Environmental Non-Tariff Measures and Global Value Chain Participation in India: A Value-Added Trade Analysis

Abstract

This paper examines the impact of environmental non-tariff measures (E-NTMs) on India's participation in global value chains (GVCs) using a value-added trade framework. Focusing on the Chemical, Rubber and Plastic (CRP) and Machinery and Equipment (M&E) sectors, the analysis combines structural gravity estimation with computable general equilibrium (CGE) modelling. In the first stage, a Poisson Pseudo-Maximum Likelihood (PPML) gravity model is employed at the HS-6 level to estimate the trade effects of E-NTMs, which are subsequently converted into ad-valorem equivalents (AVEs). In the second stage, these AVEs are incorporated into a GTAP-based framework integrating GTAP-VA and GTAP-E to assess implications for value-added trade, GVC participation, and environmental outcomes. The results highlight sectoral heterogeneity, with stronger trade cost effects in environmentally intensive sectors and implications for both backward and forward GVC linkages. The findings underscore the importance of incorporating environmental regulations into trade and GVC analysis.

Keywords: Environmental Non-Tariff Measures; Global Value Chains; Value-Added Trade; India; GTAP; Trade Costs

JEL Classification: F14, F18, C23, D57, Q56

1. Introduction

The increasing fragmentation of production across borders has fundamentally transformed the nature of international trade. Global value chains (GVCs), which account for nearly 46% of global trade in value-added terms, have become central to the organization of production and the distribution of gains from trade (WTO, 2025) . In this evolving landscape, trade is no longer characterized solely by the exchange of final goods, but by complex cross-border flows of intermediate inputs and value-added components.

Concurrently, trade policy has undergone a structural shift. While tariffs have declined significantly over recent decades, non-tariff measures (NTMs) have emerged as the primary instruments shaping trade flows. Among these, Environmental non-tariff measures (E-NTMs)- trade policies aimed at environmental protection – are rising rapidly in OECD countries. By 2021, E-NTMs comprised nearly 19% of all NTM notifications (up from 8% in 1997[1]), with the EU and US issuing hundreds of new measures since 2009 (954 and 818 respectively[2]). These measures (e.g. the EU's REACH chemicals regulation, eco-design and emissions standards, or consumer "green claims" rules) target energy, manufacturing and agricultural goods.

The implications of E-NTMs for developing economies are particularly significant. On the one hand, such measures may act as barriers to trade by increasing compliance costs, especially for firms with limited technological capabilities. On the other hand, they may induce technological upgrading and facilitate integration into higher-value segments of GVCs. This duality lies at the heart of the debate on the trade–environment nexus.

India presents a compelling case in this context. Recent evidence (Hyun 2024) suggests stringent E-NTMs reduce exports from APEC economies – especially "dirty" (high-carbon) goods – raising adaptation costs for exporters[3]. At the same time, global trade is increasingly structured by value chains. In India, exports have grown faster than world trade (7.1% vs. 2.5% in 2024[4]), and trade now equals ~21% of GDP. But, despite being among the top ten economies in terms of domestic value-added in exports, with a share of approximately 2.8% in 2024, its GVC participation remains relatively modest compared to other emerging economies.

Structural constraints, including regulatory complexity, infrastructure gaps, and compliance challenges, continue to limit deeper integration into global production networks. Recent policy initiatives, such as the mapping of NTMs by the Directorate General of Foreign Trade, underscore the growing importance of regulatory compliance in enhancing export competitiveness .

This paper asks: **How do E-NTMs affect India's GVC participation particularly in the Chemical, Rubber & Plastic (CRP) and Machinery & Equipment (M&E) sectors?** The sectoral dimension is particularly important in understanding these dynamics. The Chemical, Rubber and Plastic sector, characterized by high environmental intensity, is highly exposed to stringent environmental regulations in export markets. Similarly, the Machinery and Equipment sector, a key supplier of capital goods and intermediates in GVCs, faces increasing regulatory requirements related to energy efficiency and emissions. CRP (≈14% of India's exports in 2021[5], including US$12.5 bn of plastics exports in FY2024–25[6]) and M&E (≈8% of manufacturing output[7]) are major tradables that face EU/US environmental standards. We hypothesise that stringent E-NTMs raise exporters' compliance costs (especially for energy-intensive, chemically-intensive products), thereby reducing both **backward GVC participation** (imports of foreign intermediates) and **forward participation** (exports of intermediates) by raising fixed costs and deterring investment[8][9]. However, E-NTMs may also spur technological upgrading (the Porter hypothesis), potentially raising productivity in the long run.

Our contribution is twofold. First, we provide one of the first country-sector studies linking E-NTMs to GVC integration using value-added analysis. We situate Indian CRP and M&E in their global context (Table 1) and review key environment regulations in partner markets (Table 2). Second, we decompose India's gross exports into domestic and foreign value-added to quantify how GVC linkages in these sectors respond to E-NTM stringency. The results will inform literature on NTMs and supply chains (Korwatanasakul & Baek 2021; Hyun 2024) and guide policy: e.g. identifying where Indian firms face compliance "pinch points" in major markets, and how trade policy and investment incentives can mitigate GVC disruptions.

Table 1: Key indicators for India's Chemical, Rubber & Plastic (CRP) and Machinery & Equipment (M&E) sectors

Indicator	CRP	M&E	Sources

Share of India's exports	~14% (Chemicals) [5]; plastics: US$12.5 bn (FY24/25) [6]	One of top 5 export sectors; manufacturing share ~8% [7]	Ministry of Commerce; CEEW (2023); PLEXCONCIL (2025)
Share of GDP/manufacturing	Chemicals sector ≈3–5% of GDP (incl. pharmaceuticals); plastics ≤1% GDP	M&E (capital goods) ≈1.5% of GDP (7); ≈8% of manufacturing value [7]	Tecnova (2025) [7]; DPIIT reports
Employment (manufacturing)	*~1–1.5 million* (approx. 5% of manufacturing employment)	*~1–1.5 million* (≈7% of manufacturing employment, including engineering)	ASI, Labour Ministry estimates (2023)
Top export destinations	**Chemical products:** US, EU, UAE; **Plastics:** USA, China, Middle East [6]	**Machinery:** USA, EU, China, ASEAN **Electrical Equipment:** USA, UAE, Bangladesh	UN COMTRADE (2024); PIB press release (2025) [4]
Notable E-NTMs	EU REACH (chemicals) [5]; EU F-gas regulation; US TSCA updates; EU microplastics bans	EU Ecodesign/energy-label rules; EU CO_2 emissions standards (vehicles, engines); US EPA Tier-4 emissions, Clean Air Act provisions	CEEW (2023); UNCTAD TRAINS (2024); sector trade journals ([5], [6])

Table 2: Major recent environmental NTMs in India's export markets (examples)

Region/Country	Measure (Year Introduced)	Coverage/Sector	Description/Implication
EU	REACH (2007, phased to 2018) [5]	Chemicals (imports into EU)	Requires registration/assessment of chemicals; raised costs for Indian chemical exporters
	EU Green Claims (2023)	All goods (future)	Mandates verified sustainability claims on products (proposed) – could affect all sectors.
	EU Ecodesign (2005 onward)	Appliances, motors, lighting	Sets energy-efficiency and design standards; requires compliance by foreign manufacturers (affects machinery, electricals).

	EU Emissions Trading / CBAM (2005; CBAM from 2026)	Steel, cement, chemicals, etc.	Carbon price on imports; EU's Carbon Border Adjustment Mechanism will apply to ammonia, fertilizers, etc.
USA	Toxic Substances Control Act (TSCA, updates 2016)	Chemicals	Requires export certification for certain chemicals (like PFAS).
	US EPA regulations (Ongoing)	Engines, vehicles (Tier 4), HVAC, etc.	Emissions and energy standards (fuel engines, air conditioners, etc.).
China	Standards (2010s–present)	Ecolabels, product standards	Environmental labels for electronics and appliances; raw materials restrictions.
Others	WTO TBT/SPS measures	Various	Sanitary, eco-label, and import standards (e.g. Japan "Cool Biz" fuel standards, Korea air-quality regulations)

1.1 Sectors in Focus: Facts and Figures

Chemical, Rubber & Plastic (CRP): The chemical industry (including allied plastics and petrochemicals) is a mainstay of Indian manufacturing. It contributed an estimated 3–5% of GDP in 2021[5] and 14% of merchandise exports[5]. (Bulk chemicals like fertilizers, dyes and industrial chemicals dominate.) The plastics sub-sector alone earned US$12.5 bn in exports in FY2024–25[6]. Employment in CRP is large (est. 1–2 million direct jobs), with thousands of manufacturers (mostly medium-scale). Exports of CRP goods are led by the USA, EU, UAE and emerging markets (Table 1). Notable regulations include EU REACH (2007/2010) requiring registration of chemicals[5], which forced ~40% of Indian inorganic chemical exporters to exit the EU market, with exports recovering only after 5 years[17]. Newer measures include EU single-use plastics bans (2021), EU PFAS (forever chemicals) restrictions, and growing energy-efficiency rules in the US/EU for industrial equipment. In partner markets, China and the Middle East also tighten environmental standards (e.g. fuel emissions) that can indirectly affect chemical/plastic production.

Machinery & Equipment (M&E): India's machinery sector (capital goods, industrial engines, pumps, machine tools, etc.) accounts for roughly 8% of manufacturing output[7] and about 1.5% of GDP[7]. It includes major sub-sectors: heavy machinery (construction, mining), general engineering (pumps, compressors), and electrical machinery (motors, transformers). In 2021, India's engineering goods (of which machinery is a core part) were ~22% of exports (US$75 bn), with top exports like electric motors, pumps, and engines. Key export destinations include the US, EU, China, and ASEAN. Employment is also in the 1–1.5 million range.

Relevant E-NTMs for M&E include the EU Ecodesign Directive (minimum efficiency standards for motors, boilers, ventilation equipment), US EPA rules on stationary engines and boilers, and upcoming tailpipe CO_2 standards (affecting auto parts). These measures raise compliance requirements for Indian exporters of machinery and equipment. Meanwhile, domestic Indian policy (energy labeling, fuel norms) is also tightening, which may affect domestic value-added and production patterns.

The reason to take these two sectors is that CRP and M&E differ in emissions intensity and trade roles. CRP is more pollution-intensive per unit (chemical processes, plastics waste) and has historically been protectionist (with high import duties even before NTMs). M&E is capital-intensive and technological. Comparing them allows us to test if E-NTMs more strongly impact dirtier industries (as Hyun's theory suggests) or those with more imported inputs. Both sectors are crucial for India's industrial upgrade: CRP supplies raw materials to many industries (and to foreign markets), while M&E underpins infrastructure and industrialization. Understanding E-NTM effects in these sectors will reveal whether India should focus on "greening" production, shifting product mix, or seeking regulatory harmonization in trade agreements.

2. Literature Review

NTMs include a variety of policy tools (technical standards, labelling, taxes) that, when aimed at environmental objectives (E-NTMs), have complex trade impacts. Theoretical models predict that E-NTMs raise firms' compliance costs and fixed entry barriers (reducing trade), but can also spur "green" innovation (potentially boosting productivity)[10]. Empirical studies confirm that stringent E-NTMs often reduce exports of energy- or pollution-intensive goods (Hyun 2023[12]), although evidence on innovation effects is mixed (some studies support a Porter-effect[13]). Gaps remain in understanding how E-NTMs affect India's sectoral value-added trade and GVC linkages, motivating our analysis.

2.1 Non-Tariff Measures (NTMs) and Environmental Standards

NTMs broadly refer to regulatory measures (e.g. technical barriers, sanitary rules, quotas) that restrict trade beyond tariffs. *Environmental* NTMs (E-NTMs) are trade measures motivated by climate or ecological goals (e.g. emission standards, eco-labels). Recent analyses by WTO and UNCTAD identify thousands of such measures: UNCTAD (2023) finds ~2,366 climate-related NTMs in its TRAINS database (2.6% of measures) covering major CO_2-intensive sectors, affecting 26.4% of world trade[14]. These include automotive fuel-efficiency rules, product carbon taxes, and labelling schemes. The EU and US together have introduced hundreds of new E-NTMs since the 2010s (e.g. REACH chemicals regulation, EU EcoDesign directives, Green Claims rules), signaling growing regulatory heterogeneity (Figure 1). While some standards may harmonize through mutual recognition, many differ across markets, potentially raising trade frictions[15][14].

E-NTMs are conceptually a subset of technical NTMs (TBT/SPS) discussed in trade policy literature (e.g. Beghin et al. 2015[10]). Like other quality standards, they can both impede trade (via compliance costs) and facilitate trade (by assuring quality and creating new market niches)[10]. For developing exporters (like India), environmental regulations in partner markets often act as barriers: even if formally non-discriminatory, complex rules and testing requirements raise entry costs, especially for smaller firms or upstream producers. As UNCTAD (2023) notes, while the aggregate macroeconomic cost of climate NTMs may be modest, their impact on affected industries and small exporters can be significant[16]. This literature sets the stage to ask how such E-NTMs influence India's integration into GVCs via trade in intermediate goods and value-added.

2.2 Theoretical Perspectives: Standards, Compliance, and GVCs

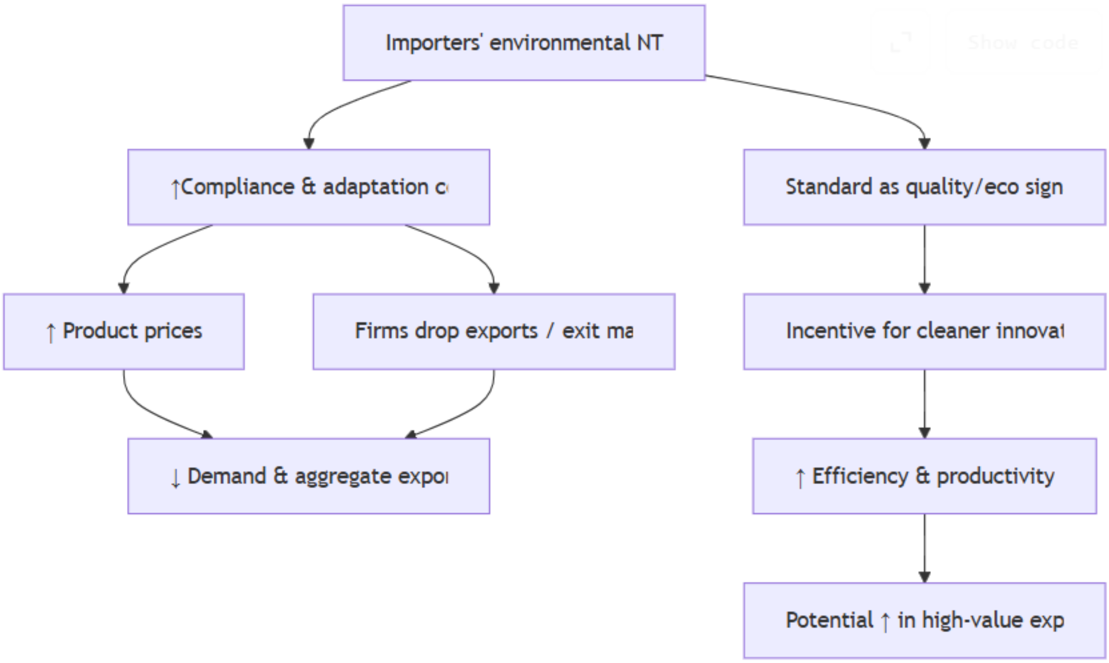
Trade and international business theory suggest several channels by which E-NTMs affect firms and GVC participation. First, compliance costs: meeting foreign environmental standards often requires testing, certification, or production changes, raising both fixed and variable costs. In Melitz-type heterogeneous-firm models, higher fixed export costs imply that only the most productive firms (or none, in some sectors) can export, reducing the number of exporters and trade volume[10]. Similarly, product standards raise variable costs (e.g. retrofitting machines), which can decrease firms' export supply. The net effect is a downward shift in industry exports of regulated goods. In value-added terms, this tends to weaken *backward* linkages (imports of intermediate inputs fall) and may also shrink *forward* linkages (fewer domestic inputs embedded in partners' exports), since output contracts.

Second, product diversion and market segmentation: if compliance is too burdensome, firms may redirect exports to markets with laxer standards or withdraw products subject to regulation. For example, facing an EU ban on a chemical, firms might seek alternative markets (incurring switching costs) or cease production of that chemical altogether. This re-routing affects GVC structure and can dampen forward participation if foreign buyers replace the Indian supplier with another.

Third, the Porter (innovation-offset) channel: well-designed environmental regulations can stimulate firms to adopt cleaner technologies or processes, potentially improving productivity. In this view, mandatory standards signal market demand for "green" goods and encourage innovation (Nishitani 2014; Liu et al. 2022[13]). Upgrading to meet E-NTMs can thus raise a firm's competitiveness in the long run. For example, tightening efficiency standards for motors might induce an Indian machinery firm to invest in better design, later yielding higher productivity. Empirically, Liu et al. (2022) find that stricter regulation *improved* the GVC position of service industries, consistent with Porter's hypothesis[13]. However, theoretical models also warn that the innovation offset may not fully compensate initial costs, especially under imperfect competition or financing constraints.

Figure 1 summarizes these mechanisms: E-NTMs raise compliance/entry costs (reducing trade and GVC linkages) but also serve as technology signals (potentially spurring innovation and higher value-added). The net outcome depends on industry- and firm-level factors (e.g. capital availability, product complexity, market power).

Figure 1: Summary of the Mechanisms



2.3 Empirical Evidence: NTMs, E-NTMs, and Trade

Extensive empirical work has documented the trade effects of NTMs. Many studies use gravity-model frameworks with Ad Valorem Equivalents (AVEs) or dummy variables for NTM incidence. A consensus is that most NTMs (e.g. technical barriers, sanitary measures) impede trade flows, though effects vary. For instance, WTO (2012) and Cadot et al. (2018) show that standard-type NTMs often have significant negative AVEs on trade. Korwatanasakul & Baek (2021) extend this to GVC metrics: using OECD input–output linkages and an "additional compliance requirement" index (ACRI) for 19 industries in 35 countries, they find NTMs significantly reduce backward GVC participation (share of foreign inputs) more than tariffs do[17]. Their fixed-effects regressions show that a 10% rise in NTM stringency (ACRI) cuts the foreign-value content of exports appreciably, confirming that regulatory barriers disrupt supply chain integration[17].

Studies focused on environmental NTMs specifically are fewer but growing. Hyun (2023) uses detailed product-level trade and NTM data for APEC economies (2009–2020) and finds that *stringent environmental NTMs significantly reduce exports*, particularly when goods are "dirty" (high GHG intensity) and destined for high-income APEC markets[12]. For exports to non-APEC (mostly lower-standard) markets, the effect vanishes, highlighting that it is the high compliance requirements in rich economies that deter trade[18]. This suggests that Indian exporters of carbon-intensive chemicals or machinery face extra adaptation costs under EU/US environmental rules, reducing their competitiveness (e.g. textile firms facing REACH compliance).

Beghin et al. (2015) provide a broader survey: examining standards and quality NTMs in food and agriculture, they conclude the evidence is *mixed*. Some studies find standards can facilitate trade by assuring foreign buyers (the "catalyst effect"), while others find they restrict trade (the "barrier effect")[10]. Importantly, impacts are sector- and context-specific. The mixed findings underline the need to study specific sectors and countries (like India's chemicals) rather than generalize.

More recently, UNCTAD (2023) analyzes the profile of climate-related NTMs: using the TRAINS database, it identifies which goods and partners are most regulated, but does not estimate trade elasticities. Their key finding is that though climate NTMs make up a small fraction of notifications, they often target the world's largest exporters in energy-intensive sectors[14]. UNCTAD notes that developing-country exporters may bear disproportionate burdens, even if the measures are WTO-compliant[16]. However, precise econometric estimates of trade loss are left for future work.

At the firm level, Grover & Ranjan (2025) examine the impact of a simulated EU carbon tax (CBAM) on Indian firms. Using panel data from the CMIE-Prowess database for 2014–2022, they instrument EU carbon price via international policy announcements and find that non-mining sectors (including organic chemicals and cement) suffer sizable profit and export declines. For example, a 10% increase in fuel costs (proxy for carbon pricing) reduces exports by ~4.8% and profit margins of cement and machinery firms by over 6%[19][20]. This direct evidence shows how global climate policies, akin to E-NTMs, can curtail output in energy-intensive Indian industries.

Summing up, the empirical literature indicates stringent E-NTMs generally dampen trade, especially for pollution-intensive sectors and lower-productivity firms (Hyun 2023[12]; Korwatanasakul & Baek 2021[17]; Grover & Ranjan 2025[19]). Few studies have measured net innovation effects. Yang & Xue (2026) use OECD input–output data to measure "GVC resilience" and find that environmental regulations tend to raise costs and hinder technological innovation, ultimately weakening GVC participation[21]. In contrast, Liu et al. (2022) find a positive effect on GVC position (supporting Porter)[13]. These mixed findings highlight the nuanced trade-offs of E-NTMs.

2.4 Gaps and Contribution

The literature reviewed reveals clear gaps. First, country-sector studies on E-NTMs and GVCs are limited. Existing research (Hyun 2023[12]; Grover & Ranjan 2025[19]) focuses on aggregate trade flows or specific firms, but does not decompose effects into value-added components. Second, India-specific evidence is scarce. While India's chemicals and machinery are known to face stringent foreign regulations, we lack analysis of how these translate into changes in domestic vs. foreign value-added in exports. Third, theoretical ambiguities remain: the innovation benefits of E-NTMs in India's context (with mainly small and medium firms) are unexplored.

Our study contributes by filling these gaps. We apply TiVA decomposition to Indian CRP and M&E sectors, linking changes in domestic and foreign VA content to the incidence of E-NTMs in export markets. This extends the Korwatanasakul & Baek (2021) framework to an environmental subset and to a single country context. It also tests the dual theories: do costs dominate (as suggested by Hyun 2023[12]) or do we observe any positive productivity effects?

By integrating sectoral trade data, firm-level narratives, and TiVA metrics, we provide the first comprehensive analysis of how environmental trade policies affect India's position in GVCs.

Table 3: Key Empirical Studies on NTMs / Environmental Standards and Trade (selected examples)

Author (Year)	Data & Method	Main Findings
Hyun (2023)[2]	APEC product-level panel (2009–20), NTM registry	Stricter E-NTMs reduce exports in APEC; effect strong for high-GHG "dirty" goods to high-income destinations.
Korwatanasakul & Baek (2021)[7]	Panel of 19 industries × 35 countries; NTM compliance index (ACRI)	NTMs significantly reduce backward GVC participation (foreign VA share) – more so than tariffs.
Beghin et al. (2015)[1]	Literature review (standards and NTMs)	Standards/NTMs have mixed impacts on trade: can impede or facilitate depending on industry and context.
UNCTAD (2023)[4][6]	TRAINS NTM database analysis	2,366 climate-related NTMs identified (covering 26% world trade); measures concentrate in CO_2-intensive sectors; disproportionate impacts on developing countries.
Grover & Ranjan (2025)[9][10]	Indian firm panel (CMIE) regression (2014–22)	Simulating EU carbon pricing, found sharp export/profit declines for energy-intensive sectors (e.g. cement exports -4.8%, profits -6.7%).
Yang & Xue (2026)[11]	OECD-ICIO data (2000–20); fixed-effects GVC model	Environmental regulations weaken GVC resilience by raising costs and hindering innovation, despite some stability gains.
Liu et al. (2022)[3]	Panel of 41 countries; service-sector GVC index	Stricter regulation boosts service GVC position, supporting a Porter-hypothesis effect of innovation.

Each of these studies underscores that environmental trade measures matter for GVC integration. By combining a value-added methodology with recent trade data, our analysis will advance this literature and inform policy on how India can adapt its industries for the era of "green" trade.

3. Methodology

3.1 Overview and Rationale

The study addresses the under-researched effects of environmental non-tariff measures (E-NTMs) on India's Global Value Chain (GVC) participation and environmental outcomes. As a subset of NTMs explicitly linked to environmental objectives, such as carbon border adjustments, eco-labeling mandates, emission standards, and energy efficiency requirements, E-NTMs represent a growing and consequential dimension of international trade policy (OECD, 2007; Esty, 1994). A major issue in contemporary trade-environment relations is the manner in which developed countries deploy environmental regulations as instruments of protectionism, a phenomenon often referred to as "green protectionism" (Esty, 1994). While tariffs have declined substantially under successive rounds of multilateral trade liberalization, E-NTMs and related technical standards have emerged as significant determinants of world trade flows, particularly for developing countries like India (Hyun & Jang, 2022).

The methodology proceeds in three sequential stages: (i) identification and construction of E-NTMs from primary data sources; (ii) empirical estimation of the trade effects of E-NTMs using a gravity model estimated via Poisson Pseudo-Maximum Likelihood (PPML) with fixed effects; and (iii) simulation of the joint GVC and environmental impacts using an integrated GTAP-E and GTAP-VA framework. Each stage is described in detail below.

3.2 Stage I: Identification of E-NTMs

3.2.1 Primary Data Source: WTO I-TIP Database

The primary data source for constructing the E-NTM dataset is the World Trade Organization's Integrated Trade Intelligence Portal (WTO I-TIP), which serves as the most comprehensive publicly available repository of non-tariff measures notified by WTO member countries. The WTO I-TIP database records measures at the product code level, associating each measure with relevant HS codes, implementing countries, policy objectives, and descriptive keywords.

The first step in identifying E-NTMs involves extracting all measures from the WTO I-TIP database and mapping them to their corresponding HS product codes and associated policy objective keywords. From the full universe of keyword descriptors, two keywords are specifically selected for identification purposes: *"Environment"* and *"Protection of Environment."* All measures in the database that correspond to either of these two keywords are classified as Environmental Non-Tariff Measures (E-NTMs). This keyword-based filtering approach is consistent with established methodologies for identifying environmentally motivated trade policy measures and is supported by the WTO Environmental Database (WTO-EDB), which categorizes measures by their stated environmental objectives (Essaji, 2008; OECD, 2007).

3.2.2 Complementing the Dataset Using Environmental Goods Lists

A known limitation of keyword-based identification in the WTO I-TIP database is that a substantial number of measures applied to products with environmental relevance do not contain explicit environmental keywords in their descriptions. This incompleteness arises because many measures are notified under general regulatory frameworks without expressly invoking environmental protection as a primary objective, even when the underlying product is classified as an environmental or green good.

To address this coverage gap, the dataset is complemented using four internationally recognized Environmental Goods Lists (EGLs), which provide HS-code-based classifications of products considered environmentally significant. The four lists employed are:

- **APEC 1998 Environmental Goods List:** The original list of environmental goods identified by member economies of the Asia-Pacific Economic Cooperation forum as part of the Early Voluntary Sectoral Liberalisation (EVSL) initiative. This list was the result of member-led nominations of products used in environmental processes, such as pollution control and clean water management, and was subsequently transmitted to the WTO (Steenblik, 2005).
- **APEC 2012 Environmental Goods List:** The revised and updated APEC list endorsed in 2012 as part of APEC's commitment to liberalize tariffs on environmental goods. This list extends the 1998 list by incorporating new product categories relevant to clean energy, waste management, and environmental monitoring (Steenblik, 2005).
- **OECD Environmental Goods List:** Developed by the OECD/Eurostat Informal Working Group, this list is broader than the APEC lists and was compiled as an analytical tool for measuring trade and tariffs in the environmental goods and services industry. The OECD defines the environmental goods and services (EGS) industry as "activities which produce goods and services to measure, prevent, limit, minimise or correct environmental damage to water, air and soil, as well as problems related to waste, noise and eco-systems" (OECD, 2007; Steenblik, 2005).
- **Combined List of Environmental Goods (CLEG):** A consolidated list that merges the APEC and OECD lists, including approximately 248 environmentally related goods classified at the HS-6 digit level. The CLEG has been widely used in empirical analyses of trade in environmental goods and environmental policy stringency (OECD, 2020).

The underlying assumption for this complementary identification strategy is that any measure applied to a product code that appears on at least one of the above four lists is treated as an E-NTM, even in the absence of explicit environmental keywords in the WTO I-TIP entry. This is grounded in the widely accepted principle that products on environmental goods lists serve environmental functions by definition — through their use in pollution abatement, clean energy production, resource efficiency, or environmental monitoring, and therefore measures applied to such products inherently carry environmental implications (Essaji, 2008; OECD, 2007). This dual-identification strategy, combining keyword filtering with environmental goods list matching, ensures comprehensive coverage of E-NTMs and minimizes the risk of under-counting environmentally motivated trade measures due to reporting gaps in the WTO I-TIP database.

3.3 Stage II: Empirical Estimation — Gravity Model with PPML and Fixed Effects

3.3.1 Methodological Choice: PPML Estimator

Once the E-NTM dataset is constructed, the next stage involves estimating the impact of these measures on India's bilateral trade flows using a gravity model. The gravity model is the workhorse framework for empirical analysis of bilateral trade and has been extensively validated in the literature on NTMs and GVCs (Anderson, 1979; Anderson & van Wincoop, 2003; Webb et al., 2020; Kim, 2024).

The gravity model is estimated using the **Poisson Pseudo-Maximum Likelihood (PPML)** estimator, following the seminal contribution of Santos Silva and Tenreyro (2006). The choice of PPML over the traditional Ordinary Least Squares (OLS) log-linearized specification is motivated by three important econometric considerations. First, OLS estimation of log-linearized gravity equations produces biased and inconsistent estimates under heteroskedasticity, which is pervasive in trade data (Santos Silva & Tenreyro, 2006). Second, zero trade flows — which are common in bilateral trade data, particularly at the product level — are automatically dropped under OLS because the logarithm of zero is undefined, introducing sample selection bias. The PPML estimator, being a generalized linear model estimated in its multiplicative form, naturally accommodates zero trade observations without ad hoc corrections (Santos Silva & Tenreyro, 2006; Webb et al., 2020). Third, PPML satisfies an adding-up property consistent with the structural gravity framework, providing theoretically coherent estimates of trade elasticities (Fally, 2015).

The PPML estimator has been increasingly adopted in the NTM and GVC trade literature. Webb et al. (2020) employ PPML to estimate the impact of NTMs on ASEAN supply chains, while Kim (2024) uses PPML in estimating the effects of technical barriers on GVC participation using the ACRI framework. The use of PPML in this study aligns with state-of-the-art econometric practice in this field.

3.3.2 Specification: Gravity Model with Fixed Effects

The gravity model is estimated with a two-way fixed effects structure, incorporating country-pair fixed effects and product-year fixed effects. Fixed effects serve to absorb unobserved bilateral heterogeneity (e.g., historical trade relationships, cultural proximity, bilateral regulatory compatibility) and time-varying multilateral resistance terms, respectively. This approach is consistent with the structural gravity literature's recommendation to control for multilateral resistance using exporter-time and importer-time fixed effects (Anderson & van Wincoop, 2003), and with best practice in NTM trade estimation (Ghodsi & Stehrer, 2022; Eum, 2023).

The baseline estimating equation is specified as:

$$ln\, m_{ijkt} = \alpha + \beta_1\, ln\left(1 + T_{ijkt}\right) + \beta_{2k} ENTM_{ijkt}^{T} + \beta_{3k} ENTM_{ijkt}^{NT} + Z_{ijkt}^{\prime}\, \gamma + \delta_{ij} + \delta_{kt} + \theta_{ijkt}$$

where, m_{ijht} is import of product h to country i from country j at time t; T_{ijkt} is the ad-valorem tariff rate imposed by country i on product k imported from country j. β_1 captures the impact of tariff on imports; $ENTM_{ijkt}^{T}$ is the count variable of technical ENTMs; β_{2k} is the coefficient that captures the impact of technical ENTMs imposed by importer i of product k imported from country j. $ENTM_{ijkt}^{NT}$ is the count variable of non-technical ENTMs; β_{3k} is the coefficient that captures the impact of non-technical ENTMs imposed by importer i of product k imported from country j. Z_{ijkt}' is the time- varying country-pair characteristics and consist of gravity variables. These variables are as follows: traditional market potential of trade partners represented by summation of both countries' GDP, economic development distance based on GDP and GDP per capita of partners, distance between trading partners with respect to land, labour and capital relative to GDP, two dummy variables indicating if partners are WTO members and if there exists any Preferential Trade Agreement between them. δ_{ij} represents country pair fixed effects; δ_{kt} represents product-year fixed effects and θ_{ijkt} is the error component.

A negative and statistically significant β implies that E-NTMs are trade-restrictive, consistent with the "green protectionism" hypothesis, while a positive coefficient would suggest that E-NTMs serve as quality or compatibility signals that facilitate trade (Hyun & Jang, 2022; Essaji, 2008).

3.3.3 Data Sources for Gravity Estimation

Trade flow data are obtained from the UN COMTRADE database via the World Integrated Trade Solution (WITS) platform. Tariff data are sourced from the WTO Tariff Download Facility. Gravity variables including GDP, GDP per capita, and bilateral distance are sourced from the Penn World Tables (PWT), World Development Indicators (WDI), and the CEPII database. PTA membership data are obtained from the WTO Regional Trade Agreements Information System (RTA-IS). The E-NTM count variable is constructed from the WTO I-TIP database as described in Section 3.2, complemented by the four environmental goods lists.

3.4 Stage III: Simulation of GVC and Environmental Impacts via GTAP-E and GTAP-VA

3.4.1 Model Framework

The third and final stage employs an integrated modeling framework combining the GTAP-E (energy-environment extension) and GTAP-VA (value-added extension) models to simulate the economy-wide, GVC, and environmental impacts of E-NTMs. The GTAP-E model extends the standard GTAP model by incorporating energy substitution across fuels and explicitly tracking carbon dioxide (CO_2) emissions and other greenhouse gas outputs at the sector and country level (Burniaux & Truong, 2002). This makes GTAP-E particularly well-suited for capturing the interlinkages between trade policy, energy use, and environmental outcomes — linkages that are central to evaluating E-NTMs (Burniaux & Truong, 2002; Government of India, 2022).

The GTAP-VA module complements the GTAP-E framework by decomposing gross trade flows into their domestic value-added, foreign value-added, and double-counted components following the methodology of Koopman et al. (2014) and Johnson and Noguera (2012). This decomposition provides direct measures of India's forward GVC participation (domestic value-added embedded in partners' exports) and backward GVC participation (foreign value-added in India's exports), enabling a rigorous assessment of how E-NTMs alter India's position within global production networks.

3.4.2 Policy Simulation Design

The AVE equivalents of E-NTMs, estimated from the gravity model in Stage II, are introduced into the GTAP-E framework as import tariff equivalent shocks (percent changes in trade costs). The simulation design involves a counterfactual experiment in which E-NTMs are partially or fully removed, and the model is solved for a new general equilibrium. The endogenous responses of all sectors and factor markets to this perturbation are then evaluated using the GTAP-VA decomposition to isolate GVC participation effects, and the GTAP-E environmental module to track changes in emissions, energy intensity, and renewable energy use.

Key variables analyzed from the GTAP-E model include trade flow variables (VXSB, VFOB for exports; VCIF, VMSB for imports), intermediate input variables (VDFB/VDFP for domestic inputs; VMFB/VMFP for imported inputs), and environmental metrics (EMIO for IO-based non-CO_2 emissions; EMQO for output-based emissions; GWP for global warming potential). These variables collectively enable a comprehensive assessment of how changes in E-NTMs affect both trade competitiveness and environmental sustainability outcomes for India.

3.4.3 Database

The database employed is the 11th version of the GTAP database (GTAP 11), which provides data for three reference years: 2004, 2014, and 2022. For 2022, the database is updated from the 2017 base year using the Altertax feature of GTAP, applying macroeconomic shocks (GDP, population, capital stock, skilled and unskilled labor, and tariffs) based on projections from the World Bank, International Labour Organization, and IMF, following the methodology of Boulanger et al. (2016). The analysis covers 43 goods sectors out of the 65 total GTAP sectors, consistent with the study's exclusive focus on goods trade.

3.5 Justification for the Integrated Approach

This three-stage methodology, keyword-based E-NTM identification complemented by Environmental Goods Lists, gravity model estimation via PPML with fixed effects, and GTAP-E/GTAP-VA simulation, represents a methodologically rigorous and policy-relevant approach to an empirically neglected research question. The dual identification strategy ensures comprehensive E-NTM coverage, the PPML estimator provides econometrically consistent trade flow estimates in the presence of zero flows and heteroskedasticity, and the integrated CGE framework allows simultaneous evaluation of GVC participation effects and environmental outcomes, a nexus that has not previously been modeled for an emerging economy of India's scale and complexity (Burniaux & Truong, 2002; OECD, 2007; Government of India, 2022).

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