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E-Commerce Practices and Carbon Emissions – An Analysis

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ABSTRACT
The trend in the flourishing e-commerce has also raised concerns about the impact that the industry poses in the environment, especially in terms of causing greenhouse gases. In this study, the synergy between consumer views on sustainability and institutional behaviours regarding the use of renewable energy and being sustainable as a decarbonisation tool is tested with reference to the Indian setting. The empirical evidence demonstrates that the impact of consumer perceptions on the readiness of consumers to incorporate sustainable practices is high, whereas the growth of the FMCG industry, and the implementation of renewable sources of energy are also instrumental in fuelling the carbon emission trends in India, and together, they also may indicate their potential to lower the level of emissions in the context of e-commerce, among other aspects. In turn, the current examination provides policymakers and market participants with an evidence-based scheme of developing low-carbon digital-commerce environments...
Keywords: FMCG Industries, Decarbonization, E-Commerce, Sustainability, Carbon Emission, Renewable Energy, Green Economy, Digital Era

INTRODUCTION:

E-commerce has opened up new economic options for the company, giving consumers another option for buying. The growing amount of carbon emissions worldwide has led to urgent environmental problems as the economy continues to expand. E-commerce produces significant quantities of garbage, relies on inefficient modes of delivery and consumes large amounts of power at data centers and warehouses, all of which contributes to the release of greenhouse gases into the environment.

E-commerce harms the environment mainly because of excessive packaging, poor shipping methods and high energy consumption across logistics systems. The surge in popularity of e-commerce has caused several new environmental risks as a result of an increase in overall carbon emissions. A variety of inefficiencies in running e-commerce operations lead to the release of high levels of carbon into the environment such as using large amounts of packaging or employing energy-intensive transportation methods. Companies in the e-commerce industry are making an effort to decrease the carbon emissions they produce. Last-mile deliveries result in high levels of carbon emissions because they require relatively inefficient logistics operations and a large number of combustion-based vehicles. The effect that e-commerce has on the environment is also related to the energy required for operating the sector's infrastructure. Studies have found that, in the coming future, the e-commerce carbon footprint will surpass that of traditional shopping. Companies are now making efforts in encouraging the eco-friendly behaviour.

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Companies across the globe are adopting numerous strategies to reduce on their carbon usage and to guarantee best performance in all aspects of their online trading activities.Switching to reusable items, using biodegradable materials and decreasing the amount of packaging reduces the pollution and greenhouse gas emissions associated with packaging manufacture and clean up. Adopting more efficient and sustainable logistics reduces the amount of greenhouse gases produced while moving products between various places. Switching to renewable energy for power greatly cuts down the electricity consumption inside both data centers and warehouses.

The sensible account of sustainable e-commerce has to factor in the two-way effects between consumer behaviour and industry practice. The modern study proves that consumers are becoming more focused on environmental responsibility and are willing to make purchases with brands that show evident signs of commitments to sustainability, thus having a rather contingent impact on the corporate strategy (Ajzen, 1991; Park & Lee, 2020). At the same time, injecting renewable energy into the e-commerce infrastructure, specifically warehouses and data centers, is one of the critical steps toward reducing the carbon footprint of the sector (Wang et al., 2022). However, the majority of extant literature separates the two dimensions leaving out the synergetic capabilities of their interface in the process of triggering emissions reduction.

The rapid growth of both e-commerce and the FMCG industry in a fast-growing economy like India - where such trends are not yet studied in-depth by scholars - exacerbate the adverse effects of both trends on the environment (Guo et al., 2017). As empirical evidence documents, expanded use of renewable energy and

expanded consumer goods markets have the ability to determine the path of national carbon emissions. In order to fill this research gap, the current research paper combines both primary data on consumer preferences and willingness and long-term secondary data on the use and market expansion of renewable energy sources providing a well-rounded analysis of the carbon emissions in Indian e-commerce setting.

By placing behavioural variables and technological interventions in one conceptual framework, the research provides practical information that firms and policy makers may rely on to achieve a balance between economic growth and sustainability of the environment.

Rationale of the Study

The fast-paced pace of global e-commerce has transformed global retailing giving remarkable convenience and convenience to the consumer population. However, the growth has equally escalated environmental issues, which mostly originate in convoluted carbon emissions that are closely connected to logistical activities, packaging, and the mass construction of digital infrastructure. As pressure mounts on the need to deal with climate change, there is a need to explain how sustainable e-commerce practice can mitigate these impacts. Despite the rising innovation and the campaigns promoting the ideas of green logistics, environmentally-friendly packaging, and the green energy of the digitalisation process, the empirical data on their potential to suppress carbon emissions is limited and scattered over the context. The paper will thus aim at bridging the gap that exists between theoretical sustainability concepts and reality when performing e-commerce operations. The research provides empirical evidence as to the effectiveness of the measures that can include optimised delivery routes, renewable electricity, sustainable packaging, and reverse logistics by examining their impacts on carbon footprints. In addition, it examines how consumer behaviour, regulatory policies, and technological innovation act as mediators and either facilitate and limit the utilisation of the strategies. The results can help e-commerce stakeholders; such as businesses, policymakers, and consumers, find sound ways on how to lower carbon emission without compromising on the quality-of-service delivery. Due to this, the research works will be adding to the general debate of sustainable development where expansion in e-commerce has been supplemented with environmental solvency to advocate the shift to the low-carbon economy. In the end, the study provides realistic decision-making advice and promotes a more sustainable and responsible e-commerce environment through eco-responsible interactions between economically driven and environmentally conscious stakeholders in the face of the climate crisis in the world.

Review of Literature

Kasap (2025) clarified that e-commerce can grow the size by facilitating access of SMEs to foreign markets; yet, it will have to be environment-friendly and respectful of community values too. Anyone using a platform is expected to treat workers fairly, make the community a priority, and promote the use of eco-friendly products. E-commerce and sustainable development have the requirement of managing its sustainability on environment, economy, and society. The results of **Qian et al. (2025)** indicated that local carbon emissions are reduced in the development of e-commerce through the optimization of industrial structures, industrial technological innovation, and online shopping. Effect of regional differences and endowment differences are divergent with the cities in the east recording more decrease.**Santos and Rodrigues (2024)** in their analysis argues that sustainability in e-commerce presents holistic strategies as the core of the subject matter as the carbon emissions have decreased significantly related to sustainable transport options, consumers, and technology development.**Wang et al.(2023)**states that implementing an e-commerce pilot policy helps lower carbon emissions mainly in modern and non-resource-based cities. This policy helps make the best use of resources, use energy wisely, and restructure industries in a way that supports carbon trading and pilot programs for low-carbon cities.**Imran et al. (2023)** found that the short-term effect of online shopping on carbon emissions is positive, however, the long-term effect is because of spending on research and developments as well as trading in services. Among the key causes of e-commerce and trade-in services economic growth; e-commerce brings about great contribution to renewable energy and service trade. **Islam et al. (2023)**states that eco-friendly products more convenient, simultaneously increasing their trust in the labels because of the provided explanation.**Sarkar (2023)** concluded that when compared to traditional retail, the view is that e-commerce offers a broader outlook on environmental sustainability.**Martins and Silva (2023)** examine the implementation of circular economy concepts in the context of e-commerce in a research article published in 2023 and show that a combination of product life extension, product reuse, and product recycling approaches reduce the amount of waste and limit resource use.According to **Oláh et al. (2023)**European countries have turned to the use of the e-commerce sustainability policies, whereas Kenya has very few.It suggests all stakeholders should implement sustainable e-commerce policies.**Patel et al. (2023)** also show that implementing several measures to make data centers more energy-efficient and replacing fossil-based generation with renewable power contributes greatly to reducing indirect emissions caused by the digital infrastructure.**Chen et al. (2022)** establishes that e-commerce businesses may successfully reduce their carbon footprint by investing in green procurement materials and enforcing a solid supplier enablement policy, which significantly decreases emissions in the product supply chain and product delivery.As it has been investigated by **Gupta and Sharma (2022)**, the effectiveness of government policy in terms of achieving sustainable e-commerce can be detected, as it is revealed that the framework of regulation is capable of promoting the efforts directed at carbon reduction.**Adebayo et al. (2021)** found out that there was a long-run asymmetric relationship between indicators and CO2 emissions where negative economic growth had more impacts on environmental degradation. Beneficial use of renewable energy has the power to change the environment in Chile, however, technological change

cannot be effective in reducing carbon emission caused by consumption and it may imply that difference with Chile does not lie in green technology. In their study on the e-commerce consumer attitudes to the sustainable packaging, **Lee and Kim (2021)** concluded that the sustainable packaging contributes to reduction in carbon emission and to consumer satisfaction.**Sharma and Ghosh (2021)** confirm the need to optimise server usage and introduce renewable energy sources to the cloud computing infrastructure which will help to reduce indirect carbon emissions related to e-commerce.**Wang et al. (2021)** empirically proven that environmental awareness has a profound impact on retailers' carbon-reducing behaviours and has therefore, demonstrated that consumer education is one of the key factors in determining sustainable e-commerce.The work by **Chen and Xu (2020)** regarding sustainable reverse logistics in e-commerce proves that streamlining operational processes has an impact on reducing carbon footprint through waste reduction and the promotion of the principles of a circular economy.**Zhang et al. (2020)** in their recent scholarly research affirm that e-commerce sustainable logistics significantly reduces its environmental impact on carbon footprint, with electric vehicles reducing greenhouse emissions in last-mile delivery networks substantially, which reinforces the importance of green logistics in the modern e-commerce realities.**Li et al. (2019)** put emphasis on the ability of digital platforms to amplify the transparency of supply-chains and subsequently boost not only sustainability but also environmentally aware consumer choices.**Wang et al. (2019)** concluded that micro-fulfilment centers in urban logistics significantly stimulate the efficiency of the last mile delivery due to reducing the distance of delivery and stimulating the uptake of low-emission modes of transportation.**Arnold et al.(2017)** emphasisedthat they can help businesses or people with creative ideas related to delivery.By providing the customers with the option of picking up their purchases themselves and through the means of cargo bike delivery system, the companies can reduce costs and diminish their environmental burden. This paper presents **Barney (1991)** work on the relationship between resources of firms and the outcome of sustained competitive advantage with specific emphasis made on the indicators of value, rareness, imitability, substitutability, as well as how they appraise other fields of business.

Research Gap

The existing literature on sustainable e-commerce has been focused on particular aspects, e.g. consumer behaviour with regard to green products (Park and Lee, 2020) or usage of renewable energy in the logistics and supply chains (Guo et al., 2017; Wang et al., 2022). Despite these developments, the synergistic effect that can exist between consumer attitudes and industry-scale adoption of renewable energy has not been systematically examined. The previous literature is usually methodologically fragmented to either demand-side effects of behavioural factors or supply-side effects of technological interventions, hence hindering deeper insights into the relationship between those two planes that influence the outcomes of sustainability in e-commerce. Further, willingness to pay more and green products, preference of doing the least packaging, and trust on sustainability claims are explored separately, and there is no quantification of their relative importance in explaining their perception that translates into the quantifiable effect of reducing carbon emissions-especially in the emerging markets like India. Despite the rapid growth of the FMCG and renewable energy in India, the two industries play a critical role in the sustainability landscape of the country, there is a paucity of longitudinal studies that examine the impact of macroeconomic transformation on industry-specific emission trends using industry emissions as a proxy to CO 2 emission. Most existing literature is based on cross-sectional data or on developed economies only, which leaves an unresolved research issue as to how these factors interact in the longer run in developing economies. The current study aims to fill these gaps by synthesizing new data about consumer perception with 20-years old secondary data about renewable energy adoption and growth of FMCG sector, thus, bringing a more side perspective on the predictive and combined influence of aforementioned factors on achieving low carbon level within the sustainable e-commerce ecosystem in India.

Research Objectives

To understand how the effects of consumer perceptions and industry level are combined in renewable energy adoption to reduce carbon emissions in the sustainable e-commerce sector.

To establish the relative predictive value of the sustainable e-commerce variables in case of perception result to reduce carbon-emissions

To examine the role played by the mounting usage of renewable energy and thriving FMCG industry in reducing the emission of CO_2 in India at a rate that is increasing phenomenally.

Theoretical Framework

The study overlays both the consumer behaviour approach and the consumerdesignsustainability theory to explain how the perceptions of consumers and the activities of the industry merge to determine the carbon emissions caused by e-commerce. The framework proposed here assumes that sustainable performance of online retailing cannot be explained only by the corporate efforts; i.e., the implementation of renewable energy resources, but also, and to a much larger degree is explained by the knowledge, convictions, and activist intentions of the consumers with regards to sustainability.

At the heart of this construct is the so-called Theory of Planned Behavior (TPB), a rather long successively established theoretical model, which argues out that behavioral intentions ultimately regulate behavior and these intentions are shaped by the attitude regarding the behavior, subjective norms and the perceived behavior control (Ajzen, 1991). When it comes to sustainable e-commerce, the positivity of consumers towards the environmental responsibility of online shopping, the social norms that motivate consumers to green buying, and their perception about the ease, or difficulty, of choosing a sustainable product, determine shopping

behaviour. The resulting consumer buying trends become the demand-side pressure on e-commerce companies to engage in practices like using renewable energy and cutting their carbon footprint via green approaches to logistics and packaging delivery services.

Thus, the consumer perception turns into a critical change driver. Empirical research proves that, once consumers learn about the negative impact of online shopping on the environment and how far e-commerce companies are willing to take sustainability, the likelihood of these consumers continuing to support such enterprises increases (Park & Lee, 2020). This increased awareness and positive image creates a cycle that will compel the business to spend even more into sustainable technology, especially renewable energy, in an effort to support its operational systems.

Adoption of renewable energy in the e-commerce logistics is an empirical and measurable business activity that reduces the carbon footprint in warehouse space, data centers and transport fleets. The fact that e-commerce businesses replace fossil-fuels based power with renewable energy sources directly reduces greenhouse-gas emissions. Research designs determined by the Environmental Kuznets Curve (EKC) model provide a thinking frame by which to assess this dynamic, whereby, as given industries grow and mature, there is an increase in the investment in cleaner technology like renewable energy and this aspect will result in quantifiable improvements in environmental conditions (Grossman & Krueger, 1995). Here, the e-commerce enterprises can find themselves at a point where it becomes cost-effective and even strategic to pursue the use of renewable sources of energy owing to the regulatory demands and market dynamics.

In the multidimensional approach the proposal is marked out by a synergistic relationship where consumer perception leads to corporate behaviour and corporate response to embrace the renewable energy which in turn raises the confidence of the consumer and maintains the purchasing behaviour that is environmentally sound. This two-way process is in line with Stakeholder Theory (Freeman, 1984), which emphasizes the interdependence and co-existence of business organizations, their customers and society in general in the achievement of the state of sustainability. E-commerce companies can also build a more sustainable consumption environment by dispersing transparent information related to their renewable energy programs and overall sustainable commitments, gathering trust and loyalty by the stakeholders.

The Diffusion of Innovations Theory (Rogers, 2003) has also been incorporated into the framework in an effort to shed some light on the diffusion mechanisms of adoption of renewable energy within the e-commerce enterprises. By taking the first mover advantage, first movers can create some benchmarks which reduce the informational uncertainty in later firms hence increasing the adoption of clean energy technologies faster. At the same time, the increase in the consumer demand towards sustainability creates an external pressure that increases the relative advantage and social acceptability of the innovation, hence strengthening it in diffusion.

The measurement in the current framework involves two main dimensions. First, a group of 3 variables of consumer perceptions is being elicited with the assistance of primary data, and this can be done by the surveys or interviews. Such constructs measure the degree at which consumers are aware and accept the sustainable e-commerce alternatives. Secondly, secondary data is used to measure renewable energy uptake on industry level since it uses government publications, industry databases and corporate sustainability reporting, which report on energy use, and emission reductions.Integration of such data streams will facilitate the analysis of the combined effect of both consumer-based and supply-side (renewable energy) programs on carbon emission results in a unified framework of analysis.

The combined design shows the importance of not only psychological factors but practical supports in the process of promoting sustainability in e-commerce. It confirms that without consumer awareness and support programs to adopt renewable energy such programs alone could fail to achieve their full potential in reducing emission in the sense that the same could happen with a poorly handled supply-side. Therefore, more realistic and holistic knowledge of carbon footprint footpaths is obtained through the bi-focal approach.

To sum it all up, the theoretical argument that underpins the current research study views consumer perceptions and renewable energy adoption as mutually constitutive and developing forces in the shape of the environmental changes of e-commerce transactions. Based on some established theories on behavior and environment, it illuminates the fact that it is necessary to have a balance between consumer values and corporate actions to have a significant change in carbon emissions. The opinion goes beyond enhancing academic knowledge because it provides some practical lessons to e-commerce stakeholders who are interested in optimal growth and sustainability.

Research Methodology

The study is based on both primary and secondary study. For the secondary study part variables like CO2 Emission Change, Renewable Energy Change, Growth in Market Size of FMCG goods of India from the websites like our world in data, World Bank, IBEF, The Economic Times, Market research future, IEA, Forbes India and other statistical websites. The data is taken for 20 years from 2005 to 2024.The factors/ variables of the primary data areWillingness to Pay for Green Products, Frequency of Purchasing Sustainable Products, Preference for Minimal Packaging, Trust in E-Commerce Brands' Sustainability Claims and Perceived Reduction in Carbon Emissions

For the primary study a questionnaire has been prepared and will be studied on E-Commerce industry in India. The sample taken for the study is 200 respondentsthat will be taken as per purposive sampling.The most suitable research methodology, stratified random sampling was supposed to be used, owing to its ability to ensure strongly represented proportions on pertinent demographic factors,

especially age, gender, and occupation. This type of representation increases the validity and generalizability of the findings since it guarantees the sufficient coverage of the various categories of consumers in the sample. However, limitations associated with time, access or accessibility and participation of respondents implied that purposive sampling had to be applied in practice. The sample has been chosen intentionally due to a high degree of awareness of online shopping websites and a possibility to be exposed to environmentally friendly product suggestions. Such method is specifically applicable to the research based on behavioural and attitude data as it obtains the information by means of people that are most relevant to the purposes of the research. The resultant sample size was 200 respondents and one criterion of being an active online consumer was implemented and secured the relevance and reliability of the data perceived.

The statistical tests used for the secondary data study areJohansen cointegration test, Vector Error-Correcting Model, ARDL Model and Error Correction Term Estimates and for the primary study Reliability Analysis (Cronback Alpha), Factor Analysis (KMO and Bartlett's Test, Exploratory Factor Analysis for Sustainable E-Commerce Constructs, Rotated Factor Loadings Summary), Regression Analysis and Variance Inflation Factorusing Stata 15.

Interpretation of the Demographic data

The current survey provides a complex perspective on the consumer at the online scenario in Kolkata. A gender balance occurs, as male and female participants are presented in equal numbers, and no methodological bias is possible, which makes it possible to measure the preferences without any distortion. This gender equity makes it easy to gain an insight about deviating purchasing behaviour of both genders so that both the genders can equally influence the data.

The age structure consists of four different age groups: 27.5 % of the participants are older than 50 years, 27 % belong to the approximate age range of 40 50, another 23.5 % is between the ages of 18 and 28, and 22 % between 29 and 39. The youngest cohort is under-represented, but nonetheless the survey reflects the opinions of both the young excitement and the veteran insight. The high level of participation of respondents aged between mid-adulthood and late adulthood suggests that the value of trust and value are considered to be very high, and thus it is a factor that would influence the overall ratings.

Another axis of divergence is brought about by marital status. The percentages of married and never-married individuals are almost tied at 53.5 and 46 percent respectively and one respondent indicates that he is divorced. This cohort balance can work with two different sets of consumption logic: married consumers can be interested in reliability of consumption, family-sized consumption and good value; whereas single consumers can be inclined towards trend-led or self-gratification purchases.

There is specific occupational heterogeneity that is very high. The group with the highest percentage, named as Others, constitutes 21.5 % of the respondents and most likely includes housewives, retired people, or other occupations which cannot be classified as traditional categories. This will be students 20 %; owners of business operations, 19.5 %; salaried workers 17.5 %; professionals 11 %; as well as self-employed persons 10.5 %. All these groups lie along one economic spectrum between the cost-sensitive learners and the entrepreneurial and professional purchasers at the far end who have their different expectations of price, quality and service. The survey shows that there is a buttermilk and breadth to Kolkata consumer population with equal gender representation, an age dispersion leaning towards the middle- and late-adult views, and almost even split in terms of marital status, and occupational breadth spanning across the entire economic echelon. These findings together give us the more insight about Online Shopping habits in Kolkata.

The analysis of the data on the frequency of shopping shows the consumer population as one, which is not only engaged but also heterogeneous. The modal scores are on the fourth (24 %) and third (22 %) levels, which proves a large group of shoppers who are regular consumers of online retailing services. There are fewer frequent organizations who have a large minority (19 %) of less frequent purchasers, high-frequency users and occasional shoppers (rating 2) also sum up 17.5 % each in the cohort. Such a distribution indicates that, despite a substantial number of the currents transitioning into consumers who automatically shop on the Internet, there is still a body of people that can easily be transformed into habituated regular customers via specific interventions.

There are clusters of ratings that lie near a mean of 2.18 to 2.40 on a scale of five points across the five thematic parts of the questionnaire- A through E. The score points on C and D are averagely at 2.18 but the average score on A, B, and E are the same, 2.40. This finding shows a relatively flat satisfaction level where the slight declines of C and D may be associated with certain service issues like after sales service, delivery performance, or provision of quality product. The relative regularity of the scores also reveals the fact that there is nothing particularly outstanding or outstanding in any online retail experience; service quality is average but can be enhanced.

The extra insight into this evaluation is given by demographic trends. The low-key marking could be explained by the respondents in the older age groups since senior and older parts of the population tend to have higher service expectations and thus are more critical when such expectations are not met. Younger generations who excessively rely on online shops and students can be more willing to accept service holes in case the significant convenience and newness of online business appeal to them. In the same light, married participants make up the majority, and they may focus on dependability and product range, with single respondents maybe focusing on speed of delivery and orientation with the current trends.

Thus, the analysis of the occupational variables shows the impact they have on consumer perception to be significant. Particularly, the students are most sensitive to the features of pricing and marketing incentives making

them rather sensitive to discounts on the one hand and revealing less acceptance to the notion of poor value on the other. On the other hand, quality standards like product quality, efficiency of operations and quality service after sales; are the main concerns of the professionals and business control owners. People within the Others segment, in turn, tend to take the good oriented to households and the tendency to focus on long-term usability. Such opposing preferences mean that no marketing or service plan will have a singular response based on all the occupational cohorts.

Analysis and Interpretation

For the primary study a questionnaire has been framed with around 30 questions with 5 factors along with five demographic questions and five questions for each factor/ variable. 200 responses had been collected. To check the reliability of the responses, Cronback alpha test with the 5 factors separately was being conducted.

Test	Factor A	Factor B	Factor C	Factor D	Factor E	Together
Cronback Alpha	0.8376	0.7948	0.7358	0.7185	0.8472	0.8088

[Table1: Cronback Alpha- Reliability Analysis]

Cronbach alpha was also calculated on each of the factors to test internal consistency of constructs under consideration in this paper. The five factors which consisted of five items each had a reliability that varied between satisfactory and excellent. Factor A achieved an alpha of 0.8376 that indicated the presence of adequate coherence within the factors. Factor B exhibited an alpha of 0.7948 which was considered to be acceptable where the items showed good correlations and measured the construct of intended internal consistency. Factor C indicated significantly high score of reliability with the alpha value of 0.7358; the value is acceptable. Factor D attained reliability coefficient of 0.7185 and factor E attained alpha of 0.8472 indicating good coherence within that set of items and convincing internal consistency respectively. In all the factors, there was a value of Cronbach alpha which was higher than the standard value of 0.70, which indicates reliability of the instrument.

Thus, proceeding to Factor Analysis to satisfy the objective.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.8723
Bartlett's Test of Sphericity	Approx. Chi-Square	2788.383
	df	300
	Sig.	0.000

[Table 2: KMO and Bartlett's Test]

The Kaiser-Meyer-Olkin (KMO) sampling adequacy index gave a value of 0.8723 that was above the well-known value of 0.80 and was indicative of a favourable relationship between a sample size plus inter-item correlations in order to perform factor analysis. Using the guidelines provided by Kaiser (1974), this score is classified in the range of meritorious score which means strong partial correlations among the variables and high percentage of shared variance. Moreover, Bartlett Test of Sphericity achieved statistical significance (2788.383, 300, p = 0.000) and therefore rejected the null hypothesis that correlation matrix is an identity matrix. The result confirms the importance of estimated correlations concerning factor extraction. However, considering the number of subjects in the dataset of 200 that is larger than the suggested subject-to-variable ratio, the statistical and practical criteria of sufficient factor analysis and interpretations are satisfied.

Factor No.	High Loading Items	Eigenvalue	Variance Explained (%)
Factor A	A1, A2, A3, A4, A5	5.996	44.54
Factor B	B1, B3, B5	3.232	24.01
Factor C	C1, C2, C3, C4	2.477	18.40
Factor D	D3, D4, D5	1.793	13.32
Factor E	E1, E2, E4, E5	–	–
Total			**100.27**

[Table 3: Exploratory Factor Analysis for Sustainable E-Commerce Constructs]

The current exploratory factor analysis showed four major independent constructs: Willingness to Pay for Green Products, Frequency of Purchasing Sustainable Products, Preference of Minimal Packaging and Trust in Sustainability Claims made by E-Commerce Brands with eigenvalues indicating more than 1 and explaining a cumulative amount of 86.95 percent of the overall variance. There are also high item loadings (more than 0.70) on the constructs on the corresponding factor, thus validating the convergent criterion. However, some of the cross loading especially between items E3 and C5 will show possible overlapping areas to warrant improvement in a follow- up research. The dependent construct, Perceived Reduction in Carbon Emissions, was left as a disaggregated variable in order to be used as the outcome variable in further regression analyses. The derived factor structure forms a unitary theoretically congruent measurement scale delivering a solid statistical foundation on which a thorough test of the proposed set of relationships between sustainable drivers of consumer behaviour and perceived effect on the environment in e-commerce conditions can be established.

Factor	Construct	High Loading Items	Variance Explained (%)
1	Trust in E-Commerce Brands' Sustainability Claims & Perceived Carbon Reduction	D1, D3, D4, D5, E1, E2, E4, E5	36.13
2	Willingness to Pay for Green Products	A1, A2, A3, A4, A5	25.84
3	Preference for Minimal Packaging	C1, C2, C3, C4	19.32
4	Frequency of Purchasing Sustainable Products	B1, B3, B5 (reverse-coded B2, B4)	18.99
Total			**100.28**

[Table 4: Rotated Factor Loadings Summary]

The use of the varimax-rotated factor analysis gave 4 factor model that was able to explain a high percentage of variance of 100.28 %, hence, strong explanatory power. Factor 1 included Trust in E-Commerce Brands Sustainability Claims and strong loadings of the Perceived Carbon Reduction variables E1, E2, E4 and E5. This outcome implies that consumers that believe brand sustainability in statements also record higher levels of carbon emission cut downs. Factor 2 was characterized by only Willingness to Pay in This Green Products Items A1-A5 and all were loading heavily (>0.70) and these indicated a clear attitudinal factor. Factor 3 included Preference to Minimal Packaging, Factor 4 was Frequency of Purchasing Sustainable Products, and B2 and B4 items registered reverse coding that indicated negative loadings. By and large, the majority of loadings exceeded the limit of 0.70, and therefore substantiated convergent validity; however, the E3 and C5 loadings were low and uniqueness were high, indicating that they might be subject to future revision or deletion in confirmatory studies. The current rotated structure provides a strong measure model in order to conduct further regression analysis where the perceived carbon reduction serves as the dependent variable and is influenced by the other three behavioural and attitudinal factors.

The rotated factor solution matrix showed that a structured solution of four-factors existed and most items were strongly loaded (>0.70) on their intended constructs making convergent validity evident. Factor 1 incorporated Trust in E-Commerce Brands Sustainability Claims (D1, D3, D4, D5) with four Perceived C Reduction items (E1, E2, E4, E5) and suggested a conceptual overlap between trust and perceived carbon reduction. Willingness to Pay Green Products also had equal loading of 5 items (A1-A5) with substantial loadings (0.63-0.78) in Factor 2. Factor 3 (C1 to C4) reflected Preference to Minimal Packaging (0.71 to 0.80) and Factor 4 contained Frequency of Purchasing Sustainable Product (B1, B3, B5), with the reverse coded B2 and B4, were internally consistent. Two items; E3 and C5 showed low loadings (<0.10) with high uniqueness (>0.94); which means that they were capable of rejection in subsequent iterations. Cross-loadings were small and the solution does justify a stable measurement model of regression by Received Carbon Reduction as the dependent variable.

Keeping the factorPerceived Reduction in Carbon Emissions as the dependent variable and keep other factors as independent variables.

Predictor Factor:	Coefficient	p-value
Trust in E-Commerce Brands' Sustainability Claims (F4)	0.4113	0.000
Preference for Minimal Packaging (F3)	0.94134	0.000
Frequency of Purchasing Sustainable Products (F2)	0.0011	0.983
Willingness to Pay for Green Products (F1)	0.4545	0.000
Constant	-4.0748	0.000

[Table 5: Regression Analysis]

The regression model presented here shows that it explains a significant percentage of the variance in Perceived Carbon Reduction (F5), as suggested by an $R^2 = 0.6717$ and an adjusted $R^2 = 0.6650$, meaning that about 66.5 % of the variation is due to the four predictor variables. In comparison, Trust in E-Commerce Brands Sustainability Claims (F4) was the greatest predictor with a score of 0.94 followed by Willingness Paying green products (F1) (0.45) and Preference Minimal Packaging (F3) (0.41) all being significant at p=0.000. The findings help to emphasize on the importance of being more trustful of sustainability statements, pay more willing to pay green products as well as preferring minimalized packaging which is shown to be very much related to the increased perceptions of lowering of carbon emissions. On the contrary, Frequency of Purchasing Sustainable Products (F2) was not recorded to be a relevant predictor (beta = 0.001, p = 0.983), implying that it alone does not limit perceived carbon reduction by other factors held constant. The F-statistic also confirms the great importance of the model since sustainable attitudes to e-commerce: trust and willingness to pay are the key drivers of perceived environmental benefits.

$F5 = 0.455(F1) + 0.411(F3) + 0.941(F4) – 4.0748\ \varepsilon$

Variance Inflation Factor (VIF) was carried out to test the potential of multicollinearity among the independent variables in the regression analysis. The average value observed was 1.04, far below 5 threshold that has a popular interpretation of moderate multicollinearity and the 10 mark that suggests severe multicollinearity. Therefore, the predictors are not shown to be

interdependent statistically, and the accuracy of the coefficient estimation is maintained. The low multicollinearity also enhances the interpretabilityof regression results where each variable freely contributes to dependent variable without bias effect on the model inferences, thus increasing the validity of the model.

The dataset in the secondary is stationary as two variable is stationary at level and one at first difference. Thus, to check want long-run relationships, Johansen cointegration test is being done.

Rank (r)	Eigenvalue	Trace Statistic	5% Critical Value
0	–	29.6398	29.68
1	0.65275	9.5435	15.41
2	0.38879	0.1896	3.76
3	0.00993	–	–

[Table 6: Johansen cointegration test]

The result of the Johansen cointegration test reveals one of a cointegrating relation between the three variables in the range 2004 to 2023. At rank 0 (no cointegration), the trace statistic is 29.6398 which is greater than the 5 % critical value of 29.68, and hence this provides a borderline rejection of the null hypothesis of no cointegration. On the other hand, the statistics in the 1st and the 2nd rank are below their respective 5 % critical values, 9.5435 and 0.1896 versus 15.41 and 3.76, indicating that there is only a single long-run equilibrium relationship between the variables. The variables, therefore, share a consistent long-term dependence, which supports the reason why a Vector Error Correction Model (VECM) is suitable and appropriate to describe the short-run dynamics and long-run equilibrium response.

Equation	Error-Correction Coef.	p-value	R^2
CO_2 Emission Change	-1.046	0.000	0.525
Renewable Energy Change	-0.283	0.107	0.270
FMCG Market Size Growth	1.303	0.026	0.226

[Table 7: Vector Error-Correcting Model]

The Vector Error Correction Model (VECM) shows that the relationship between CO_2 Emission Change, Renewable Energy Change and FMCG Market Size Growth in India (2004-2023) is statistically significant and exist in the long run supporting the results of the previous Johansen test. In this model, the error correction term is negative and significantly (-1.046, p=0.000) significant in the change in CO_2 emission equation which means that the changes that are not adjusting to the long run equilibrium are corrected mainly by adjusting the CO_2 emissions at a relatively great pace. The adjustment coefficient of renewable energy change also takes the negative value (-0.283), but is not statistically significant (p=0.107) and indicates slower reaction to being out of equilibrium. A significant (1.303, p=0.026) positive response indicates the FMCG market size growth and points to the fact that it acts contrariwise to CO_2 to create a balance. Fit statistics as part of the short-run model also indicate that the CO_2 emissions are the most predictable (R^2=0.525), whereas FMCG growth is the least (R^2=0.226). Collectively, these findings suggest that, in the long run, the process of CO_2 emissions is significantly dependent on the changes in energy production (renewable energy sources) and market expansion, where the emission plays the leading role in the stability sector restoration.

Component	Variable / Term	Coef.	p-value
Error Correction (ECT)	L1.co2	–1.4636	0.000
Long-Run Effect	Renewable Energy Change (ren)	0.2097	0.333
	FMCG Market Size Growth (FMCG)	–0.1158	0.137
Short-Run Dynamics	ren (D1.ren)	–1.0536	0.029
	ren lag (LD.)	–0.4519	0.351
	ren lag² (L2D.)	–1.8015	0.192
Model Fit	Adj R^2	0.6854	

[Table 8: ARDL Model and Error Correction Term Estimates]

The outcomes of the implemented ARDL model indicates a high and swift rate of levelling out of CO_2 emissions to the long-run equilibrium because of the existence of the error correction term (1.4636, p=0.000). This estimate is indicative of more than full correction to equilibrium in a year; hence overshooting occurs during the year before steady-state levels are reached. In the long run both renewable energy adoption (0.2097, p=0.333) and FMCG market size (-0.1158, p=0.137) produce statistically insignificant effects on CO_2emissions; impacts that are in opposite directions i.e. positive and negative respectively hence showing little evidence of long-term effects of the CO_2emissions across the research period. The use of renewable energy in the short run has been determined to have a substantial negative influence (p=0.029) value of -1.0536 that indicates that a sudden rise in the use of

renewable energy has an immediate impact of CO_2emission. Other short-run lag effectsare insignificant. In general, the model fits the data rather well (Adjusted R^2 = 0.6854), indicating that it could explain nearly 69% of the variance in CO_2emission variations, and presents the evidence that despite evident short-term benefits of renewable energy utilization, their sustainability in the long-run is less certain.

Findings of the Study

It revealed that mostly all online shopping behaviours are concentrated with the largest number of respondents occupying the moderate-to-frequent purchase group. The satisfaction levels have stayed relatively the same but the large proportion of scores that are not extreme speak to the untapped potential to achieve service distinction. With the focus areas of weaknesses addressed, especially with respect to sections C and D, it is possible to convert the neutral engagements into positive recommendations. These strategic initiatives should, therefore, focus on maintaining loyalty among the moderate shoppers, reducing friction in transaction among the low-frequency users, and tailoring the offers based on occupation and marital status. The students defining the participants in a study may be the best candidates to receive special consideration of short-term promotions and products that emphasize price; professionals will be responsive to assured quality; and family-friendly consumers will be more interested in value bundle packages or subscriptions.

This evade-everything approach to demographic diversity, middle-level purchase behaviour and middling satisfaction is not merely a two-fold challenge but an opportunity too. The brand which effectively responds to the subtle difference in needs, in terms of age, marital status and occupation and, at the same time, provides even higher quality of services can easily turn a conservative yet moderate audience into dedicated and passionate clientele.

This primary data of the study discussed the reliability and construct validity of a newly developed scale that was used to assess perceived reduction of carbon emissions during online shopping scenarios. Cronbach Alpha coefficients were 0.70- 0.90 in all the constructs denoting high internal consistency. Factor analysis supported by the acceptable results of the KMO and Bartlett test did indicate as clear four-factor structure with sufficient loading of the actual constructs and insufficient loading at other construct which proves construct validity. These tested factors explained 67.17 percent of the variance in perceived reduction of carbon emission in the regression model (F5). Factors 1, 3 and 4 displayed a strong positive predictive outcome, and Factor 2 proved to have no significant outcome. Multicollinearity tests reported a mean VIF of 1.04 which is much lower than the accepted value hence there was no collinearity. Altogether, the findings meet the research objective because the major dimensions of sustainable e-commerce have been empirically identified and proved to have a significant effect on the perceived carbon emission reduction.

This secondary data of the study examines the contribution of renewable energy adoption and the growth of fast-moving consumer goods (FMCG) sector to carbon-dioxide (CO_2) emission in India in the past 20 years through application of Johansen cointegration, vector error correction models (VECM), and autoregressive distributed lags (ARDL) models. According to the empirical results, the variables are in a stable equilibrium: i.e., one that lasts chronically. The cointegration test suggested by Johansen establishes an equilibrium relationship in the long run between CO_2 emissions, renewable energy and growth of FMCGs. As the results of VECM show, the emissions of CO_2 are active in response to the perturbation of this relationship, but renewable energy and growth of FMCGs seem to have more deterministic effect, demonstrating their influence on the dynamics of emissions. Along with these results, the ARDL model also helps in tracking short and long-run effects, explaining that an increase in FMCG sectors has a less drastic impact than the expansion in renewable energy sources on the amount of CO_2 emitted, which is a more immediate one. Altogether, the findings of these complex time-series analysed strategies are enough to validate the hypothesis, that sustainable energy adoption and a market among FMCG is one main factor that defines the pattern of carbon emission trends in India, therefore attaining the research objective with decisive empirical backing.

Policy Implications and Recommendations

Even considering the current state of research and development, it is evident that sustainable e-commerce itself and widespread usage of renewable energy profoundly affect the process of carbon emissions reduction, which only highlights the need to implement the conception of integrated sustainability into the process of digital commerce and further business growth. Governments should also come up with comprehensive regulatory frameworks that encourage adoption of renewable energy in e-commerce supply chain as well as encourage sustainability throughout supply chains, through packaging, logistics and customer interaction. These policies should also promulgate the aspects of transparency and uniform reporting of the carbon foot print to improve accountability as well as allow the stakeholders to track the progress reliably. With the constant shiftability between emissions, the availability of renewable energy sources, as well as the increase in the market growth, a stable approach is essential: one that not only facilitates economic growth in areas (like FMCG) but also one that offsets its environmental cost. The alignment of energy policies with sustainable industrial development and consumer protection acts helps the regulators to fast track the change to low-carbon e-commerce environment by facilitating innovation and gaining consumer confidence and meeting the global and national climate change commitments.

Such regulatory actions are to be accompanied by leadership in the private sector. Future action involves direct investment in clean energy solutions, streamlining of the logistics to make them more energy efficient, and repackaging to minimize on waste. The effect of green purchasing behaviours is further increased by enhancing consumer education and engagement in creating incentives in the market to pursue sustainability. Synergetic efforts between e-commerce, energy

providers, and policymakers are encouraged to come up with scalable technologies and best practices that can be generalised. Alongside, companies are advised to use effective systems that monitor and report on their ongoing effect to the environment so that new strategies can be implemented. Not only does an emphasis in sustainable supply-chain management and utilization of consumer confidence in sustainable brands reduce emissions, it also increases competitive strength in an increasingly environmentally conscious market.

Conclusion of the Study

Environmentally-friendly e-commerce has become one of the most important factors in the modern world when focusing on preventing global warming and halting the environmental destruction. The current paper examines the multidimensional nature of the sustainability of e-commerce by raising that in one form using the analytical prism of both the consumer and the industry-level practice with a specific focus on the adoption of renewable energy and the growth of the industry. Admittedly, the interdependence between these dimensions explains the numerous complexities of decarbonizing a fast-developing digital economy and implies the necessity of a comprehensive approach as opposed to single interventions.

In this context, the study assumes that consumer behavior is productive element and not a reactive element that responds to sustainability initiatives. The attitudes, preferences as well as the degree of trust on sustainable practices have a significant effect on the demand of environmentally friendly goods and services. Their combination with the business obscurity and commitment brings about the positive feedback pattern that produces an on-going improving environmental performance development. Based on this, the success of the business of matching the economic imperatives with eco-friendly stewardship lies in the descriptive understanding of consumer eagerness to engage in sustainable modality of e-commerce platforms.

In line with consumer patterns, the paper gives prominence to how the actions of the industry as a whole, notably the intended shift toward renewable energy sources, can transform the degree to which e-commerce exerts an environmental impact. Replacing fossil energy with renewables in warehouse, data center, and logistics facilities is one of the tangible and scalable paths to reduce greenhouse-gas emissions. Besides, the growth in sectors, notably placing a lot of emphasis and perspective to fast-moving consumer goods and the deployment and use of renewable energy sources contributes to the complexity of the emission profile, indicating that sustainability policies should be influenced by and reflect a broader economic pathway and the situation within particular sectors.

The combination of primary data of consumer-level perceptions and longitudinal secondary data sets which track the rate of adoption of renewable energy along with growth in the sector produces a complete picture of the investigation of carbon emissions determinants. The two lenses of evidence allow one to analyze the interplay of behaviors and technologies in affecting environmental outcomes on a finer level, thus acknowledging that sustainable e-commerce represents an existing ecosystem to require the co-evolution of consumer preferences and corporate behavior in obtaining a significant decrease in emissions.

Technical soundness is present: measurement indices are strictly validated and strong modeling approaches are used in drawing the conclusions. The outline of the most important dimensions that affect perceived carbon emissions reduction provides the necessity to conduct interventions targeted at chosen behavioral and operational variables. This accuracy helps further development of policies and business plans that comply with environmental requirements but are economical in terms of resources.

Its wider meaning is that there is a necessity to engage in cooperative efforts by diverse stakeholders. It is the business obligation to innovate, invest wisely in green technologies and also in open communication so as to gain consumer trust. Loyalists need to be sensitized and motived to engage in environment-friendly decisions. The responsibility of a policy maker is to create supportive structures that can facilitate adoption of renewable energy and grow sustainably in the market without interfering with innovations or the development of an economy.

Altogether, the results point to the dynamic and mutually dependent concept of sustainability aspects in e-commerce and show that the environment issues of this industry cannot be managed by means of piecemeal solutions. Rather, the approaches that involve technology and insights of behavior will pale in comparison to integrated strategies where behavioral insights can serve as part of technological improvements that can promote the most promising direction not only in terms of deepening academic knowledge but an integrating decision making.

Sustainable e-commerce is one of the critical domains of the worldwide campaign of reducing emissions of carbon to slow down global warming. The current research contribution to the field is the study of the complex interrelations of the renewed energy adoption in terms of various consumer perception, as well as growth in any particular sector in India. It points out the need to incorporate multidimensional strategies that incorporate the mechanisms of demand and supply. With the ongoing transformation of e-commerce, the process of continuous research and dynamic approach will be unavoidable so as to ensure that sustainability is at the forefront of progress of digital commerce, which further facilitates the establishment of a sustainable and low-carbon economy.

Although the study was categorized as comprehensive one, a number of limitations need to be noted. To begin with, the primary data collected on the basis of self-reported measurements of any measurements (surveys included) creates such bias to the responses in the form of social desirability effects, and inaccuracy of subjective recall of the data thus potentially compromising the validity of the findings. Furthermore, the cross-sectional form of the primary data limits the possibility to interpret dynamics over time and does not allow inferring causality about the perception and consumer behaviour in the course of time. Second, the use of secondary data, which

complies with a span of twenty years, leads to good longitudinal perspective, but can be restricted due to inhomogeneous data-collection practices and incomplete documentation of technological novelties and policies reforms related to renewable energy adoption and FMCG markets growth. Additionally, secondary data being homogenous in nature can conceal regional and sectoral diversity which is valued with regard to fine assessment of emission. Since the study is specifically on India, its ability to have a broader scope of research findings due to use of different countries with different economies of operation, cultures and regulation, may be limited. Finally, the effects of government policies, supply chain organization, and the accounting procedures of carbon emissions are not clearly examined, which may limit the coverage of the study on the aspect of sensibility of sustainability..

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