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Assessing the Effects of Trade-induced Technology Imitation on Economic Growth in Africa

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Abstract

This revision reconstructs a public-data panel to reassess whether imported technology exposure predicts real GDP per capita growth in sub-Saharan Africa. A diffusion model derives the income-growth outcome and predicts positive import effects, amplified by absorptive capacity and distance from the frontier. Consistently classified SITC Revision 4 trade is combined with World Bank, Penn World Table 11.0 and UCDP data. The principal complete-case sample contains 444 observations for 34 countries over 2008-2024. Both proposed interactions are estimated, alongside initial income, openness and additional confounders. The import-share coefficient is statistically inconclusive in country/year fixed effects and restricted System-GMM; the interactions and a dated low-income contrast also lack robust support. Alternative measures, controls, samples and instrument lags reveal substantial uncertainty. The earlier positive result is therefore not established in this reconstructed sample. This does not exclude firm-level learning: import composition measures potential exposure, not imitation itself. Policy should emphasize productive use, complementary capabilities and evaluation rather than infer a demonstrated growth return to import incentives.

Keywords: GDP per capita growth; technology diffusion; imitation; Africa; absorptive capacity.

1. Introduction

Imports may provide equipment, process inputs and knowledge when domestic research is costly. Learning nevertheless depends on skills, managerial capability and local production conditions (Grossman & Helpman, 1991; Cohen & Levinthal, 1990; Keller, 2021). African firm evidence distinguishes access from effective technology use and stresses complementary investments (Cirera et al., 2022; Begazo et al., 2023). An aggregate import share cannot identify reverse engineering or the firms that learn.

This revision replaces the undocumented legacy regression table with new, reproducible estimates. It tests import exposure, a continuous income-distance interaction and human-capital complementarity using the same income-growth outcome derived theoretically. Income convergence is distinguished from growth persistence; classification, denominators, sample selection and GMM diagnostics are explicit. The analysis is a reconstruction with newer data and SITC Revision 4, not an exact replication of the original 44-country sample or its database vintage (Maswana, 2015).

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2. Theoretical Framework

2.1. Technology diffusion and income growth

A parsimonious diffusion model combines imitation, absorptive capacity and frontier distance (Nelson & Phelps, 1966; Benhabib & Spiegel, 1994; Acemoglu et al., 2006). Assume labor input is proportional to population, absorbing the constant into productivity:

$$Y_{it} = A_{it}K_{it}^{\alpha}N_{it}^{1-\alpha}, \qquad y_{it} = A_{it}k_{it}^{\alpha}, \qquad 0 < \alpha < 1. \tag{1}$$

Here Y is real GDP; K is physical capital; N is population; $y = Y/N$ is real GDP per capita; $k = K/N$ is capital per capita; A is Hicks-neutral total factor productivity; α is the capital elasticity; i, t index countries and time. Employment or hours changes require additional controls when proportional labor does not hold.

Capital accumulation is $\dot{K} = sY - \delta_K K$. Applying the quotient rule yields $\dot{k} = \dot{K}/N - k\dot{N}/N = sy - (\delta_K + n)k$, where s is the investment-output ratio; δ_K is capital depreciation; $n = \dot{N}/N$ is population growth. Productivity evolves as

$$\dot{A} = \phi M^{\beta}H^{\chi}(A^* - A) + \eta R^{\psi}H^{\zeta}A. \tag{2}$$

Here M is import-based knowledge exposure; H is absorptive capacity; A^* is frontier TFP; R is domestic research effort; $\phi, \eta > 0$ are diffusion and innovation efficiencies; $\beta, \chi, \psi, \zeta > 0$ govern input responses. Trade composition and education are imperfect empirical counterparts.

Taking logarithms of (1), differentiating, and substituting both accumulation laws gives an explicit income-growth equation:

$$\begin{aligned} r^y \equiv \frac{\dot{y}}{y} &= \frac{\dot{A}}{A} + \alpha\frac{\dot{k}}{k} \\ &= \alpha\left(s\frac{y}{k} - \delta_K - n\right) + \phi M^{\beta}H^{\chi}q + \eta R^{\psi}H^{\zeta}, \end{aligned} \tag{3}$$

where $d = A/A^* \in (0, 1]$ is frontier proximity; $q = d^{-1} - 1 \geq 0$ is the technology gap; r^y is instantaneous real income growth. The annual arithmetic outcome estimated below is exactly

$$g_{it} = 100\left(\frac{y_{it}}{y_{i,t-1}} - 1\right) = 100\left[\exp\left\{\int_{t-1}^{t} r_i^y(\tau)\, d\tau\right\} - 1\right]. \tag{4}$$

Here g is annual real GDP per capita growth in percent; τ is within-year time. It approximates $100\Delta \ln y$ for small changes. The regressions therefore concern income growth, including capital deepening, rather than TFP growth alone.

2.2. Testable signs and transitional interpretation

For $q > 0$, holding the other inputs fixed, the imitation derivatives are

$$\frac{\partial r^y}{\partial M} = \phi\beta M^{\beta-1}H^{\chi}q > 0, \quad \frac{\partial^2 r^y}{\partial M \partial H} = \phi\beta\chi M^{\beta-1}H^{\chi-1}q > 0, \quad \frac{\partial^2 r^y}{\partial M \partial q} = \phi\beta M^{\beta-1}H^{\chi} > 0. \tag{5}$$

These conditional signs motivate the import slope and two interactions; they do not guarantee positive reduced-form coefficients under measurement error, confounding or equilibrium adjustment. A low-income label is not technological distance, and the model does not predict an insignificant export coefficient. AAZ motivates different imitation and innovation strategies; this simplified model does not derive its endogenous regime switch.

For fixed inputs, define $\mu = \phi M^{\beta}H^{\chi}$, $r = \eta R^{\psi}H^{\zeta}$ and $g^* = \dot{A}^*/A^*$. Then $\dot{d} = \mu(1-d) + (r - g^*)d$. If $g^* > r$, the stable relative productivity level is $d^* = \mu/(\mu + g^* - r)$. Greater exposure raises this level and transitional growth; TFP eventually grows at the frontier rate. Neither theory nor the annual regressions establish a permanent increase in balanced-growth rates.

2.3. Reduced-form interpretation

In the empirical model below, a negative growth-lag slope indicates growth mean reversion; a negative lagged-income slope is the conditional income-level association relevant to convergence. Neither is a structural convergence speed. Investment's slope is not α, because (3) also contains y/k; capability slopes are not structural returns or diffusion elasticities. Lagging does not eliminate reverse causality, dynamic fixed-effects bias, measurement error or omitted research effort.

3. Data, Measurement and Estimating Equation

3.1. Public-data reconstruction and coverage

Data were retrieved on 4-5 October 2026. The candidate panel has 48 World Bank sub-Saharan African economies, with inputs for 2007-2024. Outcome years are 2008-2024 because regressors are lagged. UN Comtrade supplies annual world-partner merchandise values in current US dollars; WDI supplies growth, income and macro controls; PWT 11.0 supplies human capital and relative TFP; UCDP OrganizedViolenceCY 26.1 supplies conflict. PWT ends in 2023, sufficient for lagged human capital in 2024. No missing observation is interpolated or replaced by zero.

SITC Revision 4 is used throughout: newer Revision 3 series require premium bulk access, whereas the Revision 4 query series begins in 2007. This changes the legacy measurement and period. Only complete six-category baskets with a positive reported total enter the baseline; omitted product records remain missing. Current territorial reporter codes exclude expired predecessor series; Sudan begins after the 2011 partition. Trade-reporting transitions and missing controls make the panel unbalanced.

Table 1. Non-overlapping SITC Revision 4 exposure basket

Code	Coverage	Hypothesized exposure
51	Organic chemicals	Formulation and process inputs
52	Inorganic chemicals	Production-process inputs
541	Pharmaceutical/medicinal products, excluding group 542 medicaments	Laboratory and formulation inputs
58	Non-primary plastics	Fabrication and adaptation
59	Other chemical materials/products	Heterogeneous process inputs
75	Office/data-processing machines	Equipment use and ICT learning

Source: United Nations (2006). Product groups indicate potential use; they are not validated observations of imitation.

Define $m_{it} = 100 \sum_{p \in \mathcal{B}} V^{IM}_{ipt} / V^{IM}_{it,all}$, with $\mathcal{B} = \{51, 52, 541, 58, 59, 75\}$. Here V^{IM} is import value; p is a product group; "all" is total merchandise imports in the same source; m is on a 0-100 percentage-point scale. Published aggregate groups are added once; "54.1" is group 541, not division 54. Exports e use the same basket over total merchandise exports. The basket mixes sophisticated equipment, inputs and final goods; it is not uniformly low technology or demonstrably easy to imitate.

3.2. Variables and observed analysis sample

The principal sample has 444 observations in 34 countries, each with at least five complete baseline years: Angola, Benin, Botswana, Burkina Faso, Cameroon, Central African Republic, Democratic Republic of the Congo, Republic of the Congo, Côte d'Ivoire, Eswatini, Ethiopia, Gabon, The Gambia, Ghana, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe. Mean growth is 1.42 percent and mean lagged import exposure is 5.46 percent (SD 2.22; range 0.45-14.13). Exact per-country and per-model years are supplied in the replication files.

The outcome g is WDI NY.GDP.PCAP.KD.ZG; $\ell = \ln y^{PPP}$ uses constant-2021-PPP GDP per capita (NY. GDP.PCAP.PP.KD); s is gross capital formation/GDP (NE.GDI.TOTL.ZS); n is population growth (SP.POP.GROW); $h = \ln H$ uses PWT's education-based human-capital index; o is exports plus imports/GDP (NE.TRD.GNFS.ZS). Growth and ratios are percentages. $Q = \ln(y^{PPP}_{US}/y^{PPP}_{i})$ is income distance from a US benchmark, not observed technological distance; alternative relative TFP uses PWT $ctfp$ (US=1). Gross secondary enrollment (SE.SEC. ENRR) is a robustness proxy, not the baseline capability stock.

$$\begin{aligned} g_{it} = {} & \rho g_{i,t-1} + \theta \ell_{i,t-1} + b_s s_{i,t-1} + b_n n_{i,t-1} + b_h h_{i,t-1} + b_M m_{i,t-1} + b_o o_{i,t-1} \\ & + b_{MQ} m_{i,t-1}(Q_{i,t-1} - \bar{Q}) + b_{Mh} m_{i,t-1}(h_{i,t-1} - \bar{h}) + Z'_{i,t-1}\gamma + \mu_i + \lambda_t + u_{it}. \end{aligned} \tag{6}$$

Here μ_i is a country effect; λ_t is a year effect; u is an error; Z holds additional controls; γ holds their slopes. Baseline means $\bar{Q} = 2.767$ and $\bar{h} = 0.622$ center the interactions. The main Q effect is absorbed by income and year effects because $Q = \ln y_{US} - \ell$.

Equation (6) approximates the income-growth mechanism locally. Its marginal growth association is $b_M + b_{MQ}(Q - \bar{Q}) + b_{Mh}(h - \bar{h})$ per percentage point of import share; a ten-point change multiplies it by ten. The mean-modifier slope is b_M; positive b_{MQ} and b_{Mh} directly test the proposed complementarities. Both interactions are estimated, alongside the main import association.

4. Estimation and Fixed-Effects Results

4.1. Interpretation, controls and identification

All specifications retain openness. The augmented block includes FDI net inflows/GDP; private-sector credit/GDP; natural-resource rents/GDP; WGI rule of law (2025-methodology 0-100 score); UCDP occurrence of state-based violence (0/1, not an armed-conflict onset); log net barter terms of trade (2015=100); electricity access (percent). WDI codes and provenance are in the codebook. R&D/GDP has sparse coverage and is not substituted for an undefined innovation index. Country and year effects absorb stable differences and common shocks; time-varying unobserved research and heterogeneous shocks remain possible confounders.

Table 2. Annual GDP per capita growth: pooled OLS and country/year fixed effects

	(1) OLS	(2) FE	(3) FE gap	(4) FE joint	(5) FE common	(6) FE controls
Lagged growth	0.276^{***}	0.100	0.096	0.096	0.122	0.119
SE	(0.072)	(0.063)	(0.066)	(0.066)	(0.092)	(0.083)
Initial log income	-0.640	-13.532^{***}	-13.776^{***}	-13.672^{***}	-23.921^{***}	-26.562^{***}
SE	(0.448)	(4.516)	(4.381)	(4.836)	(4.797)	(5.606)
Investment (%)	-0.006	0.065	0.067	0.067	0.087	0.101^{*}
SE	(0.041)	(0.062)	(0.061)	(0.061)	(0.059)	(0.054)
Population growth	-0.290	-0.858	-0.873	-0.880	-1.236	-1.165^{*}
SE	(0.423)	(0.562)	(0.566)	(0.551)	(0.739)	(0.655)
Log human capital	0.628	-1.858	-1.876	-2.615	9.484	8.394
SE	(1.086)	(6.148)	(6.122)	(8.388)	(10.157)	(11.704)
Import share m	-0.033	-0.083	-0.039	-0.044	0.030	-0.009
SE	(0.080)	(0.196)	(0.240)	(0.241)	(0.303)	(0.272)
Openness (%)	-0.002	0.051^{**}	0.053^{***}	0.053^{***}	0.020	-0.003
SE	(0.012)	(0.022)	(0.019)	(0.019)	(0.026)	(0.028)
$m\times$ centered gap	–	–	-0.117	-0.099	-0.521^{*}	-0.380
SE	–	–	(0.261)	(0.283)	(0.288)	(0.261)
$m\times$ centered capability	–	–	–	0.090	-0.928	-0.775
SE	–	–	–	(0.707)	(0.766)	(0.785)
FDI (% GDP)	–	–	–	–	–	-0.002
SE	–	–	–	–	–	(0.026)
Credit (% GDP)	–	–	–	–	–	0.140^{***}
SE	–	–	–	–	–	(0.045)
Resource rents (% GDP)	–	–	–	–	–	0.043
SE	–	–	–	–	–	(0.050)
Rule of law (0-100)	–	–	–	–	–	0.121
SE	–	–	–	–	–	(0.146)
State violence (0/1)	–	–	–	–	–	-0.953
SE	–	–	–	–	–	(0.704)
Log terms of trade	–	–	–	–	–	4.333^{*}
SE	–	–	–	–	–	(2.436)
Electricity access (%)	–	–	–	–	–	0.024
SE	–	–	–	–	–	(0.041)
Additional block	No	No	No	No	No	Yes
Observations	444	444	444	444	343	343
Countries	34	34	34	34	33	33
Outcome years	2008-24	2008-24	2008-24	2008-24	2008-22	2008-22

Notes: Country-clustered robust SE in parentheses; finite-sample correction and t_{N-1} inference. * $p < .10$, ** $p < .05$, *** $p < .01$. All columns include year effects; OLS omits country effects. Columns 1-4 use the identical complete-case sample. Columns 5-6 use an identical smaller sample; column 6 adds all seven controls listed above. Observation manifests and covariance checks are in the replication package. All regressors are lagged one calendar year.

4.2. Main findings

The baseline FE import slope is -0.083 (SE 0.196); the joint slope is -0.044 (SE 0.241). Neither is statistically distinguishable from zero. The gap and capability interactions have $p = 0.729$ and $p = 0.900$; their joint test has $p = 0.902$. The augmented estimate is also inconclusive. The reconstructed sample thus does not establish the earlier positive finding or confirm the two mechanisms. Negative point estimates do not demonstrate that imports harm growth.

The income coefficient is negative in FE but imprecise under GMM; it does not establish a stable structural catch-up rate. Positive growth persistence is not income convergence. Residual Pesaran CD is -1.32 ($p = 0.188$, 552 usable country pairs); two-lag Driscoll-Kraay inference also leaves both interactions inconclusive. Non-rejection does not rule out heterogeneous common shocks, especially in this short, unbalanced panel.

5. Dynamic-Panel Estimates and Diagnostics

Difference GMM removes country effects; System-GMM additionally uses level restrictions (Arellano & Bond, 1991; Blundell & Bond, 1998). For potentially endogenous z, representative separate restrictions are

$$E[g_{i,t-s}\Delta u_{it}] = 0, \qquad E[z_{i,t-s}\Delta u_{it}] = 0, \qquad s \geq 2, \tag{7}$$

$$E[\Delta g_{i,t-1}(\mu_i + u_{it})] = 0, \qquad E[\Delta z_{i,t-1}(\mu_i + u_{it})] = 0. \tag{8}$$

Here Δ denotes first differences; z denotes each underlying income, investment, population, capability, import, openness or interaction series. All non-year regressors are treated as potentially endogenous; lagged products instrument the interactions. System restrictions require appropriate initial conditions and changes uncorrelated with country effects. Income/capability persistence makes these assumptions substantive, not automatic.

To reduce time-instrument proliferation, GMM uses the denser 2015-2024 window, retaining 2013-2014 for lags. The lag-3 model starts in 2016. Countries with no usable differenced equations are excluded. Instruments are collapsed, with the explicit lag bounds below; year indicators are standard instruments. Two-step SE use Windmeijer's (2005) correction; one-step inference is robust. A pinned pydynpd implementation (Wu et al., 2023) was checked against its published coefficient, SE, Hansen and AR benchmark.

Table 3. Dynamic GMM estimates and complete specification diagnostics

	(1) System	(2) System joint	(3) System lag 3	(4) Difference	(5) System 1-step
Lagged growth	0.278^{***}	0.289^{***}	0.159	0.122	0.226^{***}
SE	(0.094)	(0.068)	(0.186)	(0.103)	(0.051)
Initial log income	-1.539	-3.211	-3.532	-0.935	-2.693
SE	(1.398)	(3.683)	(4.647)	(11.458)	(2.683)
Investment (%)	0.031	0.009	0.193	0.056	0.004
SE	(0.108)	(0.110)	(0.189)	(0.118)	(0.064)
Population growth	-2.434^{*}	-2.866^{***}	-2.960^{**}	-2.070	-2.543^{**}
SE	(1.352)	(0.858)	(1.490)	(1.394)	(1.040)
Log human capital	-2.472	5.950	6.726	-6.138	-1.796
SE	(7.187)	(14.304)	(12.105)	(16.061)	(10.039)
Import share m	0.292	0.349	0.935	-0.390^{*}	0.098
SE	(0.291)	(0.257)	(0.631)	(0.199)	(0.271)
Openness (%)	-0.026	-0.034	-0.061^{**}	-0.043	-0.043^{***}
SE	(0.019)	(0.022)	(0.029)	(0.099)	(0.016)
$m\times$ centered gap	–	-0.324	-0.617	0.590^{*}	-0.224
SE	–	(0.695)	(0.857)	(0.334)	(0.448)
$m\times$ centered capability	–	-1.240	-1.686	1.618	-0.061
SE	–	(1.682)	(1.519)	(1.103)	(1.082)
Steps	2	2	2	2	1
Collapsed lag bounds	2-2	2-2	3-3	2-3	2-2
Obs. / countries	312 / 34	312 / 34	285 / 34	312 / 34	312 / 34
Years	2015-24	2015-24	2016-24	2015-24	2015-24
Instruments	25	29	28	28	29
AR(1) p	0.004	0.005	0.051	0.026	< 0.001
AR(2) p	0.582	0.557	0.899	0.997	0.648
Hansen J (df)	12.11 (7)	12.22 (9)	4.89 (9)	6.79 (9)	12.22 (9)
Hansen p	0.097	0.201	0.844	0.659	0.201
Full-level C p	0.097	0.201	0.844	–	0.201
Trade-level C p	0.589	0.585	0.959	–	0.585

Notes: Outcome and scales as in Table 2; corrected robust SE in parentheses. Year effects and all seven baseline regressors appear in every model. System models include a level intercept. "Obs." counts usable differenced equations; System-GMM additionally stacks available level equations. The full-level C test uses the full model's first-step robust covariance and refits the reduced moment criterion on the same stacked data. Removing all GMM level moments exactly identifies the lag-2/lag-3 systems, so this C test equals Hansen J and is not independent evidence. The separate trade-level C test removes only the import and, where present, interaction level moments. All reported instrument covariance matrices have full rank.

Import estimates vary across methods and lag sets. All System-GMM import intervals include zero; Difference-GMM gives a negative import slope ($p = 0.0501$) and a positive gap interaction ($p = 0.0780$), neither robust across estimators. System interactions are not robustly positive. The expected AR(1) rejection appears in the principal two-step model; AR(2) is not rejected. Hansen and subset tests do not reject at 5 percent, but limited power and 29 instruments for 34 countries remain concerns (Roodman, 2009). Passing these tests cannot establish exclusion, strong instruments or causality. Difference-GMM's wide income/capability uncertainty and lag-set sensitivity reinforce this limitation.

6. Robustness, Heterogeneity and Policy

Table 4. Selected sensitivity estimates: exposure terms and samples

Specification / regressor	Coefficient (SE)	p	Obs. / countries
Basket / GDP	−0.390 (0.438)	0.380	444 / 34
Chemical share	−0.004 (0.198)	0.982	444 / 34
ICT share	−0.737 (0.815)	0.372	444 / 34
Export share, controlling imports	−0.027 (0.058)	0.640	395 / 32
Import × relative-TFP gap	−0.583 (0.357)	0.115	334 / 25
Import × gross enrollment	0.007 (0.012)	0.561	230 / 31
Exclude $\|g\| > 20$	−0.014 (0.236)	0.952	443 / 34
Exclude 2020-2021	−0.038 (0.237)	0.873	381 / 34
Before 2020	−0.026 (0.334)	0.939	286 / 34
Exclude South Africa	−0.094 (0.248)	0.707	427 / 33
PWT growth and its own lag	0.069 (0.246)	0.779	413 / 34

Notes: Country/year FE, baseline controls and country-clustered SE. Where not stated otherwise, the coefficient is on lagged m; joint models also contain both interactions. Values are unstandardized. Chemical and ICT rows report separate shares in a joint component regression. GDP denominator means basket imports/GDP, both in current US dollars. TFP and enrollment rows report their interaction coefficients. Export composition is added alongside imports; its null result is not a theoretical prediction. The package contains every coefficient and further common-sample comparisons.

A pooled interaction with fixed FY2008 low-income status tests the original grouping without reclassifying countries as they grow. The sample contains 24 LIC and 10 non-LIC countries, with 313 and 131 observations. The LIC-minus-non-LIC import slope is 0.018 (SE 0.356; $p = 0.960$), not a significant group difference. Continuous income distance is the primary heterogeneity test; a threshold or smooth-transition model has not been estimated and cannot be claimed as evidence of a regime switch.

Table 5. Joint-FE marginal associations for a ten-point import-share increase

Modifier (other held at mean)	P10 effect [95% CI]	Median effect [95% CI]	P90 effect [95% CI]
Gap	0.87 [-10.49, 12.23]	-0.58 [-5.03, 3.87]	-1.43 [-6.11, 3.26]
Capacity	-0.75 [-7.97, 6.47]	-0.47 [-5.43, 4.50]	-0.12 [-6.95, 6.70]

Notes: Growth percentage points; 95% country-clustered t intervals. One modifier is set to its observed quantile while the other is held at its baseline mean. These are conditional associations, not changes in a country's equilibrium path. A ten-point shift is large relative to the observed exposure range.

6.1. Limits of the reconstructed evidence

Leave-one-country-out import slopes range from -0.118 to 0.174; measurement and sample choices do not establish a robust positive effect. Complete-case selection may favor better reporting economies; absence of a product record need not mean absence of trade. The basket captures composition rather than total knowledge flow and can reflect consumption, re-exports, prices or capital services. Income distance is an imperfect TFP proxy, and macro education cannot measure firms' absorptive capacity. Sparse research data leave innovation incompletely controlled. Dynamic FE bias, weak internal instruments and correlated shocks limit identification. External instruments and weak-IV-robust inference have not been obtained; tariffs, transport costs or partner demand would require a defended exclusion restriction, not simply inclusion as instruments.

6.2. Conclusion

The new panel aligns the theoretical and empirical income-growth outcomes and directly estimates the proposed capability and frontier-distance interactions. It does not reproduce a statistically robust positive imitation effect, a stronger LIC return, or support for the two mechanisms. The estimates are too imprecise and sensitive to establish a causal effect or disprove technology learning.

Reducing customs delays and improving trade logistics may facilitate productive input access, but these regressions do not quantify their growth returns or justify blanket import tax incentives. Education, technical and managerial training, reliable power, connectivity, maintenance and local supplier learning remain plausible complements. Policy evaluation should measure firm-level adoption and productivity, distinguish equipment use from imitation, and assess costs and additionality (Cirera et al., 2022; Begazo et al., 2023).

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