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Decarbonizing Global Value Chains: Pathway for Low-Carbon Trade

Shikha Kumari[1], Dr. Prof. Nisha Kumari[2]

[1]*Research Scholar, Deptt. of Economics, Tilka Manjhi Bhagalpur University, Bhagalpur, Bihar*

[2]*University Deptt. of Economics, Tilka Manjhi Bhagalpur University, Bhagalpur, Bihar*

ABSTRACT

The intensification of global trade over the past few decades has resulted in the rapid expansion of global value chains (GVCs), enabling countries to specialize in different stages of production and facilitating economic growth. However, this expansion has also contributed significantly to global greenhouse gas emissions through energy-intensive production processes, transportation, and logistics. As climate change becomes one of the most pressing global challenges, decarbonizing global value chains has emerged as a crucial strategy for achieving sustainable development and meeting international climate commitments. This paper examines the pathways through which global value chains can transition toward low-carbon trade while maintaining economic competitiveness and inclusive growth. Decarbonization of GVCs requires coordinated efforts from governments, corporations, international institutions, and consumers. One of the primary pathways involves the adoption of cleaner production technologies and energy-efficient manufacturing processes. By integrating renewable energy sources, improving resource efficiency, and implementing circular economy practices, firms can significantly reduce carbon emissions throughout production stages. In addition, sustainable sourcing and green procurement policies enable companies to collaborate with suppliers that adhere to environmental standards, thereby extending sustainability efforts across the entire supply chain. Trade policy also plays a critical role in promoting low-carbon trade. Governments can incentivize green production and exports through carbon pricing mechanisms, environmental regulations, and supportive fiscal policies. Instruments such as carbon border adjustment measures, eco-labeling systems, and sustainability certification schemes can encourage firms to adopt environmentally responsible practices while preventing carbon leakage across borders. Furthermore, international cooperation and multilateral frameworks are essential to harmonize sustainability standards and ensure that developing countries are not disadvantaged in the global trading system.

Technological innovation and digitalization provide additional pathways for decarbonizing GVCs. Advanced technologies such as artificial intelligence, blockchain, and big data analytics can enhance supply chain transparency, track emissions, and improve resource management. These tools allow firms to monitor environmental performance across multiple production stages and ensure compliance with environmental, social, and governance (ESG) standards. At the same time, digital platforms facilitate collaboration between firms, suppliers, and regulators, enabling more efficient and environmentally responsible trade networks. Despite these opportunities, several challenges remain. Developing countries that participate in GVCs often face financial, technological, and institutional constraints in adopting green technologies and meeting stringent environmental standards. Without adequate support, these countries risk being marginalized in emerging low-carbon trade regimes. Therefore, capacity-building initiatives, technology transfer, and climate finance are necessary to ensure an inclusive transition toward sustainable value chains. Decarbonizing global value chains represents a critical pathway toward achieving climate goals while sustaining global trade and economic development. Through a combination of green technologies, supportive trade policies, digital innovation, and international cooperation, it is possible to create low-carbon trade systems that balance environmental responsibility with economic resilience. A coordinated global approach that includes both developed and developing economies will be essential to ensure that the transition toward sustainable global value chains is equitable, efficient, and effective in mitigating climate change.

Keywords: *Decarbonization, Global Value Chains, Low-Carbon Trade, Sustainability, ESG, Green Supply Chains, Climate Policy*

Introduction

Global production today no longer lives within national borders—it stretches, fragments, and reassembles itself across continents through what we call global value chains (GVCs). From raw material extraction in one country to manufacturing in another and final consumption elsewhere, this intricate web has powered unprecedented economic growth and trade integration. Yet, beneath this efficiency lies an uncomfortable truth: global value chains have also become major carriers of carbon emissions, embedding environmental costs deep within international trade. As production disperses geographically, so do emissions, often shifting the carbon burden toward developing economies that specialize in energy-intensive stages of production . In an era defined by climate urgency, the decarbonization of global value chains has emerged as a critical pathway toward achieving low-carbon trade and sustainable development. The traditional model of growth—fueled by fossil energy, linear production systems, and cost minimization—now stands in direct conflict with global climate commitments such as net-zero emissions targets. Trade is no longer just about comparative advantage; it is increasingly about carbon efficiency, environmental standards, and technological capability. The challenge is stark: how can economies continue to benefit from globalization while drastically reducing the carbon footprint embedded in traded goods and services? A growing body of research suggests that transitioning toward renewable energy and cleaner technologies is central to reshaping GVCs into low-carbon systems. Increased adoption of renewable energy significantly reduces carbon emissions within value chains, while also enabling economic upgrading in developing countries . However, this transition is not linear or frictionless. In the short term, industrial upgrading and structural transformation may even increase emissions before long-term gains are realized, highlighting the complexity of balancing growth with sustainability . This duality reflects a deeper tension within global trade: decarbonization is both an environmental necessity and an economic restructuring process. Trade policy plays a pivotal role in accelerating this transformation. Reducing barriers to environmental goods, promoting clean technology diffusion, and aligning trade frameworks with climate goals can facilitate the transition toward low-carbon production systems. Policies such as carbon pricing and border carbon adjustments are increasingly shaping global trade dynamics, incentivizing producers to lower their carbon intensity while discouraging carbon leakage. At the same time, international cooperation remains essential, as fragmented policies risk creating trade distortions and inequality rather than collective progress. Importantly, the decarbonization of GVCs is not merely a technological shift—it is a reconfiguration of global economic relationships. It demands coordinated action among governments, firms, and international institutions, alongside investments in green infrastructure, digitalization, and circular economy practices. Developing countries, in particular, face a delicate balancing act: integrating into global markets while avoiding carbon-intensive development pathways that could lock them into future vulnerabilities. In this context, decarbonizing global value chains represents more than a climate strategy—it is a blueprint for redefining the future of trade itself. A low-carbon trade paradigm holds the promise of aligning economic growth with ecological sustainability, transforming global production networks into engines of both prosperity and planetary resilience.

Conceptual Framework: Linking Global Value Chains and Carbon Emissions

Global Value Chains (GVCs) represent the fragmentation of production processes across countries, where each stage—from raw material extraction to final consumption—is geographically dispersed. While this system enhances efficiency and comparative advantage, it also obscures the true environmental cost of production. Carbon emissions are not merely produced; they are *embedded* within traded goods, effectively transferring environmental burdens across borders. The concept of **"carbon leakage"** becomes central here. When stricter environmental regulations in developed countries push carbon-intensive industries to relocate to regions with lax standards, emissions are not reduced—they are displaced. Thus, traditional production-based accounting of emissions fails to capture the full picture. A shift toward **consumption-based accounting** is increasingly advocated to better reflect the carbon footprint of trade. Furthermore, GVCs are shaped by lead firms—often multinational corporations—that dictate production standards, technologies, and sourcing decisions. These actors possess the power to drive decarbonization across entire supply networks, making them crucial agents in the transition toward low-carbon trade.

Drivers of Carbon Intensity in Global Value Chains: *The carbon footprint of GVCs is influenced by several structural and operational factors:*

a) **Energy Sources and Industrial Structure**:Energy-intensive industries such as steel, cement, textiles, and chemicals dominate many GVCs. In developing countries, reliance on fossil fuels significantly increases emissions intensity. The lack of access to clean energy infrastructure further exacerbates this problem.

b) **Transportation and Logistics**: Global trade relies heavily on shipping, aviation, and road transport, all of which are major contributors to greenhouse gas emissions. Long-distance transportation, multiple border crossings, and inefficient logistics systems increase the carbon footprint of goods.

c) **Technological Gaps**: Developing economies often operate with outdated, energy-inefficient technologies. Limited access to finance and knowledge restricts their ability to adopt cleaner production methods, creating a persistent carbon divide within GVCs.

d) **Consumption Patterns**: Demand from high-income countries for fast fashion, electronics, and processed goods drives large-scale production in carbon-intensive regions. Thus, consumption behavior plays an indirect but significant role in shaping emissions.

e) **Institutional and Policy Constraints**: Weak environmental regulations, lack of enforcement, and insufficient incentives for green innovation hinder the transition toward low-carbon production.

Pathways to Decarbonizing Global Value Chains: *Decarbonization of GVCs requires a multi-dimensional approach that integrates technological, institutional, and behavioral transformations.*

a) **Transition to Renewable Energy:**Replacing fossil fuels with renewable energy sources such as solar, wind, and hydropower is fundamental. Electrification of industrial processes and the adoption of green hydrogen in heavy industries can significantly reduce emissions.

b) **Technological Upgradation and Innovation:** Energy-efficient machinery, digital monitoring systems, and advanced manufacturing technologies (such as Industry 4.0) can optimize resource use and reduce emissions. Innovations in materials science, such as low-carbon cement and recycled steel, also play a key role.

c) **Circular Economy Practices:** Moving from a linear "take-make-dispose" model to a circular economy reduces resource extraction and waste. Recycling, remanufacturing, and sustainable product design can minimize emissions throughout the value chain.

d) **Sustainable Logistics and Transportation:** Decarbonizing transport through electrification, alternative fuels (like biofuels and hydrogen), and optimized supply chain management can lower emissions. Regionalization of production—shortening supply chains—can also reduce transport-related emissions.

e) **Digitalization and Transparency:** Technologies such as blockchain, IoT, and big data analytics enable real-time tracking of emissions across supply chains. Enhanced transparency encourages accountability and supports informed decision-making.

Role of Trade Policy in Promoting Low-Carbon Value Chains: Trade policy is increasingly becoming a tool for environmental governance. Governments and international institutions are integrating climate objectives into trade frameworks.

Carbon Pricing Mechanisms, Carbon taxes and emissions trading systems internalize the environmental cost of production. By putting a price on carbon, they incentivize firms to adopt cleaner technologies. **Border Carbon Adjustments (BCAs)**; BCAs aim to level the playing field by imposing carbon tariffs on imports from countries with weaker climate policies. While controversial, they can reduce carbon leakage and encourage global compliance with environmental standards. **Liberalization of Environmental Goods and Services** Reducing tariffs on renewable energy technologies, energy-efficient equipment, and environmental services can facilitate the global diffusion of green technologies. **Green Trade Agreements**. The Modern trade agreements increasingly include environmental provisions, promoting sustainable practices and cooperation among countries.

Key Indicators for Decarbonizing Global Value Chains (GVCs)

Indicator	Latest Data / Estimate	Implication for Low-Carbon Trade
Share of global trade linked to GVCs	Around **50%–70% of global trade**	Shows that decarbonizing GVCs can significantly reduce global emissions since trade and production are deeply interconnected
Countries covered in GVC datasets	**150+ countries**	Highlights global scale and the need for coordinated international policy action
Global GHG emissions (2023)	**~53 Gt CO_2-equivalent**	Indicates rising emissions pressure, reinforcing urgency for low-carbon production and trade transitions
Carbon emissions embedded in trade	Significant share of emissions tied to **intermediate goods trade**	Emissions are "outsourced" across borders, requiring consumption-based accounting

Indicator	Latest Data / Estimate	Implication for Low-Carbon Trade
Regional emission patterns in GVCs	Developing Asia and emerging economies are **net exporters of embodied carbon**	Suggests inequality—developed nations consume while developing nations bear production emissions
Carbon pricing coverage	About **24–28% of global emissions covered**	Expanding carbon pricing can incentivize greener production across value chains
Role of technology in emissions reduction	Higher technological capability reduces emissions intensity in GVC participation	Technology transfer is critical for sustainable upgrading in developing countries
GHG footprint measurement tools	OECD ICIO and air emissions accounts used globally	Enables tracking of emissions across supply chains, improving transparency and policymaking
Transformation trends in GVCs	Shift toward **digitalization, automation, and green policies**	Indicates structural transition toward low-carbon global production systems

Sources :

- World Bank (WITS) – Global Value Chains Database
- World Bank, WTO, OECD – *Global Value Chain Development Report*
- World Trade Organization (WTO) – GVC Data Portal & Reports
- OECD – Greenhouse Gas Footprint Indicators
- Asian Development Bank – *Asian Economic Integration Report 2024*
- WTO (2025) – GVC restructuring and sustainability trends

Corporate Responsibility and Governance in GVCs , Challenges and Trade-offs in Decarbonizing GVCs

Multinational corporations (MNCs) act as orchestrators of global value chains. Their procurement policies, investment decisions, and sustainability commitments have far-reaching impacts. The transition to low-carbon value chains is fraught with economic, social, and political challenges.

ESG Integration, Supplier Engagement , Disclosure and Reporting: Environmental, Social, and Governance (ESG) criteria are becoming central to corporate strategies. Firms are setting net-zero targets and aligning operations with global climate goals. Lead firms are encouraging or mandating suppliers to adopt sustainable practices, often through certification systems and capacity-building initiatives. Frameworks such as carbon disclosure reporting enhance transparency and accountability, enabling stakeholders to assess environmental performance. However, concerns remain regarding "greenwashing," where firms exaggerate their environmental commitments without substantive action.

Cost Implications, Equity and Justice Concerns, Technological Dependence, Policy Fragmentation, Measurement and Data Challenges: Green technologies and infrastructure require substantial investment. For developing countries, these costs can be prohibitive, potentially affecting competitiveness. Decarbonization may disproportionately impact low-income countries that rely on carbon-intensive industries for growth and employment. A just transition must ensure that these economies are not left behind. Developing countries may become dependent on advanced economies for green technologies, reinforcing existing inequalities within GVCs. Divergent national policies can create trade barriers and inefficiencies, undermining global cooperation. Accurately measuring emissions across complex supply chains remains a significant challenge, limiting effective policy implementation.

Opportunities for Developing Economies and Policy Recommendations: Despite challenges, decarbonization presents significant opportunities:

Green Industrialization Developing countries can leapfrog traditional carbon-intensive pathways by adopting clean technologies, positioning themselves as leaders in green manufacturing. **Employment Generation** Renewable energy, sustainable agriculture, and circular economy sectors offer new avenues for job creation. **Enhanced Competitiveness** Compliance with global environmental standards can improve market access and competitiveness in international trade . **Access to Climate Finance** International funding mechanisms, such as green bonds and climate funds, can support the transition toward low-carbon development.

To effectively decarbonize global value chains, a coordinated approach is essential: **Strengthen International Cooperation**: Align trade and climate policies through multilateral agreements. **Promote Technology Transfer**:

Facilitate access to clean technologies for developing countries. **Invest in Green Infrastructure**: Support renewable energy, sustainable transport, and digital systems.**Enhance Capacity Building**: Provide technical and financial assistance to firms and governments. **Ensure Inclusive Transition**: Address social and economic impacts through targeted policies.

Conclusion

Decarbonizing global value chains is no longer optional—it is inevitable. The very architecture of global trade is being reshaped by the imperatives of climate change. What once thrived on cost efficiency must now answer to carbon efficiency. The road ahead is complex, uneven, and at times uncomfortable. But within that discomfort lies transformation. The future of trade will not belong to the cheapest producer, but to the cleanest one. Nations and firms that adapt early will not just survive—they will define the rules of the next global order. For developing economies, the challenge is to walk a tightrope: grow, but grow green; integrate, but integrate wisely. In the end, decarbonizing GVCs is not merely about reducing emissions—it is about reimagining development itself. It asks a fundamental question: can the engines of globalization be rewired to sustain both prosperity and the planet? The answer will shape not just trade, but the destiny of generations to come.

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