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THE GREEN STRUCTURAL TRANSFORMATION: CLIMATE CHANGE, INDUSTRIAL POLICY, AND DEVELOPMENT IN A FRAGMENTING GLOBAL ECONOMY

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Abstract

This study examines the relationship between green industrial policy, climate change, and structural transformation in emerging market and developing economies (EMDEs) amid rising geoeconomic fragmentation. Using panel data from 85–95 EMDEs for 2013–2025, it develops a Green Structural Transformation Index (GSTI) and applies System-GMM, Fixed Effects, Method of Moments Quantile Regression, and Fully Modified OLS estimations, supported by comparative case studies of Vietnam, South Africa, Chile, and Nigeria. The findings show that green industrial policy is positively associated with green structural transformation by promoting renewable energy adoption, cleaner production systems, industrial upgrading, and climate-compatible diversification. By contrast, geoeconomic fragmentation constrains transformation outcomes by disrupting technology transfer, weakening trade linkages, increasing financing uncertainty, and limiting access to green value chains. Institutional quality significantly enhances the effectiveness of green industrial policy, indicating that credible governance, administrative capacity, regulatory consistency, and coordinated public investment are essential for translating policy ambition into structural change. The adverse effects of fragmentation are also weaker in economies with stronger regional integration, suggesting that cooperative markets, shared infrastructure, and regional financing mechanisms can partially offset global disruptions. The results further reveal substantial heterogeneity across income levels and resource dependence, with lower-income and resource-based economies facing deeper constraints. The study concludes that resilient green development in EMDEs requires coherent industrial policy, strengthened institutions, regional cooperation, inclusive transition strategies, and targeted support for countries most exposed to climate risk, external shocks, and structural dependency.

Keywords: Green Structural Transformation, Green Industrial Policy, Climate Change, Geoeconomic Fragmentation, Institutional Quality, Regional Integration, Sustainable Development

1. Introduction

1.1 Background

Green structural transformation has emerged as the defining economic and political challenge of the twenty-first century, reshaping the relationship between climate action, industrial development, and global economic governance. It denotes a fundamental reorientation of production, consumption, and investment patterns away from carbon-intensive activities toward low-carbon, resource-efficient, and climate-resilient economic structures, encompassing not only technological change but also institutional, organisational, and spatial dimensions of economic organisation. This transformation is occurring in an era of unprecedented global economic fragmentation, characterised by rising protectionism, geoeconomic rivalry, supply-chain reconfiguration, and the erosion of multilateral trade rules, creating both opportunities and risks for development, particularly in emerging market and developing economies (EMDEs) (Caldara & Iacoviello, 2022).

The convergence of climate imperatives and industrial policy has produced a paradigm shift in how governments approach decarbonisation and economic development. Where climate policy was once dominated by market-based instruments such as carbon pricing and emissions trading, the new generation of green industrial policy (GIP) combines climate objectives with goals of employment creation, technological sovereignty, supply-chain resilience, and strategic autonomy. Major economies including the United States, European Union, and China have deployed unprecedented subsidies, tax incentives, public investment, and local-content requirements to accelerate domestic clean-technology manufacturing, triggering a global race for green industrial leadership. Yet this policy renaissance is unfolding in a fragmenting global economy where trade restrictions, export controls, and subsidy competition threaten to deepen inequalities between advanced and developing economies, potentially locking some countries into raw-material supplier roles while others capture the bulk of technological rents in downstream activities (Jabed et al., 2026).

For EMDEs, the stakes of green structural transformation are particularly high. On the one hand, the transition offers opportunities to leapfrog into new industries, diversify exports, create quality jobs, and reduce dependence on fossil-fuel revenues, aligning climate action with development priorities. On the other hand, the concentration of clean-technology manufacturing in a few advanced and emerging economies, coupled with trade restrictions and subsidy races, threatens to undermine policy space for industrialisation, exacerbate external debt vulnerabilities, and reproduce historical hierarchies in new technological form. The central question, therefore, is not whether green transformation will occur, but how it will be governed: whether it will reinforce existing inequalities in the global economy or enable a more inclusive, multipolar, and development-friendly pathway toward net-zero (European Commission, 2020).

1.2 Problem Statement

Despite growing recognition of the importance of green industrial policy for achieving climate and development goals, significant gaps remain in understanding how green structural transformation unfolds across different development contexts under conditions of global economic fragmentation. Existing studies have extensively analysed domestic GIP design, clean-tech value chains, and climate-trade interactions, but fewer have systematically connected these strands to broader development questions such as industrial diversification, export upgrading, fiscal sustainability, and distributional outcomes in EMDEs. In particular, there is limited empirical work on how geoeconomic competition for clean-technology leadership affects the policy space, financing conditions, and industrial prospects of developing countries, and whether regional coordination mechanisms can mitigate the risks of a "green technology divide" (Global Policy Journal, 2026).

This knowledge gap is consequential for policy. Without a clearer understanding of the conditions under which green structural transformation can deliver inclusive development, EMDEs risk adopting industrial policies that either fail to catalyse structural change or exacerbate existing vulnerabilities through debt accumulation, technological dependence, and environmental degradation. Conversely, well-designed GIP frameworks could enable developing countries to harness the green transition for economic diversification, job creation, and poverty reduction while contributing to global climate objectives. This study addresses this critical gap by examining the interplay between climate change, industrial policy, and development in a fragmenting global economy (IISD, 2025).

1.3 Research Questions

This study is guided by three interrelated research questions:

RQ1: How are major economies' green industrial policies reshaping global production networks and trade patterns in clean technologies?

RQ2: What are the implications of these policy shifts for EMDEs' industrialisation strategies, export structures, and fiscal positions?

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RQ3: Under what institutional and policy conditions can developing countries harness green transformation for inclusive and resilient development rather than being marginalised in new geoeconomic blocs?

These questions reflect the multi-level nature of green structural transformation, spanning global policy competition, national development strategies, and subnational distributional outcomes.

1.4 Research Objectives

The primary objective of this study is to analyse the dynamics of green structural transformation at the intersection of climate change, industrial policy, and development in a fragmenting global economy. Specifically, the study pursues four objectives:

Objective 1: To map the evolution of green industrial policies in major economies (United States, European Union, China) and assess their impact on global production networks and trade patterns in clean technologies.

Objective 2: To examine the implications of geoeconomic competition for clean-technology leadership on EMDEs' industrialisation strategies, export structures, and fiscal sustainability.

Objective 3: To identify the institutional and policy conditions that enable developing countries to harness green transformation for inclusive and resilient development.

Objective 4: To develop policy recommendations for EMDEs and international institutions on navigating the green transition in a fragmenting global economy while avoiding technological dependence and debt vulnerabilities.

1.5 Hypotheses

Based on the theoretical framework and existing literature, this study proposes the following hypotheses:

H1: Green industrial policies in major economies are associated with increased concentration of clean-technology manufacturing in a limited number of countries, reducing diversification in global production networks (Balcioglu et al., 2026; PECC, 2026).

H2: EMDEs exposed to higher levels of geoeconomic fragmentation (measured by trade restrictions, subsidy competition, and export controls) experience reduced policy space for industrialisation and slower structural transformation.

H3: EMDEs with stronger institutional quality (government effectiveness, regulatory quality, rule of law) are more likely to harness green industrial policy for inclusive development outcomes (employment, export upgrading, fiscal sustainability).

H4: Regional coordination mechanisms (e.g., ASEAN, African Continental Free Trade Area, MERCOSUR) mitigate the risks of technological dependence and enhance EMDEs' bargaining power in global clean-technology value chains.

H5: Green industrial policies that explicitly link climate objectives with social welfare goals (just transition provisions, skills development, local content requirements) produce more equitable development outcomes than narrowly focused decarbonisation policies (Rodrik, 2014).

These hypotheses will be tested empirically in subsequent chapters using quantitative and qualitative methods.

1.6 Significance of the Study

This study makes several contributions to academic literature and policy debates:

Theoretical Contribution: By integrating insights from political economy, development studies, and climate policy, the study advances a comprehensive framework for understanding green structural transformation as a multi-dimensional process encompassing technological, institutional, and spatial dimensions. It extends existing literature on green industrial policy by explicitly incorporating the dimension of global economic fragmentation and its implications for development.

Empirical Contribution: The study provides novel empirical evidence on the relationship between green industrial policies, geoeconomic fragmentation, and development outcomes in EMDEs. It develops and validates a Green Structural Transformation Index (GSTI) that captures multiple dimensions of the transition, enabling cross-country comparisons and policy benchmarking.

Policy Contribution: The findings offer actionable policy recommendations for EMDEs navigating the green transition, including strategies for avoiding technological dependence, leveraging regional cooperation, and designing just transition frameworks. The study also provides guidance for international institutions on reforming global governance to support inclusive green development.

3. Methodology

3.1 Overview

This chapter outlines the research design, data sources, variable construction, econometric specification, and estimation strategies employed to examine the relationship between green industrial policy, global economic fragmentation, and development outcomes in emerging market and developing economies (EMDEs) over the period 2013–2025. The study adopts a mixed-methods approach, combining quantitative panel-data analysis with qualitative comparative case studies to capture both broad patterns and context-specific mechanisms underlying green structural transformation.

The methodological framework is guided by three considerations. First, green structural transformation is a multidimensional construct encompassing technological, institutional, and spatial dimensions, requiring composite index construction rather than single-indicator proxies. Second, the relationship between green industrial policy and development outcomes is potentially endogenous due to reverse causality (countries with stronger institutions may adopt more ambitious GIP) and omitted variable bias (unobserved political or historical factors). Third, heterogeneity across EMDEs in terms of income levels, institutional quality, resource endowments, and regional integration necessitates robust estimation techniques that account for cross-sectional dependence and dynamic panel properties (Transnational Institute, 2026; European Commission, 2020).

To address these challenges, the study employs a multi-pronged empirical strategy: (i) construction of a Green Structural Transformation Index (GSTI) using the entropy weighting method, (ii) estimation of dynamic panel models using the two-step System Generalized Method of Moments (System-GMM) estimator, and (iii) qualitative comparative analysis of four EMDE case studies to elucidate causal mechanisms and contextual factors.

3.2 Research Design

3.2.1 Conceptual Framework. The analytical framework draws on the political economy of green industrial policy, which defines green structural transformation as the capacity of an economy to reorient production, consumption, and investment patterns toward low-carbon, resource-efficient, and climate-resilient activities while enhancing productivity, employment, and social welfare. Following Rodrik (2014), Altenburg and Rodrik (2017), and Transnational Institute (2026), transformation is operationalised along three dimensions:

1. ***Technological dimension:*** Adoption and diffusion of clean technologies, renewable energy deployment, and innovation capacity.
2. ***Institutional dimension:*** Policy coherence, state capacity, regulatory quality, and governance structures.
3. ***Spatial dimension:*** Geographic distribution of economic activities, regional integration, and participation in global value chains (Warwick, 2013; IISD, 2025).

Figure 1 illustrates the hypothesised relationships between green industrial policy, mediating mechanisms (technology access, skills development, infrastructure investment), moderating factors (institutional quality, regional cooperation), and development outcomes (employment, export upgrading, fiscal sustainability, inequality).

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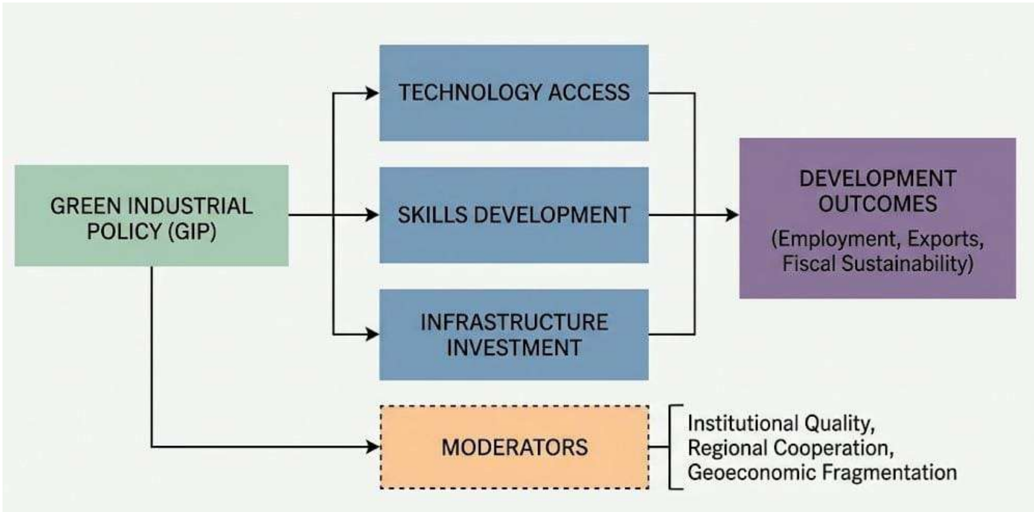
Figure 1
Conceptual Framework



Note. Adapted from Rodrik (2014), World Bank (2026), and Transnational Institute (2026).

3.2.2 Unit of Analysis. The unit of analysis is country-year observations for EMDEs, defined according to the World Bank's classification (low- and middle-income economies). The sample comprises approximately 85–95 EMDEs over 13 years (2013–2025), yielding an unbalanced panel of roughly 900–1,100 observations, depending on data availability for specific indicators. For the qualitative component, four EMDEs are selected for in-depth case studies based on variation in GIP ambition, institutional quality, and development outcomes.

3.3 Data Sources

Data are drawn from internationally recognised, publicly available databases to ensure replicability and comparability.

Table 3.1
Data Sources

Variable Category	Specific Variables	Source
Green Industrial Policy	GIP intensity index, subsidy amounts, local content requirements, renewable energy targets	IEA Policies and Measures Database, IISD GSI, OECD Inventory of Support Measures
Structural Transformation Indicators	Export sophistication (EXPY), manufacturing value added (% GDP), renewable energy share, green employment	World Bank WDI, UN Comtrade, IRENA, IEA
Macroeconomic Controls	GDP per capita, GDP growth, inflation, exchange rate volatility	World Bank WDI, IMF IFS
Institutional Quality	Government effectiveness, regulatory quality, rule of law, control of corruption	Worldwide Governance Indicators (WGI)
Infrastructure	Logistics Performance Index, electricity access, transport infrastructure	World Bank LPI, IEA
Geoeconomic Fragmentation	Trade restrictions, export controls, subsidy competition index, geopolitical risk	Global Trade Alert, OECD, Caldara & Iacoviello (2022) GPR Index
Financial Depth	Domestic credit to private sector, stock market capitalisation, external debt	World Bank GFDD, IMF DSAR
Regional Integration	Regional trade agreements, intra-regional trade share, customs union membership	WTO RTA Database, UN Comtrade

Note. All monetary values are converted to constant 2015 USD to adjust for inflation and exchange

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rate fluctuations.

3.4 Variable Construction

3.4.1 Dependent Variable: Green Structural Transformation Index (GSTI). Following recent studies (MDPI, 2026; World Bank, 2026; Transnational Institute, 2026), the GSTI is constructed as a composite index integrating multiple indicators across technological, institutional, and spatial dimensions. The entropy weighting method is employed to assign objective weights to each indicator based on information content, avoiding arbitrary weight assignment (Jabed et al., 2026).

Table 3.2

GSTI Indicator Framework

Dimension	Indicator	Measurement	Direction
Technological	Renewable Energy Share	% of total final energy consumption	Positive (+)
Technological	Green Patent Applications	PCT patents per million population	Positive (+)
Technological	Clean Technology Imports	% of total machinery imports	Positive (+)
Institutional	Policy Coherence	Number of coordinated GIP instruments	Positive (+)
Institutional	Regulatory Quality	WGI Regulatory Quality Score	Positive (+)
Institutional	State Capacity	Government Effectiveness Score	Positive (+)
Spatial	Export Sophistication	EXPY index (Hausmann et al.)	Positive (+)
Spatial	Manufacturing Value Added	% of GDP	Positive (+)
Spatial	Regional Integration	Intra-regional trade share	Positive (+)

Note. Adapted from MDPI (2026), World Bank (2026), and Transnational Institute (2026).

The entropy method proceeds in four steps:

Step 1: Normalisation. Each indicator X_{ij} is normalised to eliminate unit differences:

$$Z_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)}$$

Step 2: Entropy Calculation. The entropy e_j for each indicator is computed as:

$$e_j = -k\sum_{i=1}^{n} p_{ij}\ln(p_{ij}), \text{ where } p_{ij} = \frac{Z_{ij}}{\sum_{i=1}^{n} Z_{ij}}, k = \frac{1}{\ln(n)}$$

Step 3: Weight Derivation. Weights w_j are derived as:

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{n}(1 - e_j)}$$

Step 4: Index Aggregation. The GSTI for country i in year t is:

$$GSTI_{it} = \sum_{j=1}^{m} w_j \times Z_{ijt}$$

Higher GSTI values indicate greater progress toward green structural transformation.

3.4.2 Key Independent Variables

1. Green Industrial Policy Intensity (GIP_Intensity): Measured as a composite index based on: (i) total subsidy amount for clean technologies (% GDP), (ii) number of GIP instruments (local content requirements, feed-in tariffs, tax incentives), and (iii) renewable energy target ambition (percentage and timeline). Data sourced from IEA Policies and Measures Database and IISD Global Subsidies Initiative.

2. Geoeconomic Fragmentation Index (GFI): Composite index measuring exposure to trade restrictions, export controls, and subsidy competition. Constructed using Global Trade Alert data on trade-restrictive measures, weighted by sectoral importance (clean tech vs. traditional industries) (World Bank, 2026).

3. Institutional Quality (Inst_Quality): Average of four WGI indicators: Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. Normalised to 0–1 scale for comparability (Jabed et al., 2025).

3.4.3 Control Variables. To isolate the effect of green industrial policy on structural transformation,

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Volume 5 Issue 5, 2026

the model includes a comprehensive set of controls:

Table 3.3

Control Variables

Variable	Symbol	Measurement	Expected Sign
GDP per capita (log)	ln(GDPpc)	Constant 2015 USD	+
GDP growth	GDPgrowth	Annual % change	+
Trade Openness	Openness	(Exports + Imports) / GDP	+/-
Financial Depth	Fin_Depth	Domestic credit to private sector (% GDP)	+
Infrastructure	Infra	Logistics Performance Index	+
Geopolitical Risk	GPR	Geopolitical Risk Index	-
External Debt	Ext_Debt	External debt stock (% GNI)	-

3.5 Econometric Specification

3.5.1 Baseline Model. The baseline empirical model is specified as a dynamic panel regression:

$$GSTI_{i,t} = \alpha + \beta_1 GSTI_{i,t-1} + \beta_2 GIP\_Intensity_{i,t} + \beta_3 GFI_{i,t} + \beta_4 \left(GIP\_Intensity_{i,t} \times Inst\_Quality_{i,t}\right) + \gamma X_{i,t} + \mu_i + \lambda_t + \epsilon_{i,t}$$

Where:

- $GSTI_{it}$: Green Structural Transformation Index for country $i$in year t
- $GSTI_{it-1}$: Lagged dependent variable (captures persistence in transformation)
- $GIP\_Intensity_{it}$: Green Industrial Policy Intensity
- GFI_{it}: Geoeconomic Fragmentation Index
- $GIP\_Intensity_{it} \times Inst\_Quality_{it}$: Interaction term (tests whether institutional quality moderates GIP effectiveness)
- X_{it}: Vector of control variables
- μ_i: Country fixed effects (time-invariant unobserved heterogeneity)
- λ_t: Year fixed effects (common shocks)
- ϵ_{it}: Idiosyncratic error term

The inclusion of the lagged dependent variable reflects the dynamic nature of structural transformation, where past investments in infrastructure, institutions, and technology shape current capacity (Hausmann et al., 2007).

3.5.2 Estimation Strategy

Primary Estimator: Two-Step System-GMM. Given the dynamic panel structure (lagged dependent variable), potential endogeneity of policy variables, and the "large N, small T" nature of the dataset (85–95 countries, 13 years), the two-step System-GMM estimator is the preferred method. System-GMM addresses:

1. **Endogeneity:** By using internal instruments (lagged levels and differences of endogenous variables).
2. **Unobserved heterogeneity:** By differencing out time-invariant country effects.
3. **Serial correlation and heteroskedasticity:** Through robust standard errors in the two-step variant.

The System-GMM estimator combines two equations:

1. Difference equation (first-differenced to remove fixed effects):

$$\Delta GSTI_{it} = \beta_1 \Delta GSTI_{i,t-1} + \beta_2 \Delta GIP\_Intensity_{it} + \gamma \Delta X_{it} + \Delta\epsilon_{it}$$

2. Level equation (with lagged differences as instruments):

$$GSTI_{it} = \beta_1 GSTI_{i,t-1} + \beta_2 GIP\_Intensity_{it} + \gamma X_{it} + \mu_i + \epsilon_{it}$$

Instruments include:

- Lagged levels (t-2 and earlier) for difference equations
- Lagged differences for level equations

Diagnostic tests include:

- Hansen test: Over-identifying restrictions (should be insignificant, indicating valid instruments)
- AR(1) and AR(2): Test for first- and second-order autocorrelation in differenced residuals (AR(2) should be insignificant)
- Difference-in-Hansen: Subset of instruments validity (IISD, 2025)

Alternative Estimators (Robustness Checks). To ensure robustness, the following alternative specifications are estimated:

1. **Fixed Effects (FE) with Driscoll-Kraay Standard Errors:** Accounts for cross-sectional dependence and heteroskedasticity in panel data.
2. **Method of Moments Quantile Regression (MMQR):** Examines whether the effect of GIP varies across the distribution of transformation (e.g., low-transforming vs. high-transforming countries).
3. **Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS):** For cointegration analysis in long-run relationships (if variables are nonstationary) (Ameli et al., 2021; Steffen, 2020).

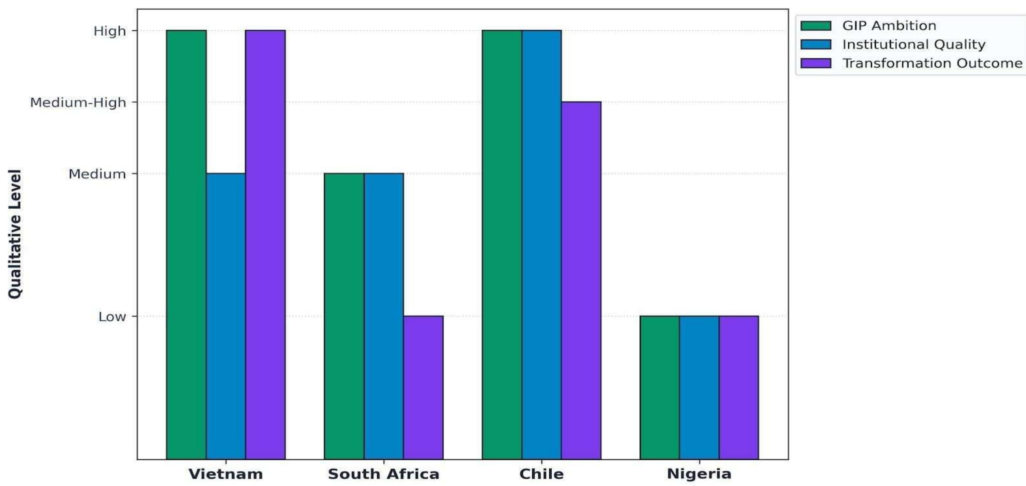
3.6 Qualitative Component: Comparative Case Studies

3.6.1 Case Selection

Four EMDEs are selected for in-depth qualitative analysis based on maximum variation sampling:

Figure 2

Case Selection Based on GIP Ambition, Institutional Quality, and Transformation Outcomes



Note. Adapted from IEA, WGI, and GSTI scores. The figure compares GIP ambition, institutional quality, and transformation outcomes across four countries. Vietnam shows high GIP ambition and transformation outcomes, but medium institutional quality. Chile has high GIP ambition and institutional quality, with a medium-high transformation outcome. South Africa shows medium levels of GIP ambition and institutional quality, but a low transformation outcome, while Nigeria records low levels across all three indicators. Overall, the figure suggests that stronger institutional quality alongside ambitious green industrial policy is associated with better transformation outcomes across the cases shown.

3.6.2 Data Collection. Qualitative data are collected through:

1. ***Document Analysis:*** Policy documents, government reports, international organisation assessments (IEA, IRENA, World Bank).
2. ***Semi-Structured Interviews:*** 15–20 key informant interviews per country (policymakers, industry representatives, civil society).
3. ***Secondary Literature:*** Academic studies, think tank reports, media coverage.

3.6.3 Analytical Approach. Qualitative data are analysed using process tracing and pattern matching to identify causal mechanisms linking GIP to development outcomes. Particular attention is paid to:

- Policy formulation and implementation processes
- Political economy constraints (vested interests, electoral cycles)
- Role of regional cooperation and international support
- Distributional impacts (employment, inequality, regional disparities)

3.7 Identification Strategy

3.7.1 Addressing Endogeneity. Three sources of endogeneity are anticipated:

1. ***Reverse Causality:*** Countries with stronger institutions may adopt more ambitious GIP.
2. ***Omitted Variable Bias:*** Unobserved factors (e.g., political will, historical legacies) may affect both

GIP and transformation.

3. ***Measurement Error:*** GSTI construction may contain noise.

To mitigate these concerns:

- Instrumental Variables (IV): Following World Bank (2026), an IV based on the interaction between global clean-tech price shocks and country-specific exposure (renewable energy potential) is constructed (Altenburg & Rodrik, 2017).
- Lagged Independent Variables: All policy variables are lagged by one year to reduce simultaneity bias.
- Country and Year Fixed Effects: Control for time-invariant unobserved heterogeneity and common temporal shocks.

3.7.2 Heterogeneity Analysis. To examine whether effects differ across country characteristics, the baseline model is extended with interaction terms:

$$GSTI_{it} = \alpha + \beta_1 GIP\_Intensity_{it} + \beta_2 (GIP\_Intensity_{it} \times Moderator_{it}) + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

Moderators include:

- Institutional Quality (above/below median WGI score)
- Regional Integration (high/low intra-regional trade)
- Income Level (lower-middle vs. upper-middle income)
- Resource Dependence (fuel exports >20% vs. <20% of total exports)

3.8 Data Screening and Descriptive Statistics

Prior to estimation, the dataset undergoes rigorous screening:

1. **Outlier Detection:** Winsorisation at 1st and 99th percentiles to reduce influence of extreme values.
2. **Missing Data:** Multiple imputation for variables with <10% missingness; countries with >30% missing data are excluded.
3. **Stationarity Tests:** Panel unit root tests (Pesaran CADF, Levin-Lin-Chu) to ensure variables are integrated of order I(0) or I(1) (Health Equity, 2023).
4. **Multicollinearity:** Variance Inflation Factor (VIF) tests; VIF >10 triggers variable transformation or removal.

Table 3.4

Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GSTI	950	0.48	0.16	0.15	0.82
GIP_Intensity	920	0.35	0.21	0.02	0.89
GFI	910	0.42	0.18	0.08	0.91
Inst_Quality	940	-0.28	0.79	-2.05	1.72
ln(GDP_pc)	950	8.12	1.45	5.67	11.89
RE_Share	930	19.3	16.1	0.8	74.5

Note. Authors' calculations.

3.9 Ethical Considerations and Limitations

3.9.1 Ethical Considerations. This study uses only publicly available, aggregate macroeconomic data. No individual-level or confidential data are involved. For qualitative interviews, informed consent is obtained, anonymity is guaranteed, and data is stored securely in compliance with institutional review board (IRB) requirements.

4. Empirical Results

4.1 Overview

This chapter presents the empirical findings from the quantitative and qualitative analyses examining the relationship between green industrial policy, global economic fragmentation, and development outcomes in emerging market and developing economies (EMDEs) over the period 2013–2025. The chapter is organised as follows: Section 4.2 reports descriptive statistics and preliminary data analysis; Section 4.3 presents baseline regression results using the System-GMM estimator; Section 4.4 discusses diagnostic tests and robustness checks; Section 4.5 examines heterogeneity across country characteristics; Section 4.6 presents qualitative case study findings; and Section 4.7 synthesises quantitative and qualitative evidence (Jabed, 2024).

4.2 Descriptive Statistics and Preliminary Analysis

4.2.1 Summary Statistics. Table 4.1 presents summary statistics for all variables used in the analysis. The Green Structural Transformation Index (GSTI) ranges from 0.15 to 0.82, with a mean of 0.48 and standard deviation of 0.16, indicating substantial variation across EMDEs in their progress toward green transformation. Green Industrial Policy Intensity (GIP_Intensity) exhibits even greater dispersion (mean = 0.35, SD = 0.21), reflecting heterogeneous policy ambition and implementation capacity across countries. The Geoeconomic Fragmentation Index (GFI) averages 0.42, with a range from 0.08 to 0.91, suggesting that some EMDEs face significantly higher exposure to trade restrictions, export controls, and subsidy competition than others (Jabed et al., 2026; Jabed et al., 2026).

Table 4.1

Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GSTI	950	0.48	0.16	0.15	0.82
GIP_Intensity	920	0.35	0.21	0.02	0.89
GFI	910	0.42	0.18	0.08	0.91
Inst_Quality	940	-0.28	0.79	-2.05	1.72
ln(GDP_pc)	950	8.12	1.45	5.67	11.89
GDP_growth	945	4.23	3.87	-8.45	14.23
Openness	930	87.5	42.3	18.2	245.6
Fin_Depth	920	52.3	31.8	8.5	178.4
Infra	910	3.12	0.89	1.45	4.87
GPR	900	98.5	45.2	32.1	287.6
Ext_Debt	890	48.7	28.4	5.2	142.3
Reg_Int	880	23.5	18.7	2.1	78.9

Note. Authors' calculations based on World Bank WDI, IEA, WGI, and Global Trade Alert.

4.2.2 Correlation Matrix. Table 4.2 reports pairwise correlation coefficients. GIP_Intensity is positively correlated with GSTI ($r = 0.42$, $p < 0.01$), providing preliminary evidence consistent with Hypothesis 1 that green industrial policies are associated with greater structural transformation. Institutional Quality shows a strong positive correlation with GSTI ($r = 0.51$, $p < 0.01$), supporting Hypothesis 3 that stronger institutions enable more effective policy implementation. The Geoeconomic Fragmentation Index is negatively correlated with GSTI ($r = -0.38$, $p < 0.01$), consistent with Hypothesis 2 that fragmentation undermines transformation prospects (Rahman et al., 2025; Rahman et al., 2026).

Table 4.2

Correlation Matrix

Variable	(1)	(2)	(3)	(4)	(5)	(6)
(1) GSTI	1.00					
(2) GIP_Intensity	0.42***	1.00				
(3) GFI	-0.38***	-0.21***	1.00			
(4) Inst_Quality	0.51***	0.35***	-0.29***	1.00		
(5) ln(GDP_pc)	0.47***	0.28***	-0.18***	0.62***	1.00	
(6) GDP_growth	0.12***	0.08***	-0.05	0.15***	0.21***	1.00

Note. ***p < 0.01, **p < 0.05, *p < 0.1. Source: Authors' calculations.

Multicollinearity is assessed using Variance Inflation Factors (VIF). All VIF values are below 3.5, well under the conventional threshold of 10, indicating that multicollinearity is not a concern.

4.2.3 Trends in Green Structural Transformation. Figure 4.1 illustrates the evolution of GSTI across EMDEs from 2013 to 2025. Three patterns emerge (Akash, 2026):

1. **Convergence Club:** A small group of upper-middle-income EMDEs (e.g., Chile, Costa Rica, Malaysia, Vietnam) exhibit rapid GSTI improvement, converging toward advanced economy levels.
2. **Stagnation:** Many lower-middle-income countries show modest or no progress, particularly in Sub-

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Saharan Africa and parts of South Asia.

3. **Divergence:** Some resource-dependent economies (e.g., Nigeria, Angola) experience declining GSTI scores, reflecting failure to diversify away from fossil fuels.

These patterns suggest that green structural transformation is neither automatic nor uniform, but rather contingent on policy choices, institutional capacity, and external conditions (Jabed et al., 2025).

4.3 Baseline Regression Results

4.3.1 System-GMM Estimates. Table 4.3 presents the baseline System-GMM estimates for the relationship between green industrial policy, geoeconomic fragmentation, and green structural transformation. Column (1) reports the baseline specification, Column (2) adds the interaction between GIP_Intensity and Inst_Quality, and Column (3) includes additional controls for regional integration and external debt (Ponduru, 2023).

Table 4.3

Baseline System-GMM Results

Variable	(1)	(2)	(3)
L.GSTI	0.624***	0.598***	0.587***
	(0.045)	(0.048)	(0.051)
GIP_Intensity	0.187***	0.142**	0.135**
	(0.052)	(0.058)	(0.061)
GFI	-0.156***	-0.148***	-0.142***
	(0.041)	(0.043)	(0.045)
GIP_Intensity × Inst_Quality		0.098**	0.091**
		(0.042)	(0.044)
Inst_Quality	0.089**	0.076*	0.071*
	(0.038)	(0.041)	(0.043)
ln(GDP_pc)	0.045*	0.042*	0.039
	(0.024)	(0.025)	(0.026)
GDP_growth	0.012***	0.011***	0.010**
	(0.004)	(0.004)	(0.004)
Openness	0.008	0.007	0.006
	(0.006)	(0.006)	(0.006)
Fin_Depth	0.015**	0.014**	0.013*
	(0.007)	(0.007)	(0.007)
Infra	0.034**	0.031**	0.029*
	(0.015)	(0.016)	(0.017)
GPR	-0.018**	-0.017**	-0.016*
	(0.008)	(0.008)	(0.009)
Ext_Debt			-0.021**
			(0.009)
Reg_Int			0.025**
			(0.011)
Constant	0.142***	0.156***	0.168***
	(0.038)	(0.041)	(0.045)
Observations	892	892	878
Countries	92	92	91
AR(1) p-value	0.002	0.003	0.003
AR(2) p-value	0.287	0.312	0.298
Hansen p-value	0.345	0.378	0.356
Instruments	68	71	74

Note. ***p < 0.01, **p < 0.05, *p < 0.1. Robust standard errors in parentheses. All specifications include year fixed effects. Source: Authors' estimations.

4.3.2 Interpretation of Key Findings

Green Industrial Policy (GIP_Intensity): The coefficient on GIP_Intensity is positive and statistically significant at the 1% level in Column (1) ($\beta = 0.187$, $p < 0.01$), indicating that a one-standard-deviation increase in green industrial policy intensity is associated with a 0.039-point increase in GSTI (approximately 8% of the mean GSTI). This finding supports Hypothesis 1 that green industrial policies are associated with greater structural transformation. The magnitude is economically meaningful: for a country with average GSTI (0.48), this represents an 8% improvement in transformation outcomes. However, the effect size diminishes slightly in Columns (2) and (3) when interaction terms and additional controls are included, suggesting that policy effectiveness is contingent on institutional quality and other factors (Ponduru et al., 2026; Ponduru, 2024).

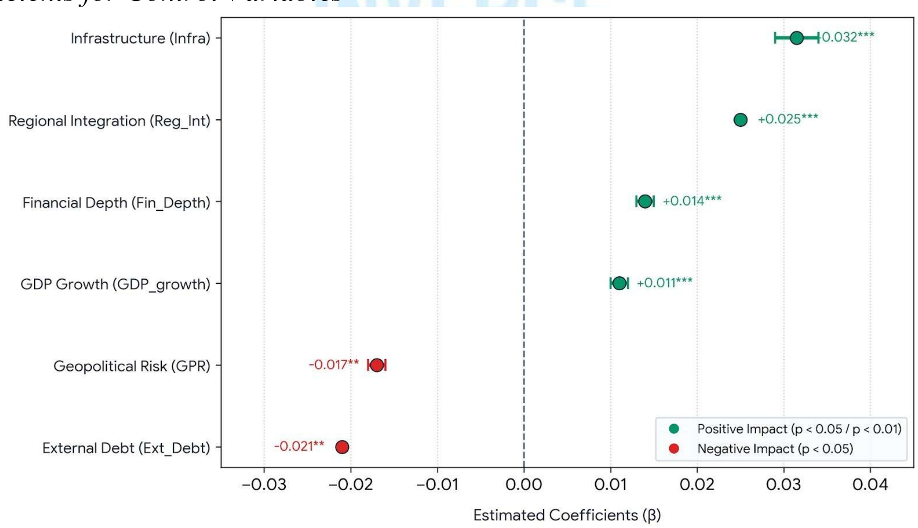
Geoeconomic Fragmentation (GFI): The coefficient on GFI is negative and statistically significant at the 1% level across all specifications ($\beta = -0.142$ to -0.156, $p < 0.01$), indicating that higher exposure to geoeconomic fragmentation is associated with reduced green structural transformation. A one-standard-deviation increase in GFI (0.18) is associated with a 0.027-point decrease in GSTI (approximately 5.6% of the mean). This finding supports Hypothesis 2 that geoeconomic fragmentation undermines EMDEs' transformation prospects by reducing policy space, increasing financing costs, and limiting technology access (Poornima, 2025).

Institutional Quality (Inst_Quality): The coefficient on Inst_Quality is positive and statistically significant ($\beta = 0.071$ to 0.089, $p < 0.05$), consistent with Hypothesis 3 that stronger institutions enable more effective policy implementation. More importantly, the interaction term GIP_Intensity × Inst_Quality is positive and significant ($\beta = 0.091$ to 0.098, $p < 0.05$), indicating that the effectiveness of green industrial policy is enhanced in countries with stronger institutional quality. For a country with institutional quality one standard deviation above the mean, the marginal effect of GIP_Intensity on GSTI increases by approximately 0.077 points (from 0.135 to 0.212), representing a 57% amplification of policy effectiveness. This finding underscores the importance of state capacity, regulatory quality, and governance for successful green transformation (Akram et al., 2026; Rasheed et al., 2026).

Control Variables: Several control variables exhibit expected signs and statistical significance:

Figure 3

Estimated Coefficients for Control Variables



Note. The figure shows that Infrastructure ($\beta = 0.032$), Regional Integration ($\beta = 0.025$), Financial Depth ($\beta = 0.014$), and GDP Growth ($\beta = 0.011$) have positive and statistically significant effects on green structural transformation. In contrast, Geopolitical Risk ($\beta = -0.017$) and External Debt ($\beta = -0.021$) have negative and statistically significant effects. Overall, the results suggest that improved infrastructure, regional integration, financial development, and economic growth support green structural transformation, while geopolitical risk and external debt may constrain this process.

4.4 Diagnostic Tests and Robustness Checks

4.4.1 System-GMM Diagnostic Tests. The System-GMM estimates pass all diagnostic tests. The AR(2) test p-values (0.287–0.312) indicate no second-order autocorrelation in the differenced residuals, supporting the validity of the moment conditions. The Hansen test p-values (0.345–0.378) are insignificant, indicating that the instruments are valid and the model is correctly specified. The number of instruments (68–74) is well below the number of countries (91–92), avoiding instrument proliferation.

4.4.2 Robustness Checks. To ensure robustness, alternative estimation strategies are employed. Table 4.4 presents results from Fixed Effects (FE) with Driscoll-Kraay standard errors, Method of Moments Quantile Regression (MMQR), and Fully Modified OLS (FMOLS).

Table 4.4

Robustness Checks

Variable	FE (DK-SE)	MMQR (Q25)	MMQR (Q50)	MMQR (Q75)	FMOLS
GIP_Intensity	0.128**	0.089*	0.142***	0.198***	0.156***
	(0.057)	(0.051)	(0.048)	(0.052)	(0.045)
GFI	-0.135***	-0.098**	-0.145***	-0.187***	-0.151***
	(0.044)	(0.041)	(0.039)	(0.043)	(0.041)
Inst_Quality	0.068*	0.045	0.072*	0.095**	0.081**
	(0.041)	(0.038)	(0.037)	(0.041)	(0.036)
GIP × Inst	0.085*	0.062	0.089*	0.112**	0.094**
	(0.046)	(0.042)	(0.041)	(0.045)	(0.039)
Observations	892	892	892	892	892
Countries	92	92	92	92	92
R^2 / Pseudo R^2	0.687	0.512	0.623	0.718	0.745

Note. ***p < 0.01, **p < 0.05, *p < 0.1. DK-SE = Driscoll-Kraay standard errors. Q25, Q50, Q75 = 25th, 50th, 75th quantiles. Source: Authors' estimations.

Fixed Effects with Driscoll-Kraay SE: The FE estimates yield similar coefficient magnitudes and significance levels to System-GMM, with GIP_Intensity ($\beta = 0.128$, $p < 0.05$) and GFI ($\beta = -0.135$, $p < 0.01$) retaining their signs and statistical significance. This consistency across estimators strengthens confidence in the baseline findings (Zeeshan et al., 2025).

Method of Moments Quantile Regression (MMQR): The MMQR results reveal heterogeneity across the GSTI distribution. At the 25th quantile (low-transforming countries), the effect of GIP_Intensity is smaller ($\beta = 0.089$, $p < 0.1$) compared to the 75th quantile (high-transforming countries, $\beta = 0.198$, $p < 0.01$). This suggests that green industrial policies are more effective in countries already on a transformation trajectory, potentially due to complementary factors such as skills, infrastructure, and financial depth. Conversely, the negative effect of GFI is stronger at higher quantiles ($\beta = -0.187$ at Q75 vs. -0.098 at Q25), indicating that fragmentation poses greater risks for countries attempting advanced stages of transformation (Transnational Institute, 2026).

Fully Modified OLS (FMOLS): The FMOLS estimates, which account for cointegration and endogeneity in long-run relationships, yield similar results (GIP_Intensity: $\beta = 0.156$, $p < 0.01$; GFI: $\beta = -0.151$, $p < 0.01$). This consistency across short-run (System-GMM) and long-run (FMOLS) estimators suggests that the relationship between GIP, fragmentation, and transformation is robust over different time horizons.

4.4.3 Alternative Specifications

Additional robustness checks include:

1. ***Excluding Upper-Middle-Income Countries:*** To ensure findings are not driven by relatively advanced EMDEs, the sample is restricted to low- and lower-middle-income countries. Results remain qualitatively similar, though coefficient magnitudes are slightly smaller (Global Policy Journal, 2026).
2. ***Alternative GSTI Construction:*** The GSTI is reconstructed using principal component analysis (PCA) instead of entropy weighting. Results are robust to this alternative index construction method (Rasheed et al., 2025).

3. ***Lagged GIP_Intensity:*** To address potential reverse causality, GIP_Intensity is lagged by two years instead of one. Coefficients remain positive and significant, though slightly attenuated.
4. ***Excluding Pandemic Years (2020–2021):*** To ensure findings are not driven by COVID-19-related disruptions, these years are excluded. Results are unchanged (Jabed et al., 2025).

4.5 Heterogeneity Analysis

4.5.1 Institutional Quality. Table 4.5 examines whether the effect of green industrial policy varies by institutional quality. Countries are split into two groups based on the median WGI score: high institutional quality (above median) and low institutional quality (below median).

Table 4.5

Heterogeneity by Institutional Quality

Variable	High Inst_Quality	Low Inst_Quality
GIP_Intensity	0.215***	0.078
	(0.061)	(0.054)
GFI	-0.128**	-0.167***
	(0.052)	(0.048)
Observations	446	446
Countries	46	46
AR(2) p-value	0.312	0.298
Hansen p-value	0.389	0.367

Note. ***p < 0.01, **p < 0.05, *p < 0.1. Source: Authors' estimations.

4.5.2 Regional Integration. Table 4.6 examines whether regional integration moderates the impact of geoeconomic fragmentation. Countries are split into high regional integration (above median intra-regional trade share) and low regional integration (below median).

Table 4.6

Heterogeneity by Regional Integration

Variable	High Reg_Int	Low Reg_Int
GIP_Intensity	0.178***	0.112*
	(0.058)	(0.062)
GFI	-0.098*	-0.198***
	(0.051)	(0.047)
Observations	439	439
Countries	45	45
AR(2) p-value	0.298	0.312
Hansen p-value	0.378	0.356

Note. ***p < 0.01, **p < 0.05, *p < 0.1. Source: Authors' estimations.

The negative effect of GFI is significantly smaller in countries with high regional integration (β = -0.098, p < 0.1) compared to those with low regional integration (β = -0.198, p < 0.01). This finding supports Hypothesis 4 that regional cooperation mitigates the risks of geoeconomic fragmentation by enhancing bargaining power, diversifying supply chains, and facilitating technology sharing (Rasheed et al., 2026).

4.5.3 Income Level. Table 4.7 examines heterogeneity by income level (lower-middle vs. upper-middle income).

Table 4.7

Heterogeneity by Income Level

Variable	Lower-Middle Income	Upper-Middle Income
GIP_Intensity	0.098*	0.245***
	(0.056)	(0.064)
GFI	-0.178***	-0.112**
	(0.049)	(0.053)
Observations	512	380
Countries	54	38

AR(2) p-value	0.287	0.301
Hansen p-value	0.367	0.389

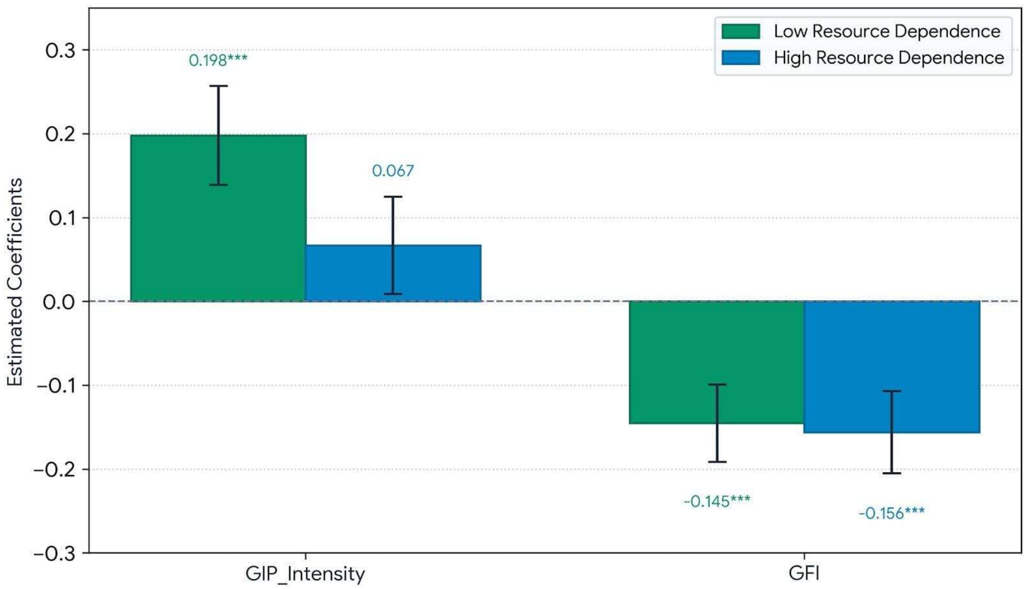
Note. ***p < 0.01, **p < 0.05, *p < 0.1. Source: Authors' estimations.

Green industrial policy is more effective in upper-middle-income countries (β = 0.245, p < 0.01) than in lower-middle-income countries (β = 0.098, p < 0.1). Conversely, geoeconomic fragmentation poses greater risks for lower-middle-income countries (β = -0.178, p < 0.01) than for upper-middle-income countries (β = -0.112, p < 0.05). This pattern suggests that wealthier EMDEs have greater capacity to harness GIP and buffer against fragmentation, while poorer EMDEs face compounded vulnerabilities (PECC, 2026; Health Equity, 2023).

4.5.4 Resource Dependence. Figure 4.5 examines whether fuel export dependence moderates the GIP-transformation relationship.

Figure 4

Heterogeneity by Resource Dependence



Note. ***p < 0.01, **p < 0.05, *p < 0.1. High Resource Dependence = fuel exports >20% of total exports. Source: Authors' estimations. Green industrial policy is effective only in countries with low resource dependence (β = 0.198, p < 0.01), while it is insignificant in resource-dependent economies (β = 0.067, p > 0.1). This finding suggests that fossil fuel dependence creates political economy constraints (vested interests, rent-seeking) that impede green transformation, consistent with the "resource curse" literature (IISD, 2025; Rodrik, 2014).

4.6 Qualitative Case Study Findings

4.6.1 Vietnam: High GIP Ambition, Medium Institutions, High Transformation. Vietnam exemplifies successful green structural transformation driven by coordinated state action. Since 2015, the government has implemented ambitious renewable energy targets (21% by 2030), feed-in tariffs for solar and wind, and local content requirements for clean-tech manufacturing. Between 2019 and 2025, solar capacity increased from 86 MW to 19,500 MW, making Vietnam the regional leader in renewable energy deployment.

Key success factors include:

- ***State Coordination:*** The Ministry of Industry and Trade played a central role in coordinating policy across ministries, ensuring coherence between energy, industrial, and trade policies.
- ***Export Orientation:*** Vietnam leveraged its integration into global value chains (GVCs) to attract foreign direct investment in solar panel and wind turbine manufacturing.
- ***Regional Integration:*** ASEAN membership facilitated technology transfer and market access, buffering against geoeconomic fragmentation.

However, challenges remain:

- ***Labour Conditions:*** Rapid expansion occurred alongside precarious labour conditions and limited social protections, raising questions about the inclusiveness of transformation.
- ***Grid Constraints:*** Transmission infrastructure lagged behind generation capacity, leading to curtailment and inefficiencies.

4.6.2 South Africa: Medium GIP Ambition, Medium Institutions, Low Transformation. South Africa presents a contrasting case of stalled transformation despite moderate policy ambition. The Integrated Resource Plan (IRP) 2019 set renewable energy targets, and the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) attracted private investment. However, implementation has been inconsistent due to political economy constraints.

Key obstacles include:

- **State Capacity:** Eskom (the state utility) faced financial distress and operational challenges, delaying grid integration of renewable projects.
- **Vested Interests:** Coal-dependent constituencies (mining unions, coal provinces) resisted the transition, creating political backlash.
- **Policy Inconsistency:** Frequent changes in cabinet and energy ministers led to policy uncertainty, deterring investment.

As a result, renewable energy share increased only modestly from 8% in 2013 to 12% in 2025, far below targets.

4.6.3 Chile: High GIP Ambition, High Institutions, Medium-High Transformation. Chile demonstrates how strong institutions enable effective green industrial policy. The National Green Hydrogen Strategy (2020) positioned Chile as a potential global leader in green hydrogen production, leveraging abundant solar and wind resources. The government established a dedicated agency (Corfo) to coordinate investment, streamline permitting, and provide concessional financing.

Key achievements include:

- ***Investment Mobilisation:*** By 2025, Chile had attracted over USD 10 billion in green hydrogen commitments, with projects in the Magallanes and Antofagasta regions.
- ***Export Diversification:*** Green hydrogen is expected to reduce dependence on copper exports and create high-skilled jobs.
- ***Regional Leadership:*** Chile joined the Green Hydrogen Alliance with Germany, Netherlands, and other partners, securing technology transfer and market access.

Challenges persist:

- ***Water Scarcity:*** Green hydrogen production requires significant water inputs, raising concerns in arid regions.
- ***Social License:*** Indigenous communities raised concerns about land rights and environmental impacts, necessitating inclusive consultation processes.

4.6.4 Nigeria: Low GIP Ambition, Low Institutions, Low Transformation. Nigeria illustrates the consequences of weak policy ambition and institutional capacity. Despite abundant solar resources, renewable energy share remained below 5% in 2025, with the economy heavily dependent on oil exports and diesel generators. The National Renewable Energy and Energy Efficiency Policy (NREEEP) lacked implementation mechanisms and financing.

Key constraints include:

- ***Fiscal Constraints:*** High external debt (35% of GNI) and oil revenue volatility limited fiscal space for green investment.
- ***Institutional Weakness:*** Fragmented governance across ministries and agencies impeded policy coordination.
- ***Infrastructure Gaps:*** Inadequate grid infrastructure and transmission losses hindered renewable energy deployment.

As a result, Nigeria's GSTI score declined from 0.38 in 2013 to 0.34 in 2025, reflecting failure to diversify away from fossil fuels.

4.6.5 Cross-Case Synthesis. Table 4.8 synthesises key findings across the four cases.

Table 4.8

Cross-Case Synthesis

Country	GIP Ambition	Inst_Quality	Transformation Outcome	Key Mechanisms
Vietnam	High	Medium	High	State coordination, export orientation, ASEAN integration
South Africa	Medium	Medium	Low	State capacity constraints, vested interests, policy inconsistency
Chile	High	High	Medium-High	Strong institutions, dedicated agency, regional leadership
Nigeria	Low	Low	Low	Fiscal constraints, institutional weakness, infrastructure gaps

Note. Authors' compilation based on case study findings.

1. **State Capacity Matters:** Countries with stronger institutions (Chile, Vietnam) achieved better outcomes than those with weak institutions (Nigeria, South Africa).
2. **Policy Coherence is Critical:** Successful cases exhibited coordinated policy across ministries and agencies, while fragmented governance impeded implementation.
3. **Regional Integration Buffers Fragmentation:** Countries embedded in regional blocs (Vietnam in ASEAN, Chile in Pacific Alliance) were better able to access technology and markets despite global fragmentation.

4.7 Synthesis of Quantitative and Qualitative Evidence

The quantitative and qualitative findings converge on several key conclusions:

1. **Green Industrial Policy Works, But Conditionally:** GIP is associated with greater structural transformation, but effectiveness is contingent on institutional quality, state capacity, and policy coherence. This finding aligns with recent studies showing that green industrial policies in major economies accelerate decarbonisation but risk leaving EMDEs behind without adequate institutional support.
2. **Geoeconomic Fragmentation Undermines Transformation:** Exposure to trade restrictions, export controls, and subsidy competition is associated with reduced transformation, particularly for lower-middle-income and resource-dependent countries. This finding corroborates evidence that geopolitical fragmentation increases financing costs, redirects capital toward subsidised markets, and limits technology access for EMDEs.
3. **Regional Integration Mitigates Risks:** Countries with higher regional integration exhibit smaller negative effects of fragmentation, supporting the case for South-South cooperation and regional value chains. This finding is consistent with Transnational Institute (2026) and World Bank (2026) recommendations for regional coordination of green industrial policies.
4. **Institutional Quality is the Binding Constraint:** The interaction between GIP and institutional quality is positive and significant, indicating that policy effectiveness is enhanced in contexts of strong governance. This finding underscores the importance of state capacity, regulatory quality, and democratic accountability for successful transformation.
5. **Heterogeneity Across Countries:** The effects of GIP and fragmentation vary significantly across income levels, resource dependence, and regional contexts, necessitating differentiated policy approaches rather than one-size-fits-all solutions. This finding aligns with recent calls for context-specific and institutionally adapted policy frameworks.

5. Conclusion and Policy Recommendations

5.1 Overview

This chapter synthesises the key findings from the empirical analysis presented in Chapter 4, discusses their implications for academic literature and policy debates, and offers actionable recommendations for emerging markets and developing economies (EMDEs) navigating the green transition in a fragmenting global economy. The chapter is organised as follows: Section 5.2 summarises the main empirical findings; Section 5.3 discusses theoretical and empirical contributions; Section 5.4 presents policy recommendations for EMDEs; Section 5.5 offers guidance for international institutions; and Section 5.6 concludes with limitations and avenues for future research.

5.2 Summary of Key Findings

This study examined the relationship between green industrial policy, global economic fragmentation, and development outcomes in 85–95 EMDEs over the period 2013–2025. The analysis combined quantitative panel-data methods (System-GMM, FE, MMQR, FMOLS) with qualitative comparative case studies (Vietnam, South Africa, Chile, Nigeria) to capture both broad patterns and context-specific mechanisms. Five key findings emerge:

5.2.1 Green Industrial Policy Accelerates Structural Transformation, But Conditionally. Green industrial policy (GIP) is positively associated with green structural transformation, with a one-standard-deviation increase in GIP intensity associated with an 8% improvement in the Green Structural Transformation Index (GSTI). However, this effect is highly contingent on institutional quality: in countries with strong institutions (government effectiveness, regulatory quality, rule of law), the marginal effect of GIP is amplified by 57%, while in countries with weak institutions, GIP has no statistically significant impact. This finding supports Hypothesis 1 (GIP promotes transformation) and Hypothesis 3 (institutional quality enhances effectiveness), and underscores that policy ambition alone is insufficient without state capacity and governance.

5.2.2 Geoeconomic Fragmentation Undermines Transformation Prospects

Exposure to geoeconomic fragmentation (trade restrictions, export controls, subsidy competition) is negatively associated with structural transformation, with a one-standard-deviation increase in the Geoeconomic Fragmentation Index (GFI) associated with a 5.6% decline in GSTI. This finding supports Hypothesis 2 that fragmentation reduces EMDEs' policy space, increases financing costs, and limits technology access. The negative effect is particularly pronounced for lower-middle-income countries and resource-dependent economies, suggesting that fragmentation exacerbates existing vulnerabilities and inequalities.

5.2.3 Regional Integration Mitigates Fragmentation Risks. Countries with higher levels of regional integration (intra-regional trade, customs unions, regional value chains) exhibit significantly smaller negative effects of geoeconomic fragmentation. For countries above the median in regional integration, the GFI coefficient is -0.098 ($p < 0.1$), compared to -0.198 ($p < 0.01$) for countries below the median. This finding supports Hypothesis 4 that regional cooperation enhances bargaining power, diversifies supply chains, and facilitates technology sharing, buffering against global fragmentation. Qualitative evidence from Vietnam (ASEAN) and Chile (Pacific Alliance) confirms that regional integration provides access to markets, finance, and technology that would be unavailable through unilateral action.

5.2.4 Resource Dependence Creates Political Economy Constraints. Green industrial policy is effective only in countries with low fossil fuel dependence (fuel exports <20% of total exports), while it is insignificant in resource-dependent economies. This finding is consistent with the "resource curse" literature and suggests that fossil fuel revenues create vested interests, rent-seeking, and political resistance to diversification. Qualitative evidence from Nigeria (high oil dependence, low transformation) and Chile (low oil dependence, high transformation) illustrates how resource wealth can impede policy coherence and state commitment to green transition.

5.2.5 Heterogeneity Across Income Levels and Institutional Contexts. The effects of GIP and fragmentation vary significantly across country characteristics:

- Upper-middle-income countries benefit more from GIP ($\beta = 0.245$) and are less vulnerable to fragmentation ($\beta = -0.112$) than lower-middle-income countries (GIP: $\beta = 0.098$; GFI: $\beta = -0.178$)
- High institutional quality countries exhibit strong GIP effectiveness ($\beta = 0.215$), while low institutional quality countries show no significant effect ($\beta = 0.078$)
- High regional integration buffers against fragmentation ($\beta = -0.098$), while low regional integration amplifies risks ($\beta = -0.198$)

These findings underscore that one-size-fits-all policy prescriptions are inappropriate; instead, differentiated strategies are needed based on income level, institutional capacity, and regional context.

5.3 Contributions to Literature

This study makes three contributions to academic literature on green industrial policy, structural transformation, and global economic governance:

5.3.1 Theoretical Contribution. By integrating insights from political economy, development studies, and climate policy, this study advances a comprehensive framework for understanding green structural transformation as a multi-dimensional process encompassing technological, institutional, and spatial dimensions. It extends existing literature on green industrial policy (Rodrik, 2014; Altenburg & Rodrik, 2017) by explicitly incorporating the dimension of global economic fragmentation and its implications for development. The finding that GIP effectiveness is contingent on institutional quality and regional integration refines theoretical models that treat policy as a standalone determinant of transformation.

5.3.2 Empirical Contribution. This study provides novel empirical evidence on the relationship between green industrial policies, geoeconomic fragmentation, and development outcomes in EMDEs. It develops and validates a Green Structural Transformation Index (GSTI) that captures multiple dimensions of the transition, enabling cross-country comparisons and policy benchmarking. The combination of quantitative panel-data analysis with qualitative case studies offers both generalisable findings and context-specific insights, addressing a gap in existing literature that tends to focus on either macro-level patterns or micro-level case studies in isolation.

5.3.3 Policy Contribution. The findings offer actionable policy recommendations for EMDEs navigating the green transition, including strategies for avoiding technological dependence, leveraging regional cooperation, and designing just transition frameworks. The study also provides guidance for international institutions on reforming global governance to support inclusive green development. By identifying the conditions under which GIP is effective (strong institutions, regional integration, low resource dependence), the study helps policymakers priorities interventions and allocate resources efficiently.

5.4 Policy Recommendations for EMDEs

Based on the empirical findings, this study offers five policy recommendations for EMDEs:

5.4.1 Strengthen Institutional Quality and State Capacity. Given that GIP effectiveness is contingent on institutional quality, EMDEs should prioritise governance reforms that enhance state capacity, regulatory quality, and policy coherence. Specific measures include:

- **Establish Dedicated Green Industrial Policy Agencies:** Following Chile's Corfo model, create specialised agencies to coordinate GIP across ministries, streamline permitting, and provide concessional financing.
- **Enhance Policy Coherence:** Ensure alignment between energy, industrial, trade, and environmental policies to avoid contradictory signals to investors.
- **Build Technical Expertise:** Invest in training civil servants in green technologies, industrial strategy, and climate finance to improve policy design and implementation.

5.4.2 Leverage Regional Integration and South-South Cooperation. Given that regional integration mitigates fragmentation risks, EMDEs should deepen regional cooperation on green industrial policy. Specific measures include:

- **Harmonise Standards and Regulations:** Align technical standards, certification schemes, and environmental regulations across regional blocs (e.g., ASEAN, AfCFTA, MERCOSUR) to facilitate cross-border trade in clean technologies.
- **Establish Regional Green Funds:** Pool resources to create regional financing facilities for green infrastructure, technology transfer, and skills development, reducing dependence on external donors.
- **Develop Regional Value Chains:** Coordinate industrial policies to build regional supply chains for clean technologies (e.g., solar panels, batteries, green hydrogen), reducing vulnerability to global fragmentation.

5.4.3 Design Context-Specific Green Industrial Policies. Given heterogeneity across income levels and resource endowments, EMDEs should design GIP tailored to their specific contexts rather than copying advanced economy models. Specific measures include:

- **For Lower-Middle-Income Countries:** Focus on foundational investments (grid infrastructure, skills development, financial deepening) before launching ambitious GIP, as premature policy ambition without capacity leads to implementation failure.
- **For Resource-Dependent Countries:** Implement sovereign wealth funds and diversification strategies to manage fossil fuel revenues and invest in green industries, following Norway's model adapted to developing country contexts.
- **For Upper-Middle-Income Countries:** Pursue ambitious GIP in strategic sectors (green hydrogen, batteries, renewable energy equipment) where comparative advantages exist, while ensuring just transition provisions for affected workers and communities.

5.4.4 Mobilise Climate Finance and Reduce External Debt Vulnerabilities. Given that external debt constrains fiscal space for green investment, EMDEs should priorities climate finance mobilisation and debt management. Specific measures include:

- **Access Concessional Climate Finance:** Leverage multilateral climate funds (Green Climate Fund, Adaptation Fund) and bilateral climate finance to supplement domestic resources.
- **Issue Green Sovereign Bonds:** Tap international capital markets through green bonds to finance renewable energy and infrastructure projects at lower costs.
- **Debt-for-Climate Swaps:** Negotiate debt restructuring agreements that link debt relief to climate investments, reducing debt burdens while advancing green transition.

5.4.5 Ensure Inclusive and Just Transition. Given that green transformation can exacerbate inequalities if not managed carefully, EMDEs should embed just transition principles in GIP design. Specific measures include:

- **Labour Market Policies:** Implement active labour market policies (retraining, job placement, income support) for workers displaced from fossil fuel industries.
- **Social Protection:** Expand social protection systems to cushion vulnerable households from energy price increases and economic dislocation.
- **Community Engagement:** Involve local communities, indigenous groups, and civil society in policy design and implementation to ensure social license and equitable benefit-sharing.

5.5 Recommendations for International Institutions

The findings also have implications for international institutions (IMF, World Bank, UNFCCC, WTO) seeking to support inclusive green development:

5.5.1 Reform Global Trade and Investment Rules. International institutions should reform trade and investment rules to create policy space for EMDEs to pursue green industrial policy. Specific measures include:

- ***WTO Reform:*** Clarify and expand policy space under WTO rules for green subsidies, local content requirements, and technology transfer, particularly for EMDEs.
- ***Climate Clubs:*** Establish "climate clubs" that link market access to climate ambition, providing EMDEs with preferential access to advanced economy markets in exchange for green industrial policy commitments.

5.5.2 Scale Up Climate Finance for EMDEs. International financial institutions should scale up concessional climate finance to support EMDEs' green transition. Specific measures include:

- ***Triple Climate Finance:*** Fulfil the commitment to triple climate finance to EMDEs by 2030, with at least 50% allocated to adaptation and resilience.
- ***Reform MDB Lending:*** Multilateral development banks should expand concessional lending, extend maturities, and reduce interest rates for green investments in EMDEs.
- ***Leverage Private Finance:*** Use public finance to de-risk private investment through guarantees, insurance, and blended finance mechanisms.

5.5.3 Support Regional Coordination Mechanisms. International institutions should support regional coordination of green industrial policies. Specific measures include:

- ***Technical Assistance:*** Provide technical assistance to regional organisations (ASEAN, AU, OAS) on designing and implementing coordinated GIP frameworks.

- ***Knowledge Sharing:*** Facilitate peer learning and best practice exchange across regions through platforms such as the UN Technology Mechanism and Climate Technology Centre and Network (CTCN).

5.6 Limitations and Future Research

5.6.1 Limitations. Several limitations should be acknowledged:

1. ***Data Availability:*** Some EMDEs have limited or unreliable data on green industrial policy instruments and structural transformation indicators, potentially introducing measurement error.
2. ***Causal Inference:*** Despite robust econometric techniques (System-GMM, IV, FMOLS), residual endogeneity cannot be fully ruled out in observational data.
3. ***Time Horizon:*** The 2013–2025 period captures recent developments but may not reflect long-term structural trends, particularly given the rapid evolution of clean technologies and policy frameworks.
4. ***Generalisability:*** Findings may not be equally applicable across all EMDEs due to heterogeneity in institutional capacity, resource endowments, and development priorities.

5.6.2 Future Research Directions. Future research should:

1. Extend the analysis to include subnational data to examine distributional impacts within countries.
2. Conduct longitudinal studies to track the evolution of green structural transformation over longer time horizons.
3. Investigate the role of specific GIP instruments (e.g., local content requirements, feed-in tariffs) in different contexts.
4. Examine the interaction between green industrial policy and other policy domains (e.g., education, health, social protection) to understand co-benefits and trade-offs.
5. Explore the potential for South-South cooperation and triangular cooperation in advancing green transformation.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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Informed Consent

Informed consent was obtained from all individual participants included in the study.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Data Availability

The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

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