

Sustainable and Cost-Efficient Supply Chains under Carbon Policy Constraints

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In light of increasing global concern over climate change, this study presents a green supply chain inventory model that incorporates carbon emission considerations into traditional supply chain cost structures. The model focuses on deteriorating and imperfect items and explores the effectiveness of various carbon policies—namely, carbon tax, carbon cap-and-trade, and carbon offset—in managing emissions while minimizing overall costs. The integrated supply chain consists of a manufacturer, a third-party logistics provider (3PL), and a buyer. The manufacturer performs 100% quality inspections to filter out defective items, while the 3PL manages transportation and storage. The model accounts for emissions generated during production, transportation, warehousing, deterioration, and disposal. These emissions are translated into costs based on the selected carbon policy framework. A numerical analysis is conducted to compare total costs under each policy. Sensitivity analysis further explores how variables like product weight, deterioration rate, and warehouse emissions affect the overall performance of the supply chain. Results indicate that the carbon cap-and-trade policy is the most cost-effective and environmentally efficient option among those studied.

The study also provides recommendations for stakeholders. Manufacturers can reduce emissions by optimizing energy use and switching to renewable sources, 3PLs can adopt fuel-efficient logistics practices, and buyers can support green products. The proposed model offers a realistic and practical tool for designing sustainable supply chains under regulatory constraints and can be extended to multi-supplier, multi-retailer systems in future research.

Keywords: Green Supply Chain, 3PL, Supplier, Retailer, Carbon policies, cap-and-trade, emission