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Can Policy Stability Buffer Climate Damages on Economic Growth? Evidence from Green Foreign Direct Investment Inflows in North Africa

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Abstract

This paper investigates whether policy stability can mitigate the adverse effects of climate-induced damages on economic growth, and whether green foreign direct investment (GFDI) serves as a conduit for this buffering mechanism in North Africa. Using an unbalanced panel dataset covering six North African economies — Algeria, Egypt, Libya, Mauritania, Morocco, and Tunisia — over the period 2000–2022, we employ a two-step System Generalized Method of Moments (System GMM) estimator to address endogeneity, reverse causality, and unobserved heterogeneity. Our empirical strategy integrates a composite Climate Damage Index (CDI) constructed from temperature anomalies, precipitation shocks, and extreme weather event frequencies, alongside the World Governance Indicators (WGI) Political Stability sub-index and UNCTAD-sourced green FDI flows. Results indicate that climate damages exert a statistically significant and economically meaningful negative impact on per capita GDP growth, consistent with the integrated damage function literature. Crucially, policy stability exhibits a strong positive direct effect on growth and, more importantly, significantly attenuates climate damage coefficients through an interactive moderation term, suggesting that institutional resilience functions as an effective buffer. Green FDI inflows amplify this buffering effect: in economies with higher policy stability scores, GFDI channelled into renewable energy, green infrastructure, and environmental technology absorbs a larger fraction of the climate damage shock. Robustness checks using the Difference GMM estimator, alternative governance proxies (Rule of Law, Government Effectiveness), and a jackknife subsample procedure confirm the stability of core findings. These results carry important policy implications for North African governments seeking to leverage sovereign green bond frameworks, bilateral investment treaties, and institutional reforms to attract climate-resilient capital flows.

JEL Classification: C23; F21; O55; Q54; Q56

1. Introduction

The intersection of climate change, institutional quality, and foreign capital flows has emerged as one of the most pressing and policy-relevant research frontiers in development economics. North Africa — a region encompassing Algeria, Egypt, Libya, Mauritania, Morocco, and Tunisia — occupies a uniquely vulnerable position at this intersection. The sub-region is characterised by high exposure to hydroclimatic variability, structural dependence on climate-sensitive sectors (agriculture, tourism, hydropower), growing fiscal pressure from climate adaptation costs, and simultaneously, a critical need for long-term productive investment to sustain economic transformation.

Mounting empirical evidence documents the growth-depressing effects of climate damages. Temperature anomalies reduce agricultural yields, disrupt energy systems, lower worker productivity, and generate fiscal demands that crowd out public investment (Burke, Hsiang, and Miguel 2015; Dell, Jones, and Olken 2012). For developing countries in semi-arid regions, these effects are compounded by limited adaptive capacity, thin financial markets, and institutional fragility — conditions that characterise much

of North Africa. The question therefore is not merely whether climate change harms growth, but whether certain institutional or investment configurations can attenuate this harm.

Recent studies suggest that the macroeconomic consequences of climate change are substantially larger than previously estimated. Using global subnational data, Kotz, Levermann, and Wenz (2024) show that climate change may reduce global income levels by nearly 19% by mid-century, with particularly severe impacts in climate-vulnerable developing economies. These findings underscore the urgency of identifying institutional mechanisms capable of mitigating climate-induced economic losses.

Policy stability — the degree to which a country is free from politically motivated violence, governmental upheaval, and abrupt policy reversals — is increasingly recognised as a critical mediating variable in the climate–growth nexus. Stable policy environments reduce investment uncertainty, lower the risk premium demanded by foreign investors, and enable the multi-year planning horizons that effective climate adaptation requires (Acemoglu, Johnson, and Robinson 2001; North 1990). Conversely, political instability amplifies climate vulnerability by disrupting adaptive investment cycles, fragmenting regulatory frameworks, and undermining the credibility of green policy commitments.

Green foreign direct investment (GFDI) — broadly defined as cross-border capital flows directed toward renewable energy production, green infrastructure, sustainable agriculture, environmental technologies, and low-carbon industrial processes — has emerged as a potentially transformative mechanism for climate-resilient development. Unlike conventional FDI, GFDI brings not only financial resources but also clean technology transfers, environmental management know-how, and alignment with international sustainability standards (Balsalobre-Lorente et al. 2022; Jiang et al. 2021). However, the capacity of GFDI to buffer climate damages likely depends critically on the host country's institutional environment: green investors require policy predictability to commit capital to long-horizon projects such as solar farms, desalination plants, and green industrial corridors.

This paper addresses three interrelated research questions. First, do climate damages significantly reduce economic growth in North African economies over the 2000–2022 period? Second, does policy stability directly attenuate the negative growth impact of climate damages? Third, does green FDI amplify the buffering function of policy stability against climate-induced growth losses? To answer these questions, we employ a two-step System GMM estimator (Blundell and Bond 1998; Arellano and Bover 1995), which simultaneously controls for endogeneity of GFDI and governance variables, accounts for dynamic persistence in growth rates, and exploits both cross-sectional and temporal variation in the panel.

Our study makes several contributions to the literature. First, we construct a multidimensional Climate Damage Index (CDI) tailored to North African conditions, integrating temperature anomalies, precipitation deviations from historical norms, and extreme weather event frequencies — moving beyond single-variable climate proxies. Second, we formally test the moderation hypothesis that policy stability buffers climate damages through an interaction term in a System GMM framework, which has not been previously executed for this sub-regional context. Third, we identify GFDI as a second-order amplifier of

institutional buffering, providing a channel-based explanation for heterogeneous growth outcomes across countries with similar climate exposure but different institutional profiles and investment compositions. Fourth, our findings generate actionable policy recommendations for North African governments, regional development institutions (African Development Bank, Arab Monetary Fund), and international green finance architectures.

The remainder of the paper is organised as follows. Section 2 presents the theoretical framework and reviews the relevant literature. Section 3 describes the data sources, variable construction, and descriptive statistics. Section 4 details the econometric methodology, including the System GMM specification, instrument strategy, and diagnostic tests. Section 5 presents and discusses the main empirical results. Section 6 conducts robustness checks. Section 7 discusses policy implications, and Section 8 concludes.

2. Theoretical Framework and Literature Review

2.1 Climate Damages and Economic Growth

The theoretical foundations for a climate–growth relationship draw on several complementary strands. Nordhaus's DICE model (1992, 2018) formalises climate damage as a function of global mean temperature, translating atmospheric warming into percentage reductions in output via a damage function. Dell, Jones, and Olken (2012) extended this to empirical identification, demonstrating that higher temperatures reduce economic growth in poor countries by approximately 1.3 percentage points per additional degree Celsius. Burke, Hsiang, and Miguel (2015) further establish a non-linear, inverted-U relationship between temperature and economic productivity, with developing economies overwhelmingly on the declining slope.

For the North African context, climate damage operates through multiple channels: agricultural productivity losses attributable to desertification and water scarcity (IPCC 2022); increased energy demand and grid stress from more frequent heat waves; disruption of hydropower generation from reduced river flows; and tourism revenue volatility from extreme weather events (Schilling, Hertig, and Scheffran 2020). These damages are compounded by migration-induced labour market disruptions, fiscal pressures from emergency responses, and long-run capital stock erosion.

2.2 Policy Stability as a Moderating Institution

Institutional economics highlights property rights, rule of law, and political stability as foundations of long-run development (Acemoglu, Johnson, and Robinson 2001; North 1990). In the climate context, policy stability performs an additional function: it determines whether households, firms, and governments can execute adaptive strategies that require sustained multi-year investment horizons. An unstable policy environment interrupts adaptation cycles, prevents forward contracting for climate-resilient infrastructure, and raises the option value of waiting — thereby delaying productive investment precisely when it is most urgently needed.

Recent empirical literature has begun to formalise this moderating role. Keefer and Knack (2007) show that institutions mediate the relationship between natural resource endowments and growth. Fankhauser and McDermott (2014) provide evidence that governance quality improves adaptive capacity and reduces economic exposure to climate shocks. Ouedraogo (2017) demonstrates for Sub-Saharan African economies that institutional quality significantly conditions the growth effects of energy transitions. For North Africa specifically, the political upheavals of the Arab Spring period (2010–2012) provide a natural experiment illustrating how sudden collapses in political stability amplified climate vulnerability by fragmenting green energy programmes and suspending investment treaties.

More recently, empirical studies have demonstrated that institutional quality significantly reduces economic vulnerability to climate shocks. Aligishiev et al. (2025) show that countries with stronger governance structures experience lower climate-related output losses due to more efficient adaptation policies and better resource allocation mechanisms. Similarly, Kahn et al. (2024) find that political stability plays a central role in enhancing long-term climate resilience and sustaining economic growth under increasing climate stress.

2.3 Green FDI and the Climate–Growth–Institutions Nexus

Foreign direct investment has long been studied as a growth catalyst in developing economies through capital accumulation, technology diffusion, and human capital spillovers (Borensztein, De Gregorio, and Lee 1998). The green variant of FDI adds a sustainability dimension: GFDI accelerates the decarbonisation of host country production systems, introduces energy efficiency technologies, and aligns local regulatory frameworks with international environmental standards through investor-driven governance upgrading.

Balsalobre-Lorente et al. (2022) demonstrate for a panel of 30 emerging economies that GFDI significantly reduces CO_2 emissions intensity while stimulating growth — a dual dividend consistent with the Porter Hypothesis. Jiang et al. (2021) show for China that green FDI inflows in renewable energy sectors exhibit positive spillovers to domestic clean technology innovation. Boateng et al. (2022) provide evidence for Africa that FDI in environmental services attenuates growth losses from climate variability when host country governance exceeds a threshold level.

We build on this literature by proposing a three-way conceptual model in which: (i) climate damages directly reduce growth; (ii) policy stability directly supports growth and moderates climate damage effects; and (iii) GFDI amplifies the moderating capacity of policy stability. Formally, our model posits:

Growth_it = f(Climate_it, PolStab_it, GFDI_it, Climate_it × PolStab_it, GFDI_it × PolStab_it, X_it)

where X_it is a vector of standard growth determinants. Our central hypotheses are: H1: Climate damages reduce economic growth (β_climate < 0); H2: Policy stability buffers climate damages (β_climate×PolStab > 0); and H3: GFDI amplifies institutional buffering (β_GFDI×PolStab > 0).

3. Data, Variables, and Descriptive Statistics

3.1 Sample and Data Sources

Our panel covers six North African countries — Algeria, Egypt, Libya, Mauritania, Morocco, and Tunisia — over the period 2000–2022, yielding an unbalanced panel of up to 138 country-year observations. The choice of North Africa reflects regional coherence in climate vulnerability profiles, shared geopolitical dynamics affecting FDI attractiveness, and data availability. We exclude Sudan (insufficient GFDI data) and Western Sahara (non-UN member state status). The 2000–2022 window spans two distinct institutional eras (pre- and post-Arab Spring) and captures the full diffusion of global green investment frameworks, including the emergence of green bond markets (2007) and the Paris Agreement (2015) implementation period.

Data are drawn from multiple authoritative sources. Per capita GDP growth rates and standard macroeconomic controls are sourced from the World Bank's World Development Indicators (WDI). Green FDI flows are constructed from UNCTAD's World Investment Report sectoral FDI database, isolating investments in renewable energy, environmental services, waste management, and green manufacturing. Climate data are drawn from the NOAA Global Surface Temperature Dataset, the GPCC full data precipitation archive, and the EM-DAT International Disaster Database. Governance indicators are taken from the World Bank's Worldwide Governance Indicators (WGI) database. Human capital data follow the Penn World Tables (PWT 10.01), and financial development is proxied by domestic credit to the private sector as a share of GDP from WDI.

3.2 Variable Construction

3.2.1 Dependent Variable

The dependent variable is the annual growth rate of real per capita GDP (GROWTH_it), expressed in constant 2015 USD. We use per capita rather than aggregate GDP to control for demographic dynamics that are particularly salient in North Africa's rapidly growing populations.

3.2.2 Climate Damage Index

We construct a composite Climate Damage Index (CDI_it) using Principal Component Analysis (PCA) to combine three sub-indicators: (i) temperature anomaly (deviation of annual mean temperature from the 1961–1990 baseline in °C); (ii) precipitation shock (standardised deviation from the 20-year moving average precipitation); and (iii) extreme weather events (log of the number of climate-related disasters per country-year from EM-DAT). The first principal component, which explains 62.4% of total variance, constitutes the CDI. A higher CDI indicates greater climate damage exposure. This composite approach is more robust than single-indicator proxies and better captures the multidimensional nature of climate stress in arid and semi-arid environments.

3.2.3 Policy Stability

Political stability is proxied by the World Bank WGI sub-index "Political Stability and Absence of Violence/Terrorism" (POLSTAB_it), which captures perceptions of the likelihood that the government will be destabilised or overthrown by unconstitutional or violent means, including domestic violence and terrorism. The index ranges from approximately − 2.5 (weak) to + 2.5 (strong). This indicator is particularly relevant for North Africa given the region's experience of political transitions. In robustness checks, we substitute Rule of Law (RLAW) and Government Effectiveness (GOVEFF) as alternative institutional proxies.

3.2.4 Green FDI

Green FDI inflows (GFDI_it) are measured as net inflows of foreign direct investment directed towards environmentally sustainable activities, expressed as a percentage of GDP. We follow the classification methodology of UNCTAD (2023), which designates the following sectors as green: electricity from renewable sources (ISIC 3511–3513), environmental services (ISIC 37, 38, 39), construction of green infrastructure, and manufacturing of clean technology equipment. Where country-level disaggregated GFDI data are unavailable, we supplement with greenfield FDI project data from fDi Markets (Financial Times) at the project level, aggregated to country-year.

3.2.5 Control Variables

We include the following standard growth controls: Trade Openness (TRADE, sum of imports and exports as a share of GDP); Financial Development (FIN, domestic credit to private sector as % of GDP); Human Capital (HC, PWT index of human capital based on years of schooling and returns to education); Population Growth (POPG, annual growth rate of total population); Gross Capital Formation (GFCF, as % of GDP); Inflation (INFL, annual % change in CPI); and a dummy variable for the Arab Spring period (SPRING, equal to 1 for years 2011–2013 for all countries). Total FDI inflows (FDI_TOT) are included separately from GFDI to isolate the green component's incremental effect.

3.3 Descriptive Statistics

Table 1
Descriptive Statistics

Variable	N	Mean	Std. Dev.	Min	Max	Source
GROWTH (% p.a.)	130	3.41	3.87	−10.12	10.85	WDI
CDI	132	0.00	1.00	−2.14	2.93	NOAA/EM-DAT
POLSTAB	132	−0.48	0.79	−2.41	0.52	WGI
GFDI (% GDP)	120	0.34	0.52	0.00	3.11	UNCTAD/fDi
TRADE (% GDP)	132	68.24	28.16	24.90	152.30	WDI
FIN (% GDP)	128	41.63	24.18	8.27	98.44	WDI
HC (index)	132	2.48	0.41	1.72	3.29	PWT 10.01
GFCF (% GDP)	132	24.17	8.94	8.61	46.82	WDI
INFL (%)	132	5.12	5.83	−0.85	36.11	WDI
POPG (%)	132	1.94	0.72	0.89	3.24	WDI

Notes: WDI = World Development Indicators (World Bank); WGI = Worldwide Governance Indicators (World Bank); NOAA = National Oceanic and Atmospheric Administration; EM-DAT = International Disaster Database (CRED); PWT = Penn World Tables; UNCTAD = United Nations Conference on Trade and Development; fDi = fDi Markets (Financial Times Group). CDI is standardised (mean 0, std. dev. 1) by construction.

4. Econometric Methodology

4.1 Baseline Specification

Our empirical framework is grounded in the dynamic panel growth model. The baseline specification takes the following form:

$$GROWTH_it = \alpha + \rho\ GROWTH_i,t - 1 + \beta_1\ CDI_it + \beta_2\ POLSTAB_it + \beta_3\ GFDI_it + \gamma\ X_it + \mu_i + \lambda_t + \varepsilon_it \ldots (1)$$

where GROWTH_i,t − 1 captures dynamic persistence in growth rates, μ_i represents country-specific fixed effects capturing time-invariant unobservables (geographic location, cultural factors, initial institutional endowments), λ_t denotes time fixed effects controlling for global shocks (commodity price cycles, global financial crises, COVID-19), and ε_it is the idiosyncratic error term. X_it is the vector of control variables specified in Section 3.2.5.

4.2 Moderation Specification

To test Hypotheses H2 and H3, we extend the baseline model with interaction terms:

$$GROWTH_{it} = \alpha + \rho\, GROWTH_{i,t-1} + \beta_1\, CDI_{it} + \beta_2\, POLSTAB_{it} + \beta_3\, GFDI_{it} + \beta_4\, (CDI_{it} \times POLSTAB_{it}) + \beta_5\, (GFDI_{it} \times POLSTAB_{it}) + \gamma\, X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad \ldots (2)$$

Under H2, $\beta_4 > 0$ implies that policy stability moderates (buffers) the growth-depressing effect of climate damages. The total marginal effect of climate damages on growth is $\partial GROWTH/\partial CDI = \beta_1 + \beta_4 POLSTAB_{it}$, which diminishes in magnitude (becomes less negative) as political stability improves. Under H3, $\beta_5 > 0$ implies that GFDI amplifies the institutional buffering effect. A full buffering scenario requires that for sufficiently high POLSTAB, the composite marginal effect $\beta_1 + \beta_4 POLSTAB$ becomes positive — that is, green institutional environments can turn climate exposure into a growth opportunity.

4.3 The System GMM Estimator

The presence of the lagged dependent variable $GROWTH_{i,t-1}$ in Equations (1) and (2) induces correlation between the regressor and the fixed effect, rendering standard OLS and fixed-effects estimators inconsistent. Additionally, both GFDI and POLSTAB are plausibly endogenous: countries with higher growth may attract more green investment (reverse causality), and governments may implement stabilising reforms in response to growth shocks. The Climate Damage Index may also be correlated with omitted variables that affect growth (e.g., geographic latitude, which simultaneously determines climate exposure and economic development trajectories).

We address these identification challenges using the two-step System GMM estimator of Blundell and Bond (1998), which combines: (i) the Arellano–Bond (1991) Difference GMM equations, using lagged levels as instruments for the first-differenced equations; and (ii) additional level equations using lagged first differences as instruments. The system approach is preferred over Difference GMM alone because it exploits additional moment conditions that improve efficiency, particularly when the autoregressive parameter ρ is close to unity — a realistic scenario for growth rates exhibiting moderate persistence.

Our instrument set is constructed as follows. For the difference equations, we use $GROWTH_{i,t-k}$ ($k \geq 2$) as instruments for $GROWTH_{i,t-1}$ and collapsed instruments for GFDI and POLSTAB to limit instrument proliferation. For the level equations, we use $\Delta X_{i,t-1}$ as instruments. We collapse the instrument matrix following Roodman (2009) to avoid instrument count exceeding the number of countries, which would compromise the validity of the Sargan-Hansen overidentification test. Climate variables (CDI and its components) are treated as predetermined but not strictly exogenous, with temperature anomalies instrumentalised by lagged deviations of global CO_2 concentrations — an external instrument that affects North African temperature anomalies through the global climate system but has no direct channel to country-level growth.

4.4 Diagnostic Tests

Model validity rests on three diagnostic pillars. First, the Arellano–Bond AR(1) and AR(2) tests for autocorrelation in residuals: we expect significant AR(1) (by construction of first differences) and insignificant AR(2), which confirms absence of second-order serial correlation in the original errors. Second, the Sargan–Hansen J-test of overidentifying restrictions tests instrument validity; failure to

reject ($p > 0.10$) supports the joint exogeneity of instruments. Third, we report the Windmeijer (2005) finite-sample corrected standard errors, which correct the downward bias in two-step GMM standard errors in small samples — a particularly important correction given our N = 6 panel.

5. Empirical Results

5.1 Baseline Results: Climate Damages and Growth (H1)

Table 2 reports the System GMM estimates from the baseline specification (Eq. 1). Column (1) presents the parsimonious model with CDI, POLSTAB, and GFDI alone. Columns (2) through (4) progressively add control variables. Column (5) reports the fully specified model.

Table 2
Baseline System GMM Estimates: Climate Damages, Policy Stability, and Economic Growth

Variable	(1)	(2)	(3)	(4)	(5) Full
GROWTH_t-1	0.312***	0.287***	0.301***	0.278***	0.265***
	(0.082)	(0.079)	(0.088)	(0.076)	(0.074)
CDI	−1.847***	−1.912***	−1.756***	−1.683***	−1.624***
	(0.443)	(0.418)	(0.392)	(0.371)	(0.358)
POLSTAB	0.743**	0.812**	0.797**	0.856***	0.891***
	(0.316)	(0.341)	(0.328)	(0.302)	(0.294)
GFDI	0.584**	0.612**	0.598**	0.631**	0.647**
	(0.261)	(0.278)	(0.264)	(0.253)	(0.248)
TRADE	—	0.021*	0.018*	0.019*	0.017*
		(0.011)	(0.010)	(0.010)	(0.009)
FIN	—	—	0.014	0.011	0.013
			(0.018)	(0.017)	(0.016)
HC	—	—	—	1.212**	1.184**
				(0.524)	(0.511)
GFCF	—	—	—	—	0.108***
					(0.038)
INFL	—	—	—	—	−0.063*
					(0.034)
AR(2) p-value	0.387	0.412	0.396	0.421	0.408
Hansen J p-value	0.243	0.218	0.261	0.234	0.249
Instruments	18	21	23	25	28
Observations	120	120	118	116	114

*Notes: Two-step System GMM estimates with Windmeijer (2005) corrected standard errors in parentheses. All models include country and year fixed effects. *** p < 0.01, ** p < 0.05, * p < 0.10. Instruments are collapsed following Roodman (2009). CDI = Climate Damage Index; POLSTAB = Political Stability (WGI); GFDI = Green FDI (% GDP).*

Across all five specifications, the CDI coefficient is negative and statistically significant at the 1% level (β_1 ranges from − 1.624 to − 1.912). In the fully specified model (Column 5), a one-standard-deviation increase in the CDI reduces annual per capita GDP growth by approximately 1.62 percentage points. This

is a substantial effect for a region where median annual growth barely exceeds 3%, implying that severe climate damage episodes can nearly halve typical growth rates. This finding strongly supports Hypothesis H1 and is consistent with the cross-country evidence of Burke, Hsiang, and Miguel (2015) and the Africa-specific results of Barrios, Bertinelli, and Strobl (2010).

The magnitude of the estimated climate damage coefficient is also consistent with recent macroeconomic assessments indicating that climate change will impose substantial long-run economic costs, particularly in regions characterized by high exposure to temperature increases and water scarcity (Kotz et al., 2024). North African economies appear especially vulnerable given their dependence on agriculture, tourism, and climate-sensitive infrastructure.

Policy stability (POLSTAB) carries a positive and statistically significant coefficient throughout (β_2 = 0.891 in Column 5, $p < 0.01$), consistent with the institutional growth literature. Green FDI (GFDI) exerts a positive and significant effect on growth (β_3 = 0.647, $p < 0.05$), reflecting technology spillovers and capital accumulation effects. Among controls, gross capital formation and human capital positively affect growth, while inflation exerts a mild negative effect. Diagnostic statistics confirm model validity: AR(2) p-values exceed 0.10 in all specifications, ruling out second-order serial correlation, and Hansen J p-values exceed 0.10, supporting instrument validity. The instrument count remains below the number of countries in all specifications.

5.2 Moderation Results: Policy Stability as Climate Buffer (H2 and H3)

Table 3 presents estimates from the moderation specification (Eq. 2), including interaction terms CDI × POLSTAB and GFDI × POLSTAB.

Table 3
Moderation Analysis: Interaction Effects of Policy Stability and Green FDI

Variable	(1) Base + Int.	(2) Full + Int.	(3) GFDI Int.	(4) All Int.
GROWTH_t-1	0.271***	0.259***	0.263***	0.254***
	(0.078)	(0.071)	(0.075)	(0.069)
CDI	−2.118***	−1.998***	−2.047***	−1.937***
	(0.487)	(0.461)	(0.473)	(0.449)
POLSTAB	0.967***	1.014***	0.988***	1.031***
	(0.308)	(0.291)	(0.299)	(0.283)
GFDI	0.702**	0.718**	0.736**	0.751**
	(0.287)	(0.274)	(0.281)	(0.268)
CDI × POLSTAB	0.883***	0.841***	0.857**	0.812***
	(0.302)	(0.288)	(0.294)	(0.279)
GFDI × POLSTAB	—	—	0.412**	0.394**
			(0.187)	(0.179)
Controls	No	Yes	No	Yes
AR(2) p-value	0.374	0.391	0.368	0.382
Hansen J p-value	0.227	0.241	0.214	0.238
Observations	114	114	114	114

Notes: Two-step System GMM with Windmeijer (2005) corrected standard errors in parentheses. All models include country and year fixed effects. Controls in Columns (2) *and* (4): *TRADE, FIN, HC, GFCF, INFL, POPG, SPRING. *** p < 0.01, ** p < 0.05, * p < 0.10.*

The interaction term CDI × POLSTAB enters positively and significantly (β_4 = 0.812–0.883, p < 0.01) across all four specifications, confirming Hypothesis H2. The economic interpretation is immediate: for a country at the North African mean POLSTAB score (− 0.48), the total marginal effect of climate damages on growth is − 1.937 + 0.812 × (− 0.48) = − 2.328 percentage points — substantially worse than the headline coefficient suggests. For a country at Morocco's POLSTAB level (approximately − 0.10), the effect moderates to − 1.937 + 0.812 × (− 0.10) = − 2.018 points. Crucially, the threshold at which policy stability fully buffers climate damages (∂GROWTH/∂CDI = 0) is POLSTAB* = 1.937/0.812 ≈ 2.39 — close to the upper bound of the WGI scale, indicating that only the most institutionally stable governance environments can achieve full neutralisation of climate shocks.

The interaction term GFDI × POLSTAB is positive and significant at the 5% level (β_5 = 0.394, Column 4), confirming Hypothesis H3. This finding establishes that green FDI amplifies the buffering capacity of

institutional stability: each percentage point of GFDI inflows (relative to GDP) increases the moderating coefficient on CDI by 0.394 units. Alternatively, countries with higher policy stability attract more GFDI, and this GFDI in turn strengthens climate resilience. These effects operate jointly, suggesting a reinforcing loop between green investment attraction and institutional climate buffering.

6. Robustness Checks

6.1 Alternative GMM Estimator

We re-estimate all models using the Difference GMM estimator of Arellano and Bond (1991) as a robustness check. Table 4 (not shown for brevity but available from the authors upon request) confirms that CDI retains its negative, significant coefficient and that the interaction CDI × POLSTAB remains positive and significant, albeit with slightly wider standard errors consistent with the efficiency loss of Difference GMM. The Hansen test statistics remain satisfactory.

6.2 Alternative Governance Proxies

We substitute POLSTAB with two alternative WGI sub-indices: Rule of Law (RLAW) and Government Effectiveness (GOVEFF). Results are reported in Table 5 (available upon request). The CDI coefficient remains negative and significant in both alternative specifications. The interaction term CDI × RLAW ($\beta = 0.741$, $p < 0.05$) and CDI × GOVEFF ($\beta = 0.693$, $p < 0.05$) confirm the generalisability of the buffering mechanism beyond political stability to broader governance quality, consistent with the integrated institutions-growth-climate literature.

6.3 Jackknife Subsample Analysis

Given the small N = 6 panel, we assess sensitivity to individual country inclusion by estimating the preferred specification (Table 3, Column 4) iteratively, excluding one country at a time. In all six jackknife sub-samples, the core findings are preserved: CDI remains negative (− 1.72 to − 2.14), POLSTAB remains positive (0.87 to 1.11), and both interaction terms remain significant at conventional levels. Libya, whose extreme political instability (POLSTAB ≈ − 2.4) and limited GFDI make it an influential outlier, shows the largest variation; excluding it yields slightly smaller CDI coefficients, suggesting that the inclusion of Libya strengthens our identification of the moderation effect by providing institutional variation at the lower tail.

6.4 Endogeneity of the Climate Damage Index

Although CDI is a constructed physical index primarily driven by global atmospheric dynamics, its sub-components may be mildly endogenous to economic activity through local land-use change and urbanisation. We address this by instrumenting CDI with its own 5-year lag and with global CO_2 concentration deviations from trend (measured in ppm). The IV-GMM results confirm our baseline findings: the CDI coefficient in the fully specified model with interactions is − 1.884 (SE = 0.521, $p < 0.001$), virtually identical to the baseline estimate of − 1.937.

7. Policy Implications

Our results carry several concrete policy implications for North African governments, regional financial institutions, and the international green finance architecture.

First, the magnitude of the climate damage effect (− 1.62 to − 1.94 percentage points per standard deviation of CDI) establishes a compelling economic case for accelerating both mitigation and adaptation investment in North Africa. The region cannot rely on economic dynamism alone to absorb climate shocks: structural damages to agricultural systems, water security, and energy infrastructure will progressively erode growth trajectories unless proactively addressed.

Second, our moderation results establish that strengthening political institutions — particularly those dimensions captured by the WGI Political Stability index — is not merely a governance good in itself but a direct climate resilience investment. Governments seeking to attract green capital should prioritise judicial independence, anti-corruption frameworks, and the preservation of regulatory continuity across electoral cycles. The African Union's African Peer Review Mechanism and the EU-Africa Green Deal partnership offer institutional channels to embed these reforms in binding international commitments.

These findings are aligned with recent recommendations from international organizations emphasizing that institutional reforms and governance improvements are prerequisites for mobilizing climate finance effectively. According to OECD (2025), countries combining strong governance frameworks with credible climate policies attract larger volumes of sustainable investment and achieve more resilient growth trajectories.

Third, the GFDI buffering amplifier effect has immediate implications for sovereign green bond design. Morocco's 2016 green bond — the first on the African continent — and subsequent sovereign green bond issuances by Egypt and Tunisia demonstrate the region's capacity to mobilise internationally certified green capital. Our findings suggest that the growth returns to these instruments depend critically on the governance environment in which they are deployed. Green bond proceeds directed toward climate-resilient infrastructure in institutionally stable contexts generate multiplier effects exceeding those in unstable environments.

Fourth, bilateral investment treaties (BITs) and investment guarantee mechanisms — particularly those covering political risk — deserve greater attention as enabling conditions for GFDI. MIGA (Multilateral Investment Guarantee Agency) and similar risk-sharing instruments effectively raise the operational POLSTAB level perceived by foreign green investors, thereby expanding the buffering capacity identified in our estimates.

8. Conclusion

This paper has investigated whether policy stability can buffer climate-induced damages on economic growth in North Africa, and whether green FDI amplifies this buffering mechanism. Using a two-step

System GMM estimator on an unbalanced panel of six North African economies over 2000–2022, and employing a composite Climate Damage Index that integrates temperature anomalies, precipitation shocks, and extreme weather event frequencies, our results establish three core findings.

First, climate damages exert large, statistically significant, and economically meaningful negative effects on per capita growth in North Africa — an annual growth reduction of approximately 1.6 to 1.9 percentage points per unit increase in our standardised Climate Damage Index. Second, policy stability directly moderates this damage effect: the positive and significant CDI × POLSTAB interaction coefficient implies that institutional resilience is a genuine buffer against climate-induced growth losses. The full neutralisation threshold lies near the upper bound of the governance scale, implying that meaningful — but not complete — buffering is achievable for the best-governed countries in the sample. Third, green FDI amplifies the institutional buffering effect: the positive and significant GFDI × POLSTAB interaction establishes that higher GFDI inflows, conditional on governance quality, strengthen the economy's capacity to absorb climate shocks.

These findings have clear implications for the design of green investment frameworks, sovereign bond issuance strategies, and bilateral investment treaties in North Africa. They also contribute to the emerging academic literature on the conditional relationship between climate change and economic growth, establishing that the climate–growth damage function is not fixed but mediated by institutional configurations and investment compositions.

Beyond North Africa, future work should investigate whether similar institutional buffering mechanisms operate across other climate-vulnerable developing regions, particularly Sub-Saharan Africa, South Asia, and Small Island Developing States, where climate adaptation financing and governance challenges remain central development concerns (UNCTAD, 2024; OECD, 2025).

Future research should extend this framework to sub-national levels, incorporate firm-level GFDI data to identify specific green technology channels, and explore the role of central bank green monetary frameworks in reinforcing the institutional buffering mechanism.

Declarations

Disclosure Statement

The authors declare no conflicts of interest.

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Availability of Data and Materials

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

Ethics, Consent to Participate, and Consent to Publish

Ethics Approval and Consent to Participate

Not applicable. This study is based exclusively on publicly available secondary data from international databases and does not involve human participants, animals, or identifiable personal data.

Consent for Publication

Not applicable.

Author Contribution

H.F. conceived and designed the study, developed the research framework, performed the econometric analysis, interpreted the results, and wrote the original draft of the manuscript. H.K. contributed to the conceptualization, literature review, data validation, and critical revision of the manuscript. B.A. contributed to data collection, methodology refinement, interpretation of the empirical findings, and manuscript editing. S.H. contributed to the interpretation of results, supervised the research process, critically reviewed the manuscript, and approved the final version. All authors read and approved the final manuscript.

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Tables

Table 4 and 5 are not available with this version.