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Driving the Green and Low-Carbon Economy Through Digital Innovation: Insights from China's Inclusive Carbon Benefit Mechanism

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Abstract: Climate change mitigation requires not only industrial transformation but also behavioral shifts at the consumer level. This systematic analysis examines China's pioneering inclusive carbon benefit policies, which integrate digital technologies to incentivize low-carbon behaviors among individuals and small- to medium-sized enterprises. Since the concept's inception in 2009, carbon inclusion has evolved into a national strategy, formally recognized in China's 2022 climate policy framework. This analysis synthesizes policy developments, standardization efforts, and practical implementations across 39 case studies, categorizing them into government-led, firm-led, and hybrid models. Findings highlight that diversified, government-guided mechanisms with active private sector participation are the most effective in promoting sustained green behavior, enhancing public engagement, and contributing to China's dual carbon goals of achieving carbon peak by 2030 and carbon neutrality before 2060 (hereafter referred to as "dual carbon goals"). The integration of digital platforms, standardized emission accounting, and incentive structures has transformed voluntary actions into measurable carbon assets. The study also explores emerging practices in advanced carbon accounting, including the concept of Scope 4 emissions, and evaluates China's role in setting global precedents for digitalized carbon neutrality frameworks. Challenges such as inconsistent standards, limited market incentives, and integration barriers are discussed, alongside recommendations for policy enhancement and broader application. In conclusion, China's carbon inclusive approach demonstrates a scalable model for fostering green lifestyles through multi-stakeholder collaboration and digital innovation. This mechanism offers valuable insights for global efforts in consumer-end emission reduction and highlights the critical role of behavioral change in achieving climate targets. It will contribute to advancing digitalized climate governance and offer practical insights for policymakers worldwide.

Keywords: inclusive carbon benefit, low-carbon behavior, digital carbon neutrality, consumer emission reduction, climate policy, sustainable lifestyle, carbon accounting

1. Introduction

Addressing climate change requires a coordinated dual track approach: transforming production systems across industrial sectors, manufacturing processes, and supply chains to minimize environmental impact and carbon footprint, while developing evidence based strategies to promote and normalize sustainable consumption behaviors throughout society [1]. Traditional emission reduction strategies have focused on policy frameworks and technological advances in renewable energy, industrial manufacturing, transportation, and agriculture. However, there has been a significant shift in research and policy attention toward understanding and influencing consumption behavior patterns at the end of the global value chain [2]. This shift is crucial, as recent the United Nations Environment Programme assessments reveal that household consumption activities, lifestyle choices, and behavioral patterns now account for nearly two thirds of global greenhouse gas (GHG) emissions. This sobering statistic underscores the urgent need for widespread lifestyle transformation as an essential component in addressing the impacts of anthropogenic climate change [1].

In response to this challenge, the People's Republic of China has pioneered an innovative mechanism called carbon inclusion, a voluntary, digital framework that rewards low carbon behaviors among citizens and enterprises nationwide. This initiative breaks from traditional carbon reduction approaches by engaging participants directly at the grassroots level through a digital ecosystem. Using advanced technologies like mobile internet, big

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data computing technology, artificial intelligence, and blockchain systems, the framework tracks and records daily green actions. These actions range from choosing eco friendly transportation and energy efficient consumption to participating in recycling and supporting sustainable products. The system transforms these environmental behaviors into verified carbon assets, which carry both social recognition and economic value within the broader green economy framework [3].

Since its initial conceptualization in 2009, the carbon inclusion framework has evolved significantly through multiple developmental stages. What began as small scale localized pilot programs, designed to test and validate core concepts, gradually expanded in both scope and sophistication. Through systematic evaluation and refinement of these trials, the framework gained broad recognition and support from stakeholders across sectors. This momentum and proven effectiveness led to its formal incorporation into China's comprehensive climate action policies by 2022 [4]. The mechanism serves several crucial functions in advancing sustainable development: it catalyzes ecological education, raises environmental consciousness through direct engagement, and integrates green finance principles with digital carbon neutrality practices.

Compared with other carbon neutrality perception studies, such as those examining public awareness and ESG integration in China [5], cross cultural interpretations of carbon neutrality concepts [6], or sector specific analyses like spectral clustering of plant diversity impacts [7]—this research differs in three key ways: (1) it focuses on operational mechanisms rather than perceptions alone; (2) it examines consumer end behavioral integration into formal carbon markets; and (3) it situates China's model in a comparative global governance context.

China's "dual carbon" goals, reaching peak carbon emissions before 2030 and achieving carbon neutrality by 2060, represent a monumental undertaking that requires extensive participation across all sectors of society. The success of these objectives depends on mobilizing and maintaining long term commitment from diverse stakeholders. The carbon inclusion framework provides a structured, accessible pathway to engage both individuals and small to medium sized enterprises (SMEs) through policy incentives, commercial reward systems, and standardized carbon accounting methods.

Despite its success in promoting sustainable behaviors, the framework faces challenges: the need for unified implementation standards, development of more effective incentives, and integration across diverse digital and policy ecosystems [6]. These issues, along with concerns about data privacy, equitable participation, and long term market viability, will be examined in this paper.

Against this backdrop, this study is guided by the following research question: How can China's Inclusive Carbon Benefit Mechanism (ICBM), as a digitally enabled policy innovation, effectively mobilize consumer end behavioral change to contribute to national and global climate goals, and how does it compare to similar mechanisms internationally? This question addresses a relatively underexplored area of climate governance, how to systematically integrate individual and small enterprise actions into national carbon reduction strategies through digital innovation and market linked incentives.

To address the research question, this study systematically analyzes the historical development, governance models, and implementation outcomes of China's carbon inclusion policy through 39 case studies. It also compares China's experience with similar initiatives in the European Union's Personal Carbon Allowances (PCAs) and South Korea's Carbon Point Program, and evaluates the mechanism's potential as a transferable model for global climate governance.

2. Methods and Analysis

2.1 Historical development and evolution of China's inclusive carbon benefit policy

The conceptualization and implementation of China's carbon inclusion framework represent a groundbreaking approach that emerged in 2009, driven by an increasing recognition of the critical need for broader public engagement in emission reduction initiatives [8]. This mechanism distinguishes itself from conventional carbon trading schemes, which predominantly focus on industrial sector regulations. Instead, carbon inclusion targets behavioral modifications at the consumer level through sophisticated digital infrastructure designed to record, quantify, and reward environmentally conscious actions. The framework's foundation integrates "Internet + Big Data + Carbon Finance" in a comprehensive ecosystem that transforms voluntary environmental behaviors into recognized carbon assets with measurable economic value [8].

Significant policy developments and institutional milestones include following: 1) The 2021 "Action Plan for Carbon Peak by 2030", establishing guidelines for enhanced public participation and sustainable consumption [4]. 2) The incorporation of carbon inclusion into China's 2022 Annual Report on Policies and Actions to Address Climate Change, elevating it to national strategic importance [9]. 3) The development of standardized methodologies for carbon reduction accounting, such as the Guidelines for Quantifying GHG Emission Reductions of Citizens' Green and Low Carbon Behaviour (see Appendix Table A1 for details).

These developments mark a transition from fragmented pilot programs to a sophisticated, multi stakeholder framework coordinating government agencies, private enterprises, NGOs, and digital platforms.

2.2 Comprehensive standardization and technical Infrastructure development

Robust measurement standards are a cornerstone of the carbon inclusion framework, ensuring transparency, operational credibility, and interoperability across platforms [10, 11]. Since 2015, China has introduced multiple technical specifications covering: digital verification of second hand trading platforms, real time carbon tracking in digital refueling systems, citizen green behavior quantification across diverse activity types.

Advanced platforms such as the Green Inclusive Cloud, also known as Carbon Emission Reduction Digital Account Book, provide third party verification and cross platform integration [12]. These infrastructures support Monitoring, Reporting, and Verification (MRV) processes, linking individual behaviors to aggregated, verifiable national carbon datasets.

2.3 Expanded research and analysis methodology

2.3.1. Research design

This study adopts a comparative multi case design to analyze how diverse operational models of China's carbon inclusion framework function in practice. By combining policy analysis, document review, and structured case study evaluation, we assess both governance structures and measurable outcomes. The study follows a systematic review approach to ensure comprehensiveness and reproducibility.

2.3.2. Case selection criteria

Cases were included if they met all of the following conditions: 1) operational maturity – at least 6 months of active implementation; 2) documented low carbon behavior tracking with measurable indicators; 3) defined incentive mechanisms (monetary or non monetary); 4) publicly accessible records from government, corporate, or NGO sources; and 5) representativeness of one of the three governance models identified in preliminary scoping.

From an initial pool of 87 identified programs, 39 cases were selected to ensure diversity in governance model, geographic region, and sectoral focus.

2.3.3. Data sources

We drew upon 1) national and provincial policy documents; 2) technical standards and guidelines; 3) government and NGO sustainability reports; 4) peer reviewed literature (2009-2024); 5) corporate ESG disclosures; and 6) digital platform usage data (where available).

2.3.4. Coding and reliability procedures

A coding framework was developed to categorize data into five analytic dimensions: 1) initiating and participating entities and their roles; 2) emission reduction scenarios and behavioral contexts; 3) standardized accounting methods and verification procedures; 4) incentive structures and uptake metrics; and 5) public engagement and scalability potential.

2.4 Link to discussion and policy relevance

The methodological design not only enables a systematic evaluation of China's ICBM but also directly links to the discussion and recommendations. By identifying governance strengths and weaknesses across models, the study informs 1) policy design improvements (Section 3.6); 2) comparative insights with international programs such as the EU's PCAs and South Korea's Carbon Point Program (Section 4.1); and 3) global transferability potential for digitally enabled carbon inclusion mechanisms.

This methodologically robust approach enables a thorough and nuanced understanding of how the carbon inclusion framework operates within China's complex policy ecosystem, effectively highlighting successful implementation strategies, identifying operational challenges, and illuminating promising areas for future enhancement and optimization.

3. Findings and discussion

The extensive analysis of China's carbon inclusion initiatives has revealed a sophisticated landscape of operational models, each designed to maximize public participation in national emission reduction efforts[13]. Through detailed examination of 39 comprehensive case studies, three distinct implementation frameworks have emerged, showcasing varying approaches to governance structures, market mechanisms, and citizen engagement strategies.

3.1 Different types of ICBM

3.1.1. Government-led ICBM

These initiatives represent the foundation of public sector environmental engagement, with governmental bodies taking the lead in developing and maintaining structured participation platforms (Appendix Table A2). Through these systems, citizens can systematically accumulate environmental credit points by engaging in verified sustainable activities, ranging from household energy conservation measures to the adoption of eco-friendly transportation alternatives. The incentive structure is carefully designed to integrate with everyday consumption patterns, offering tangible rewards that effectively reinforce and sustain environmentally conscious behavioral modifications [3].

While these government-initiated platforms command considerable public confidence and benefit from robust policy support frameworks, they encounter several operational challenges: limited capacity for cross-sector enterprise collaboration, incomplete development of comprehensive emission reduction measurement standards, and constraints in scaling operations due to resource limitations in promotional activities and operational management. Although the strong focus on public welfare ensures precise alignment with national environmental objectives, the restricted participation of diverse stakeholders has resulted in somewhat limited innovation potential and reduced adaptability in implementation strategies.

3.1.2. Firm-led ICBM

The private sector approach to carbon inclusion demonstrates significant innovation in leveraging advanced digital ecosystems to seamlessly integrate sustainable choices into consumers' daily routines (Appendix Table A3). These platforms employ sophisticated real-time interaction capabilities, including mobile application-based activity tracking and instantaneous reward systems, effectively creating immersive "green engagement zones" that naturally guide users toward more sustainable consumption patterns [3, 14].

Nevertheless, these corporate-driven mechanisms frequently operate within isolated technological environments, resulting in several significant challenges: fragmented approaches to carbon accounting methodologies, substantial difficulties in consolidating carbon assets across different platform ecosystems, and ongoing sustainability concerns in the absence of comprehensive policy support frameworks. Despite demonstrating remarkable strengths in user engagement and operational agility, these firm-led initiatives often struggle to expand beyond their corporate boundaries and achieve meaningful integration with broader national carbon reduction strategies.

3.1.3. Government-led diversified ICBM with private sector collaboration

This advanced implementation model represents the most sophisticated and effective approach, combining strategic government oversight with dynamic market participation. It integrates government authorities, private enterprises, academic institutions, NGOs, and media partners in coordinated efforts to mobilize public engagement in emission reduction (Appendix Table A4) [10, 15, 16].

The success of these programs rests on three key pillars: 1) comprehensive standardization: unified, scientifically validated carbon accounting methodologies ensure credibility and interoperability across platforms; 2) multidimensional incentives: reward mechanisms range from consumption vouchers to green credit systems, maintaining high participant motivation; and 3) advanced data architecture: platforms like the Green Inclusive Cloud aggregate, verify, and analyze carbon reduction data across systems.

China's diversified model also overcomes limitations seen in simpler mechanisms. Government led systems often lack private sector innovation, while firm led models may be fragmented and commercially constrained. The diversified approach addresses these issues through 1) interoperability – shared Monitoring, Reporting, Verification (MRV) standards allow cross platform credit transfer and aggregation; 2) stakeholder breadth – government legitimacy attracts public trust, while market actors contribute agility and user experience innovation; and 3) scalability – integration with digital finance tools and e commerce ecosystems broadens participation without proportional increases in administrative costs.

In short, this model demonstrates that multi stakeholder governance is critical for scaling voluntary low carbon actions into measurable climate outcomes. The lessons drawn here are applicable beyond China, offering a replicable template for jurisdictions with sufficient digital infrastructure and political coordination capacity.

3.2 Advancing carbon accounting: the emergence of Scope 4

Contemporary greenhouse gas accounting frameworks, which traditionally encompass Scope 1 (direct emissions from owned sources), Scope 2 (indirect emissions from purchased energy), and Scope 3 (all other indirect emissions in an organization's value chain), have demonstrated significant limitations in their ability to capture and quantify the nuanced impacts of behavioral interventions that are increasingly facilitated by carbon inclusion initiatives [11]. These conventional frameworks, while effective for measuring organizational carbon footprints, lack the sophisticated mechanisms necessary to account for emissions reductions achieved through individual behavioral changes and digital platform-enabled sustainability practices. In response to these limitations, innovative carbon inclusive platforms have begun pioneering a new frontier in emissions accounting through Scope 4 (alternatively termed Scope 3+) methodologies. These cutting-edge accounting systems are specifically designed to develop and implement sophisticated measurement and verification protocols for tracking emissions reductions that result from behavioral modifications and digital interventions across increasingly complex supply chains and consumption cycles [15, 16].

Groundbreaking pilot initiatives, particularly those integrated with the Green Inclusive Cloud platform, are revolutionizing the way we track and measure environmental impact. These innovative projects demonstrate the remarkable potential of comprehensive digital carbon accounting systems to transform individual actions into measurable climate benefits. Through sophisticated data collection and verification mechanisms, these systems can accurately quantify and validate emissions reductions that result from various lifestyle modifications - from transportation choices to energy consumption patterns. The success of these pilot programs in creating reliable, verifiable measurements of behavioral change has established valuable precedents that are helping shape the development of future global carbon management frameworks. By proving that individual actions can be effectively measured and validated at scale, these initiatives are paving the way for more inclusive and comprehensive approaches to global climate action [17].

3.3 Carbon finance and market integration

China's carbon market currently consists of two pillars: China National Emissions Trading System (ETS) and China Certified Emission Reduction (CCER) market [18]. Both focus on large-scale production-side reductions but neglect consumption-side emissions [19, 20]. An independent carbon inclusion market would address this gap by creating a comprehensive system covering both production and consumption.

From the perspective of applicable entities, the independent carbon inclusion market complements existing reduction mechanisms. The national carbon market targets large enterprises with annual emissions exceeding 26,000 tons of CO_2 equivalent, while the CCER market focuses on entities capable of investing in large projects, both excluding SMEs and the general public [21]. The carbon inclusion market, centered on individuals, households, communities, and SMEs, can effectively activate the enormous emission reduction potential on the consumption side.

Economically, the carbon inclusion market uniquely links low-carbon behavior with consumption incentives and financial services. It connects personal carbon accounts with green credit and preferential rates, creating a "reduction-points-benefits" value chain that boosts participation and generates economic multiplier effects. Governance-wise, it establishes a "multi-stakeholder" model where government sets rules, enterprises provide resources, and the public contributes through daily behaviors, fostering innovation through collaborative participation.

The market addresses insufficient public motivation through diverse incentives combining economic value, social recognition, and service preferences. Examples include Luzhou's "Green Sprout Points," where goods exchange appeals to housewives, priority services attract seniors, and recognition motivates youth. The People's Bank of China's carbon accounts offer loan interest benefits to relevant groups.

Operating independently, the carbon inclusion market cultivates public carbon asset awareness. As individual reductions gain value through circulation and trading, people recognize the economic worth of environmental externalities [22]. This shift extends beyond immediate "digital red packets" to deeper behavioral changes through "carbon account scarcity." Future financial integration will make carbon assets persistent drivers of green living.

The market provides an institutionalized channel for public environmental governance participation. By recording and rewarding individual contributions, it creates an "environmental democracy" mechanism with a "behavior-signals-policy" feedback loop that promotes bottom-up governance innovation and spontaneous participation.

Through government-led platforms using privacy computing technology, the carbon inclusion market breaks data silos by connecting multiple sources for unified collection and value integration. This creates a streamlined experience that reduces participation complexity. Long-term, it will influence production by shaping consumption habits, as consumer choices drive enterprise adjustments in a "demand-pull" transformation that complements traditional environmental policies.

Carbon-inclusive transactions convert consumer actions into tradable assets, unlike conventional systems focused on industrial emitters. Early examples include Taiping Insurance's 2009 offset of 8,026 tons CO_2 through Beijing transport credits. The 2021 "Tianfu Carbon Benefit" initiative represents integration with corporate ESG goals. While nascent, market value is growing, as shown by Wangfujing's "Green Living Plan" and Xinwang Bank's carbon neutrality achievements.

Incentive design evolves in three stages: 1) initial stage—governments issue consumption coupons and service discounts for green behavior during pilots; 2) intermediate stage—platforms partner with businesses for expanded rewards across goods, utilities, and insurance; and 3) advanced stage—carbon credits integrate into "carbon wallets" for monetary exchange, tax benefits, or credit collateralization. Linking with China's digital RMB enables seamless carbon finance, transforming inclusion from behavior tracking to comprehensive green finance.

Integration with national and international markets is critical for carbon inclusion advancement. China's ETS currently covers only the power sector but plans industry expansion [23, 24]. Including consumer credits would diversify and increase market liquidity.

This requires 1) harmonizing inclusion standards with national MRV systems, 2) legal recognition of individual credits as financial assets, and 3) certification protocols accepted by international markets. "Bridge standards" would enable global trading of Chinese behavioral credits, financialize green behavior and strengthen

international cooperation. As digital platforms improve, including individual behaviors in national accounting becomes both feasible and necessary [25]. Carbon inclusion's future connects micro-actions with macroeconomic structures through robust market design.

3.4 Governance and policy challenges

Despite its promise, carbon inclusion faces several systemic challenges. First, the absence of a unified legal framework recognizing individual carbon credits as formal assets creates inconsistencies in implementation and reduces investor confidence. Current practices rely on voluntary compliance, industry self regulation, or fragmented provincial guidelines, a structure that limits market maturity and standardization [26].

Second, fiscal incentives and enforceable mandates remain insufficient to attract sustained participation from key stakeholders such as financial institutions, utilities, and transportation providers. While some cities have experimented with carbon linked tax reductions or green subsidies, these remain exceptions rather than the rule [27]. Efforts are underway to link carbon wallets with China's digital RMB (e CNY), laying the groundwork for seamless integration of behavioral credits into digital payment ecosystems. Studies on factors influencing individuals' adoption of digital currency electronic payment in China highlight that perceived usefulness, trust, and government endorsement strongly influence adoption rates [28]. While such integration could expand carbon finance opportunities, it also introduces regulatory, interoperability, and cybersecurity challenges that require careful oversight.

Third, regional disparities in digital infrastructure and administrative capacity affect the ability to run effective carbon inclusion platforms. Coastal megacities benefit from advanced digital ecosystems, while rural and interior provinces may lack the necessary systems, personnel, or internet penetration for real time carbon accounting.

Fourth, risks related to data privacy, digital inclusion, and market over financialization are emerging:

1) Data privacy: Behavioral carbon tracking requires granular personal data on consumption and mobility, raising concerns over surveillance, data misuse, and insufficient anonymization safeguards.
2) Digital inclusion: Populations with limited internet access or digital literacy risk exclusion from participation, exacerbating social inequities in climate action.
3) Over financialization: If carbon credits become overly speculative assets, market volatility could undermine their credibility as climate policy instruments.

3.5 Global transferability perspective

While China's ICBM operates within a unique governance and digital infrastructure context, the underlying framework, standardized MRV, incentive diversification, and multi stakeholder collaboration, is adaptable to other national settings. High income economies can integrate the model into existing digital payment and carbon trading systems, while developing countries can begin with smaller scale pilots tied to donor funded green infrastructure projects. By embedding legal recognition, interoperability, and social equity into the foundation of carbon inclusion, policymakers can create a scalable, globally relevant tool for mobilizing consumer end climate action.

Comparable initiatives exist in other regions:

1) EU PCAs propose allocating citizens a carbon budget, with over spending requiring offset purchases [29, 30]. While conceptually aligned, PCAs remain largely at the policy proposal stage and lack the market integrated digital infrastructure already present in China's ICBM.
2) South Korea's Carbon Point Program (CPP) rewards verified reductions in household resource use [31, 32]. However, its scope is narrower, primarily household utilities, and lacks China's broader integration with SMEs, e commerce platforms, and emerging green finance tools.
3) Japan's Green Life Point Program incentivizes eco friendly purchases with redeemable points [33, 34], yet its MRV systems remain less standardized compared to China's national guidelines.
4) To address waste management issues in developing cities, a mobile app-based rewards system to boost recycling efforts in Kampala, Uganda, which indicated that tailored incentives could lead to higher engagement [35]. Thus, China's approach offers the most fully operational national example of a multisector, digitally integrated behavioral carbon mechanism to date.

By embedding MRV standardization, diversified incentives, and multi stakeholder collaboration into a national system, China's ICBM provides a replicable framework adaptable to varied governance and technological contexts [36]. For countries with advanced digital ecosystems, adoption could be rapid, leveraging existing e payment platforms and carbon markets. For developing economies, gradual implementation through localized pilots tied to green infrastructure investment can lay the groundwork for scaling. Ultimately, the integration of behavioral carbon credits into both domestic and international carbon markets represents an under utilized but potentially transformative pathway toward achieving global net zero goals.

3.6 Strategic recommendations for scaling carbon inclusion

To realize the full potential of China's ICBM and address the governance challenges outlined above, five strategic actions are proposed. These recommendations are structured to be actionable in China while also offering a transferable blueprint for other jurisdictions.

1) Legislative support and legal recognition: (i) Enact national legislation formally recognizing individual and SME carbon inclusive credits as legally, tradable assets. (ii) Define their status within existing environmental and financial regulations to reduce legal uncertainty, attract investment, and facilitate integration with carbon markets. (iii) The EU's proposed PCA framework similarly seeks legislative recognition to underpin enforceability.
2) Standardization and international alignment: (i) Accelerate refinement of carbon accounting standards, particularly for behavioral and Scope 4 emissions. (ii) Develop bridge standards that align with international certification systems (e.g., VCS, Gold Standard) to enable Chinese behavioral credits to participate in global voluntary carbon markets. (iii) Collaborate with emerging digital MRV protocols for interoperability across national and cross border platforms.
3) Strengthened public–private partnerships (PPPs): (i) Foster co development between government agencies, fintech firms, e commerce platforms, utilities, and NGOs to expand low carbon activity scenarios. (ii) Ensure data governance frameworks are embedded in PPP agreements, addressing privacy and security concerns from the outset. (iii) Draw from South Korea's Carbon Point Program experience in leveraging utility companies as trusted data partners.
4) Equity, inclusion, and digital access: (i) Target under represented groups through subsidized device access, community based reporting mechanisms, and simplified participation options for non smartphone users. (ii) Partner with rural cooperatives, local NGOs, and schools to increase awareness and facilitate enrollment. (iii)

Incorporate inclusive design principles into platform development to ensure accessibility across demographics.

5) Financial sector readiness and carbon wallet integration: (i) Develop financial literacy programs for individuals and SMEs to manage carbon assets effectively. (ii) Pilot carbon wallet–e CNY integration in select regions, with robust cybersecurity and anti fraud safeguards in place before scaling. (iii) Avoid speculative market behavior by linking credit value to verified emission reductions rather than purely market demand.

3.7 Limitations and future research directions

While this study offers a comprehensive multi case analysis, several limitations should be acknowledged: 1) data access, in which many platform operators consider detailed participation and transaction data proprietary, limiting independent verification of some outcomes; 2) case scope, whereby the 39 cases were chosen for operational maturity and representativeness, but newer experimental pilots may reveal additional governance innovations; and 3) comparative depth wherein I=international comparisons draw on secondary literature rather than primary field research, which could be expanded in future studies.

Building on these findings, future research should 1) conduct cross country empirical testing of Scope 4 accounting methodologies to assess consistency and comparability across digital behavioral carbon schemes; 2) explore longitudinal impacts of carbon inclusion on lifestyle changes, credit market development, and policy uptake; 3) investigate equity impacts to ensure that digital and financial integration does not inadvertently exclude vulnerable populations; and 4) model macroeconomic effects of large scale behavioral credit trading, including potential influences on industrial production patterns and green investment flows.

4. Conclusion

This study set out to answer the research question: How can China's ICBM, as a digitally enabled policy innovation, effectively mobilize consumer end behavioral change to contribute to national and global climate goals, and how does it compare to similar mechanisms internationally?

The findings demonstrate that China's ICBM successfully operationalizes consumer end emission reduction at scale by integrating standardized carbon accounting (including emerging Scope 4 methodologies), diversified incentive systems, and robust multi stakeholder collaboration. The analysis of 39 representative cases revealed that government led diversified models with private sector participation achieve the highest effectiveness in mobilizing sustained low carbon behaviors into comprehensive national emission reduction strategies [37].

Compared with international counterparts, such as the EU's proposed Personal Carbon Allowances, South Korea's Carbon Point Program, Japan's Green Life Point Program, and Uganda's mobile recycling rewards system, China's mechanism stands out for its nationwide operational maturity, cross sector integration, and linkage to emerging green finance instruments. This positions it as the most advanced real world example of a digitally integrated behavioral carbon mechanism to date.

The implications extend beyond China. Embedding behavioral carbon credits into national and international climate governance frameworks could unlock a currently under utilized source of emission reductions. As countries seek pathways to meet net zero targets, the integration of digitally verified, market linked consumer actions offer a scalable complement to industrial decarbonization strategies.

In conclusion, China's ICBM illustrates that climate governance need not be limited to top down industrial regulation. When paired with digital innovation, robust standards, and inclusive incentives, citizen driven climate action can become a measurable, tradable, and impactful component of the green and low carbon economy both domestically and worldwide.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors note that the Green Inclusive Platform is both an object of analysis in this study and the institutional affiliation of the first author and some co-authors. This relationship is disclosed for transparency. The study does not receive any direct financial support from the platform for the preparation of this manuscript. All analyses are conducted independently for academic research purposes.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Author Contribution Statement

Li Zhang: Conceptualization, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition. **Dongjie Sun:** Methodology, Software, Resources, Data curation, Funding acquisition. **Lan Tao:** Conceptualization, Writing – review & editing, Supervision, Funding acquisition. **Jingzhe Ren:** Methodology, Investigation, Project administration. **Xue Yu**: Validation, Formal analysis, Investigation, Writing – original draft, Visualization. **Yizheng Zhang:** Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Visualization. **Fangyi Yang:** Validation, Investigation, Writing – original draft. **Hongying Zeng:** Conceptualization.

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Appendix

Table A1
China's carbon inclusive standards

Issuing unit of standard	Standard name	Issued time
China Association for Standardization	Technical specifications for assessing greenhouse gas emission reductions for alternative travel in new energy vehicles	22 October 2021
China Society of Automotive Engineers	Carbon emission reduction accounting method for electric vehicle travel	11 November 2021
China Certification and Accreditation Association	Technical specifications for assessment of greenhouse gas emission reductions for private passenger carpooling projects	21 December 2021
All-China Environment Federation	Guidelines for quantifying greenhouse gas emission reductions of citizens' green and low carbon behaviour	29 April 2022
China Society of Technology Economics	Technical specifications for project-based greenhouse gas emission reduction assessment - Second-hand trading platform	20 June 2022
China Energy and Environmental Service Industry Alliance	Technical specifications for carbon emission reduction evaluation of digital refueling methods of fuel vehicles	18 September 2022
All-China Environment Federation & Green Inclusive Science and Technology	Guidelines for quantifying greenhouse gas emission reductions of citizens' green and low carbon behaviour - Travel behaviour: electric charging spot Living Behaviour: Smart Waste Sorting	14 November 2024

Table A2
List of cases of government-led single-governmental-platform carbon inclusive mechanism

Region	Leading entity	Platform/App name	Start-up time	Development entities	Co-operating enterprise(s)	Scenarios of low carbon behavior	Emission reduction standards	User engagement	Incentive mechanism
Beijing City	Beijing Municipal Commission of Transport/Beijing Municipal Bureau of Ecology and Environment	Beijing MaaS Platform	September 8, 2020	Gaode Map/Baidu Map	Gaode/Baidu	When traveling by bus, subway, bicycle, walking and other green travel methods, citizens can use the app for route planning and navigation, and get the corresponding carbon energy at the end of the trip	Methodology for low carbon travel and carbon emission reduction in Beijing (Trial)	By September 2022, over one million users had participated in green travel	"Government + a few enterprises" consumption mechanism
Gansu Province	Department of Ecology and Environment of Gansu Province	Silutanhui	April 17, 2021	Lanzhou Environment Energy Exchange	NA	Green lifestyle (walking, Q&A, low-carbon shoot, sign-in, etc.)	Carbon footprint measurement developed by the Carbon Finance and Green Development Laboratory of Gansu Finance Society	NA	"Government + a few enterprises" consumption mechanism
Chongqing City	Chongqing Ecological Environment Bureau	Tanhuitong	October 22, 2021	Chongqing Credit Co., Ltd	Drip electric network car travel, Hello Bike travel, Chongqing Department Store, Yonghui Superstores, Yukuaiban	Walking, taking public transportation, participating in clothing collection, garbage sorting, online bill payment, etc.	Public announcement lists of Chongqing "Tanhuitong" Methodology	NA	"Government + a few enterprises" consumption mechanism
Shenzhen	Shenzhen Ecological Environment Bureau	Blue Planet	December 17, 2021	Shenzhen Tencent Computer System Co., Ltd.	Tencent	Taking public transportation via Tencent's Ride Code	Carbon Inclusion Methodology of Shenzhen's Low Carbon Public Travel system (Trial)	By August 2022, the number of users had exceeded 0.8 million	"Government + a few enterprises" consumption mechanism
Zhejiang Province	Zhejiang Provincial Development and Reform Commission	Zhejiang Tanpuhui	March 29, 2022	Zhejiang Provincial Energy Group Company Ltd.	Alipay Ant Forest, Tiger Recycling, Cainiao Guoguo	The scenario system in Ant Forest	Ant Forest low carbon scenario algorithms	By October 18, 2022, the number of users had exceeded one million	"Government + a few enterprises" consumption mechanism

Table A2
(Continued)

Region	Leading entity	Platform/App name	Start-up time	Development entities	Co-operating enterprise(s)	Scenarios of low carbon behavior	Emission reduction standards	User engagement	Incentive mechanism
Jiangxi Province	Jiangxi Provincial Development and Reform Commission	Jiangxi Ditanshenghuo (Low Carbon Living)	April 27, 2022	Digital Jiangxi Technology Co., Ltd.	Alipay Ant Forest	The scenario system in Ant Forest	Ant Forest low carbon scenario algorithm	NA	"Government + a few enterprises" consumption mechanism
Tianjin	Tianjin Municipal Transportation Commission	Jintanxing	June 25, 2022	Tianjin Highway Society	Hangzhou Tongka Liancheng (https://www.allcitygo.com/index.html), Alipay Ant Forest	Walking, bus, subway and other green travel methods	Ant Forest low carbon scenario algorithm	NA	"Government + a few enterprises" consumption mechanism
Shenzhen	Shenzhen Ecological Environment Bureau	Carbon Inclusion for Low Carbon Power Consumption by Residents	June 29, 2022	Shenzhen Power Supply Bureau of China Southern Power Grid Technology	China Southern Power Grid Technology Co., Ltd.	The power bill payment platform records the emission reductions generated by residents' low-carbon power consumption	Carbon Inclusion Methodology for Low-Carbon Power Consumption of Shenzhen Residents (Trial)	NA	"Government + a few enterprises" consumption mechanism
Ningxia Hui Autonomous Region	Ningxia Hui Autonomous Region Development and Reform Commission	Ningxia Tanpuhui	September 22, 2022	Ningxia Huayan Qulian Technology Co, Ltd	Alipay Ant Forest, "My Ningxia" government affairs app	The scenario system in Ant Forest	Ant Forest low carbon scenario algorithm	The number of the participants has exceeded 10,000 so far	"Government + a few enterprises" consumption mechanism
Jiangxi Province	Jiangxi Provincial Government Offices Administration	Lvbao Tanhui	September 27, 2022	Jiangxi Provincial Government Offices Administration	Subway (Luluxing App), TELD, Meisenbao	Green procurement, energy-saving transformation, new energy utilization by public institutions and personal green work, green travel, green consumption, garbage sorting, "clean plate" action by individuals, and other green low-carbon behaviors	NA	NA	"Government + a few enterprises" consumption mechanism

Table A3
List of cases of enterprise-led single-corporate-platform carbon inclusion mechanism

Region	Leading enterprises and development entities	Platform/App name	Start-up time	Scenarios of low carbon behavior	Emission reduction standards	User engagement	Incentive mechanism
				Carbon inclusive platform of digital-platform enterprises			
Nationwide	Ant Group	Ant Forest	August 27, 2016	Low-carbon behaviors such as green travel, travel reduction, recycling, paper and plastic reduction, energy saving and conservation recorded by Ant Group	Algorithm support from China Beijing Green Exchange and other institutions	By August 2022, the number of participants in Ant Forest has exceeded 650 million	The enterprise bears the costs such as tree planting
Nationwide	Jingdong Logistic	Green Logistics Project	June 5, 2017	Green Shipping	On June 5, 2022, Jingdong Logistic officially released original packaging standards and certification processes	Over 300,000 enterprises and hundreds of millions of consumers have participated	Redeeming physical gifts and gift certificate rewards
Nationwide	NIO	Blue Point Project	January 10, 2020	Driving a NIO car; replacing batteries	CMS 048 V01 Emission Reduction through Electric and Hybrid Vehicles, CMS-048-V01 Methodology of Emission Reduction through Electric and Hybrid Vehicles	A total of over 120,000 users participated	The points received can be used in the NIO Mall
Nationwide	Kuaidian	Carbon Accounts for Car Owners	August 10, 2021	Charging new energy vehicle batteries	CM-0998-V01 Greenhouse Gas Emission Reduction Methodology of Electric Vehicle Charging Stations and Charging Piles	The first to develop user carbon accounts in the battery charging industry, with over 280,000 users participating in the carbon reward point initiative	Accumulated carbon reduction directly offsets charging fees and can be redeemed for charging service vouchers with multiple platforms
Nationwide	Hello Bike	Little Blue c Carbon Account	August 25, 2021	Riding shared bikes	Developed national carbon emission reduction algorithms for shared bikes/ shared motorcycles in collaboration with Guangzhou Emissions Exchange (CEEX) and Guangzhou CEPREI Certification Body Services Co., Ltd.	Hello Bike users have ridden a total of 32.3 billion kilometers	Getting accomplishments in Public Service public welfare achievements (planting coral) or redeeming travel benefits

Table A3
(Continued)

Region	Leading enterprises and development entities	Platform/App name	Start-up time	Scenarios of low carbon behavior	Emission reduction standards	User engagement	Incentive mechanism
Nationwide	Meituan	Digital RMB Low Carbon Card	September 9, 2021	Cycling; avoiding disposable tableware; avoiding plastic bags, etc.	Report on Bike-sharing Contribution to Pollution" jointly released by the Environmental Development Center of the Ministry of Ecology and Environment, and the China Environmental United Certification Center Co., Ltd.	Over 10 million users signed up to participate, of which three million users downloaded and set up personal digital RMB accounts during the campaign	Digital RMB cash-back
Nationwide	S.F.	Green Carbon Energy	Late November 2021	Use of circular packaging, use of same-city rush delivery, use of electronic receipt, use of photo of receipt	N/A	N/A	Carbon energy can be redeemed for membership points, which can be used to offset shipping costs and redeem gifts at the mall
Nationwide	Air China	Low carbon flight trip	Late January 2022	Self-service check-in, receiving electronic invoices, constantly bringing one's own water cup; participating in public welfare, etc.	ICAO Carbon Emissions Calculator Methodology	No relevant data	Offsetting flight carbon emissions
Nationwide	Ele.me	e-Point Carbon	April 20, 2022	Choosing not to use disposable dishware, and order small meals on Ele.me platform	Group Standards for Guidelines for Quantification of Carbon Emission Reduction through Food Waste Reduction in Catering Industry	By the end of August, the number of "e-point Carbon" users has exceeded 25 million	Accessed to 88 Carbon account, where green points can be redeemed for coupons
Nationwide	Jingdong Retail	Green Project	May 31, 2022	Buy "green" labeled goods	N/A	Sold over 42 million pieces of green and low-carbon goods under the Green Project	Discounts on "green" labeled items; green points can be redeemed for rare badges, low-carbon goodies, and large coupons

Table A3
(Continued)

Region	Leading enterprises and development entities	Platform/App name	Start-up time	Scenarios of low carbon behavior	Emission reduction standards	User engagement	Incentive mechanism
Nationwide	Full Truck Alliance	Carbon Road Project	June 5, 2022	Reducing the "three empty" (empty driving, vacancy, empty load) and other acts of using platform functions	Technical Specification for Assessment of Greenhouse Gas Emission Reduction of Intelligent Matching System for Road Freight	N/A	Drivers can receive subsidies or redeem benefits
Nationwide	GAC	Owner's carbon ledger	July 1, 2022	Driving specific Toyota models	Technical Specification for the Assessment of Greenhouse Gas Emission Reductions through Alternative Travel by New Energy Vehicles	Over three months, the cumulative number of emission reduction participants has exceeded 50,000 and the number of emission reductions has exceeded 2.4 million	Receiving specific prizes by ranking
Nationwide	Alibaba	88 Carbon Accounts	August 8, 2022	Scenarios of food, clothing, housing and transportation recorded by Ele.me, Cainiao Network Technology, Xianyu, Tmall, and other Alibaba Group companies	N/A	N/A	Green Points can be used to get discounts when purchasing specific products on Taobao
Nationwide	Caocao Mobility	Carbon Benefit Mileages	October 13, 2022	Getting points for taxi rides	N/A	N/A	Rewards provided by the company itself, priority dispatch, discount coupons, etc.
Carbon Inclusion Platform for Financial Enterprises							
Quzhou	Quzhou Rural Commercial Bank	Personal Carbon Account	Mid-August 2021	Green payment, green travel, green life, etc.	Guidelines for Accounting and Evaluation of Carbon Emissions from Industrial Enterprises' Carbon Accounts; Provincial group standards for Management of Bank Personal Carbon Accounts	More than 2.33 million carbon accounts have been established in six major areas, including 2,392 industrial enterprises, 97 energy enterprises, 55 enterprises in the transportation sector, 109 construction entities; the rest are residents' accounts	Credit "green list" system

Table A3
(Continued)

Region	Leading enterprises and development entities	Platform/App name	Start-up time	Scenarios of low carbon behavior	Emission reduction standards	User engagement	Incentive mechanism
Rizhao City	Rizhao Bank	Personal Carbon Account	January 2022	Green Living, Green Payments, Green Credit, and Green Government	N/A	By March 10, over 30,000 citizens have participated in the campaign, and the platform has issued nearly 118 million personal carbon points	Redeeming reward points for gifts
Nationwide	China CITIC Bank	Personal Carbon Account	April 22, 2022	Applying for e-cards, e-bills; living bill payment, etc.	Support from Shanghai Environment Energy Exchange	By the end of August, the number of registered users of "CITIC Carbon Account" has reached 400,000	Basic fee wavering, fast-track approval, green financial information, green financial advisory
Over 50 cities	China Construction Bank	Personal carbon ledger	May 6, 2022	Public transportation travel, food and beverage delivery, online government affairs processing, etc.	Algorithm support from China Beijing Green Exchange and other institutions	N/A	Credit card limit upgrades, installment benefits, bank card payment discounts, benefits redemption at reward point mall
Nationwide	Ping An Bank	Low carbon homeland	May 10, 2022	Low carbon travel; digital finance; online business processing	Support from Shanghai Environment Energy Exchange	N/A	Redeeming benefits; planting trees
Hunan Province	Hunan Branch of Postal Savings Bank of China	C Post	June 24, 2022	Green finance, green life, green countryside, green public welfare	N/A	N/A	Making donations; participating in charity programs
Shanghai	Shanghai Pudong Development Bank	Personal Carbon Account	July 20, 2022	B-end: green credit, green bonds, etc. C-end: green travel; installment of new energy vehicles payment, paperless business processing, green scenario consumption	Support from Shanghai Environment Energy Exchange	N/A	Base fee waiver; spending cashback; benefit redemption

Table A3
(Continued)

Region	Leading enterprises and development entities	Platform/App name	Start-up time	Scenarios of low carbon behavior	Emission reduction standards	User engagement	Incentive mechanism
Wuhan	Hankou Bank	Personal Carbon Account	August 25, 2022	Walking, bus and subway, living bill payment, etc.	N/A	N/A	Carbon reduction incentives, public welfare donations, financial services
Qingdao	Qingdao Rural Commercial Bank	Tanhuitong	October 9, 2022	Power bill payment; prepaying cell phone bills; green credit	N/A	N/A	Redeeming coupons and other benefits
Carbon Inclusion Platform for Corporate Employees							
Nationwide	State Power Investment Corporation (SPIC)	Low carbon e-point	August 25, 2021	Green travel, household photovoltaic, "clean plate" action, voluntary suspension of motor vehicles, etc.	Algorithm support from China Beijing Green Exchange and other institutions	The 140,000 SPIC employees are expected to reduce carbon emissions by 2.32 million tons annually by 2035.	Redemption in e-buying mall; Certificate of Yingshanhong public welfare activities; Emission reduction in forestry carbon sink projects
Nationwide	Lenovo	Letanquan	June 14, 2022	Low-carbon travel, low-carbon commuting, online meetings, second-hand clothing, book donations, etc.	Based on self-developed carbon accounting platform	N/A	Redeeming benefits; low-carbon public welfare

Table A4
List of cases of government-led multi-stakeholders- platform carbon inclusion mechanisms

Region	Leading entity	Platform/App name	Start-up time	Development entities	Co-operating enterprise(s)	Scenarios of low carbon behavior	Emission reduction standards	User engagement	Incentive mechanism	Data source
2022 Beijing Winter Olympic Games	Organizing Committee of 2022 Beijing Winter Olympic	Low Carbon Winter Olympics	July 2, 2020	China Hubei Emission Exchange Co., Ltd.	Meituan, Baidu, "Clear Plate", Trailer Home, Coca-Cola, Dibao Technology, Vortexinfo	Based on many scenarios, enterprises walking, cycling, motor vehicle suspension, "Clean Plate" action, garbage sorting, ETC, public transport travel and other seven categories of a variety of green low-carbon behaviors	"Directives for Group Standards for Quantifying Green House Gas Emission Reduction of Citizens' Green and Low-Carbon Behavior", and "Guidelines for Quantifying Greenhouse Gas Emission Reductions of Citizens' Green and Low Carbon Behavior" group standards and related algorithms	During the campaign, over 2.7 million people participated, with a cumulative carbon reduction of nearly 30,000 tons	"Government + Diverse enterprises" consumption mechanism	https://baike.baidu.com/item/低碳冬奥/51006056
Luzhou City, Sichuan Province	Luzhou Ecological Environment Bureau	Green Shoots Points	December 7, 2020	Beijing Green Inclusive Network Technology Co., Ltd.	Luzhou Bank, Luzhou Bus and Subway, "Clear Plate"	Green emission reduction scenarios based on green city, green government, green travel, green consumption, and green catering in multiple dimensions	"Directives for Group Standards for Quantifying Green House Gas Emission Reduction of Citizens' Green and Low-Carbon Behavior" and Related Algorithms	By March 2022, the number of downloads of Green Shoots Points has approached 70,000	"Government + Diverse enterprises" consumption mechanism	https://baike.baidu.com/item/绿芽积分/62690579

Table A4
(Continued)

Region	Leading entity	Platform/App name	Start-up time	Development entities	Co-operating enterprise(s)	Scenarios of low carbon behavior	Emission reduction standards	User engagement	Incentive mechanism	Data source
Beijing City	Beijing Municipal Commission of Development and Reform	Green Life Season	August 10, 2022	Beijing Energy Conservation And Environmental Protection Center	Meituan, Ali Local Life, Ele.me, JD, Kuaidian, Gome, Dazhong, Bank of Communications, Bank of Beijing, China Coffee Association Beijing, City Railway Construction, Metro, Dadi Cinema, Din Tai Fung, Ren Xiaomi, Tootoo Gongshe, Grand Pacific, XinMeat, Toread, Loulan Meview, etc.	A variety of green and low-carbon behaviors practiced on major Internet platforms in seven categories: clothing, food, housing, transportation, use, work, digital finance, etc.	Guidelines for the Group Standards of the Quantification of Carbon Emission Reduction via Citizens' Green Behaviors, related algorithms, Methodology of Low Carbon Travel in Beijing, etc.	By October 21, carbon ledgers have been established for over 12 million people, leading to emission reductions of around 40,000 tons	"Government + Diverse enterprises" consumption mechanism	https://baijiahao.baidu.com/s?id=18430540552334319444&wfr=spider&for=pc
Shanxi Province	Department of Ecology and Environment of Shanxi Province	Sanjin Green Life	September 18, 2022	Shanxi Environmental Energy Trading Center, Beijing Green Inclusive Network Technology Co., Ltd., Shanxi Low Carbon Environmental Protection Industry Group, and Shanxi Xiangrui Energy Co., Ltd.	Meituan, Qingju, GAC Toyota, Kuaidian, Ele.me, "Clear Plate", Love Sorting and Love Recycling, Pick Up and Recycle (Shishang huishou), Pocket Garbage Sorting, Didi Chuxing, Ivxing Dibao, Guodian Shanxi	A variety of green and low-carbon behaviors in the six major areas of clothing, food, housing, transportation, travel, and use practiced on major Internet platforms	"Directives for Group Standards for Quantifying Green House Gas Emission Reduction of Citizens' Green and Low-Carbon Behavior" and "Guidelines for Quantifying Greenhouse Gas Emission Reductions of Citizens' Green and Low Carbon Behavior" group standards and related algorithms	By October 21, the cumulative number of platform participants has exceeded 1,064,000 and the cumulative number of emission reductions has exceeded 16,353,000	"Government + Diverse enterprises" consumption mechanism	https://baike.baidu.com/reference/19788580/533aYdO6cr3_z3kATPGlz6rzZCaVMd_6ubTXBORzzqIP0XOpX5nyFJs64dkn97lgGx2Fs5YtecERgq-e5QgIC8fUQc-81S6pmn3b9UT-PLy7-J-Ngyk9RDqpQAAOlK2w