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RESEARCH ARTICLE

How do hard regimes absorb, overlap, and squeeze out soft regimes? Insights from global carbon markets

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Abstract

Varieties of regimes exist in carbon markets, but little is known about regime interactions within this complex. This article particularly focuses on interactions between voluntary carbon markets (VCMs) and compliance carbon markets (CCMs) and treats VCMs as soft regimes while CCMs as hard regimes. It utilizes comparative case studies and grounded theory to dissect drivers of carbon market linkages and regime interactions. We argue that institutional complementarities of participants, market boundaries, and operation rules exist between VCMs and CCMs, providing prerequisites for interactions between soft and hard regimes. Furthermore, there are four types of causal mechanisms for regime interactions, namely cognitive, rule, behavioral, and functional interactions, which mainly occur in the direction of VCMs toward CCMs. In addition, regime interactions within carbon markets evolve dynamically. Soft regimes are contingent on the development of hard regimes, which can gradually absorb, overlap, and squeeze out soft regimes. This research advances our understanding of complex regime interactions within carbon markets and provides theoretical insights for the transformation of future carbon markets.

Keywords Carbon market · Climate change · Regime interaction · Regime complex

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1 Introduction

Carbon pricing is a critical market-based policy tool to curb greenhouse gas (GHG) emissions. Served as direct carbon pricing tools, carbon markets help transform production, consumption, and investment toward low-carbon and sustainability (World Bank, 2017). Varieties of carbon markets operating at the national, regional, or international levels have been established to address global climate challenges, and the close linkages among them expect to form a network of global carbon markets. Such a network can improve market efficiency and enhance the effectiveness of emission reductions. Currently, carbon markets consist of compliance carbon markets (CCMs) and voluntary carbon markets (VCMs). The former is bound by laws of jurisdictions or international treaties or agreements. CCMs—such as the European Union Emissions Trading System (EU ETS) and the Clean Development Mechanism (CDM)—require participants to surrender allowances or credits to meet mandated regulatory targets. The latter is established for emission reductions based on voluntary purposes. Firms and individuals purchase carbon credits to offset their emissions rather than required by any regulatory entities.

Existing studies have pointed out that VCMs can be complementary to CCMs (Boston Consulting Group, 2021), and linking these two carbon markets expects to produce positive results. Specifically, the linkages between VCMs and CCMs attract numerous participants and expand carbon market coverage. Meanwhile, such linkages enhance market efficiency and provide regulated entities with various decarbonization options to reduce compliance costs. The linkages also help accelerate achieving climate targets (Streck, 2021). Despite the potential benefits of linking VCMs and CCMs, most existing studies treat these two carbon markets relatively independently and analyze their institutional designs, evolution processes, and emission reduction performance separately (Kreibich & Hermwille, 2021; Michaelowa et al., 2019). Consequently, the processes and forms of linkages between both carbon markets remain unclear. Therefore, our core research questions are: What is the rationale for linking VCMs and CCMs? What types of linkages exist? And what conditions affect linkages between these two carbon markets?

Building upon studies on institutions in global governance (Abbott & Faude, 2021), this article focuses on regime interactions through the lens of interactions between hard and soft regimes. Drawing from the concepts of *soft law* and *hard law*, we argue that CCMs represent the essences of hard regimes while VCMs resemble soft regimes. *Hard law* emphasizes the legally binding obligations that are precise and authoritative, while *soft law* is weak in legal arrangements (Abbott & Snidal, 2000). Analogically, we define *hard regimes* as governance mechanisms implemented by authorized regulators with an enforceable system of rules. They formulate explicit and quantifiable governance targets, standards, and sanctions. Hard regimes can constrain actors' behaviors, and regulated entities may face severe penalties if they fail to fulfill their obligations. We treat CCMs as hard regimes because they design explicit compliance targets, and participants are subject to rules established by government entities and laws. In contrast, *soft regimes* are governance mechanisms implemented by the non-governmental

public sector. They are based on a voluntary system of rules, with non-compulsory governance objectives and non-specific target audiences. Some experimental governance mechanisms implemented by government departments also fall into this category. The rule-setting is more fragmented than hard regimes, and no single agency has full regulatory authority, which makes participants susceptible to less enforcement. In this sense, we view VCMs as soft regimes because market entry and exit are entirely voluntary, and no hierarchal actors exist to govern transactions.

Global carbon markets are still in the early stage of development, and intricate linkages exist between/among different CCMs and VCMs. However, this paper mainly focuses on regime interactions between CCMs and VCMs, i.e., the interaction between hard and soft regimes, to reveal the dynamic evolution of carbon market governance mechanisms. The *unit of analysis* is the linkages between VCMs and CCMs, rather than the individual carbon market per se. The linkages between VCMs and CCMs at multiple levels constitute a global carbon market network. We utilize grounded theory to abstract theoretical concepts from cases (Glaser & Strauss, 2017) and comparative case studies to generate theory (Yin, 2009). Through retracing and coding main carbon market linkages, we summarize the processes and driving factors of regime interactions within global carbon markets. We discover institutional complementarities between VCMs and CCMs, providing prerequisites for interactions between soft and hard regimes. There are four types of causal mechanisms for regime interactions, namely cognitive, rule, behavioral, and functional interactions. In addition, we argue that regime interactions within carbon markets are dynamic. Cognitive and rule interactions usually occur at the early development stage of target institutions, when VCMs as soft regimes start to be absorbed by CCMs as hard regimes. Behavioral and functional interactions usually occur at the middle development stage, and soft regimes overlap with hard regimes. As target institutions mature, institutional interactions may gradually shrink or even terminate, and hard regimes eventually squeeze out soft regimes.

This study makes two significant contributions. First and theoretically, systematically building the landscape of the linkages between VCMs and CCMs advances understanding of the types, processes, and driving forces of regime interactions within global carbon markets. Traditional regime complex theory primarily concerns interstate regimes and largely neglects the role of private regulation, which is the "soft" part of regimes (Abbott, 2012; Raustiala & Victor, 2004). This paper investigates both public and private regulations in the case of carbon market governance, intending to expand theoretical horizons of institutional theories. Second and in practice, clarifying the linkages between VCMs and CCMs can help provide theoretical references for policymakers to reform existing carbon markets. The Glasgow Climate Pact, adopted at the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), recognizes the roles of VCMs in channeling finance and technology for climate change mitigation and helping accelerate countries' compliance with more ambitious Nationally Determined Contributions (NDCs). Thus, exploring the linkages between VCMs and CCMs is conducive to providing guidelines to improve the governance performance of carbon markets.

The rest of the paper proceeds as follows. Section 2 reviews the types of regime interactions and complex governance mechanisms of global carbon markets. Section 3 proposes a theoretical framework for regime interactions. Section 4 systematically illustrates the existing linkages between VCMs and CCMs and analyzes how carbon market linkages occur. Afterward, we present case summaries of carbon market linkages and discuss dynamic interactions between hard and soft regimes in Sect. 5. Section 6 summarizes the main findings and future research implications.

2 Literature review

2.1 Transnational governance, regime complex, and regime interactions

Existing studies have highlighted the role of private regulations that constitutes an important dimension of transnational climate governance. Sovereign states are traditionally the main actors in international affairs. However, due to the cross-border nature of climate change issues, non-state and subnational actors are also significant governors for addressing global challenges (Abbott et al., 2016; Hale, 2020; Sending & Neumann, 2006; Strange, 1996). Transnational governance arises when non-state and/or subnational actors in at least two different countries connect and cooperate through transnational networks, follow the same rules and practices, and seek to direct behaviors toward common public goals (Andonova et al., 2009; Biersteker & Hall, 2002). In VCMs, independent third-party regimes play the primary role of governors, providing stakeholders with rules defining the scope of eligible carbon reduction projects, detailed guidance on the calculation of baselines and projected emission reductions, and the certification of project sustainability and carbon credit quality. They form transnational climate governance featured by non-state actors (Lovell, 2010).

Global carbon markets are one of typical regime complexes. The builders of VCMs and CCMs differ, and public and private regulations constitute the regime complex of carbon markets. Based on the regime complex theory in global governance (Raustiala & Victor, 2004), different regimes can interact with one another in multiple forms (Eberlein et al., 2014; Young, 1996). The plurality and complexity of regimes within a particular issue area can increase "regime density" (Young, 1996), thereby enhancing the possibility and frequency of regime interactions. Regime interactions refer to the fact that governance actors and regimes engage with and affect the performance of each other (Eberlein et al., 2014; Gehring & Oberthür, 2009; Oberthür & Stokke, 2011).

Young (1996) proposed four types of regime interactions: "embedded," "nesting," "clustering," and "overlap," describing how issue-specific regimes interact with the broad institutional framework, and how regimes integrate and interact with one another. Related to Young (1996), some studies have further classified the forms of regime interactions as "competition," "coordination," "cooptation," and "chaos" (Eberlein et al., 2014). As private regulations are voluntary, interactions between private and public regulations mainly feature "coordination" or "cooptation" rather than intense "competition" (Green, 2013). Specifically, coordination

among regimes can begin with emulation to deliberate collaboration, either directly through networks and peer-to-peer interactions or indirectly based on common cognitive framing of issues or objectives (Eberlein et al., 2014). The aforementioned "nesting" interaction may also result in coordination through hierarchical arrangements, where the hierarchical authority of a regime is used to achieve coherence. In addition, "cooptation" interaction implies agreements on rule settings and even certain degrees of subordination to the rules of another regime (Green, 2013). Finally, "overlap" interaction may lead to chaos.

Existing studies have cleavages in regime interaction impacts. On the one hand, interactions can produce positive results under certain conditions. In the interactions between private and public regulations, the effectiveness of the former relies on the supplementing and strengthening of the latter (Mayer & Gereffi, 2010). Meanwhile, private regulations can provide references for public rule makers (Sabel & Zeitlin, 2010). On the other hand, the regime complex may produce negative consequences. The complexity generates some ambiguities in regime interactions, allowing actors to choose the strategies that best serve their interests strategically, that is, forum shopping (Busch, 2007; Raustiala & Victor, 2004). Thus, while one regime may directly or indirectly affect the performance of another, whether the impacts are positive or negative is uncertain in the existing literature.

2.2 The regime complex of global carbon markets

For carbon markets, there are two types of uncertainties in regime interactions. First, interaction entities are uncertain. Carbon markets involve non-state actors, such as international non-governmental organizations (INGOs) in addition to sovereign states. Whether interactions occur among carbon markets constructed by different entities depends on different conditions. Second, interaction impacts are uncertain. The linkages between VCMs and CCMs may create complementary effects, provide various participants with flexible and diversified ways of compliance, and incentivize additional participants to engage in carbon markets. However, such linkages may also intensify opportunism and hinder substantial GHG emission reductions. Existing studies indicate that fragmented governance of VCMs can exacerbate governance risks when linking VCMs and CCMs. The risks include the difficulties in testing for the "additionality" of emission reductions generated by VCMs (Gillenwater et al., 2007), the "double counting" (Kollmuss et al., 2008) due to the absence of unified monitoring, reporting, and verification (MRV) mechanism in VCMs, and the low costs of purchasing carbon credits, which can easily lead to "greenwashing" and "carbon leakage."

However, the effectiveness of the particular regime depends on the characteristics and interactions with other regimes (Young et al., 1999). As mentioned above, the linkages among VCMs and CCMs mean larger market coverage, more diversified market participants, and more flexible trading mechanisms, which can enhance market efficiency and emission reduction effectiveness. To better connect with CCMs, some standard-setting entities have already formulated stringent regulations to mitigate governance risks in VCMs and enhance the quality of carbon credits (Lederer,

2012; Newell & Paterson, 2010). Meanwhile, given the fragmentation of VCMs, public regulations require high when interacting with VCMs to ensure environmental integrity and market effectiveness once the two markets link. For instance, corresponding adjustments for VCM transactions are required in Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) to avoid "double counting," and the International Civil Aviation Organization (ICAO) Council approves whether the emission units from VCMs are eligible for compliance. In this sense, the development of transnational climate governance is related to the capacity of public regulations to create an enabling environment (Andonova et al., 2017; Green, 2017). Public regulators can initiate, direct, expand, and strengthen transnational governance (Hale & Roger, 2014). Thus, VCMs work under the shadow of public regulations to some extent (Bulkeley et al., 2014; Verbruggen, 2013), and their effectiveness depends on the interaction with public ones.

Additionally, although the risks of environmental integrity exist, varieties of linkages between VCMs and CCMs have been observed in the real world. For instance, the state of California utilizes VCMs to accumulate relevant regulatory rules and experiences before establishing its Carbon Cap-and-Trade Program, and it further allows high-quality carbon credits generated by VCMs to be used for compliance purposes. The linkages between CCMs and VCMs in California lay a solid foundation for compliance market development and provide a cost-effective means for regulated entities to enhance carbon reduction performance. Therefore, we cannot treat the two carbon markets separately and need to explore regime interactions from a more holistic perspective (Keohane &Victor, 2011; Raustiala & Victor, 2004). However, existing studies lack a systematic overview of the interactions between both carbon markets, and the factors that affect the establishment of carbon market linkages remain unclear.

Therefore, our study intends to categorize the different types of carbon market linkages. The unit of analysis is the linkages between VCMs and CCMs, rather than the individual carbon market per se. Focusing on the systematic landscape of the linkages between VCMs and CCMs, we investigate carbon market linkages with specific cases and reveal the driving factors that affect the occurrence and dynamic evolution of regime interactions.

3 The theoretical framework for regime interactions

3.1 Institutional complementarities between hard and soft regimes

Facing with same policy objectives, VCMs and CCMs are complementary in institutional designs, including participants, market boundaries, and operation rules, which makes both carbon markets have certain institutional complementarities. The following elaborates on institutional complementarities in detail.

The first one is the complementarity of participants. In CCMs, sovereign states or local governments impose strict restrictions on the eligibility of participants. Firms belonging to specific industries can engage in CCMs, making limited industries covered. By contrast, VCMs do not restrict participant types, and any buyer

for voluntary purposes can freely purchase carbon credits to offset their carbon emissions. In this sense, in jurisdictions with limited regulation scope for GHG emissions, VCMs provide incentives to reduce emissions, especially for small and medium-sized businesses or retail consumers who have difficulty measuring their emissions and cannot participate in compliance markets (Boston Consulting Group, 2021). Thus, VCMs play a transitional role until the regulations of CCMs are scaled up, and the linkages between the two carbon markets help encourage a broad range of emitters to participate in carbon markets.

The second one is the complementarity of market boundaries. Although CCM coverage is limited to specific jurisdictions, international voluntary carbon credits can flow globally, unrestricted by sovereign national boundaries. Considering that buyers worldwide are free to sell and buy carbon credits, VCMs are more liquid and flexible than CCMs. In addition, the project types available in international VCMs are more diverse and can meet buyers' different demands. Some projects developed in VCMs are more concerned about local economic, social, and environmental impacts, which can meet the demands of buyers that intend to achieve co-benefits (Kountouris et al., 2014).

The third one is the complementarity of operation rules. VCMs and CCMs are complementary in project decision-making and approval processes. For example, CDM projects must be registered through the CDM Executive Board. Private sectors or the World Bank usually provide carbon financing, and all participants must be signatories to the Kyoto Protocol. By contrast, international VCMs are governed by independent third-party carbon crediting standards and have a more streamlined project approval process (Lang et al., 2019; Lovell, 2010). Meanwhile, the rule-setting of VCMs and CCMs may have distinct priorities. The Gold Standard (GS) and Verified Carbon Standard (Verra), the two major carbon credit standards in international VCMs, emphasize the significance of achieving sustainable development goals in their project assessment systems more.

Those institutional complementarities connect the two seemingly distinct types of carbon markets, laying the foundation for global carbon markets. VCMs and CCMs are consistent in their policy targets and aim to mitigate climate change. The different institutional designs of both carbon markets form complementarities to a certain extent, which possesses the potential to expand market participants, enhance market liquidity, and achieve sustainable development goals. However, for institutional complementarities to play a real role in the carbon market operation, substantial interactions between VCMs and CCMs must occur, that is, regime interactions.

3.2 Causal mechanisms for regime interactions

Regime interactions imply causal relationships in which source regimes affect target regimes (Oberthür & Gehring, 2006). Exploring causal mechanisms opens the black box of regime interactions (Coleman, 1990; Hedström & Swedberg, 1998). Based on existing studies, we propose four causal mechanisms for regime interactions—cognitive, rule, behavioral, and functional interactions.

The first one is cognitive interaction, which refers to source regimes providing new information, knowledge, or other ideas to target regimes. This form of regime interaction assumes that actors have limited capacities for information acquisition and processing (Risse, 2000; Simon, 1972). The cognition levels and preferences of decision-makers in target regimes may be altered if source regimes can provide new information or knowledge (Haas, 1992), but this case is based entirely on the latter's voluntariness. When decision-makers of source and target regimes have close relationships or historical ties, we can assume that cognitive interaction occurs.

The second one is rule interaction, which occurs when source regimes provide institutional infrastructure, such as standards, procedures, and rules, to target regimes. When facing common functional challenges in institutional dimensions, such as monitoring, verification, enforcement, and decision-making, actors of target regimes may see certain practices of source regimes as models for learning. At this point, standards and rules diffuse from one institution to another, and they can be learned and imitated by the actors of target regimes. However, learning is a complex process that is usually not simply replicated but adapted and modified to suit the specific demands of target regimes (Haas, 1990). For example, the procedural, methodological, and technical practices of VCMs provide "testing grounds" for CCMs (Kollmuss et al., 2008), which policymakers can use to improve market construction and operation.

The third one is behavioral interaction, which means that source regime behaviors directly impact target regimes. Source regimes can create incentives, directly changing target regimes' behavior patterns. Such interaction requires a certain overlap in the rule systems of source and target regimes. Otherwise, the behavior patterns in one regime cannot be directly recognized or adopted by the other. For instance, behavioral interaction in carbon markets occurs when carbon crediting standards in VCMs implement stringent self-regulation to ensure carbon credit quality and thus make CCMs allow those carbon credits in VCMs to be used for compliance purposes.

The fourth one is functional interaction in which source regimes affect the functional orientations or ultimate governance objectives of target regimes. This interaction depends on the "functional link" (Young, 2002) among the ultimate governance targets of regimes involved at the impact level. Functional interaction occurs if the actual or declared goals of target regimes are changed due to the influences of source regimes. In carbon markets, the governance goals of one market may be expanded from emission reductions to broader socio-economic co-benefits such as sustainable development through interactions with the other.

The four causal mechanisms mentioned above delineate the interactions between hard and soft regimes. Either hard or soft regimes can be source regimes and vice versa. Given the varieties of regimes in carbon markets, the interactions between hard and soft regimes exist in diversified domains, or we can call them fields.

3.3 Fields of regime interactions

The field refers to "a community of organizations that partakes of a common meaning system and whose participants interact more frequently and fatefully with one another than with actors outside the field" (Scott, 1995, p. 56). Regulative, normative, and cultural-cognitive structures determine the behavior of organizations within the field (Scott, 1995). Carbon markets cover different levels of market builders, from local governments, central governments, and international organizations to INGOs. These actors provide fundamental norms, rules, and standards for carbon market building and operation, which shapes the behavior of participants. Given the varieties of regimes in carbon markets, the linkages between CCMs and VCMs occur in different fields, reflecting the interactions between soft and hard regimes.

In terms of market builders and the main transaction subject matter, CCMs and VCMs can be subdivided into different categories. Specifically, CCMs include ETS based on cap-and-trade or baseline-and-credit systems (CCM I, i.e., California's Carbon Cap-and-Trade Program, and British Columbia Greenhouse Gas Industrial Reporting and Control Act) constructed by supranational organizations, sovereign states or subnational actors. However, this paper does not discuss the sub-types of ETS operating within jurisdictions separately. Meanwhile, CCMs contain the compliance carbon crediting market based on projects (CCM II, i.e., CDM) constructed by international treaties or agreements. International compliance markets may also operate based on cap-and-trade systems, such as international emissions trading under Article 17 of the Kyoto Protocol. However, given that this sub-type is scarce, this paper only focuses on project-based CCMs at the international level.

Likewise, VCMs can be divided into the project-based domestic voluntary carbon crediting market (VCM I, i.e., China Certified Emission Reduction [CCER] Scheme) structured by sovereign states or subnational actors, and the project-based international voluntary carbon crediting market organized by independent third-party institutions (VCM II, i.e., the GS). Based on the carbon market classification, four fields exist in which carbon market linkages occur, as shown in Table 1. The following section provides a stylized description and analyzes regime interactions of each linkage between VCMs and CCMs according to the four fields mentioned above.

Institutional complementarities constitute the basis for regime interactions of carbon markets. Regime interactions delineate causal relationships among regimes and thus open the black box of how hard and soft regimes interact. Building upon the four fields, we intend to further illustrate the linkages between VCMs and CCMs through in-depth case analysis.

4 The landscape of linkages between VCMs and CCMs

4.1 The field of jurisdictional public governance: regime interaction between CCM I and VCM I

In this field, CCMs and VCMs are created and regulated under public regulations. The institutional interaction occurs mainly in the direction of VCMs toward CCMs.

Table 1 Fields of carbon market linkages

		VCMs (soft regimes)	
		Project-based voluntary carbon crediting markets constructed by sovereign states or subnational actors (VCM I)	Project-based voluntary carbon crediting markets constructed by independent third-party institutions (VCM II)
CCMs (hard regimes)	ETS constructed by supranational organizations, sovereign states, or subnational actors (CCM I)	Jurisdictional public governance (CCM I–VCM I)	Public–private governance (CCM I–VCM II)
	Project-based compliance carbon crediting markets based on international treaties or agreements (CCM II)	International public governance (CCM II–VCM I)	Transnational governance (CCM II–VCM II)

Source: Authors

Soft regimes, to a certain extent, foster and contribute to the development of hard regimes. Moreover, high-quality carbon credits from VCMs can be traded into CCMs and used as compliance offsets.

Case 1: The linkage between China's CCER scheme and its ETS pilots

China's voluntary carbon crediting market, the CCER scheme, started in 2012 and was subsequently traded on ETS pilots. Before establishing a national ETS market, China had established seven regional pilot markets in 2013. In 2017, the National Development and Reform Commission (NDRC) of the People's Republic of China announced plans to establish a national ETS. In the same year, the CCER scheme announced the filing suspension, and no new carbon credits would be issued, but the issued carbon credits could continue to be traded. The CCER scheme and China's ETS pilot markets overlapped in time and were closely linked.

First, CCER carbon credits are traded into ETS pilots and used as offsets for enterprises when allowances are insufficient. In CCER transactions, pro-environmental firms voluntarily develop GHG emission reduction projects. For firms with high carbon emissions, when freely issued allowances cannot meet actual carbon emissions, firms can either purchase the excess allowances of others or directly implement carbon emission reduction projects to obtain certified emission reductions (CERs). Meanwhile, such firms can also obtain CERs by purchasing in the CCER scheme to offset a certain percentage of carbon emission allowances in ETS pilots. Therefore, high-quality CERs provide cost-effective emission reduction options for regulated companies and enhance CCM effectiveness (Li et al., 2019; Ye et al., 2021). The acceptance of transaction subject matter of VCMs by CCMs implies that hard and soft regimes overlap in this process.

Second, the CCER scheme has expanded the trading entities of ETS pilots, encouraging a wider range of enterprises to participate in emission reductions and promoting carbon market effectiveness. As achieving China's carbon peaking and carbon neutrality goals and ambitious NDCs require the active participation of all industries, the CCER scheme helps reach such targets through enabling more firms that voluntarily develop carbon emission reduction projects to enter markets. Providing direct financial incentives to develop voluntary emission reduction projects, the CCER scheme is conducive to mobilizing social forces to participate in various emission reduction activities.

Whether VCMs are standardized is critical to ensure access to CCMs. Regulators suspended CCER project approval and filing in 2017 due to irregularities emerging in transactions. In the pilot stage, CCER trading volume rose sharply before the end of the compliance period and then fell rapidly after that. The high volatility and the low market price reduce participants' long-term confidence in the market (Lo & Cong, 2017). Meanwhile, CCER trading suffers from opaque transaction prices, which creates an obstacle to enforcing regulation and identifying market risks. Given that the regulatory entities of the CCER scheme and ETS pilots are national government agencies, whether the CCER scheme can be restarted in future depends on public regulators' confidence in its standardization. NDRC formulated and regulated the CCER scheme and pilot carbon markets, and strong historical connections

existed between them. At the end of 2018, the administrative authority of the national carbon market was shifted from the NDRC to the Ministry of Ecology and Environment. The restart of the CCER scheme requires further improvement in the management of filing and approval, revision of existing methodologies, and enhancement of market transaction transparency. Thus, although the CCER scheme can affect the trading of pilot markets, such impacts depend on the trust from the compliance market. In this case, if hard regimes distrust the standardization of soft regimes, regime interactions are hard to continue.

4.2 The field of public–private governance: regime interaction of CCM I and VCM II

In this field, CCMs established by national, subnational, or supranational actors interact with international VCMs, and the interaction occurs mainly in the direction from VCMs to CCMs. Similar to the field of jurisdictional public regulations, VCMs as soft regimes provide the transaction subject matter (i.e., high-quality carbon credits) to CCMs as hard regimes. Moreover, VCMs can directly nurture and enable CCM establishment by providing knowledge, information, and rules.

Case 2: The linkage between CAR and California's Carbon Cap-and-Trade Program

The Climate Action Reserve (CAR) is a privately managed and international carbon crediting standard. With the approval of the California Air Resources Board (CARB), a public regulatory authority, CAR serves as the Offset Project Registry for California's Carbon Cap-and-Trade Program. It takes the responsibilities of listing eligible carbon offset projects, facilitating verifications, and issuing Registry Offset Credits that can be converted into compliance uses.

CAR has multiple linkages with California's Carbon Cap-and-Trade Program. First, CAR provides high-quality carbon credits to compliance markets and helps regulated entities reduce emissions cost-effectively. Soft regimes overlap with hard regimes in transaction subject matter acceptance. Such interaction offers an economic incentive to improve emission performance and helps accelerate climate mitigation targets. Second, CAR provides regulatory preparation for establishing California's Carbon Cap-and-Trade Program, including knowledge, rules, and market infrastructure. CAR, formerly known as the California Climate Action Registry (CCAR), was created by the state of California in 2001. At that time, given that the state of California planned to regulate carbon emissions in the region and help businesses prepare for upcoming regulations, the state government first created CCAR. These early experiences and rules about emission reductions in CCAR were instrumental in establishing California's Carbon Cap-and-Trade Program. CCAR was later delegated to a private entity and eventually evolved into CAR (Green, 2017).

Third, CAR provides policy lobbying for California's Carbon Cap-and-Trade Program. CCAR and its members have affected California's climate change policies, such as the Global Warming Solutions Act of 2006 (AB 32), and persuaded legislators to recognize early reduction actions properly. After AB 32 was passed, CAR's extensive

experience and expertise in managing carbon offset programs led to its inclusion in California's Carbon Cap-and-Trade Program (CAR, 2023b). Fourth, CAR increases stakeholder numbers and social consensus for developing carbon markets. CCAR started with 23 charter members and then gradually grew to over 350 members, including companies, universities, cities and counties, government agencies, and environmental organizations (CAR, 2023a). All members have committed to voluntarily calculate and publicly report their GHG emissions according to CCAR standards. CCAR has gathered wide social consensus and good reputation in practice, which makes public regulators satisfied with its early performance.

However, considering environmental integrity and the overall emission reduction quality of future carbon markets, the carbon credit proportion for compliance uses is declining. From 2013 to 2020, the limit for regulated entities using offset credits for compliance obligations was 8%. The proportion has decreased to 4% from 2021 to 2025 (CARB, 2021). The shrinking share of carbon credit use indicates that hard regimes may eventually squeeze out soft regimes.

Case 3: The linkage between Verra and Malaysian ETS

In collaboration with the Ministry of Finance and the Ministry of Environment and Water, the Malaysian stock exchange established a VCM in December 2022. It used the international voluntary carbon crediting standard, Verra, to ensure carbon credit quality. In future, the Government of Malaysia plans to establish a domestic ETS and carbon tax system.

Although the CCM is not established, the engagement of a well-developed voluntary carbon crediting standard can help ensure environmental integrity. Given that Verra is a widely recognized global standard that has developed various climate-friendly projects, policymakers believe that building a credible and well-functioning VCM in advance can lay an early foundation for the Malaysian ETS (International Carbon Action Partnership, 2022). Specifically, Verra provides participants with relevant knowledge and experience of how to engage in carbon markets, which may contribute to those who intend to enter ETS in future. Buyers can gain first-mover advantages through participation in VCMs to prepare for future compliance (Andonova et al., 2017). Meanwhile, the VCM establishment can encourage a wide array of participants to reduce emissions by providing cost-effective ways, thus forming a societal foundation for promoting more diversified carbon pricing, such as ETS, in future. The collaboration between VCM and CCM expects to accelerate the achievement of the country's net-zero target.

In this case, the VCM as soft regime can provide valuable information and experience to market participants and governors when the CCM is at the early development stage, laying the foundation for further engagement with the CCM as hard regime.

Thus, in terms of Cases 2 and 3, the standardization and high credibility of soft regimes and the demands of hard regimes regarding compliance costs, market efficiency, and environmental integrity are essential conditions for their interactions. In addition, international competition, regulatory preparation, policy lobbying, and social consensus drive such institutional interactions.

4.3 The field of international public governance: regime interaction between CCM II and VCM I

In this field, CCM II interacts with domestic voluntary carbon crediting markets. Interactions between hard and soft regimes are bidirectional: on the one hand, some domestic voluntary carbon crediting standards provide eligible compliance carbon credits for CCM II to improve compliance effectiveness and contribute to compliance market development. On the other hand, CCM II affect the rule-setting of domestic voluntary carbon crediting markets, thus forming rule compatibility.

Case 4: The linkage between CDM and China's CCER scheme

CDM is a project-based carbon offset scheme that allows high-income countries to purchase carbon credits from carbon reduction projects in low- or middle-income countries to meet their emission reduction goals partially under the Kyoto Protocol. CDM is the major source of carbon credits in CCM II. Before 2012, China participated in CCM II primarily through CDM and was the largest host of CDM projects (Bayer et al., 2013). However, since 2013, the EU, as the largest demander of CDM projects, only purchased newly registered CDM projects from least developed countries and no longer accepted CERs from countries, such as China and India, resulting in a significant decrease in the number of CDM projects issued in China (European Commission, 2023). The dramatic changes in the supply–demand relationship in international compliance markets have led China to turn its attention to domestic markets, and it set out to establish a voluntary carbon crediting market in 2012.

CDM and the CCER scheme interact closely. On the one hand, CDM methodologies provide essential references for China's CCER scheme, and the two achieve rule compatibility. In terms of additionality, project baseline scenario setting, regulation implementation, and emission reduction measurement, most methodologies for CCER projects come from CDM. Specifically, 174 out of 200 methodologies follow existing CDM methodologies (Lo & Cong, 2017; Wei & Xiao, 2022). Adopting market-familiar CDM methodologies helps reduce transaction costs. On the other hand, the CCER scheme achieves market substitutions for CDM. After the EU's withdrawal from China, the CCER scheme has been promoting voluntary emission reduction projects by Chinese domestic enterprises and helping establish ETS pilots.

Case 5: The linkage between CORSIA and China's CCER scheme

In 2016, the ICAO, a specialized agency of the United Nations, established CORSIA, which is the first global carbon market driven by an international industry organization with unified MRV guidelines. CORSIA is similar to CCM II and has a pilot phase from 2021 to 2023, a voluntary participation phase from 2024 to 2026, and a mandatory participation phase from 2027 to 2035. The market requires participating airlines to purchase carbon credits to offset any increase in carbon emissions from international flights that exceeds the emission baseline.

As the primary transaction subject matter in CORSIA, carbon credit development can affect the cultivation of a global carbon market for the aviation industry. VCM

standardization is crucial for entering CCMs. The ICAO Council has documented eight eligible emission units for compliance, including CERs from China's CCER scheme. However, this scheme still needs to be improved in terms of social and environmental risk management systems, pricing mechanisms, verification systems, and assessment systems for sustainable development contributions, otherwise its recognition and use in international carbon markets may be compromised (Wei & Xiao, 2022). The CCER scheme's carbon credits entrance to CORSIA demonstrates how hard regimes overlap with soft regimes.

As seen in Cases 4 and 5, CCM II and VCM I are authorized by public sectors with high requirements for institutional standardization. Thus, determining whether source regimes are standardized is critical to interactions. In addition, supply–demand changes and market expansion expectations are drivers for VCM establishment and acceptance by public sectors.

4.4 The field of transnational governance: regime interaction between CCM II and VCM II

In this field, CCM II interacts with VCM II. Regime interactions are also bidirectional: soft regimes provide relevant knowledge, information, rules, and high-quality carbon credits to hard regimes for compliance uses. Meanwhile, hard regimes provide soft regimes with preliminary frameworks and starting points for market development.

Case 6: The linkage between GS and CDM

Concerns about the effectiveness of CCM II have driven the creation and development of some international voluntary carbon crediting standards. The CDM projects have been long criticized for lacking sustainable development benefits (Paulsson, 2009). This is because host countries enjoy considerable discretion over how to define and apply sustainable development standards on CDM projects (Phillips et al., 2013). Given the unwillingness of host countries to give up their sovereign rights, there is no uniform guidance to ensure that CDM projects can bring sustainable development benefits to local communities.

In this context, GS was created to address sustainability issues arising from CDM projects. GS established a standard for assessing CDM project quality while providing project developers with a methodology that can yield real environmental benefits. The certification procedures developed by GS help differentiate carbon credits in terms of whether CDM projects meet the sustainability criteria (Newell & Paterson, 2010). GS is based on the guidance provided by the CDM Executive Committee in the first edition of its Project Design Document and is directly compatible with the life cycles of CDM projects (World Wide Fund for Nature, 2002). Although the methodologies adopted by GS adhere to those in CDM, GS is more concerned about the positive economic, environmental, and social impacts of projects on local communities than with CDM. Thus, international voluntary carbon crediting standards expand CCM II targets, making them further focused on contributions to the sustainable development of host countries.

Case 7: The linkage between GS and international carbon markets under UNFCCC (Article 6 compliance market under the Paris Agreement)

The Paris Agreement sets long-term targets of limiting global temperature by midcentury and expects all countries to update NDCs every five years. Given the increasingly ambitious climate pledges, substantial efforts are needed to involve more stakeholders. In this vein, VCMs can engage more to assist countries in achieving their NDCs and global climate targets collaboratively under Article 6 of the Paris Agreement.

Specifically, Article 6.2 of the Paris Agreement allows countries to transfer carbon credits from emission reductions to help other countries achieve their climate goals, which is known as "internationally transferred mitigation outcomes" (ITMOs). The authorized ITMOs can be used for NDC compliance, "international mitigation purposes" other than NDC achievement, and "other purposes" such as voluntary climate commitments. Furthermore, Article 6.4 proposes creating a mechanism for voluntary participation by parties to promote emission reductions and sustainable development, which provides the basic framework for developing an improved CCM II after CDM.

With the growth of international CCMs under UNFCCC, VCM activities from host countries may be incorporated in Article 6.2 or 6.4 in future to serve the emerging compliance demands through aligning with the framework and rules of the Paris Agreement. In this sense, voluntary carbon crediting standards such as GS has been actively developing principles and guidance for building a new international compliance carbon market. For instance, the Swedish Energy Agency has officially partnered with GS. The revised rule, framework, and institutional infrastructure designed by GS can facilitate Sweden's access to high-quality ITMOs and activities under Article 6 (GS, 2021). Adopting well-developed international voluntary carbon crediting standards can reduce transaction costs while ensuring carbon credit quality, environmental integrity, and substantial contribution to sustainable development goals, thereby enhancing the overall effectiveness of international CCMs. The established rules, principles, and best practices of VCMs contribute to developing international CCMs under UNFCCC, which illustrates how hard regimes absorb soft regimes in the early stage.

Case 8: The linkage between CORSIA and Verra, CAR, and GS

VCM II provides eligible carbon credits for CCM II to achieve international compliance targets. Voluntary carbon crediting standards with stringent self-regulation, such as CAR, Verra, and GS, are eligible emission units recognized by CORSIA, and they provide diversified compliance tools for the CORSIA. It displays the overlap between hard and soft regimes when the transaction subject matter of VCMs is accepted.

Similar to Case 5, the quality and standardization of carbon credits generated by international standards are valued as those from VCM I, which must fulfill the Emission Unit Eligibility Criteria adopted by the ICAO Council. The Criteria incorporate additionality, permanence, the avoidance of double-counting, and others. The Technical Advisory Body is set to assess whether carbon-offsetting programs meet the Criteria for compliance uses and make recommendations to the ICAO Council.

In this sense, due to the consideration of environmental integrity, only high-quality carbon credits can be accepted by the ICAO Council. Meanwhile, compared with China's CCER scheme, some voluntary carbon crediting standards, such as GS pioneering in achieving sustainable development, may serve the CORSIA better in this dimension.

As presented from Case 6 to Case 8, the factors contributing to the regime interactions between CCM-II and VCM-II are not only the methodologies and standardization of source regimes but also the concerns arising from target regimes on emission reduction costs, market efficiency, and environmental integrity. Meanwhile, early historical ties and the recognition of target regimes by sovereign states or local governments are related to regime interactions.

5 Case summary and discussion

5.1 Regime interactions among carbon markets

We summarize the carbon market linkages of the eight cases mentioned above (Table 2). First, regime interactions among carbon markets are directional, most occurring in the direction of VCMs to CCMs. As illustrated in Fig. 1a and b, in all eight cases, VCMs affect CCMs, except for Cases 4 and 6. Interactions from VCMs to CCMs cover all causal mechanisms of regime interactions, including cognitive, behavioral, rule, and functional interactions. Conversely, only rule interaction exists in the reverse interaction from CCMs to VCMs (Cases 4 and 6).

Second, behavioral interaction is the primary type of VCMs affecting CCMs. As shown in Fig. 1b, four of the six regime interactions in which VCMs affect CCMs have behavioral interaction. Soft regimes provide the transaction subject matter, namely, high-quality carbon credits, to hard regimes, which displays how hard regimes overlap with soft regimes. However, behavioral interaction does not necessarily lead to functional interaction. For target regimes regarding CCM I (e.g., Cases 1 and 2), behavioral interaction is accompanied by functional interaction, that is, to reduce compliance costs. For target regimes involving CCM II (e.g., Case 5 and 8), behavior interaction does not bring functional interaction.

Third, rule interaction occurs in bidirectional linkages, both appearing at the early stage of target regimes. As presented in Fig. 1a, rule interaction from CCMs to VCMs (Cases 4 and 6) occurs in the early stage of VCM establishment. For example, the CCER scheme was initially set up to accept CDM methodologies, and GS used the same principles, methodologies, and life cycles as CDM to enhance CDM project credibility. Reverse rule interaction is similarly seen from VCMs to CCMs. As in Case 7, GS provides the rules and guidelines for Switzerland to engage in international carbon markets under UNFCCC. In Cases 4, 6, and 7, regimes where rule interaction occurs all have strong historical ties to one another or have the same institutional basis, such as all signing the Kyoto Protocol and the Paris Agreement.

Table 2 Fields, regime interactions, and dynamic evolution of global carbon market linkages

Fields	Linkages: Source regimes → target regimes	Regime interactions: Source regimes → Target regimes			Institutional complementarities	Dynamic regime interactions
Jurisdictional public regulations (CCM I–VCM I)	① CCER → China's ETS pilots	○ Transaction subject matter	→	○ Behavioral interaction: China's ETS pilots allow voluntary carbon credits to be used for compliance ○ Functional interaction: reduce compliance costs	○ Participant complementarity ○ Market boundary complementarity	The CCER scheme was suspended in 2017 due to irregularities in market transactions and the restart date is undecided
Public–private governance (CCM I–VCM II)	② CAR → California's Carbon Cap-and-Trade Program	○ Transaction subject matter ○ Market rules	→	○ Behavioral interaction: California's Carbon Cap-and-Trade Program allows voluntary carbon credits to be used for compliance ○ Functional interaction: reduce compliance costs ○ Rule interaction: CAR provides regulatory preparation	○ Participant complementarity ○ Market boundary complementarity ○ Operation rule complementarity	The proportion of VCM carbon credits for compliance uses is declining
	③ Verra → ETS in Malaysia (under consideration)	○ Information, knowledge, and experience	→	○ Cognitive interaction: Verra provides knowledge and experience of how to engage in carbon markets	○ Participant complementarity	The Government of Malaysia plans to establish a domestic ETS in future, laying the foundation for more interactions between VCMs and CCMs

Table 2 (continued)

Fields	Linkages: Source regimes → target regimes	Regime interactions			Institutional complementarities	Dynamic regime interactions
		Source regimes → Target regimes				
International public regulation (CCM II–VCM I)	④ CDM → CCER	○ Market rules	→	○ Rule interaction: 174 of the 200 methodologies for CCER projects follow CDM methodologies	○ Operation rule complementarity	China was once the largest host of CDM projects, but the sharp drop in international CER demands made China choose to develop CCER
	⑤ CCER → CORSIA	○ Transaction subject matter	→	○ Behavioral interaction: CORSIA allows voluntary carbon credits to be used for compliance ○ Functional interaction: reduce compliance costs	○ Participant complementarity ○ Market boundary complementarity	CORSIA has three phases: pilot, voluntary, and mandatory. After entering the third phase, regime interaction forms may change

Table 2 (continued)

Fields	Linkages: Source regimes → target regimes	Regime interactions			Institutional complementarities	Dynamic regime interactions
		Source regimes → Target regimes				
Transnational governance (CCM II–VCM II)	⑥ CDM → GS	○ Market rules	→	○ Rule interaction: GS uses the similar methodologies as CDM ○ Functional interaction: GS focuses on broader sustainability goals	○ Operation rule complementarity	GS served CDM projects in the early days, but GS has grown into a globally recognized carbon crediting standard
	⑦ GS → International carbon markets under UNFCCC	○ Cognition and experience ○ Market rules ○ Principle and guidance	→	○ Cognitive interaction: GS provides information and best practices for participating in international carbon markets ○ Rule interaction: international carbon markets adopt rule, framework, and infrastructure designed by GS ○ Functional interaction: international carbon markets accept broader sustainability goals	○ Participant complementarity ○ Market boundary complementarity	With the development of international carbon markets under UNFCCC, VCMs expect to engage more to help achieve ambitious climate pledges
	⑧ Verra/CAR/ GS → CORSIA	○ Transaction subject matter	→	○ Behavioral interaction: CORSIA allows voluntary carbon credits to be used for compliance ○ Functional interaction: reduce compliance costs	○ Participant complementarity ○ Market boundary complementarity	CORSIA has three phases: pilot, voluntary, and mandatory. After entering the third phase, regime interaction forms may change

Source: Authors

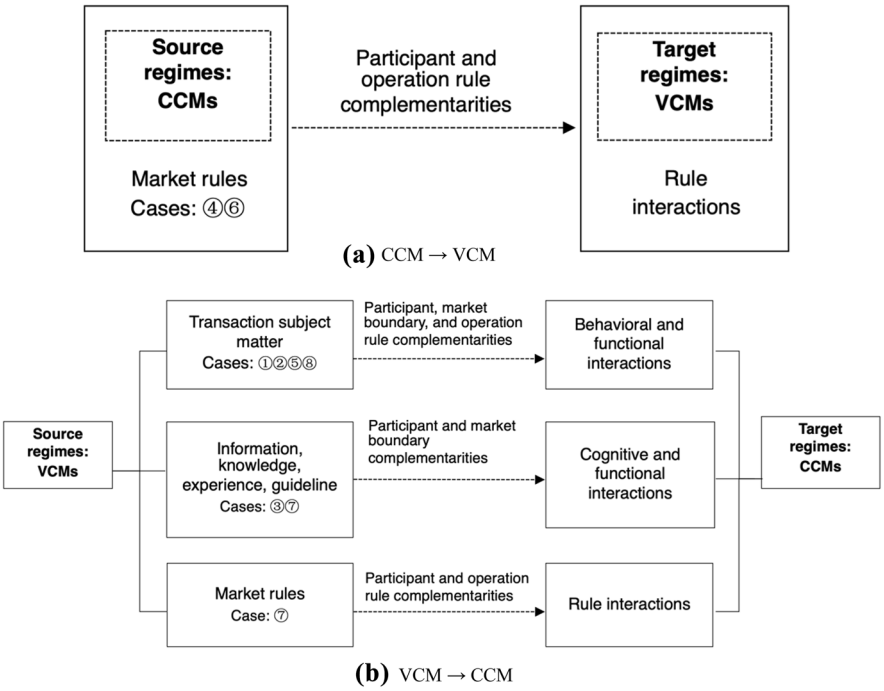

Fig. 1 Processes of carbon market linkages. *Note*: Institutional complementarities constitute the basis for regime interactions of carbon markets, so they are represented by dotted lines. Source: Authors

Fourth, cognitive interaction only appears in the unidirectional linkage from VCMs to CCMs, and occurs in the early stage of hard regimes. As shown in Cases 3 and 7, Verra and GS from VCM II affect the future Malaysian ETS and the activities under Article 6 of the Paris Agreement. These cases illustrate how hard regimes absorb soft regimes at the early stage of market establishment. Participant complementarity, especially the willingness of governments in target regimes to collaborate, is necessary for cognitive interaction to arise.

5.2 The dynamic interactions between hard and soft regimes

Interactions between hard and soft regimes are dynamic. Soft regimes are contingent on the development of hard regimes. Figure 2 reveals such dynamic evolution of regime interactions. First, cognitive and rule interactions usually occur early in the establishment of hard regimes. Although rule interaction tends to occur in a bidirectional way, we mainly focus on rule interaction following the direction of VCMs to CCMs in the dynamic interaction analysis, given that regime interactions in carbon markets mainly occur in the direction of VCMs to CCMs. We regard VCMs as soft regimes and CCMs as hard regimes, and the above interactions are processes in which hard regimes gradually absorb soft regimes. We surmise that because CCMs

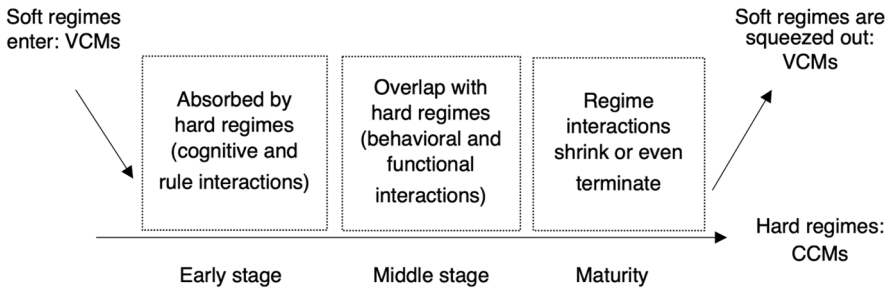

Fig. 2 Dynamic evolution of regime interactions. Source: Authors

have rigid and standardized rule systems and are usually operated by public regulators with coercive power, CCMs are likely to be affected when they are at the initial stage of development. Once regimes become "hardened," that is, formed standardized rule systems, cognitive interaction may stop, but CCMs can still export rules, which, in turn, affects the rule formation of VCMs.

Second, behavioral and functional interactions usually occur in the middle development stage of hard regimes, a process in which soft and hard regimes overlap. To ensure rigid regulations and market effectiveness, soft regimes introduce a certain proportion of the transaction subject matter to improve the operational efficiency of hard regimes (Cases 1, 2, 5, 8). Whether the carbon credits of soft regimes can enter the carbon markets of hard regimes depends mainly on the degree of standardization of soft regimes. As soft regimes become further standardized, if VCMs provide high-quality carbon credits and receive wide recognition from carbon markets, the transaction subject matter from VCMs can be accepted into CCMs for trading (Cases 2 and 8). However, once the standardization of VCMs encounters doubts, behavioral interaction is expected to terminate (Case 1). Therefore, hard regimes enjoy a highly dominant power to determine the timing and conditions of soft regimes' entry and exit in regime interactions.

Third, regime interactions may shrink or terminate when hard regimes mature, a process in which hard regimes squeeze out soft regimes. As CCMs gradually grow and expand, the percentage of voluntary carbon credits used for compliance decreases (Case 2), or even VCMs may be squeezed out by CCMs. Some CCMs resist even the carbon credits endorsed by international treaties or agreements. The EU ETS previously allowed regulated entities to use carbon credits certified by CDM. However, as of Phase IV (2021–2030), the EU ETS will no longer allow the use of any international carbon credits for compliance purposes (European Commission, 2023). We attribute the predominant position of hard regimes to the degree of market cohesion when interacting with soft regimes. The current fragmented governance of VCMs makes itself susceptible to risks concerning environmental integrity, which may bring high costs that increase the opportunism of greenwashing and weaken the willingness for deep decarbonization. In contrast, CCMs with a unified and strict MRV system are more reliable in contributing substantially to achieving climate targets. For instance, the EU has announced an ambitious NDC that will

reduce GHG emissions by at least 55% by 2030, compared to 1990 levels in European Climate Law. It explicitly states that international carbon credits will not be used to achieve its NDC. The EU case demonstrates that countries with rigorous climate targets prefer CCMs to VCMs, and hard regimes may eventually squeeze out soft regimes.

The dynamic evolution of VCM absorption, overlap, and squeezing by CCMs may reveal the future development of global carbon markets. CCMs in various countries and regions tend to be integrated, making the network of CCMs expand. Carbon credits from VCMs may gradually withdraw from CCMs and no longer be used for compliance, as broader CCM market boundaries can bring more participants, more market-based carbon prices, and more effective economic incentives. However, given that VCMs incorporate a wide range of stakeholders and provide diverse knowledge, methodologies, and tools, they may still be active around CCMs and complement global carbon markets at the present stage.

6 Conclusion

Most existing studies treat VCMs and CCMs independently, and they lack explorations on interactions within the regime complex of carbon markets . We collect eight cases of VCM and CCM linkages, and analyze the process of regime interactions, drivers of carbon market linkages, and the dynamic evolution through comparative case studies and grounded theory.

We find that institutional complementarities exist in VCMs and CCMs. Given the shared governance targets, complementarities of participants, market boundary, and operation rules lay the foundation to connect various carbon markets into a global network. Meanwhile, institutional complementarities among various carbon markets constitute the basis of regime interactions between hard and soft regimes. Specifically, regime interactions in carbon markets are directional, with most occurring from VCMs to CCMs. Behavioral interaction is the primary type of how VCMs affect CCMs. Depending on target regimes, for target regimes involving domestic ETS, behavioral interaction is accompanied by functional interaction, whereas for those involving compliance carbon crediting markets, behavioral interaction does not lead to functional interaction. Moreover, rule interaction occurs in bidirectional linkages, whereas cognitive interaction appears only in the unidirectional linkage from VCMs to CCMs.

Our research also explores dynamic regime interactions. Cognitive and rule-based interactions usually occur in the early establishment stage of hard regimes, whereas behavioral and functional interactions usually occur in the middle stage. Regime interactions are expected to shrink or terminate when hard regimes mature. If VCMs are regarded as soft regimes and CCMs as hard regimes, then carbon market linkages are processes in which hard regimes gradually absorb, overlap, and squeeze out soft regimes.

Our results have potentially important implications. First, our paper presents a general theoretical framework for carbon market linkages and illustrates regime

interactions between hard and soft regimes with in-depth case analysis. Future research can examine the differences in the strength of regime interactions for specific carbon market linkage fields. Second, we point out that regime interactions within carbon markets are dynamic, and the degree of standardization of VCMs positively affects their interactions with CCMs, whereas the maturity of CCMs may reduce their willingness to link with VCMs. Future research can combine more qualitative or quantitative data to test the above research hypotheses systematically.

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Data availability Not applicable.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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