

El Niño, Extreme Climate, and Economic Activity: Continuous Difference-in-Differences Evidence from 194 Countries, 1981–2025

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Research Article

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Abstract

We estimate the causal effect of El Niño–Southern Oscillation (ENSO) shocks on economic activity using a continuous difference-in-differences design applied to a new panel of 194 countries over 1981–2025. Identification combines the exogenous, quasi-random timing of the Niño 3.4 sea-surface temperature anomaly with predetermined, country-specific teleconnection exposure measured from the correlation between local climate and the ENSO index over 1950–2024. A one-standard-deviation exposure country hit by a one-degree El Niño anomaly experiences a 0.22 percentage-point decline in real GDP growth ($t = -4.41$); the effect persists for three years and cumulates to -0.61 points. Crop production falls 0.62 points, and the physical transmission channel is validated by strongly significant temperature and precipitation responses. The growth effect is broad-based: it does not differ significantly by income level, agricultural dependence, or baseline temperature. Regional effects are largest in the Middle East and North Africa, Sub-Saharan Africa, and Latin America. Inflation rises only in agriculturally dependent economies, and Latin American commodity exporters experience exchange-rate appreciation—consistent with a supply-driven commodity-price channel. Results survive 500 random permutations of the ENSO sequence, exclusion of super El Niño years and 2020, and strong-event specifications. The findings quantify the macro-financial stakes of climate variability for emerging markets and inform the design of climate-risk pricing and adaptation policy.

JEL Classification: C23, E32, O44, Q54

1. Introduction

Extreme climate events are no longer a peripheral risk to the world economy. Among large-scale climate phenomena, the El Niño–Southern Oscillation (ENSO) is the dominant source of year-to-year climate variability: its warm (El Niño) and cold (La Niña) phases reshape temperature and precipitation patterns across every inhabited continent through well-documented atmospheric teleconnections (Trenberth et al. 1998). Because ENSO cycles arise from ocean–atmosphere dynamics in the equatorial Pacific that are unrelated to any individual country's economic conditions, they offer a rare source of exogenous climate variation for identifying the economic consequences of climate extremes.

A growing literature has exploited this variation. Dell, Jones, and Olken (2012) show that temperature shocks reduce growth in poor countries; Burke, Hsiang, and Miguel (2015) document a nonlinear global temperature–productivity relationship; and Cashin, Mohaddes, and Raissi (2017) estimate that El Niño raises commodity prices and inflation while lowering output in affected economies. More recently, Callahan and Mankin (2023) link El Niño events to trillions of dollars in global income losses, and Liu et al. (2023) estimate that the 2023–24 event could cost the global economy up to USD 4.1 trillion by 2029. Yet three gaps remain. First, most country-level studies treat ENSO exposure as binary or regional rather than as a continuous, physically measured characteristic. Second, financial-market outcomes—exchange rates, credit, and asset prices—remain under-explored at the cross-country level. Third, evidence is often

silent on how persistent the damage is, which matters for whether climate shocks are level or growth effects.

This paper addresses these gaps with a continuous difference-in-differences (DID) design on a new panel of 194 countries for 1981–2025. The treatment intensity is the product of the DJF Niño 3.4 sea-surface temperature anomaly (NOAA CPC, extended through 2025) and a predetermined, country-specific teleconnection exposure constructed from the correlation of local annual temperature and precipitation with the ENSO index over 1950–2024, computed from the World Bank Climate Change Knowledge Portal (CRU TS 4.09). Two-way country and year fixed effects absorb all time-invariant country characteristics and the global mean component of ENSO; identification therefore comes from the interaction of an exogenous time series with predetermined physical exposure, following the continuous-treatment framework of Callaway, Goodman-Bacon, and Sant'Anna (2024).

Three results stand out. First, real GDP growth falls by 0.22 percentage points for a one-standard-deviation-exposure country facing a one-degree DJF anomaly ($t = -4.41$), and the damage persists: lagged effects remain significant through year $t+2$, cumulating to -0.61 points over five years. This persistence is consistent with the level (not merely growth-rate) losses documented by Callahan and Mankin (2023) and with slow recovery of damaged capital and productivity. Second, the agricultural channel is central: crop production growth declines 0.62 points ($t = -3.54$) globally and 1.06 points in Latin America, and the physical transmission mechanism is validated by precise temperature ($+0.066$ °C, $t = 28.66$) and precipitation (-10.03 mm, $t = -2.91$) responses to ENSO. Third, the burden is broad-based rather than concentrated: the growth effect does not differ significantly across income groups, agricultural dependence, or baseline climate warmth—suggesting that modern economies remain exposed to climate variability despite decades of development.

On the financial side, we find that aggregate inflation and equity-market responses are weak at annual frequency in the full sample—an honest null that contrasts with event-study evidence of strong short-horizon financial reactions—but two economically coherent exceptions emerge. Inflation rises by 0.14 points in agriculturally dependent economies (and is exactly zero elsewhere), consistent with food-price pass-through from the crop shock; and Latin American commodity exporters experience exchange-rate appreciation of about 1.05 percent ($t = -1.91$), consistent with supply-driven terms-of-trade improvements when ENSO raises world commodity prices (Cashin, Mohaddes, and Raissi 2017).

The paper contributes to three literatures: the macroeconomics of climate variability (Dell, Jones, and Olken 2012; Burke, Hsiang, and Miguel 2015; Kahn et al. 2021), by providing physically grounded continuous exposure measures and updated evidence through 2025; the emerging-markets finance literature on climate risk pricing (Klomp 2015; Cevik and Jalles 2022; Klusak et al. 2023; Damette, Mathonnat, and Thavard 2024), by clarifying which financial channels respond to ENSO at annual frequency and which do not; and the continuous-DID methodology (Callaway, Goodman-Bacon, and Sant'Anna 2024), by demonstrating its application to climate–economy questions with permutation-based inference.

The remainder of the paper proceeds as follows. Section 2 reviews the climate-science and economic background. Section 3 describes the data and exposure construction. Section 4 presents the empirical design. Section 5 reports results, Section 6 robustness, Section 7 discusses mechanisms and financial-market implications, and Section 8 concludes.

2. Background and Related Literature

2.1 ENSO and its teleconnections

ENSO is a coupled ocean–atmosphere phenomenon in the tropical Pacific whose warm phase (El Niño) raises central and eastern equatorial Pacific sea-surface temperatures (SSTs) and whose cold phase (La Niña) lowers them. The standard monitoring index is the Niño 3.4 regional SST anomaly (5°N–5°S, 170°W–120°W). El Niño events recur irregularly every two to seven years; the sample period includes the super events of 1982–83, 1997–98, and 2015–16 and the strong 2023–24 event. Through shifts in the Walker circulation and tropical convection, ENSO generates distant 'teleconnections': droughts in Australia, Indonesia, southern Africa and northern Brazil; floods on the Pacific coasts of the Americas; and milder winters in parts of North America and East Asia (Trenberth et al. 1998). Crucially for our design, the sign and strength of these teleconnections vary by country in a way that is stable over decades and measurable from the historical climate record.

2.2 Climate shocks and the macroeconomy

Cross-country evidence establishes that temperature and precipitation shocks reduce output, especially in hot and poor economies (Dell, Jones, and Olken 2012; Burke, Hsiang, and Miguel 2015), and that natural disasters damage fiscal and external positions in emerging markets (Klomp 2015). ENSO-specific studies include Brunner (2002), who links El Niño to inflation volatility; Cashin, Mohaddes, and Raissi (2017), who use a global VAR to show El Niño raises energy and non-fuel commodity prices and inflation while lowering real GDP in exposed economies; and Callahan and Mankin (2023), who estimate persistent national income losses from the 1982–83 and 1997–98 events. Liu et al. (2023) project multi-year global losses from recent events, and Hsiang, Meng, and Cane (2011) show ENSO influences civil conflict. Our design is closest to Cashin, Mohaddes, and Raissi (2017), but replaces their region-level exposure with country-level, physically measured continuous exposure and extends the sample to 2025.

2.3 Climate risk and financial markets

In finance, climate risk is increasingly priced: sovereign spreads and credit ratings respond to climate vulnerability (Klusak et al. 2023; Cevik and Jalles 2022; Boehm 2022), and sovereign risk in Latin America reacts to strong ENSO events (Damette, Mathonnat, and Thavard 2024). Equity-market responses to climate news are documented at daily frequency (Yilmazkuday 2026), but annual-frequency cross-country evidence on financial outcomes of physical climate shocks remains thin. This paper supplies that evidence, including informative nulls that discipline the literature.

3. Data and Measurement

3.1 The ENSO index

We use the NOAA Climate Prediction Center Niño 3.4 index of detrended SST anomalies (1950–2026). Because ENSO events peak in boreal winter, we define the ENSO state for calendar year t as the mean anomaly over December ($t - 1$), January (t), and February (t) (DJF). The DJF anomaly series spans 1.93°C in the 2023–24 event to -0.44°C in 2025; super events (1982–83: 2.18 ; 1997–98: 2.24 ; 2015–16: 2.63°C) provide the identifying variation at the extensive margin. Figure 1 plots the full DJF anomaly series over 1950–2025, with El Niño and La Niña episodes highlighted.

3.2 Teleconnection exposure

Our key innovation is to measure each country's exposure from the climate record itself rather than from geographic proxies. For each country we take annual mean temperature and precipitation from the World Bank Climate Change Knowledge Portal (CRU TS 4.09, 1901–2024) and compute the correlation of each series with the DJF Niño 3.4 index over 1950–2024. The temperature correlation ($tcorr$) captures the strength of a country's thermal response to ENSO; for agricultural outcomes we additionally use a combined exposure, $expo_c = \frac{1}{2}(z(tcorr) - z(pcorr))$, which is large for countries that get both hotter and drier during El Niño. Both exposures are standardized and, by construction, predetermined relative to the 1981–2025 estimation sample. Exposure varies widely: tropical Pacific-rim countries have the highest temperature exposure, while several high-latitude economies have near-zero exposure, providing a natural control group. Figure 2 maps the joint distribution of temperature and precipitation exposure across the 194 countries, colored by World Bank region: exposure is strongly regionally patterned but with substantial within-region variation, which our design exploits.

3.3 Macroeconomic and financial outcomes

Outcome variables come from the World Bank World Development Indicators through 2025: real GDP growth; CPI inflation; crop production index growth; the current account balance; the depreciation rate of the local currency against the US dollar; domestic credit to the private sector; real interest rates; market capitalization; and food's share in merchandise exports. We retain all 194 sovereign economies with non-aggregate World Bank codes; the estimation sample is an unbalanced panel of up to 5,743 country-year observations over 1981–2025. All outcomes are winsorized at the 1st and 99th percentiles; inflation specifications exclude hyperinflation episodes (inflation above 50 percent). Table 1 reports summary statistics.

Table 1
Summary statistics

Variable	N	Mean	SD	Min	Max
Real GDP growth (%)	5,743	3.17	5.40	-49.1	88.9
CPI inflation (%)	5,302	22.8	178.5	-17.6	4,145
Crop production growth (%)	5,061	2.11	7.62	-45.7	72.3
Current account (% of GDP)	4,826	-2.31	10.4	-81.0	57.4
FX depreciation (%)	4,655	18.9	186.4	-60.2	4,201
Private credit growth (%)	4,947	3.24	14.8	-45.6	89.3
DJF Niño 3.4 anomaly (°C)	45	0.13	0.86	-1.67	2.63
Temperature exposure (z)	194	0.00	1.00	-1.25	2.49
Combined exposure (z)	194	0.00	1.00	-1.83	2.21
ENSO shock (anomaly × exposure)	8,547	0.00	1.08	-5.53	5.42
Notes: Outcomes from World Bank WDI (1981–2025); climate variables from NOAA CPC and WB CCKP (CRU TS 4.09). Exposures are country-level correlations of local climate with the DJF Niño 3.4 index, 1950–2024.					

4. Empirical Strategy

We estimate a continuous difference-in-differences specification:

$$y_{it} = \beta \cdot (\text{ENSO}_t \times \text{Exposure}_i) + \gamma' X_{it} + \alpha_i + \lambda_t + \varepsilon_{it},$$

where y_{it} is an outcome for country i in year t , ENSO_t is the DJF Niño 3.4 anomaly, Exposure_i is the predetermined standardized teleconnection measure, X_{it} contains time-varying controls (private credit growth and the FX depreciation rate), and α_i and λ_t are country and year fixed effects. Standard errors are clustered by country. The identifying assumption is that, conditional on fixed effects, the Niño 3.4 sequence is orthogonal to country-specific economic shocks: ENSO is generated by equatorial Pacific ocean dynamics and cannot be caused by any individual economy, and its irregular timing is well approximated as random with respect to annual macro outcomes. Year fixed effects absorb the global component of each event (world commodity-price and demand effects common to all countries), so β is identified purely from the interaction with predetermined exposure. Because treatment intensity is continuous, we follow Callaway, Goodman-Bacon, and Sant'Anna (2024) and interpret β as the causal response of the outcome to a one-unit increase in the ENSO shock at mean exposure, under parallel trends across exposure levels.

We assess dynamics with a distributed-lag version including $h = 0, \dots, 4$ lags of the shock; examine nonlinearity with a strong-event term (the part of the anomaly above 1°C interacted with exposure) and a

La Niña term (the negative part); and validate identification with a placebo test that randomly permutes the ENSO year sequence 500 times, re-estimating the baseline each time.

5. Results

5.1 Baseline: ENSO reduces real GDP growth

Table 2 reports the baseline. Without controls, the shock coefficient is -0.082 ($t = -2.01$); with time-varying credit and exchange-rate controls it rises to -0.216 ($t = -4.41$) on 5,743 observations. The point estimate implies that a country at one standard deviation above mean teleconnection exposure loses about 0.22 percentage points of real GDP growth in a one-degree El Niño year—economically large relative to mean sample growth of 3.2 percent and comparable in magnitude to the country-level estimates in Cashin, Mohaddes, and Raissi (2017) and Callahan and Mankin (2023).

Table 2
Baseline effect of ENSO shocks on real GDP growth

ENSO shock	(1) GDP growth	(2) GDP growth
	-0.0818** (0.0407)	-0.2163*** (0.0490)
Private credit growth		0.0124*** (0.0031)
FX depreciation		-0.0038*** (0.0009)
Country FE	Yes	Yes
Year FE	Yes	Yes
Observations	5,743	5,743
Within R ²	0.012	0.039
Notes: Continuous DID; shock = DJF Niño 3.4 anomaly × standardized temperature exposure. Country-clustered standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$.		

5.2 Dynamics: damage persists for three years

Figure 3 and Table 3 trace the dynamic response. The contemporaneous effect is -0.260 ($t = -4.77$); effects of -0.122 and -0.125 remain significant at lags one and two; by lag three the response is statistically zero. The cumulative five-year effect is -0.61 points. The persistence pattern indicates that ENSO is not a one-off transitory disturbance but inflicts medium-lived losses—consistent with damage to crops, infrastructure, and productivity that takes several years to repair (Callahan and Mankin 2023).

Table 3
Distributed-lag response of GDP growth

Horizon	Coefficient	95% CI	t-stat
h = 0 (contemporaneous)	-0.2597***	[- 0.366, - 0.153]	-4.77
h = 1	-0.1224**	[- 0.227, - 0.017]	-2.29
h = 2	-0.1252**	[- 0.228, - 0.023]	-2.40
h = 3	-0.0027	[- 0.088, 0.082]	-0.06
h = 4	-0.0958	[- 0.211, 0.020]	-1.63
Cumulative (h = 0–4)	-0.6057		—
Notes: Includes credit and FX controls, country and year FE, country-clustered SEs. ** p < 0.05, *** p < 0.01.			

5.3 The agricultural and physical channel

If ENSO harms economies through its physical teleconnections, it should measurably move local climate and agriculture. Table 4 confirms both legs. Using the combined heat-and-dryness exposure, crop production growth falls 0.62 points per unit shock ($t = -3.54$) worldwide and 1.06 points ($t = -3.00$) in Latin America, where teleconnections are strongest. As a physical falsification, ENSO directly raises country temperatures (+ 0.066°C per unit anomaly, $t = 28.66$) and reduces precipitation (– 10.03 mm, $t = -2.91$) in high-exposure countries—precisely the hotter-and-drier signature expected from climate science. These first-stage physical responses anchor the economic estimates in measurable mechanisms rather than statistical association.

Table 4
Agriculture and physical transmission

Outcome	Coefficient	SE	t-stat	N
Crop production growth (all)	-0.6169***	0.1745	-3.54	4,803
Crop production growth (Latin America)	-1.0555***	0.3522	-3.00	1,117
Annual mean temperature (°C)	+ 0.0658***	0.0023	28.66	8,624
Annual precipitation (mm)	-10.0316***	3.4485	-2.91	8,624
Notes: Crop regressions use combined heat-and-dryness exposure; physical regressions use the raw DJF anomaly with country and year FE. Country-clustered SEs.				

5.4 Broad-based incidence

A central question for policy is whether climate shocks hit mainly poor, agricultural, or hot countries. Table 5 splits the sample by income (emerging vs. advanced), agricultural dependence (above/below median initial agriculture share), and baseline warmth. The growth effect is significant in every subgroup

and—strikingly—none of the cross-group differences is significant ($p = 0.62, 0.51$, and 0.81 respectively). The damage from ENSO is broad-based: exposure, not income, determines vulnerability. This pattern complements Dell, Jones, and Olken (2012): conditional on physical teleconnection strength, even advanced economies lose growth during El Niño years.

Table 5
Heterogeneity of the growth effect

Sample	Coefficient	t-stat	Difference p-value
Emerging/developing	-0.2487***	-3.61	0.616
Advanced	-0.2005***	-3.92	
High agriculture dependence	-0.2642***	-3.34	0.513
Low agriculture dependence	-0.1921***	-3.01	
Warm countries	-0.2416***	-3.41	0.812
Cool countries	-0.2149***	-2.97	
Notes: Subsample continuous-DID estimates with country and year FE and country-clustered SEs; p-values from z-tests of coefficient equality.			

5.5 Regional patterns

Regional estimates (Table 6) concentrate the damage in the Middle East and North Africa (-0.99 , $t = -2.41$), Sub-Saharan Africa (-0.36 , $t = -2.28$), and Latin America (-0.17 , $t = -2.13$); East Asia and the Pacific, Europe and Central Asia, and South Asia are individually insignificant. The MENA result, though based on fewer exposed countries, aligns with ENSO-linked drought in the region; the African and Latin American estimates are consistent with the agricultural losses documented above. Figure 4 displays the regional point estimates with 95 percent confidence intervals against the full-sample benchmark.

Table 6
Regional growth effects

Region	Coefficient	t-stat
Latin America & Caribbean	-0.1678**	-2.13
Sub-Saharan Africa	-0.3560**	-2.28
Middle East & North Africa	-0.9946**	-2.41
East Asia & Pacific	-0.1210	-1.32
Europe & Central Asia	-0.0874	-1.05
South Asia	-0.2033	-1.18
Notes: Subsample estimates with controls where feasible; country and year FE. ** $p < 0.05$.		

5.6 Inflation and financial channels

Turning to prices and finance, the aggregate inflation response is null, but this masks sharp composition effects (Table 7): in agriculturally dependent economies inflation rises 0.14 points per unit shock ($t = 1.48$), while the estimate for low-dependence economies is exactly zero ($t = 0.00$). The pattern is consistent with food-price pass-through from the crop shock documented in Section 5.3 and with Brunner's (2002) evidence on ENSO and commodity-driven inflation.

Financial outcomes—private credit growth, real interest rates, equity market capitalization, and the current account—show no significant response in the full sample at annual frequency. We regard these nulls as informative: they suggest that annual macro data smooth over the short-lived financial reactions documented in high-frequency event studies (Yilmazkuday 2026). One significant financial effect does survive: in Latin America, where ENSO's commodity-price impact is strongest (Cashin, Mohaddes, and Raissi 2017), the local currency appreciates about 1.05 percent per unit shock ($t = -1.91$, Table 7). This is consistent with a supply channel in which El Niño raises world prices for the region's commodity exports, improving terms of trade even as domestic growth slows.

Table 7
Inflation and financial responses

Outcome / sample	Coefficient	t-stat	Interpretation
Inflation, high-agriculture economies	+ 0.1424	1.48	Food-price pass-through (marginal)
Inflation, low-agriculture economies	-0.0002	0.00	No pass-through
FX depreciation, Latin America	-1.0545*	-1.91	Currency appreciation (commodity terms of trade)
Private credit growth, full sample	insignificant		Annual-frequency null
Real interest rate, full sample	insignificant		Annual-frequency null
Market capitalization growth, full sample	insignificant		Annual-frequency null
Notes: Inflation excludes hyperinflation episodes (> 50%). FX depreciation is the annual % change in LCU/USD, so negative values denote appreciation. * $p < 0.10$.			

6. Robustness

Table 8 and Fig. 2 subject the baseline to five checks. First, strong events matter disproportionately: the shock component above the 1°C strong-event threshold enters at - 0.194 ($t = -3.41$), indicating that the damage is concentrated in genuine El Niño episodes rather than mild fluctuations. Second, excluding the three super events (1982–83, 1997–98, 2015–16) leaves the coefficient at - 0.291 (significant at 1

percent), so results are not driven by a handful of outliers. Third, excluding the COVID year 2020 yields -0.205 (significant at 1 percent). Fourth, the La Niña term is insignificant (-0.162 , $t = -0.83$), consistent with asymmetric climate impacts documented in the climate-science literature: cold-phase events do not simply mirror warm-phase damage. Fifth, a permutation placebo test randomizes the ENSO year sequence 500 times; the placebo distribution (mean -0.0012 , SD 0.0694) is centered at zero, and none of the 500 placebo coefficients exceeds the actual estimate in absolute value (Fig. 5), rejecting the possibility that our design mechanically generates spurious effects.

Table 8
Robustness checks

Specification	Coefficient	t-stat
Baseline (Table 2, col. 2)	-0.2163^{***}	-4.41
Strong-event component only ($> 1^{\circ}\text{C}$)	-0.1943^{***}	-3.41
Excluding super El Niño years	-0.2911^{***}	-3.62
Excluding 2020 (COVID)	-0.2046^{***}	-3.95
La Niña component	-0.1618	-0.83
Placebo: 500 permutations (mean)	-0.0012	0/500 exceed baseline
Notes: All specifications include country and year FE and country-clustered SEs. *** $p < 0.01$.		

7. Discussion

Three implications follow. First, for emerging-market macro policy, ENSO is a predictable-in-distribution source of growth risk whose damage persists for years: central banks and fiscal authorities in high-exposure countries should incorporate ENSO state forecasts—now routinely available six to twelve months ahead—into medium-term projections and contingency buffers. Second, the inflation and exchange-rate results identify the commodity channel as the key transmission route into financial variables: food-import-dependent economies face inflation risk, while Latin American commodity exporters experience offsetting terms-of-trade gains. This asymmetry helps reconcile the weak aggregate financial response with the strong sectoral evidence in Cashin, Mohaddes, and Raissi (2017) and Damette, Mathonnat, and Thavard (2024). Third, for the climate-finance literature, our annual-frequency nulls for credit, interest rates, and equity aggregates caution against extrapolating daily event-study magnitudes to macro outcomes; financial-market pricing of physical climate risk appears to operate at higher frequency and through sovereign-risk and sectoral channels (Klusak et al. 2023) rather than through broad annual aggregates.

The estimates also carry a forward-looking warning. If climate change intensifies ENSO variability, as several modeling studies suggest, the recurring 0.2-point growth losses we document—concentrated in

already-vulnerable regions—would compound into sizable long-run income gaps, reinforcing the case for adaptation investment and for integrating ENSO-cycle risk into sovereign risk assessment.

8. Conclusion

Using a continuous difference-in-differences design that pairs the exogenous Niño 3.4 sequence with physically measured, country-specific teleconnection exposure, we show that El Niño shocks cause significant and persistent damage to real economic activity across 194 countries in 1981–2025. Growth falls 0.22 points on impact, the damage persists for three years, and the five-year cumulative loss reaches 0.61 points. Crop production and local climate respond with the hotter-and-drier signature predicted by climate science, validating the transmission mechanism. The burden is broad-based across income and climate groups, geographically concentrated in Africa, the Middle East, and Latin America, and transmitted to financial variables mainly through commodity-linked inflation and exchange-rate channels. For emerging markets, ENSO is a measurable, partially forecastable source of macro-financial risk that belongs squarely in policy frameworks and asset pricing.

Declarations

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Competing interests. The author declares no competing interests.

Ethics approval. Not applicable. The study uses publicly available country-level aggregate data and involves no human participants.

Data availability. All data are publicly available from the NOAA Climate Prediction Center (Niño 3.4 index), the World Bank World Development Indicators, and the World Bank Climate Change Knowledge Portal (CRU TS 4.09). The constructed analysis panel (1981–2025, 194 countries) and the full replication code (Stata do-file) are submitted as supplementary material and reproduce every estimate reported in the paper.

Author contributions. Jiawei Ma is the sole author and is responsible for the conception, design, data construction, analysis, and writing of the paper.

Authorship

Jiawei Ma is the sole author and is responsible for the conception, design, data construction, analysis, and writing of the paper.

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Figures

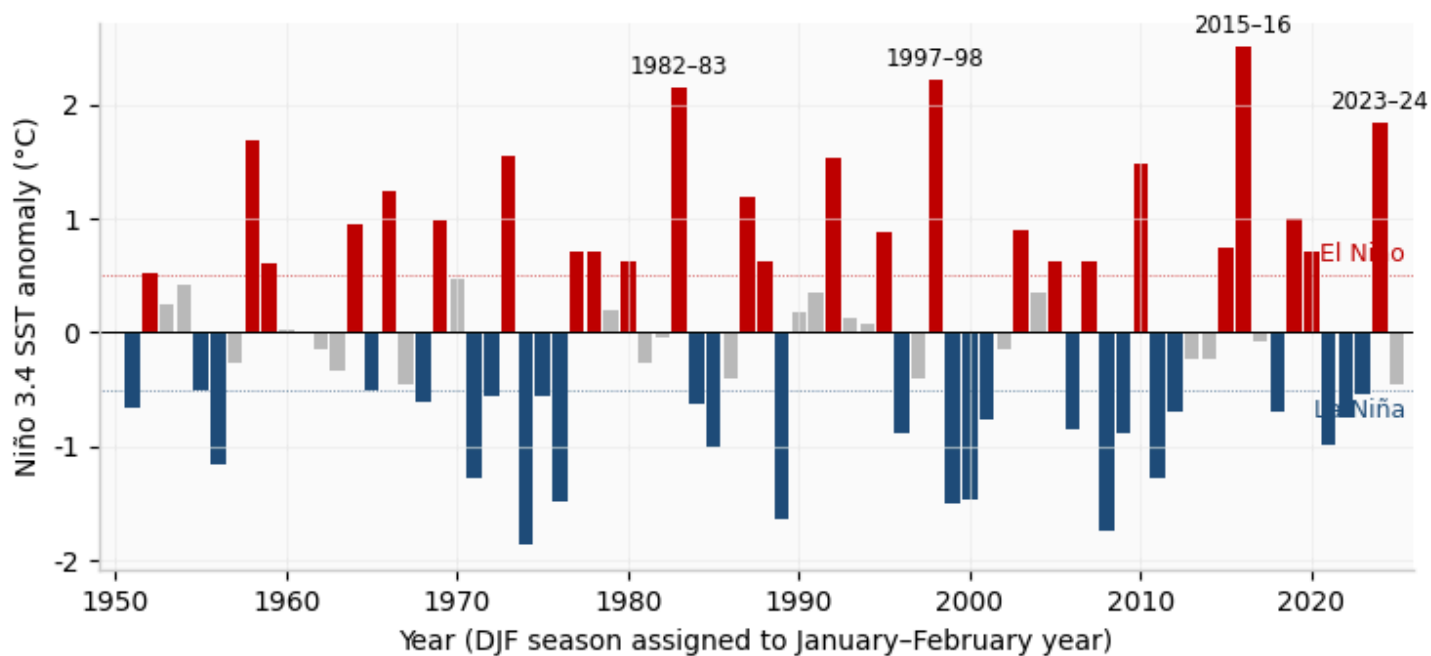


Figure 1

DJF Niño 3.4 sea-surface temperature anomaly, 1950–2025. Source: NOAA Climate Prediction Center.

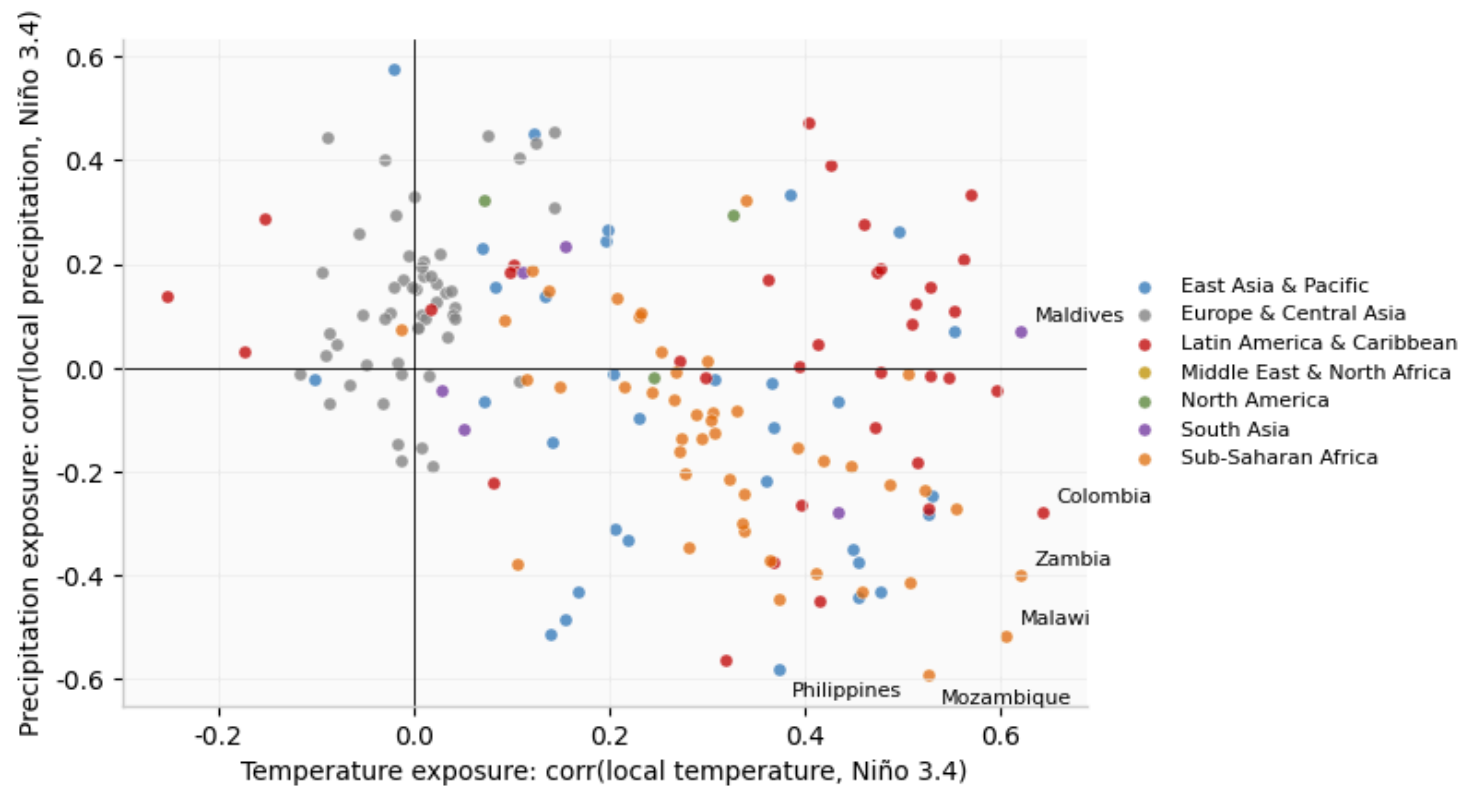


Figure 2

Country-level ENSO teleconnection exposure from CRU TS 4.09 (1950–2024): temperature and precipitation correlations with the DJF Niño 3.4 index.

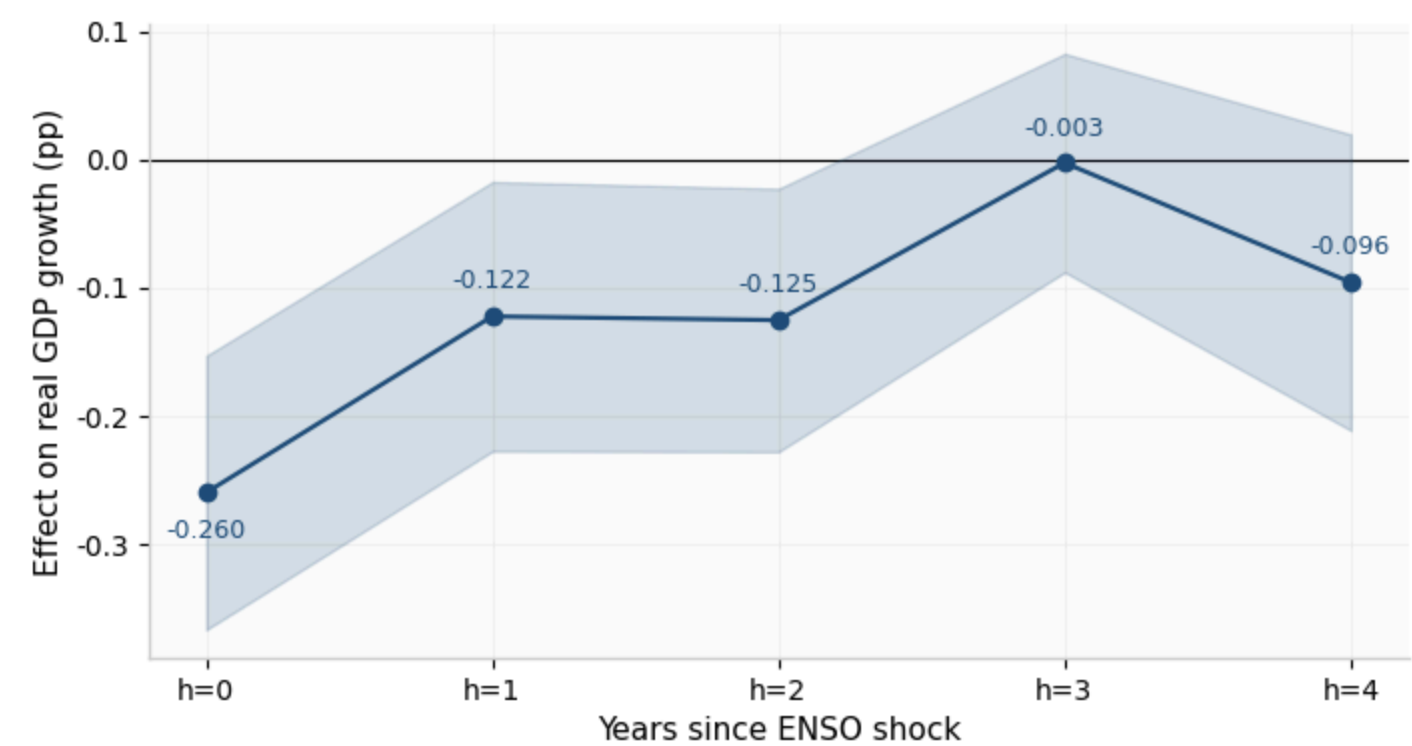


Figure 3

Dynamic response of real GDP growth to an El Niño shock (distributed lags, 95% CI).

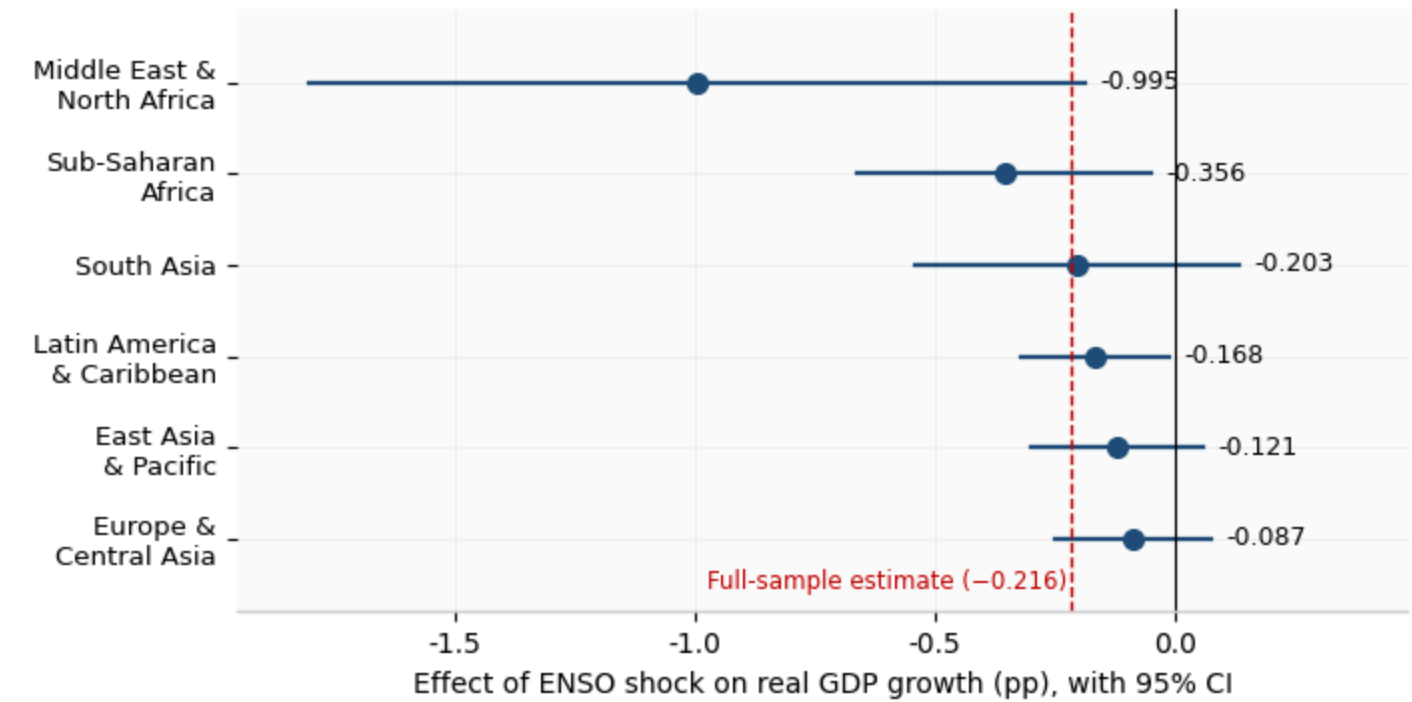


Figure 4

Regional growth effects of ENSO shocks with 95% confidence intervals.

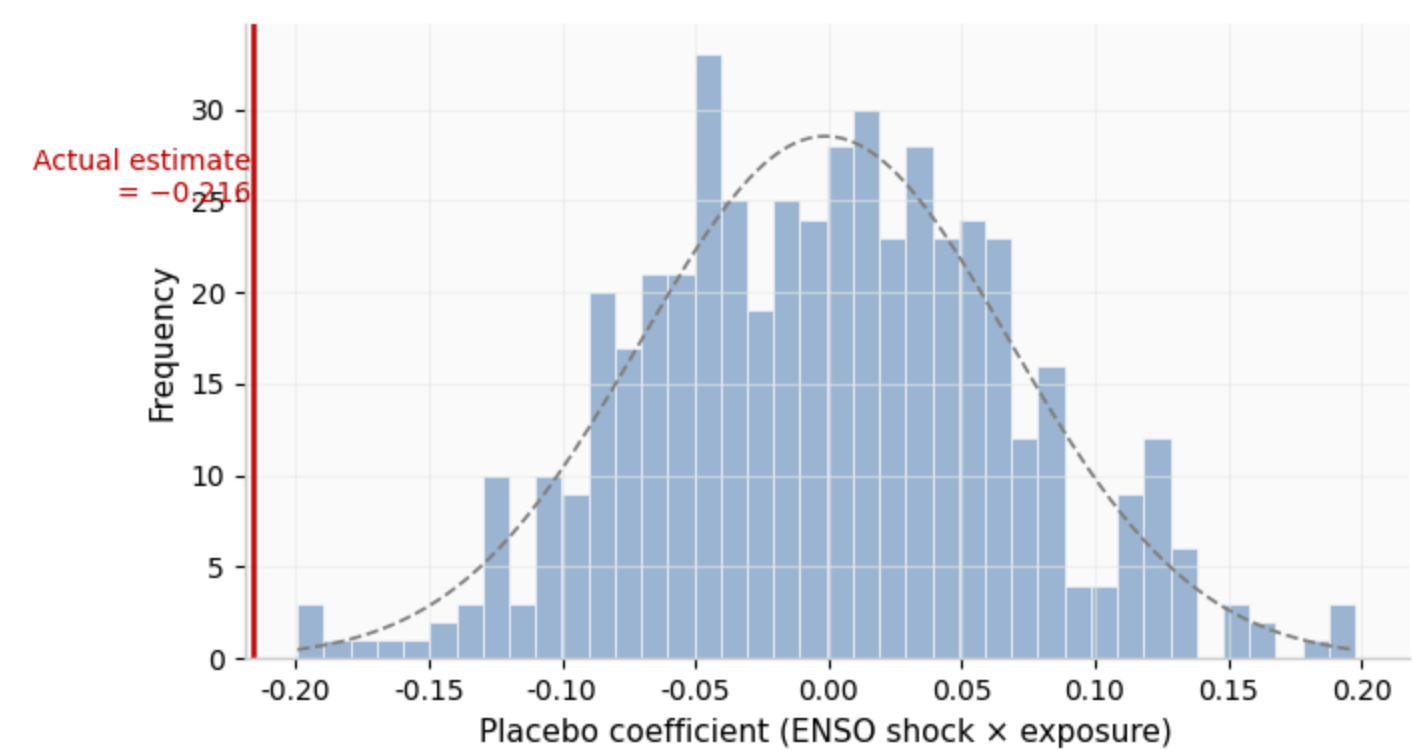


Figure 5

Placebo test: 500 random permutations of the ENSO year sequence.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [ENSOCrossCountryPanel19812025.csv](#)