with Verra holding the largest market share with 71.3 percent of all issued shares since 2002 followed by the Gold Standard (GS) with 16.7 percent (Bravo et al., 2023, p. 51). Although Verra's Verified Carbon Standard (VCS) differs in methodology from the GS, their revenue models are similar: revenue is derived from both fixed fees for account holders and variable credit fees per issued credit (Root & Krause, 2023, p. 30). Besides overseeing established regulations, these entities manage registries where carbon credits are issued, transferred, and retired. For third parties, the registry serves as a vital source of information about buyers and sellers, the number of transactions, and the types of credits traded (Üblackner, 2023, pp. 6–7). Standards-setting bodies have the authority to approve project methodologies and designate validation and verification bodies to conduct audits (Chen et al., 2021, p. 4; Root & Krause, 2023, p. 29).

In addition to the standards-setters, integrity initiatives such as the Integrity Council for the Voluntary Carbon Market (ICVCM) serve as additional, voluntary mechanisms for evaluating the quality of crediting methodologies. The ICVCM does not maintain its own registry but focuses primarily on quality issues to elevate standards across VCMs. Additionally, the ICVCM aims to bridge the gap between local communities and stakeholders on the supply side of carbon credits, including standards-setting bodies and project developers (Ziegler, 2023, p. 22). Once the PDD has been prepared, the outlined plans are validated by an external auditor. Following the initial phase of project implementation, another external auditor reviews the project to assess its tangible efficacy (Root & Krause, 2023, p. 14). After certification by a standard and listing on its registry, project developers have the right to issue and sell carbon credits (Root & Krause, 2023, p. 15).

An analysis of the cost structure of credit creation indicates significant variation depending on project size and type (Root & Krause, 2023, pp. 25–29). However, approximately 66 percent of the costs are allocated to registration, encompassing project validation and verification fees, document preparation, and issuance fees (Root & Krause, 2023, p. 24). Standards-setting bodies play a crucial role as market guardians. Recent developments in additional integrity initiatives aim to enhance market credibility and transparency but may also contribute to market fragmentation (Chen et al., 2021, p. 13). These and other challenges associated with VCMs are discussed in detail in Section 4.

3.2.2. Intermediation

Upon the creation and listing on a designated registry, carbon credits become available for purchase. End-buyers can purchase them directly from project developers or through intermediaries who sell them at a markup on the secondary market. This intermediary ecosystem includes exchanges, brokers, online resellers, and crypto bridging platforms. Exchanges, brokers, and online resellers play a pivotal role in identifying demand for credits (Chen et al., 2021, pp. 4–5; Root & Krause, 2023, p. 15). Brokers and resellers primarily engage in marketing activities and leverage direct contacts to connect with end-buyers. In contrast, exchanges facilitate transactions through standardized contracts with predefined criteria, enabling buyers to acquire credits without specifying individual units. For smaller transactions (fewer than 100 credits), online resellers play a significant role, accounting for two-thirds of total retirement transactions (Root & Krause, 2023, p. 36). Brokers typically handle larger transactions and may not necessarily assume ownership of the credits (Root & Krause, 2023, p. 37).

Continuing from the roles of intermediaries, exchanges serve as platforms where carbon credit holders can list their assets for sale or place orders based on specific criteria. Once listed, credits can be purchased by any exchange member, with both buyers and sellers incurring transaction fees in addition to registration and annual membership fees. The fee structure fluctuates based on factors such as the exchange platform utilized, the price of carbon credits, and the volume of trades. For instance, in a transaction involving 10,000 credits valued at 10 USD per tonne, both the buyer and seller could incur fees ranging from 0.05 percent to 10 percent (Root & Krause, 2023, p. 40). Root & Krause (2023, p. 41) estimate that exchanges constitute up to 23 percent of VCMs credit transactions, with buyer data only publicly available on certain registries. Crypto bridging entities leverage blockchain technology to tokenize carbon credits, enabling their subdivision into smaller units than the tCO_2e (Root & Krause, 2023, p. 42). This development could enhance the transparency of transactions and the accuracy of tracking.

3.2.3. Retirement

Retirement refers to the acknowledgment of reducing or removing one tCO_2e upon the purchase of a carbon credit. In 2023, credit retirement amounted to 160 $MtCO_2e$ with a slight increase of 2.6 $MtCO_2e$ compared to 2022 (Ecosystem Marketplace, 2024, p. 4). Once retired, carbon credits become ineligible for further trading or retirement. End-buyers comprise a diverse range of entities, including corporations, individuals, non-governmental organizations (NGOs), and public entities. When an entity retires a corresponding quantity of carbon credits, they typically claim ‘carbon neutrality’, meaning they have balanced their own carbon emissions by funding projects that reduce an equivalent amount of CO_2 from the atmosphere (Cornillie et al., 2021, p. 4). Delta Air Lines, Shell, The Boeing Company, and DPDgroup (Chen et al., 2021, pp. 11–12) are among the top buyers of the market and face pressures to purchase carbon credits. These organizations are to a large extent driven by climate-neutral pledges that rely heavily on purchasing carbon credits (Battocletti et al., 2023, p. 20).

According to a study by Lou et al. (2023, p. 1) another motivation for purchasing carbon credits is ensuring competitiveness in a market where climate-neutral products are in greater demand. Additionally, private individuals engage in VCMs to reduce their personal carbon footprints, offsetting the environmental impact of activities such as travel or events (Bravo et al., 2023, p. 6). The retirement process occurs through registries managed by standards-setting entities, either by end-buyers or intermediaries. While smaller registries may explicitly require the identification of buyers of retired credits, larger ones typically do not (Root & Krause, 2023, p. 46). As indicated by Root & Krause (2023, p. 49), 40 percent of all retired credits lack public traceability back to the retiring entity (see Section 4).

The retirement of carbon credits marks the final stage in their life cycle, connecting the abstract concept of carbon offsetting to tangible climate protection claims by organizations and individuals. This process already touches upon significant challenges within the VCM ecosystem, particularly regarding transparency, traceability, and the credibility of carbon neutrality claims, which will be discussed in the following sections.

3.2.4. Further Affected Stakeholders

(1) Governments

The host country, where carbon reduction projects are executed, has two critical responsibilities. Firstly, it must approve these carbon reduction projects to ensure they align with national priorities and contribute to the country's Nationally Determined Contributions (NDCs) under the Paris Agreement (Fearnehough et al., 2020, pp. 45–46). Additionally, the host country affects the projects' transparency and integrity while addressing potential risks, which will be further discussed in the next section (Ahonen et al., 2022, pp. 239–240).

Countries that purchase carbon credits interact with VCMs at two levels: First, they recognize and integrate purchased carbon credits into their own climate policies. Some national governments, including those of Colombia and South Africa, are incorporating carbon credits from VCMs into their compliance markets (Bravo et al., 2023, p. 16; Fearnehough et al., 2020, p. 35). Second, the regulatory environment in the target countries can encourage the purchase of high quality carbon credits, supporting global efforts to mitigate climate change (Bravo et al., 2023, p. 16).

(2) Indigenous Peoples and Local Communities (IPLCs)

IPLCs are impacted by VCMs activities in various ways depending on the project type. Increasingly, VCM activities qualify for co-benefits, meaning that alongside the creation of carbon credits, additional SDGs are met (Fearnehough et al., 2020, p. 38). These co-benefits are also verified by standards-setting bodies. Some types of projects can be viewed as forms of Foreign Direct Investment from the global North to the global South, contributing to economic growth and sustainable development in host countries. For instance, promoting renewable energy can enhance energy access as a tool for sustainable development by providing basic needs, facilitating productive activities, and protecting the local environment (Mori-Clement, 2019, p. 223).

In the context of forest conservation projects, IPLCs might be affected differently. IPLC territories encompass at least 36 percent of the world's intact forest ecosystems (Fa et al., 2020, p. 135), which are significant for carbon storage and biodiversity. Therefore, IPLCs interact with VCMs as both proprietors and guardians of the lands where these activities occur. However, there are instances where IPLCs are involuntarily involved in VCM initiatives, with activities taking place on their lands without proper consultation or recognition of their rights (Bravo et al., 2023, pp. 78–79; Dunne & Quiroz, 2023). Section 4 provides an analysis of potential violations in this context.

4. Dysfunctions of VCMs

As VCMs have developed, they have exhibited a range of dysfunctions that raise questions about their viability as effective climate mitigation tools. These issues have persisted since the establishment of the Clean Development Mechanism (CDM) under the Kyoto Protocol (Cames et al., 2016) and continue to present challenges (Fischer & Knuth, 2023). For some, there has been a dynamic interplay of discovery, attention, and reform, while others remain intractable (see Section 6.2.2). To systematically analyze the market dysfunctions, they can be categorized into regulatory, ecological, and social challenges.[4] Table 1 presents an overview of these dysfunctions.

[4] This classification should not be viewed as rigid, as there are numerous interactions among the dysfunctions. For example, double counting, is not merely an ecological dysfunction; it could be avoided with properly applied governance. Nevertheless, its impact compromises environmental integrity, which is why it is included under ecological dysfunctions (Fearnehough et al., 2020, p. 44). Additionally, in the long run, it also has social implications (see Section 4.2.3). This example illustrates the interactions between different types of dysfunctions, demonstrating how primary ecological issues also encompass regulatory and social dimensions. Furthermore, the dysfunctions also differ in the individual sectors in which the projects are located.

Table 1

Overview of the regulatory, ecological, and social issues of VCMs

Regulatory	Ecological	Social
Fragmented standards and accounting frameworks High number of initiatives and methodologies leading to difficulties in assessing projects Limited transparency and traceability Inclusion of NDCs	Compromised environmental integrity Issues of (1) additionality, (2) permanence, (3) double counting, (4) carbon leakage and rebound effects Contribution to overall emissions remains subject to debate	Uneven share of profits Unequal development Exclusion of interest groups Potential negative impacts on IPLCs

Source: Authors′ elaboration

4.1. Regulatory Dysfunctions

First, VCMs operate with limited to no regulatory oversight by governments (Chen et al., 2021, p. 1). Instead, the markets have given rise to two main regulatory bodies: standards-setting entities and verification and validation bodies. Recently, a third body has emerged, providing additional certification standards aimed at enhancing trust and guaranteeing a certain quality level of carbon credits (ICVCM, 2024). However, the proliferation of competing standards and accounting frameworks can cause confusion. VCMs are rapidly evolving markets where new methodologies are introduced due to technological advancements, and older ones are discontinued due to inherent issues (Üblackner, 2023, p. 15). This fragmentation and lack of harmonization through governance bodies necessitate that the quality of carbon credits be verified by third parties specializing in this field (Root & Krause, 2023, p. 52).

Second, transparency is crucial to ensure that the unregulated VCMs can operate fairly and effectively. Transparency in VCMs is essential for several reasons. It enhances market efficiency by providing all participants with access to complete and accurate information, which helps in making informed decisions regarding the purchase and sale of carbon credits. Transparency also builds credibility, as it allows for the verification of claims made by project developers and credit buyers, thereby fostering trust among stakeholders (Ziegler, 2023, p. 49).

However, numerous scholars have criticized VCMs for their lack of transparency (Kreibich & Hermwille, 2021, p. 941; Root & Krause, 2023, pp. 48–54; Wyburd, 2024, p. 4). Although improvements have been reported, particularly in price oversight and standardized contracts for various credit types, significant transparency gaps remain in areas where full public disclosure is crucial (Wyburd, 2024, p. 4). A study by Carbon Market Watch (2024) found that all primary standards-setting entities fall short of achieving document transparency in their registries, making it difficult for independent reviewers or stakeholders to make informed decisions (Wyburd, 2024, p. 4). Furthermore, Root & Krause (2023, pp. 48–54) reported that approximately 40 percent of all credits retired are retired anonymously, which hinders the traceability of credit buyers and accountability.

4.2. Ecological Dysfunctions

Numerous scholars analyzing VCMs have highlighted significant ecological dysfunctions that compromise environmental integrity. As Schneider & La Hoz Theuer (2019, pp. 3–4) note, there is no precise definition of environmental integrity. For the purposes of this paper, environmental integrity[5] is defined as the scenario in which the predicted reduction or removal of CO_2e is equal to the realized reduction or removal of CO_2e (Schneider & La Hoz Theuer, 2019, pp. 3–4). Although the emission impacts of projects can only be monitored and measured to a limited extent, they are crucial for determining the ecological quality of carbon credits. Failure to account for these impacts leads to ecological impairments of the credits.

The key indicators and concepts of ecological dysfunctions discussed in this paper are additionality, permanence, double counting, and carbon leakage or rebound effects. These indicators have been chosen because they address the fundamental aspects of whether carbon credits represent real, measurable, and long-term reductions in greenhouse gas emissions (Michaelowa et al., 2019, pp. 24–27; Schneider & La Hoz Theuer, 2019, pp. 3–4).

(1) *Additionality* ensures that carbon credit projects lead to emission reductions that would not have occurred without the carbon credit revenue (Battocletti et al., 2023, p. 14).

[5] Environmental integrity, as referenced in the Paris Agreement, lacks a precise definition but is generally understood through three possible interpretations. These include ensuring that international transfers do not lead to an increase in global GHG emissions, maintaining global emissions at levels that would have occurred without such transfers, or achieving an overall decrease in global GHG emissions through these transfers (Schneider & La Hoz Theuer, 2019, pp. 3–4).

(2) *Permanence* addresses the long-term stability of carbon storage, ensuring reductions are not reversed over time (Badgley et al., 2022, p. 2).
(3) *Double counting* prevents the same emission reduction from being counted more than once, maintaining the integrity of reported reductions (Fearnehough et al., 2020, p. 44).
(4) *Carbon leakage and rebound effects* account for potential increases in emissions elsewhere as a result of the project, ensuring the net benefit to the climate is accurately measured (Battocletti et al., 2023, p. 12; Machnik et al., 2021, p. 24).

These indicators are analyzed in detail below. A comprehensive understanding of these ecological dysfunctions enables a more thorough evaluation of the overall environmental impacts of VCMs.

4.2.1. Additionality

Additionality is crucial for the environmental integrity of VCMs because it ensures that carbon credit projects result in genuine emission reductions that would not have happened without the financial incentive of the credits (Battocletti et al., 2023, p. 14). In general, there are two types of additionalities: financial and regulatory. Financial additionality means that the project would not have occurred without the incentive provided by carbon credit revenues. Regulatory additionality means that the activity is carried out independently of in-place or future regulations (Battocletti et al., 2023, p. 14).

However, a lack of environmental integrity and additionality has been claimed by Cames et al. (2016, pp. 10–11) for credits stemming from CDM. This issue is particularly relevant for credits from VCMs, as the methodologies of CDM projects are largely used by standards-setting entities of VCMs (Michaelowa et al., 2019, p. 17; Üblackner, 2023, p. 41). For example, Cames et al. (2016, pp. 10–11) found in their cross-sector analysis that the probability of additionality varies significantly by project type. Industrial gas projects and methane projects have the highest likelihood of being additional, while biomass power projects have a medium likelihood (Cames et al., 2016, p. 10). Nevertheless, the study concluded that approximately 85 percent of the analyzed projects had a low likelihood that emission reductions are additional and not overestimated (Cames et al., 2016, p. 11). Further reinforcing this concern, Calel et al. (2021, p. 2) found that about 52 percent of wind power projects analyzed would likely have been implemented even in the absence of CDM funding.

Relevant studies on the criteria of additionality and environmental integrity within VCMs have primarily focused on Reducing Emissions from Deforestation and Forest Degradation (REDD+) projects (Guizar-Coutiño et al., 2022; West et al., 2020, 2023).[6] West et al. (2023) concluded that "most projects have not reduced deforestation" (2023, p. 1) , with approximately 94% of these projects unlikely to result in additional carbon emission reductions. In an analysis of 12 REDD+ projects in the Brazilian Amazon, West et al. (2020) found that most of the projects did not effectively reduce deforestation (p. 1). Similarly, Guizar-Coutiño et al. (2022) found that the average reductions in deforestation were significantly lower than originally claimed (pp. 1–2).

The narrative of ecologically ineffective carbon credits was addressed by the German weekly newspaper *Die Zeit*, which published a joint investigative report in collaboration with the British daily newspaper *The Guardian*, which led to a critical juncture in the credibility crisis of VCMs in 2023. This research-based ecological critique highlighted significant flaws in numerous offsetting claims within the VCMs. Drawing on the studies by Guizar-Coutiño et al. (2022) and West et al. (2023), the investigation concluded that approximately 90 percent of the credits issued by the standards setting entity Verra are essentially worthless *phantom credits*, failing to represent any genuine reductions in carbon emissions (Fischer & Knuth, 2023). Verra disputes the findings of this investigation, asserting that they are largely inaccurate due to the methodologies employed, which fail to incorporate "project-specific factors" (VERRA, 2023).

Additionality always depends on counterfactual scenarios. Counterfactuals inherently lead to uncertainty about the real avoided emissions (Franki, 2022, p. 186). As one researcher interviewed by Ziegler (2023) stated "there is no 100 percent certainty in any project [as long as VCMs rely on counterfactuals]" (p. 35). This makes additionality impossible to assess accurately, hard to verify, and leads to a vulnerable point within the theory of VCMs (see Section 6.2.2). The challenge of ensuring additionality within VCMs exemplifies an inherent weakness that casts significant doubts on the credibility and effectiveness of these markets.

[6] Although only one project type is analysed in these studies, this is of significance in the wider context of VCMs, as REDD+ projects account for 25 percent of all carbon credits issued in 2020 (Chen et al., 2021, p. 8).

4.2.2. Permanence

While CO_2 emissions from fossil fuels persist in the atmosphere for hundreds to thousands of years (Badgley et al., 2022, p. 2; Collins et al., 2013, p. 1106), carbon stored in biological sinks, such as forests, soil or the ocean, is more transient and increasingly at risk due to climate change. This discrepancy creates a fundamental imbalance when temporary carbon storage is used to offset permanent fossil carbon emissions, as the expected lifespan of biological carbon storage is inherently shorter (Badgley et al., 2022, p. 2).

Addressing this inherent conflict between the different lifetimes of carbon in the active and passive carbon cycles remains challenging. Although governance bodies require that carbon credits be permanent, the definition of 'permanent' is debated. Verra, for instance, mandates an extended 40-year minimum permanence monitoring period starting in 2024 (Verra, 2023). In contrast, high-quality carbon credits typically adopt a 100-year benchmark for carbon avoidance or removal to establish a standard of permanence (Bravo et al., 2023, pp. 44–45).

Additionally, standards-setting entities employ 'buffer mechanisms', which set aside 10-20 percent of issued credits to cover potential reversals of emission reductions (Fritsch, 2023; Michaelowa et al., 2019, pp. 25–26). Although the effectiveness of buffer pools is not well-researched and there is limited data for VCMs, Badgley et al. (2022, p. 1) found that within the first ten years of California's climate protection program, estimated carbon losses from wildfires consumed at least 95% of the buffer pool contributions intended to protect against project-specific risks over a 100-year period.

Projects particularly vulnerable to natural disasters or activities like illegal logging face significant risks. To ensure that VCMs maintain environmental integrity and function effectively as a climate change mitigation tool, these reversal risks must be incorporated into financing strategies (Battocletti et al., 2023, p. 14). Temporary reductions or removals have limited impact on the long-term goal of stabilizing and reducing GHG concentrations in the atmosphere, merely postponing emissions rather than preventing them.

4.2.3. Double Counting

Double counting refers to the situation where a single emission reduction is accounted for multiple times, compromising the credibility and effectiveness of carbon markets by falsely inflating reported reductions without achieving corresponding global emissions reductions. According to Fearnehough et al. (2020, p. 44) and Schneider & La Hoz Theuer (2019, p. 4), there are three primary forms of double counting:

(1) *Double Issuance:* This occurs when two carbon credits are issued for the same emission reduction or removal, with both credits being used to meet climate targets. This can happen if the same project is registered under different carbon crediting frameworks.
(2) *Double Use:* This transpires when the same carbon credit is used multiple times to meet climate targets or goals, potentially through duplication across registries or claiming the retirement of one credit for several purposes.
(3) *Double Claiming:* This arises when both the end-buyer of a carbon credit and the host country claim ownership of the same reduction or removal.

In the context of the Paris Agreement and NDCs, double claiming poses the most significant challenge (Fearnehough et al., 2020, p. 44). When carbon credits are traded across borders, a critical question is whether the host country or the buyer's country should account for the reduction or removal activities. Article 6.2 of the Paris Agreement provides clear guidelines for the trade of emission certificates between countries, but Article 6.4 does not offer the same clarity for transactions between private parties (Cullenward et al., 2023, p. 1086). Cullenward et al. (2023) assert that "[c]arbon offsets are incompatible with the Paris Agreement" (p. 1086). Apart from the legal uncertainties, double counting also raises considerable problems with regard to issues of justice (see Section 4.3).

4.2.4. Carbon Leakage and Rebound Effects

Carbon leakage occurs when emissions reductions or removals at one source lead to an increase in emissions at another location or sector (Battocletti et al., 2023, p. 12). Standards-setting entities aim to incorporate these effects (Verra, 2021a), although they remain challenging to quantify (Filewod & McCarney, 2023, p. 790; Guizar-Coutiño et al., 2022, p. 10). These entities typically use a *leakage discount factor* to account for potential leakage (Filewod & McCarney, 2023, p. 790). According to an investigation of the credit rating agency BeZero, nature-based solutions are particularly prone to leakage risk (Parker et al., 2022). While Guizar-Coutiño et al. (2022, p. 10) found no significant leakage within a 10 km radius of the studied REDD+ project areas, West et al. (2020, p. 3) identified potential leakage in some projects, suggesting that these projects may be overvalued.

There are two significant issues related to the methodologies used by standards-setting entities in the context of carbon leakage. First, international leakage is usually not addressed. This occurs when carbon leakage crosses national boundaries. For example, conserving forests instead of logging them can reduce the global supply of wood, causing wood prices to rise. The higher prices may encourage forest owners in other regions to increase logging to take advantage of the higher prices (Battocletti et al., 2023, p. 12; Machnik et al., 2021, p. 24).

Second, concerns arise regarding potential rebound effects. Rebound effects can manifest in two ways. First, revenue from carbon credits can act as a subsidy, reducing the cost of products or services, potentially increasing demand and emissions elsewhere that are not accounted for in the project's assessment (Calvin et al., 2015, p. 595; Machnik et al., 2021, p. 24). Second, indirect rebound effects might occur at the consumer level. For instance, individuals who buy climate-neutral products may subsequently engage in climate-damaging activities, influenced by a sense of "moral licensing" from their previous good deeds, which now prompts them to participate in problematic behaviors (Reimers et al., 2021, pp. 1–2). This would have a doubly negative character if the previously purchased product had not been climate-neutral at all but had only suggested this.

4.3. Social Dysfunctions

The so-called co-benefits of carbon credits, such as the fulfillment of additional SDGs, have gained increasing importance in recent years (Ecosystem Marketplace, 2024, p. 17). Consequently, VCMs projects are intended to contribute to poverty reduction, support local households through additional income, and improve land use rights. However, scholars are increasingly reporting unjust developments (Bayrak & Marafa, 2016; Dunne & Quiroz, 2023; Pearse & Böhm, 2014; Ziegler, 2023). An analysis by CarbonBrief (2023) of various REDD+ projects shows that these projects can negatively impact IPLCs if not managed properly. Critical issues include a lack of consultations with IPLCs on decisions that directly affect them, violations of their land rights, and, in severe cases, expropriations and displacements. Bayrak and Marafa (2016) reach a similar conclusion, emphasizing that "economic inequality, deprivation of livelihoods, and human rights violations" (p. 10) can be consequences of such projects. Therefore, it is particularly important that global decision-making processes incorporate methods that consider representatives of various non-state interests, including IPLCs (Bayrak & Marafa, 2016, p. 7).

Recent integrity initiatives such as the ICVCM include IPLCs as decision-makers (Ziegler, 2023, p. 22). Nevertheless, actors from the global North continue to dominate decisions (Ziegler, 2023, p. 55). This imbalance is also reflected in the geography of the markets: 90 percent of the projects are located in the Global South, while a large portion of the profits remain with companies in the Global North (Ziegler, 2023, p. 55; see Section 3.1). Governance bodies do not address the justice issues related to the geography of the markets and double claiming. Under the Paris Climate Agreement, all countries will eventually aim for net-zero emissions (Cullenward et al., 2023, p. 1086). Currently, affordable emissions certificates are predominantly purchased by companies headquartered in the Global North from countries in the Global South, driven by the pursuit of cost-effective climate impact (Chen et al., 2021, p. 2). However, as the global demand for carbon credits escalates and the most accessible and cost-effective emission reduction projects become exhausted, the price of carbon credits is anticipated to increase (Blaufelder et al., 2021, p. 2). This rise in costs is likely to shift the financial burden to the Global South, which also needs to achieve net-zero emissions.

The analysis of dysfunctions within VCMs uncovers significant regulatory, ecological, and social challenges that compromise their effectiveness and credibility. Examining the theoretical foundations of VCMs in the following section will provide a deeper understanding of the roots of these dysfunctions.

5. Analysis of the Assumptions of VCMs

The theoretical underpinnings of VCMs are rooted in neoclassical and environmental economics. These schools of thought provide the foundational principles that guide the design and implementation of carbon markets (Stoddard et al., 2021, p. 665). This section explores the assumptions and key concepts from these economic theories, including externalities and property rights, which are crucial in understanding the functioning and potential dysfunctions of VCMs (Wiesmeth, 2003, p. 39).

Neoclassical economics does not consider the environment as an independent category. Instead, it describes nature as an “exogenous datum” included under the factors of land in production factor theory (Ptak, 2008, p. 35). Environmental economic theory extends this view by addressing allocation issues in the environmental domain, drawing on equilibrium theories formulated using an inductive mathematical formalism. In this context, cost-benefit integrated assessment models are used in order to “get the prices right” (Stoddard et al., 2021, p. 665).

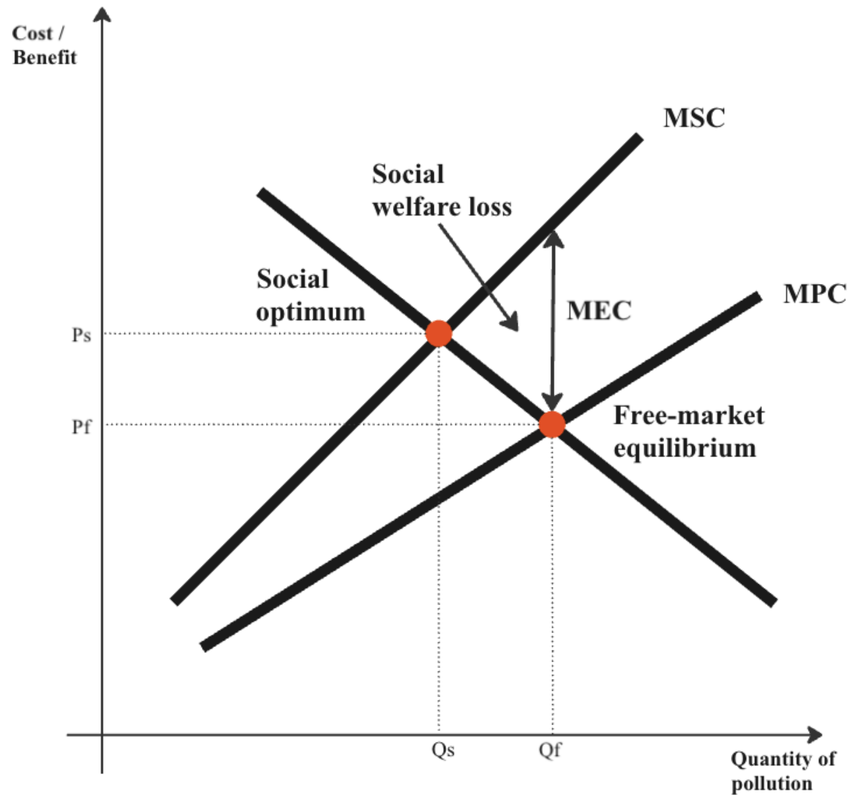
The concepts of ‘negative externalities’ and ‘property rights’ are crucial for environmental economic theory and the theoretical description of VCMs (Wiesmeth, 2003, p. 39). Externalities, such as the consequences of climate change, are monetized as social costs to correct market failures (Stoddard et al., 2021, p. 665). Climate change is regarded as stemming from multiple market failures encompassing various unaddressed inefficiencies within market dynamics (Ptak, 2008, p. 35).

This understanding is grounded in two seminal publications: ‘The Economics of Welfare’ (Pigou, 1933), which distinguished between private and social marginal costs, and ‘The Problem of Social Cost’ (Coase, 1960), which introduced the ‘Coase Theorem’ and the associated allocation of property rights to address the allocation problem within a market mechanism.

Marginal private costs (MPC) are the costs of producing an additional unit of a good. Marginal social or marginal external costs (MEC) include the broader societal costs or damages from producing this good (Sturm & Vogt, 2011, pp. 18–21). Marginal private benefit (MPB) can be gauged by the selling price of the good, while marginal social benefit (MSB) refers to the total benefit to society from producing an additional unit (Pigou, 1933, pp. 125–131). Companies that emit GHG strive for a free-market equilibrium where MPC equals MPB, disregarding MEC. In the absence of marginal external benefits (MEB), the MSB curve aligns with MPB. Thus, the achievement of a social optimum or efficient equilibrium, where marginal social cost (MSC) equals MSB, remains elusive, leading to a decline in social welfare. This implies that society sacrifices more resources to produce an additional unit of the commodity than it gains from its consumption (Ziegler, 2023, pp. 27–28). The following figure illustrates these considerations:

Figure 2

Social cost associated with a negative production externality



Source: Authors' illustration based on Daly & Farley (2004, p. 417) and Ziegler (2023, p. 28)

Firms engage in production out of profit interest, not societal interest, using environmental factors as resources and waste sinks (Wiesmeth, 2003, pp. 41–43). This use leads to environmental damage outside the market structure, which is summarized in the concept of negative externalities and represents market failure. In the case of climate change, these refer to the costs or damages from GHG-emitting activities borne by society and future generations (Wissen, 2022, p. 214). According to Pigou (1933, pp. 125–131), these negative external effects must be monetized to be avoided. Accordingly, market failure arises from excluding the environment from microeconomic general equilibrium equations. Pigou (1933, p. 168) suggested resolving this through taxes or subsidies, one cornerstone market-compatible approach today.

The second one stems from the ideas of Coase (1960, pp. 39–44), who proposed a market-liberal solution for dealing with negative externalities. He argued that taxes to internalize negative external effects can be made redundant, because, with the right allocation of property rights, market participants could eliminate externalities and allocate resources efficiently, achieving social and private optima. The polluter and the affected party engage in bilateral negotiations on pollution licenses and determine a transfer amount for marginal social costs incurred, without involvement from governmental or regulatory bodies.

Efficient allocation would occur regardless of who holds ownership rights; however, the contract hinges on the affected party holding property rights—without ownership, there would be no basis for negotiation or compensation for the externalities (Lohmann, 2006, p. 59; Sturm & Vogt, 2011, pp. 38–39).

This analysis hinges on several assumptions: (1) transaction costs must be sufficiently small, (2) availability of complete information, and (3) measurability and accessibility of damages. Due to the unique characteristics of climate change, these fundamental assumptions of the Coase theorem are often not met (Wiesmeth, 2003, pp. 94–95). Despite the Coase theorem's limitations – stemming from differing actors on the supply and demand sides, transaction costs, information asymmetries, and fundamental inherent uncertainty – it still forms the basis for market-based instruments such as the carbon markets today (Calel, 2011, p. 12). For contemporary climate policy, these instruments represent a fundamental solution in addressing climate change (Stoddard et al., 2021, p. 665).

Although Coase's theorem is not directly applicable to VCMs due to the absence of negotiations between emitters and those affected by emissions, subsequent scholars such as Montgomery (1972) and Tietenberg (1974) have extended his ideas to these contexts. These now form the theoretical basis for VCMs, leading to the following conclusions: First, similar to the bilateral trade proposed by Coase, VCMs internalize negative externalities without government intervention. Here, licenses[7] (also known as pollution rights or carbon credits) are traded between two independent parties through the registries of standard-setting bodies. Second, these pollution rights are transferable (Nell et al., 2008, p. 176). It does not matter where, when, and how emission reductions or removals are realized. The global atmosphere is shared, meaning GHG emissions contribute to global warming regardless of location or form. The timing is determined by permanence, as pollutants remain in the atmosphere for decades

[7] In light of recent developments, the Gold Standard (2024) suggests that some polluters may now market carbon credits as "impact credits" rather than pollution rights. This shift in terminology tempers the strict interpretation of the Coase theorem, as it does not necessarily imply a clear reduction or removal.

to millennia. Therefore, it is the accumulated global concentration of GHGs that matters, not the specific emission times (Badgley et al., 2022, p. 2; Leonardi, 2017, p. 77). Third, the price for carbon credits is determined by the market equilibrium, where carbon credits supply meets demand, representing the most efficient solution at the lowest cost (Montgomery, 1972, p. 396). This price signals the cost of emissions to the actors and incentivizes cost-efficient reduction measures. The bid with the highest price receives the right to emit GHGs or pollute. The aim of this mechanism is to efficiently allocate resources and minimize the total cost of reducing emissions (Montgomery, 1972, p. 409). Fourth, it is more cost-efficient and equivalent to remove emissions elsewhere or save them through efficient technology or renewable energy investments. Therefore, countries with advantageous locations, like those in the Global South, should be involved in the process, which would simultaneously strengthen innovation in the field of low-carbon technologies in underdeveloped regions (Leonardi, 2017, p. 77; Verra, 2021b).

As described in this section, the theoretical foundations of VCMs are rooted in neoclassical and environmental economics, particularly through the application of concepts like externalities and property rights. However, the assumptions underlying these theories often do not hold in practice, especially given the complexities and unique challenges posed by climate change. Transitioning from theory to reality requires a critical assessment and adaptation of these assumptions to address the inherent market dysfunctions and ensure the effectiveness of VCMs in achieving genuine environmental and social outcomes. In the following, these model assumptions are linked to the reality of VCMs and the market dysfunctions described in Section 4.

6. Ecological Economics Informed Critique

Despite the compelling theoretical arguments presented in the preceding section for efficient resource allocation within VCMs, they have historically failed to meet their ecological and social goals (see Section 4). This section explores four concepts of ecological economics – power relations, fundamental uncertainty, information asymmetries, and commodification of nature – to highlight VCMs' limitations and the driving forces that underlie these markets. To illustrate these dysfunctions in action, a hypothetical worst-case scenario is presented, demonstrating how these issues play out in VCMs.

Ecological economics is an interdisciplinary field examining the relationships between ecological systems and economic activities (Daly & Farley, 2004, pp. 6–7) and offers a possible perspective for criticizing orthodox economic theories and instruments. Ecological economics emphasizes the embeddedness of the economy in the biophysical limits of nature incorporating physics, energy, material flows, and ecosystems into their economic analysis (Spash, 2017, pp. 5–7). In this section, it will be used to provide a perspective on dysfunctions of VCMs and its underlying assumptions. The following four concepts critically examine VCMs from an ecological economics perspective. These categories overlap, highlighting their interrelated nature rather than strict delineation:

(1) *Power relations* are peripheral in orthodox economic theory, which presumes homogeneous preferences and rational, utility-maximizing behavior. Ecological economics, however, emphasizes the role of power (Stör, 2017, pp. 141–142), integrating social and political spheres and viewing the economy as embedded within society (Salleh, 2017, p. 55).

(2) *Fundamental uncertainty* and dynamic changes are fundamental to ecological economics, contrasting with orthodox economic views (Koch, 2017, pp. 440–441; Vatn, 2017, p. 36). In VCMs, uncertainty about counterfactual scenarios plays a significant role in contributing to the ecological problems observed in these markets.

(3) *Information asymmetries* refer to situations where different actors lack equal access to information. Orthodox economic theory typically assumes rational decision-makers and informed agents, whereas Daly and Farley (2004, pp. 241–257) stress the importance of limited knowledge in decision-making processes.

(4) *The commodification of nature* describes the process by which natural resources and ecosystems are converted into commodities or economic goods that can be bought, sold, and traded in markets (Polanyi, 1944, p. 76). This includes assigning monetary value to elements of the natural world, such as clean air, water, biodiversity, and carbon, integrating them into market systems (Gunderson, 2017, pp. 1–3).

6.1. Thought Experiment: Potential Worst-Case Scenario

While Section 3.1 illuminated the theoretical processes of VCMs, the following thought experiment illustrates their potential implementation in a worst-case scenario[8]: Company A, a

[8] This example is based on the theoretical considerations of Lohmann (2006, p. 61).

steel producer in the Global South, needs to replace an outdated blast furnace. According to the company's cost-benefit analysis, continuing to operate it is deemed economically unfeasible. Aware of VCMs, Company A engages a certified carbon market project developer to create a PDD. The PDD aims to demonstrate that the old blast furnace could have continued operating longer and that its replacement is economically viable only with additional income from carbon credits. Standard-setting organizations validate the PDD. Post-validation and verification, Company A becomes a new provider of carbon credits, traded in a registry. Exchanges and other market participants profit from buying and reselling these credits, increasing transaction costs. Subsequently, Company B, based in the Global North, purchases carbon credits from Company A. Company B uses these credits to offset its avoidable GHG emissions. For Company B, using VCMs is significantly cheaper than direct emission reductions, enabling it to market its products as carbon neutral. Consumers buy these products believing in their climate neutrality, *morally licensing* their unsustainable consumption patterns (see also Section 4.2.4.). In such a case, VCMs not only fail as climate protection instruments but also support greenhouse gas-emitting activities at various levels, deepen path dependencies, and actively hinder necessary climate protection efforts.

This thought experiment embodies the concepts selected for analysis, which will be discussed subsequently. These include (1) Power relations, (2) Fundamental uncertainty, (3) Information asymmetries, and (4) Commodification of nature.

6.2. Linking Dysfunctions and Theory

While environmental economic theory suggests otherwise, VCMs are marked by high transaction costs, opacity, fundamental uncertainty, information asymmetries, and power dynamics that can lead to unequal distribution and overvalued carbon credits. The following section offers a perspective connecting the markets dysfunctions with these shortcomings of the orthodox theory.

6.2.1. Power Relations

The power dynamics within VCMs reflect structures of economic and political dominance that prioritize profit and the maintenance of existing systems. While VCMs involve various stakeholders, power distribution remains uneven (Battocletti et al., 2023, p. 26). The centralization of power within multinational corporations, financial intermediaries, and standards-setting bodies highlights a system where market mechanisms are often skewed toward the interests of powerful actors, predominantly from the Global North, who view climate change as an economic opportunity rather than an existential threat (Lohmann, 2006, pp. 59, 224).

The system's oversight and regulatory bodies, intended to ensure standards and accountability, are financially dependent on the corporations they regulate, operating under the *issuer pays model*, where income relies on project developer fees (Battocletti et al., 2023, p. 25–27). This dependency creates inherent conflicts of interest that favor market growth over rigorous standards, allowing standards-setting organizations and validation bodies to prioritize the volume of certified credits over stringent quality control (Battocletti et al., 2023, p. 26). As a result, standards can become diluted to satisfy powerful clients, leading to inflated or overvalued offsets (Vatn, 2017, p. 31).

This dependency highlights how VCMs are shaped by political and social dynamics rather than purely economic principles. As Pearse and Böhm (2014, p. 332) observe, "carbon markets are political constructs, constituted by the constellation of social forces that dominate them." A primary force behind these markets has been the fossil fuel industry, which leverages VCMs to legitimize its business model and circumvent stringent regulatory requirements (Kill, 2015, p. 19; Lohmann, 2006, pp. 59, 224). By aligning market mechanisms with corporate agendas, VCMs function less as climate solutions and more as tools for maintaining the status quo, diverting attention from the deeper systemic changes needed to address the climate crisis.

The structure of VCMs reveals a continuation of colonial power relations, where natural resources from the Global South are commodified and sold to fulfill climate commitments of the Global North. Pearse & Böhm (2014, p. 330) argue that VCMs reproduce colonial dynamics, appropriating land, forests, and resources from less wealthy nations to offset emissions from wealthier countries. This exploitation of *natural capital* follows a long history of resource extraction and capital accumulation by global powers, where the Global South supplies the environmental benefits while receiving limited economic returns or social benefits in return (Salleh, 2017, p. 52).

This colonial legacy also manifests in academia: Within VCM projects, two schools of thought have emerged—the "pro-poor" and "do-no-harm" schools (Bayrak & Marafa, 2016, p. 8). The former advocates for improving the conditions of affected communities, while the latter argues that projects should not harm these communities. The existence of these schools highlights the architecture of VCMs as instruments of the Global North implemented in the Global South.

Finally, the temporal orientation of VCMs reveals an underlying bias toward present-day stakeholders at the expense of future generations. VCMs operate within a limited timeframe tailored to the needs and interests of current stakeholders. Future generations, who will be most affected by the long-term impacts of climate change and current market decisions, have no means to voice their concerns or interests in current market processes (Daly & Farley, 2004, pp. 188–189). The absence of future generations in VCM decision-making processes implies that potentially more sustainable and long-term oriented strategies may not be considered.

6.2.2. Fundamental Uncertainty

Quantifying CO_2 emissions as a singular measure – one tonne of CO_2 – initially seems straightforward. However, the right to emit one tonne of CO_2, granted through activities of avoidance, reduction, or removal by the registries of regulatory bodies, introduces significant complexity. Relying on seemingly apolitical and unambiguous counterfactual scenarios significantly contributes to the ecological problems observed in these markets (Lohmann, 2009b, p. 511). The following dysfunctions stem from this fundamental and insurmountable uncertainty: (1) Additionality, (2) Permanence, (3) Carbon leakage and rebound effects.

The crux of the issue lies in the singularity of the *baseline world*, a necessary construct to distinguish it from numerous other theoretically possible scenarios. As explained by Lohmann (2009b, p. 511), disentangling a single baseline requires framing the political question of what would have happened without the projects as a matter of technical prediction within a deterministic system. This approach assumes nearly perfect knowledge is achievable. Such an approach reduces relevant impacts such as international displacement, socio-economic development, biodiversity, land-use changes, and other side effects to mere methodological risks and uncertainties (Leonardi, 2017, pp. 78–80). Therefore, Lohmann (2009a, p. 2) concludes that GHGs are an unmanageable commodity.

In summary, the theoretical foundation of the baseline scenario underpinning VCMs, shaped by a deterministic and depoliticized future, fails to address the complex and multidimensional nature of environmental impacts. This reductionist approach, focusing on a single baseline, oversimplifies and overlooks critical dimensions of ecological and socio-economic consequences, leading to substantial methodological risks and uncertainties in assessing climate protection projects.

6.2.3. Information Asymmetries

Information asymmetries can occur in all markets but escalate with the complexity and abstraction of markets. VCMs exemplify such highly complex markets, where assessing the qualities, costs, and benefits of traded emissions rights is particularly challenging. Emissions credits in VCMs fall into the category of *credence goods*—commodities whose qualities, costs, and benefits are difficult to verify even after purchase (Battocletti et al., 2023, p. 26).

This difficulty creates information asymmetries regarding product attributes among different market participants. Suppliers possess complete information about quality criteria, while end-buyers must rely on the limited public data provided by standards-setting organizations (Wyburd, 2024, p. 4). As noted above, suppliers have little incentive to improve quality since the controlling entity, the standards-setting entities, depend on income generated by the quantity of credits issued. This is also true for identified transparency deficiencies (see Section 4.1). In other markets, buyers act as a quality control authority. In VCMs, this is not possible due to information asymmetries.

Additionally, the diversity and complexity of climate protection projects add to these information asymmetries. Projects vary widely – from renewable energy installations to forest conservation efforts – each employing different methods to calculate and verify emission reductions. This diversity complicates standardization, making it difficult for buyers to make informed decisions. The absence of standardized metrics and transparent reporting mechanisms means that buyers cannot easily compare the quality of different compensation projects or assess the actual impacts of their investments (Wyburd, 2024, p. 4).

Another information asymmetry arises between companies purchasing carbon credits to achieve carbon neutrality and consumers. Carbon credits have mainly been sold as offsets – a license to emit. However, this approach rests on two untested assumptions: first, that the described market dysfunctions will not occur (Cames et al., 2016; Guizar-Coutiño et al., 2022; West et al., 2020, 2023), and second, that there is a meaningful link between the price paid and the economic value of the compensated emissions reduction (Kill, 2015, pp. 18–19). Carbon credit prices are shaped by market mechanisms and buyer willingness to pay, which does not necessarily reflect the true social costs of greenhouse gas emissions. It would be coincidental if the price of a tonne of CO_2e on the VCMs corresponds to the social costs of the GHG.

6.2.4. Commodification of Nature

The valuation process involves assigning a monetary value to nature, incorporating aesthetic, practical, and ethical aspects, thereby turning it into a commodity with a measurable market value (Gómez-Baggethun, 2017, pp. 445–446). This process makes "heterogeneous productive phenomena" comparable and reduces them to the level of money as the sole measure of value (Martineau & Lafontaine, 2019, p. 488).

This mechanism enables the decoupling of relevant production, circulation, and consumption processes over large temporal and spatial distances. VCMs are markets where the monetary valuation of the right to emit takes center stage. They are referred to by Castree (2008, pp. 146–147) as *environmental fixes* because they attempt to resolve contradictions between economic and ecological interests by fully integrating the environment into the process of capital accumulation. This process can potentially lead to alienation from the actual subject of consideration – nature (Spash, 2017, p. 12). By objectifying and economizing nature within VCMs, it is transformed into an abstract and standardized exchange value, displacing the emotional and personal relationship with nature (Martineau & Lafontaine, 2019, p. 488). This process of commodification transforms individuals' relationship with nature into an instrumental and alienated perspective, where the qualitative value of nature is lost in favor of a quantitative and tradable value (Martineau & Lafontaine, 2019, pp. 499–500).

The economic valuation of natural resources reduces complex, diverse, and often irreplaceable elements of nature to simple, tradable units. This process of monetization and commodification contributes to the perception that only what has direct economic value is worth protecting. Consequently, aspects of nature that cannot be easily expressed in monetary terms are at risk of being overlooked or undervalued (Kill, 2015, p. 10).

7. Policy Implications, Future Directions and Conclusion

This paper supports existing criticisms of market-oriented environmental solutions, particularly those that commodify nature and heavily rely on economic assessments through three key findings. First, there is a need to reevaluate and restructure the commodities traded on VCMs. Second, adjusting the incentives of standards-setting bodies can improve market efficacy and credibility. Third, state intervention can address regulatory issues more effectively.

Firstly, the role of carbon offset credits needs reevaluation. The commodities traded in VCMs are carbon offset credits intended to compensate for environmentally harmful behavior. However, if these credits are inflated and do not correspond to the actual tonnes of CO_2e they claim to offset, they fail to achieve the intended climate impact. This issue arises from the ecological dysfunctions discussed earlier. If a credit is compromised by any of these dysfunctions, it is ineffective as a climate protection instrument. Therefore, such carbon credits should not be sold as pollution rights or offsets but managed differently. One proposed solution is to shift from “offset claims” to “impact claims” (or non-compensatory claims). The Gold Standard (2024), among others, predicts this development: “It is expected that some … [end-buyers] may adopt different claims [than offsetting their emissions] when retiring carbon credits”. This approach would enable organizations to contribute to climate financing without claiming ownership of emission reductions. End-buyers would be incentivized to acquire high-quality claims, investing specific amounts of money, which they could report as a financial contribution. This shift moves away from the practice of purchasing the maximum number of credits for the least amount of money. Such investments could be compared to the company’s total profit, providing a more contextual understanding based on the company’s size. The future demand for this type of product remains to be determined.

Secondly, some scholars advocate for more robust regulatory frameworks, viewing the current dysfunctions in VCMs as “the growing pains of a maturing set of means to address the climate crisis” (Miltenberger et al., 2021, p. 5) suggesting these issues are surmountable. In that realm, VCMs are dynamic tools that can quickly adapt to external conditions (Üblackner, 2023, p. 24). While the analysis of this paper suggests that there are surmountable dysfunctions, it also postulates that there are some problems that are not surmountable. For example, the complexity of predicting counterfactual scenarios, as well as potential alienation from nature due to commodification cannot be overcome. However, one major challenge which can be overcome lies in the certification process of credits, where Battocletti et al. (2023, pp. 36–38) identify a lack of incentives for detecting low-quality credits. Therefore, they propose a reward system tweaking the incentives for standards-setters. NGOs would be allowed to sue standards-setters and VVBs for inaccuracies, with successful NGOs receiving financial rewards from a fund financed by governments and corporations. Instead of monetary sanctions for standard-setters, the focus would be on reputational sanctions, ensuring that litigation outcomes are publicized to reinforce accountability. Implementing these changes could enhance the robustness and credibility of VCMs.

Thirdly, an alternative solution might involve more direct state regulation. Some dysfunctions might only be resolved outside of free-market mechanisms. For example, issues such as fragmented standards and accounting frameworks, or the limited transparency and traceability, could be better addressed through stricter regulatory frameworks. A model comparable to environmental standards could establish consistently high-quality requirements. Independent oversight, free from profit motives or the number of certified compensations, would ensure objectivity and focus the review process on environmental protection. Additionally, a more holistic solution would involve integrating labor and social aspects into these practices. This approach would ensure that projects meet not only environmental goals but also promote social justice and fair labor conditions. National and international guidelines and regulations could facilitate this integration by creating a framework that considers the broader societal impacts of compensation projects. Participatory approaches, involving affected local communities, are another area for improvement. Ensuring local voices are heard and considering the specific impacts on communities in the Global South can mitigate potential negative effects of climate protection initiatives.

Despite these proposed solutions, the analysis indicates that some fundamental problems may be insurmountable. The inherent exploitation of mechanisms, associated fraud, the singularity of the baseline world, and the potential alienation from nature through commodification are challenges that these solutions cannot entirely address. Therefore, while incremental improvements can enhance the effectiveness and credibility of VCMs, their foundational limitations necessitate a broader reconsideration of their role and implementation in global climate policy.

Three limitations emerged from addressing the research question in this paper, potentially affecting the results and conclusions. First, the research might be limited by the data analysis methods used. The qualitative literature analysis involved examining and comparing various sources and perspectives on the topic. Although this approach provides valuable insights, it may also be subject to biases or limitations in the sources or perspectives analyzed. Potential biases from source selection and interpretation could also influence the results. A preference for critical sources could lead to selection bias, while confirmation bias might skew the findings by interpreting information to confirm pre-existing assumptions. Including non-peer-reviewed sources, such as reports and documents from interest groups, might also affect the objectivity and reliability of the study.

Second, the paper's focus might restrict the research. The analysis centers predominantly on the ecological economics perspective to examine and critique the theory of VCMs. The analysis centers on the ecological economics perspective to examine the theory, which, while valuable, offers a limited scope. This singular focus may omit important insights and considerations from other relevant disciplines. Perspectives from environmental sociology, political ecology, or critical geography, for example, could offer nuanced insights into how social inequalities, cultural contexts, and institutional arrangements affect the functioning of VCMs. By not incorporating alternative perspectives, the research risks creating a biased perception that may overlook critical factors influencing VCMs.

Third, the quality of available data is a significant issue in some areas. High-quality and transparent data are not always accessible, severely limiting the ability to evaluate VCMs. Often, available data comes from interest groups with vested interests in certain outcomes. Moreover, the study's goal of evenly representing the multifactorial influences of all actors complicates the analysis, as not all market participants have equal opportunities to communicate. Areas with limited data availability include VCM prices, double counting problems, permanence assessments within VCMs, evaluations of international leakage and rebound effects, and analyses of the role of local communities in decision-making processes.

Building on this investigation and the categorization of various dysfunctions, a quantitative impact assessment could significantly contribute to evaluating VCMs' overall effect on the carbon cycle. Specific areas for further research include the above-mentioned areas with limited data availability. Additionally, closer collaboration between grassroots movements and the scientific community could be beneficial, as these possess detailed local knowledge that can be utilized to more effectively study the impact of VCMs on IPLCs. Longitudinal studies tracking the long-term impacts of VCM projects would also be highly advantageous. Such studies could help understand the projects' actual effectiveness over time and assess whether the targeted climate goals are sustainably achieved. Long-term data could offer insights into the stability and permanence of the environmental effects achieved by VCMs, enriching the discussion about their benefits and efficiency.

Furthermore, exploring alternative models that move away from market-based solutions should be intensified. Decommodifying nature would mean conservation and restoration efforts occur independently of financial gains. Such initiatives could prioritize ecological and social justice by granting local communities more involvement in decision-making processes, with profit motives not taking precedence.

Given the challenges presented by the escalating climate crisis and the increasing number of organizations and individuals seeking to offset their carbon emissions, it is anticipated that interest in VCMs will surge significantly. As more entities consider these markets as a potential solution for compensating their carbon footprints, it becomes imperative to rigorously scrutinize their effectiveness and sustainability. The contributions of this paper highlight that the current state of VCMs is inadequate in addressing the complex issues they aim to mitigate. Despite their potential, VCMs are fraught with critical shortcomings, such as lack of transparency, questionable additionality, permanence of carbon offsets, and adverse socio-economic impacts on local communities. This paper underscores the urgent need for reevaluation and reform within VCMs to ensure they contribute meaningfully to global climate goals. Without significant improvements and stricter regulatory frameworks, VCMs risk perpetuating environmental and social injustices, thus failing to deliver on their promise of genuine climate mitigation. Therefore, it is crucial that the mechanisms regulating these markets adapt to address the regulatory, ecological and social dysfunctions these markets cause.

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