

CRITICAL MINERALS AND GREEN TRANSITION IN AFRICA

Policy Trade-Offs Between Industrial Growth and Environmental Sustainability

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Background - Africa's Strategic Mineral Advantage

Africa holds **world-critical reserves** of cobalt, lithium, manganese, and rare earth elements.

These minerals power **batteries, solar PV, and wind technologies** driving the clean energy revolution (*IEA, 2023; Hund et al., 2020*).

This places Africa at the **epicentre of the global green industrial transition.**

Problem - The Mineral Wealth Paradox

Several mineral-rich economies (e.g., DRC, Namibia, Zimbabwe) remain stuck in raw resource dependence.

Extraction is largely enclave-based, generating weak industrial spillovers (*Barma et al., 2012*).

Weak environmental oversight threatens sustainability outcomes (*Kebede, 2021*).

Result: Abundant minerals, limited industrial transformation.

Policy Questions and Research Focus

Can critical minerals drive Africa's industrial transformation?

What are the environmental trade-offs of mineral expansion?

Balancing industrial growth ambitions with environmental sustainability goals in Africa's green transition.

Core Policy Questions

Literature Review

Integrates three perspectives:

Conceptual: Defines key ideas

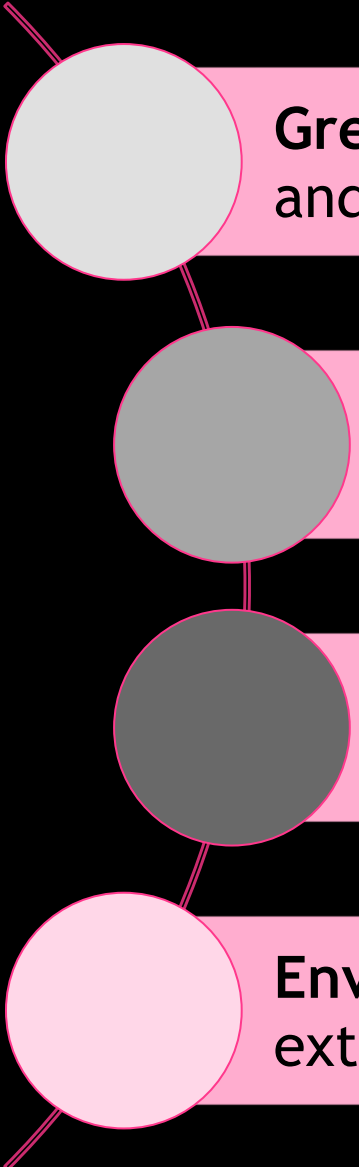
Theoretical: Explores guiding economic and environmental theories.

Empirical: Examines evidence from existing studies.

Positions the study within broader academic and policy debates.

Reviews research on **critical minerals, industrial transformation, and environmental sustainability** in Africa's green transition.

Conceptual Review



Green Industrialisation: Sustainable industrial growth using low-carbon and resource-efficient technologies (UNECA, 2016; Andreasson, 2023).

Critical Minerals: Key minerals required for clean energy technologies but prone to supply risks (IEA, 2023; Hund et al., 2020).

Industrial Value-Added: Industry's net contribution to economic output and structural transformation (World Bank, 2023).

Environmental Trade-Offs: Environmental costs linked to mineral extraction and processing (Sovacool et al., 2020).

Theoretical Review

Resource-Based Industrialisation Theory

Natural resources can drive industrial growth with strong policies and value-chain development (Hirschman, 1958; Morris et al., 2012; Ado et al., 2022; UNECA, 2020).

Environmental Kuznets Curve (EKC)

Environmental degradation rises with early growth but declines as cleaner technologies emerge (Grossman & Krueger, 1995).

Empirical Review

Industrial Growth & Economic Outcomes

Critical minerals can drive **industrial growth** if backed by strong governance, infrastructure, and stakeholder engagement (Boafo et al., 2024; Cao et al., 2024; Chen et al., 2024).

Poor regulation risks **repeating the resource curse** with social and ecological harms.

Environmental, Health & Social Outcomes

Mining often fuels **pollution, health hazards, and community disruption** in weakly governed areas (Tweneboah, 2024; Ajumobi, 2025).

Bioremediation and phytomining offer promising, cleaner alternatives (Nkuna et al., 2022; Akinbile & Mbohwa, 2025).

Research Gap

Evidence on **industrial gains vs. environmental trade-offs** remains limited, especially in panel studies assessing green-energy mitigation.

Scope & Data:

Focus on DRC, Namibia, Zimbabwe (2000-2024); data from WDI (World Bank, 2024).

Variables:

- Mineral exports (MEXP)
- Industrial value-added (INDVA),
 - CO₂ per capita (PKCE),
 - Lagged emissions (LACO),
- Foreign direct investment (FDIV),
 - Renewable energy (RECN),
 - Infrastructure (INFRA),
 - Education (EDUC).

Methodology

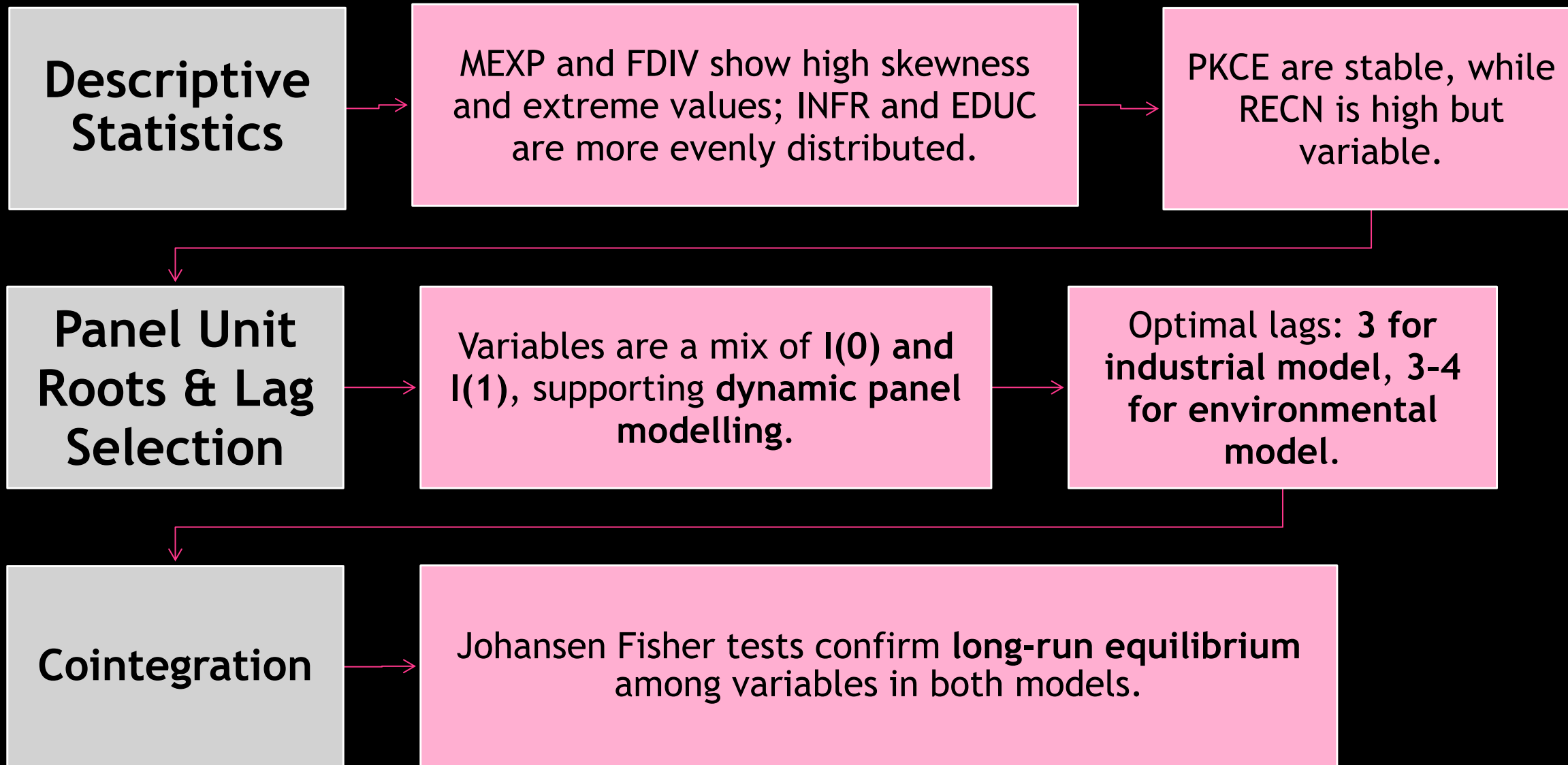
• Models:

- 1. *Industrial Growth*: $INDVA = f(MEXP + FDI + INFRA + EDUC)$
- 2. *Environmental Trade-Offs*: $PKCE = f(LACO + MEXP + INDVA + RECN)$

• Estimation:

- **PMG-ARDL captures short-run heterogeneity and long-run effects**, handles I(0)/I(1) variables, and accounts for country-specific dynamics (Pesaran et al., 1999; Chudik et al., 2016; Turan & Akay, 2021).

Preliminary Tests



PMG-ARDL Results - Industrial Growth (Model 1)

Variable	Long-Run (Coeff, p)	Short-Run (Coeff, p)
MEXP	2.75, <0.000	-2.30, 0.072
EDUC	0.08, 0.036	-2.54, <0.000
INFR	-0.18, <0.000	2.03, 0.016 (lag 2)
FDIV	0.03, 0.689	-0.31, <0.000 (lag 2)
COINTEQ01	-	-0.91, 0.125

Takeaway: Mineral exports and education are strong long-term drivers; infrastructure effects are delayed; FDI has weak influence; short-run adjustments are weak.

PMG-ARDL Results - Environmental Trade-Offs (Model 2):

Variable	Long-Run (Coeff, p)	Short-Run (Coeff, p)
LACO	-28.25, 0.000	7.14, 0.2145
MEXP	-0.10, 0.000	0.03, 0.3245
INVA	0.07, 0.000	-0.02, 0.3092
RECN	-0.12, 0.000	0.01, 0.6864
COINTEQ01	-	-0.28, 0.3232

Takeaway: In the long run, industry activity increases emissions, while persistent emissions, mineral exports, and renewable energy consumption constrain it, and short-run adjustments are weak, indicating slow recovery from shocks.

Post-Diagnostic Tests

Purpose: Ensure model robustness, reliability, and interpretability using scaled coefficients and confidence intervals.

Model	Key Drivers	Reliability
Model 1	MEXP, EDUC (positive); INFR, FDI (negative)	MEXP consistent; others mixed
Model 2	INVA (positive); RECN, LACO, MEXP (negative)	All highly significant

Takeaway: Model 2 provides strong, interpretable results; Model 1 shows variability, requiring cautious inferences.

Discussion of Key Findings

Industrial Potential of Minerals

- Mineral exports are the strongest long-term driver of industrial growth.
- Supports **Resource-Based Industrialisation Theory**, (Hirschman, 1958; Ado et al., 2022).
- Human capital enhances conversion of resource wealth into sustained industrial output (Chen et al., 2024; Boafo et al., 2024).

Domestic Conditions & Short-Run Dynamics

- Weak infrastructure and limited FDI constrain growth align with **resource-curse literature**.
- Short-run adjustments are slow and volatile, reflecting market swings and lagged effects of infrastructure and skills.

Discussion of Key Findings

Environmental Trade-offs

- Persistent emissions and mineral exports impose long-term ecological costs, consistent with **Environmental Kuznets Curve (EKC)** theory (Grossman & Krueger, 1995).
- Industrial value-added can partially decouple growth from environmental harm through downstream processing and cleaner technologies (Nkuna et al., 2022; Akinbile & Mbohwa, 2025).
- Renewable energy adoption shows transitional inefficiencies; short-run environmental impacts are minimal (Cao et al., 2024; Tweneboah, 2024; Ajumobi, 2025).

Strategic Industrial Policy Implications/Recommendations for Africa

Move Beyond Raw Exports

- Local processing and refining
- Battery and green-tech manufacturing

Invest in Human Capital

- Technical and engineering education
- Mineral-specific skill ecosystems

Align Infrastructure Strategically

- Energy systems linked to industrial corridors
- Transport networks tied to beneficiation hubs

Green Transition Imperatives

Accelerate renewable energy integration in mining

Incentivise cleaner extraction technologies (bioleaching, innovation)

Strengthen environmental monitoring frameworks

Embed emissions standards into mineral licensing regimes

Industrialisation without environmental governance risks long-term fragility.

The Big Takeaway

Africa's critical minerals can anchor industrial transformation.

But:

- Growth effects are structural and long-term
- Environmental costs are real and persistent
- Renewable energy is central to resolving the trade-off
- The future of African industrial policy lies in integrating:

Minerals + Manufacturing + Green Energy + Governance

Final Reflection for Policymakers

The question
is not
whether
Africa should
mine.

The question is:

- ✓ Who captures the value?
- ✓ Who bears the environmental cost?
- ✓ And how can policy ensure both prosperity and sustainability?

Thank you