

A Study on the Impact of Green Trade Barriers on China's Manufacturing Exports and Response Strategies in the Context of Carbon Peaking and Carbon Neutrality

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Abstract: As global trade governance increasingly incorporates environmental standards, mechanisms such as the EU Carbon Border Adjustment Mechanism (CBAM) create growing compliance pressures and cost burdens for China's manufacturing sector. This study examines the transmission mechanisms through which green trade barriers (GTBs) affect firm-level innovation and competitiveness. The analysis identifies several structural constraints that may limit the effectiveness of innovation-based adaptation: an energy system constraint associated with the high carbon intensity of the national power grid; a resource-allocation dilemma in which short-term compliance costs may reduce long-term R&D investment; disparities in carbon accounting and digital capabilities; and a strategic tendency toward product-level compliance rather than deeper process-oriented decarbonization. In response to these constraints, this study proposes an implementation framework structured around an Actor–Tool–Timeline matrix. Policy recommendations include promoting green power trading through reforms in energy-use allocation, expanding transition finance to ease adjustment pressures on SMEs, and developing public digital platforms for carbon verification. Furthermore, the study argues that sustained long-term competitiveness depends on stronger indigenous innovation capacity and greater participation in international rule-making, while drawing on the principle of common but differentiated responsibilities (CBDR) to respond to emerging forms of environmentally driven trade restriction.

Keywords: Green trade barriers (GTB); EU CBAM; Porter hypothesis; Low-carbon transition; Indigenous innovation capacity; Green finance; Common but differentiated responsibilities (CBDR)

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1. Introduction

The global economic architecture is going through a weighty structural transformation driven by the imperative of climate mitigation. In response to this, developed economies, most conspicuously the European Union (EU), are endorsing progressively more stringent climate policies. A most significant feature of this shift is the propagation

of green trade barriers (GTBs), which the EU’s Carbon Border Adjustment Mechanism (CBAM) exemplifies. Designed to mitigate “carbon leakage” by internalizing the environmental costs of imports, these measures, while bolstering global climate ambitions, impose asymmetric detriments on developing economies ^[1,2]. Nations like China, where manufacturing are commonly of high carbon intensity, face particular vulnerability (**Table 1**).

Table 1. Main events in the legislative process of CBAM

Date	Main events
Dec 2019	European Green Deal announced, first proposing CBAM
Jul 2021	Formal legislative proposal published by the European Commission
Jun 2022	European Parliament adopts its more ambitious position
Dec 2022	Provisional political agreement reached between EU institutions
May 2023	CBAM Regulation signed into law
Oct 2023	Transitional period begins (reporting only)
1 Jan 2026	Definitive system starts (financial obligations begin)

Source: Legislative Train Schedule, European Parliament

As a preeminent exporter and carbon emitter, China stands at the center of this evolving storm. Concomitantly, the nation is pursuing ambitious domestic decarbonization via its “dual carbon” targets, achieving a carbon peak by 2030 and neutrality by 2060 ^[3,4]. This convergence of external trade barriers and internal regulatory mandates creates a “dual pressure” on China’s manufacturers. Paradoxically, the carbon footprint of Chinese exports, including renewable energy infrastructure such as wind turbines, photovoltaic panels, and lithium batteries, often exceeds that of the developed counterparts, which renders these strategic industries substantially prone to carbon tariffs (**Table 2**) ^[5].

Table 2. CO₂ emissions (Mt CO₂)

Region	2022	2023	2024
World	36 819	37 270	37 566
United States	4 717	4 567	4 546
European Union	2 683	2 455	2 401
China	12 013	12 552	12 603

Source: International Energy Agency, Global Energy Review 2025 Dataset

Navigating this conundrum requires green technological innovation (GTI), widely recognized as the primary mechanism for reconciling economic competitiveness with environmental sustainability ^[6,7]. While GTI offers a path to cleaner production and international compliance, substantial barriers hinder this transition ^[8]. Firms confront noteworthy constraints while financing, as eco-innovation features prodigious capital investment, extended payback periods, and technical unpredictability ^[9,10]. These challenges are further exacerbated by climate policy uncertainty (CPU), which complicates the regulatory environment and may negatively stimulate short-term “pollution migration” over genuine structural reform ^[3,11].

Furthermore, firm-level heterogeneity plays a critical role in adoption; robust financial health and access

to internal capital are prerequisites for green investment ^[12]. Evidence from other emerging markets supports this, identifying financial constraints and institutional voids as primary impediments to green innovation ^[13]. Consequently, a holistic understanding of the interplay between external trade friction, domestic policy uncertainty, and firm-level capabilities is essential.

Against this backdrop, this study innovates by developing an integrated analytical framework that simultaneously incorporates external green trade barriers, domestic climate policy uncertainty, and firm-level financial constraints to explain the heterogeneous green technological innovation responses of Chinese manufacturing firms under the “dual-carbon” agenda. Theoretically, it extends and connects strands of research on the Porter hypothesis, pollution-haven dynamics, and global value chains by reframing green trade barriers not merely as exogenous cost shocks, but as conditional drivers of green upgrading whose effects are mediated by institutional and financial factors. Practically, the research aims to provide actionable evidence for designing coordinated trade, industrial, carbon-market and green-finance policies that can alleviate firms’ financing bottlenecks, reduce their compliance risks under mechanisms such as CBAM, and transform mounting external and internal pressures into a sustained impetus for low-carbon transition and export competitiveness in China’s manufacturing sector.

2. Literature review

2.1. Carbon peaking and carbon neutrality

The “dual-carbon” targets, peaking carbon dioxide emissions before 2030 and achieving carbon neutrality before 2060, were formally articulated by President Xi Jinping at the 75th UN General Assembly in 2020. President Xi framed this commitment as a necessary “green revolution,” urging the international community to exceed the minimum requirements of the Paris Agreement and transition toward a sustainable “green recovery” in the wake of the COVID-19 pandemic ^[14]. In the five years following this announcement, China operationalized these pledges into a robust “1+N” policy framework, establishing specific carbon reduction plans across 31 provinces and all major industrial sectors to systematically decouple economic growth from carbon emissions ^[15].

By mid-2025, this strategic pivot resulted in measurable advancements in China’s energy structure and ecological capacity. Coal consumption fell to 53.2% of the energy mix, while renewable energy installed capacity surpassed 2.15 billion kilowatts, achieving national wind and solar targets six years ahead of schedule. Furthermore, China reduced energy intensity per unit of GDP by 11.6% between 2020 and 2024 and solidified its status as the global leader in forest carbon sinks. These domestic efforts also generated positive global spillover effects, driving down the costs of wind and photovoltaic power generation by over 60% and 80% respectively over the preceding decade ^[16].

2.2. Green trade barriers

Literature identifies “Green Trade Barriers” as trade measures implemented primarily by developed economies under the auspices of environmental protection. While intended to mitigate climate change, scholars frequently debate whether these measures serve as genuine environmental tools or as instruments of “environmentally driven trade restriction” designed to shield domestic markets ^[1,2,18]. Current research focuses predominantly on two mechanisms: the European Union’s Carbon Border Adjustment Mechanism (CBAM) and broader Green Technical Barriers to Trade (GTBT). CBAM represents a novel policy tool aimed at preventing “carbon leakage” and

preserving the competitiveness of EU industries by levying a carbon price on imports of carbon-intensive goods^[1,19]. Its initial scope targets high-emission sectors, including steel, aluminum, cement, fertilizer, electricity, and hydrogen, with potential for future expansion^[19,20]. Concurrently, GTBTs encompass a wider array of regulations, such as eco-labeling mandates, carbon footprint disclosures, and rigorous environmental product standards^[18].

2.3. Impacts of green trade barrier

2.3.1. Economic and trade impacts of green trade barriers

The consensus within recent studies is that these barriers impose significant economic pressure on the Chinese manufacturing sector. The immediate effect of mechanisms like CBAM is the erosion of price competitiveness. By internalizing the cost of embedded emissions, these barriers increase both production and export costs for Chinese manufacturers^[2]. Simulations using the GTAP-E model indicate that the implementation of CBAM could reduce China's export volumes and values, while worsening its terms of trade with key international partners^[2]. This vulnerability is unevenly distributed, showing a high concentration in energy-intensive industries. Sectors such as steel, aluminum, and chemicals are identified as the most exposed^[1,20]. For instance, Wang *et al.* (2025) project that under severe scenarios, the organic chemicals and plastics sector could face carbon tariffs equating to 22% of its export value to the EU. In aggregate terms, estimates suggest that while current proposals might result in USD 1.4 billion in tariffs (0.3% of 2021 exports), expanded scenarios could escalate costs to USD 33.7 billion, affecting nearly 7% of export value^[19].

2.3.2. Firm-level innovation and strategic responses

Beyond direct economic costs, green trade barriers act as a catalyst for industrial adaptation. Li (2025) posits that these external pressures significantly stimulate "green product innovation" among Chinese exporters, compelling firms to develop environmentally friendly products to maintain market access. However, the same study highlights a critical limitation: GTBTs do not appear to significantly drive "green process innovation", the upgrading of internal production technologies. This suggests that while firms are quick to adopt market-facing compliances, they may hesitate to undertake deeper, systemic operational changes. Furthermore, firm-level responses are heterogeneous. Innovation effects are most pronounced in State-Owned Enterprises (SOEs), which benefit from resource access and policy alignment, and in firms with high export dependence that face immediate market pressure. The primary mechanisms driving this innovation are identified as increased R&D investment and the alleviation of financing constraints for green projects^[18].

2.3.3. Financial, policy, and systemic challenges

A recurring theme is the indispensable role of financial constraints as a barrier to green innovation and adaptation. Studies on EU and Chinese firms alike identify financial resources as a major obstacle to adopting environmental innovations^[9,13]. Consequently, green finance (e.g., green credit) and government subsidies are highlighted as essential policy tools to overcome these barriers and guide corporate^[3,12,17]. Furthermore, the literature calls for strengthening China's domestic carbon market and aligning its carbon price with international levels to mitigate CBAM costs and provide clear long-term signals to industry^[1,2].

2.4. The Porter hypothesis

The Porter Hypothesis proposes a counterintuitive relationship between environmental regulation and industrial

competitiveness. It asserts that well-designed environmental regulations can stimulate innovation, which may partially or fully offset compliance costs and potentially enhance a firm's competitiveness ^[7]. This hypothesis challenges the traditional static view, which posits an inevitable trade-off between ecological goals and economic performance, arguing instead that in a dynamic competitive framework, regulatory pressure can overcome organizational inertia and information gaps, prompting firms to discover more resource-productive and profitable processes and products ^[7].

The theoretical foundation for this argument is provided by Ambec and Barla, who model how environmental regulation can reduce agency costs within a firm ^[21]. In their model, a regulator's commitment to limiting output for a polluting technology reduces the informational rent a manager can extract by misreporting a low-cost, clean technology as a high-cost, polluting one. This reduction in rent increases the firm's marginal benefit from investing in R&D to discover the cleaner, more productive technology. Consequently, under certain conditions, environmental regulation can simultaneously increase both R&D investment and the firm's expected profit, providing a formal rationale for the Porter Hypothesis ^[21].

2.5. Comprehensive review

The extant literature provides a foundational understanding of the tension between China's domestic decarbonization and the intensifying external pressure of green trade barriers. As evidenced above, scholarly consensus acknowledges that while the "dual-carbon" strategy has optimized China's energy structure, mechanisms like the EU CBAM and GTBTs pose an immediate threat to the price competitiveness of manufacturing exports, particularly energy-intensive sectors ^[2,16,19].

However, an examination of the literature reveals three gaps that this study aims to address as follows:

- (1) There is a divergence between the static, macro-level loss forecasts provided by CGE models and the need for dynamic, micro-level analysis of how heterogeneous firms, specifically SOEs versus private entities, navigate these barriers ^[2];
- (2) The distinction between "product" versus "process" innovation remains under-explored within the Porter Hypothesis framework; while Li suggests GTBs stimulate market-facing compliance, it remains unclear whether these pressures drive the deep, systemic process innovation required for long-term decarbonization or merely impose compliance costs that crowd out productive investment ^[18];
- (3) Existing research lacks a comprehensive framework that integrates financial constraints with essential enablers like digitalization and policy uncertainty ^[9,11]. Consequently, this study intends to bridge these gaps by applying the theoretical insights of Ambec and Barla to construct an integrated analytical framework, specifically exploring how financial capabilities and policy signals moderate the transmission of external trade shocks into substantive internal process innovations ^[21].

3. Analysis

3.1. Infrastructure constrains firm-level efforts

A primary structural constraint facing is imposed by the national energy grid. While individual firms may optimize internal energy efficiency, their aggregate carbon footprint remains heavily penalized by the external power supply. Data indicates a stark disparity: China's grid emission factor stands at 557 gCO₂/kWh, more than double the EU's average of 241 gCO₂/kWh ^[19]. Consequently, indirect (Scope 2) emissions account for approximately

11% of the total implicit carbon in China's exports to the EU ^[19]. This creates a systemic bottleneck where firm-level decarbonization efforts face diminishing returns. As Tang *et al.* argue, the high carbon intensity of the grid is a policy-level issue beyond the control of individual manufacturers ^[5]. Without aggressive macro-level energy transition strategies, even highly efficient factories remain vulnerable to carbon tariffs, effectively capping their competitiveness based on their geographic location rather than their operational excellence.

3.2. Compliance costs crowd out innovation

The analysis reveals a vital tension between the intent of GTBs (to spur innovation) and their financial impacts in reality. Theoretically, regulatory pressure should incentivize R&D; however, the immediate compliance costs, such as carbon tariffs which instantly erode export margins, risk crowding out the very capital required for green transition ^[12]. Pernet *et al.* emphasize that internal finance is central for funding risky, innovative green technologies ^[2]. When compliance costs deplete this liquidity, firms are compelled to divert their resources from long-term R&D to offset the short-term tariff payments. This paradox is also disproportionately distributed. Li finds that State-Owned Enterprises (SOEs) possess resource buffers and policy alignment that shield them from this shock ^[18]. In contrast, private firms and SMEs, which often face tighter financing requirements and rely seriously on internal cash flow, are overly squeezed. This creates a “crowding out” effect where the financial burden of complying with regulations prevents the investment in deep technology needed to survive future ones ^[9].

3.3. A digital divide restricts market access

Beyond financial constraints, a significant “digital divide” is emerging as a non-tariff barrier. The analysis suggests that the competitive threshold is shifting from simply lowering emissions to proving them through verifiable data. Li notes that GTBTs increasingly mandate rigorous carbon footprint disclosures and eco-labeling. However, meeting these requirements demands sophisticated Monitoring, Reporting, and Verification (MRV) systems that many firms lack ^[18]. This creates a dual capability gap for SMEs. As Ahmad (2025) highlights, small firms lack not only the technical capacity for physical decarbonization (e.g., CCUS) but also the administrative capacity for complex carbon accounting. In Global Value Chains (GVCs), lead firms demand traceability that requires suppliers to possess advanced digital infrastructure ^[12]. Consequently, Chinese SMEs risk growing compliance pressures not necessarily because they are too polluting, but because they suffer from an information asymmetry that prevents them from engaging in credible “compliance signaling.”

3.4. Superficial compliance undermines deep decarbonization

Ultimately, the responding strategies of Chinese firms exhibit an alarming asymmetry. Li demonstrates that GTBs substantially drive green product innovation (visible changes to end-products) but have no statistically significant effect on green process innovation (systemic changes to production methods) ^[18]. This suggests a rational but short-sighted survival strategy: firms prioritize market-facing changes that secure immediate access over costlier, invisible operational overhauls. This “superficial compliance” represents a long-term strategic trap. While product tweaks may satisfy current eco-labeling requirements, they fail to address the fundamental carbon intensity of production. Tang *et al.* and Tian *et al.* warn that deep decarbonization, such as the adoption of low-carbon production technologies in steel or aggressive energy switching, is required to align with global climate goals ^[5,20]. By focusing on the product rather than the process, manufacturers leave themselves vulnerable to future, stricter iterations of GTBs that will inevitably target the lifecycle emissions of the production system itself.

4. Analysis of implementation path and strategy

4.1. Implementation paths

4.1.1. Regulatory reform overhauls the energy market

At the regulatory level, the path forward requires a fundamental overhaul of energy market mechanisms. The Central Government (specifically the NDRC) and local authorities must prioritize decoupling energy consumption rights from carbon emissions control within the next 1–2 years. This regulatory shift is the prerequisite for liberating the market for Green Electricity Certificates (GECs). By establishing a unified national green power trading market that integrates inter-provincial transmission, the government creates a path for manufacturers to offset Scope 2 emissions independently of their regional grid's carbon intensity ^[19]. Concurrently, the National ETS must be expanded to cover high-impact export sectors, specifically steel, cement, and aluminum, to align domestic carbon prices with international benchmarks, thereby mitigating the direct tax burden of mechanisms like CBAM. In the medium term (3–5 years), this path extends to the physical infrastructure, where local governments in renewable-rich regions (e.g., Xinjiang, Inner Mongolia) spearhead the construction of “Zero-Carbon Industrial Parks.” These zones, powered by dedicated renewable grids, provide a structural shield for local export-oriented industries ^[5].

4.1.2. Financial mechanisms inject liquidity

To resolve the funding gap facing private firms and SMEs, the financial path must move beyond simple credit expansion to structural risk mitigation. State-owned commercial banks and policy funds act as the engines, but they require a government-backed starter mechanism. The critical path involves the deployment of “Transition Finance” instruments backed by aggressive risk-sharing. Immediate implementation requires policy banks to introduce targeted low-carbon transition loans for process re-engineering, supported by a government guarantee mechanism that underwrites a significant portion (e.g., 50–70%) of default risk. This direct governmental “backstop” is essential to correct market failures in risk pricing and overcome the lending reluctance identified above ^[4]. This intervention ensures that immediate compliance costs do not crowd out R&D budgets. As the path matures, specialized vehicles such as a “Green Technology Equipment Fund,” capitalized with fiscal investment to absorb first-loss risks, must be established to finance capital-intensive technologies like CCUS and hydrogen metallurgy, ensuring private enterprises are not excluded from deep decarbonization due to collateral constraints ^[1].

4.1.3. Capacity building bridges the digital gap

To resolve the funding gap facing private firms and SMEs, the financial path must move beyond simple credit expansion to structural risk mitigation. State-owned commercial banks and policy funds act as the engines, but they require a government-backed starter mechanism. The critical path involves the deployment of “Transition Finance” instruments backed by aggressive risk-sharing. Immediate implementation requires policy banks to introduce targeted low-carbon transition loans for process re-engineering, supported by a government guarantee mechanism that underwrites a significant portion (e.g., 50–70%) of default risk. This direct governmental “backstop” is essential to correct market failures in risk pricing and overcome the lending reluctance identified above ^[4]. This intervention ensures that immediate compliance costs do not crowd out R&D budgets. As the path matures, specialized vehicles such as a “Green Technology Equipment Fund,” capitalized with fiscal investment to absorb first-loss risks, must be established to finance capital-intensive technologies like CCUS and hydrogen metallurgy, ensuring private enterprises are not excluded from deep decarbonization due to collateral constraints ^[1].

4.2. Strategic orientations

4.2.1. Deep technology pursues sovereignty

The first strategic orientation involves a pivot from “superficial compliance” (minor product tweaks) to stronger indigenous innovation capacity. Rather than merely reacting to Western standards, China’s strategy must be to redefine the global energy paradigm. A paramount embodiment of this strategy is the Burning Plasma Experimental Superconducting Tokamak (BEST) currently under construction in Hefei. While mechanisms like CBAM penalize the carbon intensity of current industrial processes, strategic projects like BEST represent a leap toward a future of limitless, zero-carbon baseload power. By striving for commercialized nuclear fusion, alongside the acceleration of green hydrogen and CCUS, China adopts a strategy of defining the next generation of energy technology ^[19]. This strategic orientation aims to protect the manufacturing base from future regulatory ratcheting by transitioning China from a rule-taker in the global green trade system to a rule-maker.

4.2.2. Diplomacy recalibration frames equity

The second strategic orientation is diplomatic, focusing on reframing the international discourse surrounding historical equity. Within frameworks like the Conference of Parties (COP), China must move beyond a defensive stance regarding its current emission flows to an offensive strategy rooted in the principle of Common But Differentiated Responsibilities (CBDR). This strategy posits that trade barriers like CBAM are illegitimate if they are not paired with robust mechanisms for Capacity Building and Technology Transfer. Drawing on Jones and Adam (2023), the strategic narrative should highlight that withholding low-carbon technologies behind intellectual property walls, while simultaneously taxing carbon-intensive imports, constitutes trade restrictions ^[1]. By championing a framework where market access is conditionally linked to technology sharing, China mobilizes support from the Global South, demanding a transition that acknowledges the West’s historical carbon debt while securing the technical means for its own industrial upgrading.

5. Conclusion

Global trade governance is undergoing a vital paradigm shift, which transforms environmental sustainability from a peripheral ethical standard into a central determinant of market access. As mechanisms like the EU’s Carbon Border Adjustment Mechanism (CBAM) redefine the rules of trade, China’s manufacturing sector stands at a precarious juncture. The analysis confirms that while Green Trade Barriers (GTBs) pose an immediate threat to export competitiveness, they simultaneously serve as an external coercive force that aligns with and accelerates China’s domestic “Dual Carbon” objectives. However, the primary barrier to adaptation lies not in the direct cost of compliance, but in a set of entrenched structural incompatibilities unique to the Chinese context. The analysis identifies the energy system constraint imposed by the coal-dominant grid which renders firm-level efficiency insufficient, alongside a “resource-innovation paradox” where financial constraints threaten to crowd out R&D investment. Furthermore, a dangerous asymmetry has emerged where firms prioritize “superficial” product compliance over the deep process innovation required for long-term decarbonization. These findings suggest that the mechanism of the “Porter Hypothesis” is not automatic; the ability of regulation to spur innovation is profoundly contingent upon first overcoming the “digital divide” and financial liquidity gaps. To resolve these structural constraints, a synchronized domestic strategy must pivot from reactive compliance to proactive reinforcement of indigenous innovation capacity. This study proposes a coordinated “Actor–Tool–Timeline” implementation matrix to guide this transition, where the state must decouple energy rights to unlock green

power trading; the financial sector must provide risk compensation to fuel transition finance; and industry actors must build the digital infrastructure for verifiable carbon accounting. Crucially, long-term competitiveness lies in defining tomorrow's energy paradigms. As symbolized by the investment in the "BEST" superconducting tokamak, China must look beyond meeting today's standards and invest in breakthrough technologies like nuclear fusion and hydrogen metallurgy. To end with, the strategy must extend beyond the factory floor to diplomacy to reassert historical equity. By defending the principle of common but differentiated responsibilities (CBDR) and accentuating the historical carbon debt of developed nations, China can advocate for a fairer global climate governance framework, one that links trade restrictions to genuine technology transfer. In doing so, China can transform the external pressure of GTBs from a protective barrier into a catalyst for a high-quality, systemic industrial revolution.

Disclosure statement

The author declares no conflict of interest.

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