

Climate Transition Risk and Stock Market Dynamics in Emerging Economies: A Panel ARDL Approach Brazil, China, India and South Africa, 2015-2025

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Abstract

This study examines the relationship between climate transition risk and stock-market dynamics in four major emerging economies - Brazil, China, India and South Africa - using monthly data from January 2015 to December 2025. Climate transition risk is proxied primarily by country-specific climate policy uncertainty (CPU), while inflation, the bilateral exchange rate against the US dollar, the CBOE Volatility Index (VIX), Brent crude oil prices and geopolitical risk are incorporated as macro-financial controls. The master panel contains 528 country-month observations. Because the South African national CPU series begins in July 2018, the principal country-CPU Panel ARDL analysis uses a balanced July 2018-December 2025 sample of 360 observations; the unavailable pre-July-2018 South African CPU observations are not imputed. Cross-sectional-dependence diagnostics indicate substantial common shocks, while unit-root diagnostics support a mixture of $I(0)$ and $I(1)$ variables and no evidence that the core variables are $I(2)$. The preferred baseline specification is approximately ARDL(2,1). Pooled Mean Group (PMG) estimates show that country-specific CPU is statistically insignificant in both the long run (0.0590, $p=0.271$) and short run (0.0012, $p=0.535$). In contrast, short-run inflation, exchange-rate changes and VIX changes are statistically significant. Error-correction behaviour is heterogeneous, with significant convergence for Brazil but weak or absent adjustment in the other markets. An extended model including Brent and geopolitical risk preserves the null CPU result. A robustness model using global CPU over the complete 2015-2025 panel yields only marginal long-run evidence ($p=0.059$). The findings suggest that emerging equity markets are more consistently associated with conventional macro-financial shocks than with country-specific climate-policy uncertainty, while global transition-policy signals may have a limited longer-run role. Residual cross-sectional dependence and heterogeneous adjustment imply that the PMG estimates should be complemented by cross-sectionally augmented estimators before strong long-run generalizations are made.

Keywords: climate transition risk; climate policy uncertainty; emerging markets; stock market dynamics; Panel ARDL; PMG; cross-sectional dependence

1. Introduction

The global transition toward lower-carbon production and consumption changes regulation, expected cash flows, financing costs, energy demand, technology choices and investor perceptions of risk. These channels can transmit climate-transition risk to equity markets. The transmission may be particularly complex in emerging economies because they combine rapid structural transformation, heterogeneous energy systems, differing policy capacities and substantial exposure to global financial and commodity shocks.

This study focuses on climate policy uncertainty as a direct policy-related dimension of transition risk. Unlike physical-climate indicators, CPU captures uncertainty surrounding the direction, timing and intensity of climate policy. Equity markets may respond through revisions to expected corporate profitability, discount rates, sectoral allocation and foreign capital flows. The expected sign is not necessarily negative: policy uncertainty can increase risk premia and delay investment, but credible transition policy can also reduce long-horizon uncertainty and stimulate investment in transition-compatible sectors.

The study makes a deliberate distinction between broad stock-market dynamics and market efficiency. The dependent variable is the national stock-market index in local-currency terms, transformed to its natural logarithm for long-run modelling, while monthly log returns are retained for descriptive and short-run interpretation. The paper therefore does not infer informational efficiency from the Hurst exponent or other efficiency measures.

The empirical design uses a harmonized monthly panel for Brazil, China, India and South Africa from 2015 to 2025. These countries provide economically important emerging-market cases and genuine national CPU coverage, although the South African CPU series begins only in July 2018. The analysis combines Panel ARDL/PMG estimation with Mean Group comparison, cross-sectional-dependence diagnostics and robustness specifications using global CPU and additional common shocks.

The contribution is threefold. First, the paper uses genuine country-specific CPU rather than copying a global uncertainty series across countries. Second, it distinguishes short-run market responses from longer-run equilibrium relationships. Third, it treats cross-sectional dependence and heterogeneous adjustment as substantive features of emerging markets rather than as minor diagnostics. The results show no statistically significant average country-CPU effect in either horizon, while exchange-rate movements, inflation and VIX exhibit stronger short-run relationships. This null climate-policy result is informative because it indicates that broad emerging equity indices may absorb transition-policy information differently from more directly transition-exposed assets.

1.1 Research objectives

RO1. Examine the long-run relationship between country-specific climate policy uncertainty and stock-market performance in selected emerging economies.

RO2. Investigate the short-run effects of changes in climate policy uncertainty on emerging stock markets.

RO3. Estimate the speed and heterogeneity of adjustment toward long-run equilibrium following deviations from equilibrium.

RO4. Assess the robustness of the results to global climate policy uncertainty and additional global risk controls.

1.2 Research questions and hypotheses

RQ1. Is country-specific climate policy uncertainty significantly related to stock-market performance in the long run?

RQ2. Do changes in country-specific climate policy uncertainty significantly affect stock-market performance in the short run?

RQ3. Do the four emerging markets exhibit significant and homogeneous error-correction behaviour?

RQ4. Are the results robust to global CPU, Brent crude oil prices and geopolitical risk?

The hypotheses are intentionally non-directional. H1 states that country-specific CPU has a statistically significant long-run relationship with stock-market performance; H2 states that changes in country-specific CPU have a statistically significant short-run relationship; and H3 states that deviations from the long-run relationship are corrected through a negative and statistically significant error-correction term.

2. Literature Review and Conceptual Framework

2.1 Climate transition risk and equity markets

Climate-related financial risk is commonly divided into physical risk and transition risk. Transition risk arises from policy, technological, legal and market changes associated with movement toward a lower-carbon economy. For equity investors, these changes can affect expected revenues, operating costs, stranded-asset risk, financing conditions and required returns. Adediran, Bewaji and Oyadeyi (2023) show that climate risk is relevant to stock-market predictability and market outcomes, while Mondal and Bauri (2024) document

valuation consequences of climate-transition exposure among selected Indian listed firms. These studies support the proposition that climate-related information can enter asset prices, but they do not imply that the effect must be uniform across countries or horizons.

2.2 Climate policy uncertainty as transition risk

Climate policy uncertainty is particularly relevant because firms and investors respond not only to enacted policy but also to uncertainty about future carbon constraints, subsidies, standards and transition pathways. A rise in CPU can increase the option value of waiting, raise discount rates or shift portfolio allocation. Conversely, periods of active policy debate may coincide with greater transition investment and repricing opportunities. The present study therefore avoids imposing a predetermined coefficient sign.

2.3 Emerging-market heterogeneity and common shocks

Emerging equity markets are jointly exposed to global risk sentiment, US-dollar conditions, energy prices and geopolitical shocks. At the same time, domestic inflation, exchange rates, market structure and policy credibility differ substantially. This combination makes cross-sectional dependence and heterogeneous short-run responses likely. A model that ignores common shocks may overstate the precision of country-level climate coefficients, while a model that imposes complete homogeneity may suppress economically meaningful differences.

2.4 Panel ARDL and the research gap

Panel ARDL methods are useful when variables are a mixture of $I(0)$ and $I(1)$, provided none is $I(2)$, and when the research question distinguishes long-run equilibrium coefficients from heterogeneous short-run adjustment. The PMG estimator of Pesaran, Shin and Smith (1999) imposes common long-run slopes while allowing short-run coefficients, intercepts and error variances to differ across groups. Peša, Wrońska-Bukalska and Bosna (2017) demonstrate the usefulness of ARDL panel methods for stock-market and macroeconomic relationships in transition economies. The gap addressed here is not simply the absence of a particular estimator; it is the limited evidence on whether country-specific climate-policy uncertainty produces persistent stock-market relationships across emerging economies once domestic and global macro-financial conditions are considered.

2.5 Conceptual framework

The conceptual mechanism is: climate policy uncertainty $\rightarrow$ revisions to expected cash flows, discount rates, investment timing and investor risk perceptions $\rightarrow$ stock-market valuation and returns. Domestic inflation and exchange rates capture macro-financial conditions, while VIX captures global risk sentiment. Brent crude oil and geopolitical risk are added in an extended model to test whether the CPU result is sensitive to energy-market and geopolitical shocks.

3. Data and Variable Construction

The analysis uses monthly observations for Brazil, China, India and South Africa. The master panel spans January 2015 to December 2025 and contains 528 country-month observations (4 countries x 132 months). National stock-market indices are measured in local-currency terms. CPI and exchange-rate series are harmonized monthly macroeconomic series. Country-specific CPU is taken from the Global Climate Policy Uncertainty database. VIX, Brent crude oil and geopolitical risk are common global factors.

The country-specific CPU series is complete for Brazil, China and India over the study period, whereas South Africa begins in July 2018. The 42 unavailable South African observations from January 2015 through June 2018 are treated as structural source gaps and are not interpolated, replaced with global CPU or otherwise fabricated. Accordingly, the principal country-CPU Panel ARDL specification uses the balanced July 2018-December 2025 sample: 90 months for each of four countries, or 360 observations.

The principal dependent variable is the natural logarithm of the local-currency stock-market index, $\ln(\text{Stock})$. Monthly stock return is computed as 100 times the first difference of $\ln(\text{Stock})$. Inflation is the year-on-year percentage change in the CPI, requiring 2014 CPI presample observations to construct inflation from January

2015. The exchange rate is expressed as local-currency units per US dollar and transformed to $\ln(\text{FX})$. Brent is transformed to $\ln(\text{Brent})$. CPU is retained in its observed scale.

Variable	Operationalization	Expected role
ln Stock Market	Natural log of national stock-market index in LCU	Dependent variable
Country CPU	National climate policy uncertainty index	Main transition-risk regressor
Inflation	$100 \times (\text{CPI}_t / \text{CPI}_{t-12} - 1)$	Domestic control
ln FX	Natural log of LCU per USD	Domestic financial control
VIX	Monthly global volatility index	Global risk control
ln Brent	Natural log of Brent crude price	Energy-market robustness control
GPR	Geopolitical risk index	Global robustness control
Global CPU	Global climate policy uncertainty	Alternative transition-risk measure

Source discipline is central to the dataset. Monthly national observations are not generated from annual values, and structural gaps are preserved. This prevents artificial time-series variation and avoids overstating the effective sample size.

4. Econometric Methodology

4.1 Preliminary diagnostics

The analysis begins with descriptive statistics, pairwise correlations and variance-inflation factors. Cross-sectional dependence is then assessed using a Pesaran-type CD statistic. Because significant dependence is present, unit-root assessment emphasizes cross-sectionally augmented diagnostics rather than relying exclusively on first-generation panel tests.

4.2 Integration and Panel ARDL suitability

The ARDL framework permits regressors that are $I(0)$ or $I(1)$ but not $I(2)$. The diagnostics indicate a mixed integration pattern: country CPU, VIX, GPR and global CPU behave as stationary or strongly mean-reverting series, while $\ln(\text{FX})$, inflation in the balanced sample and $\ln(\text{Brent})$ show greater persistence and become stationary after differencing. The stock-market level is borderline in the shorter balanced sample but behaves more clearly as $I(1)$ over the longer 2015-2025 window. No core variable shows evidence requiring an $I(2)$ classification. This pattern permits ARDL estimation, although long-run inference must remain sensitive to the relatively small cross-sectional dimension.

4.3 PMG-ARDL specification

The error-correction representation can be written as:

$$\Delta Y_{it} = \phi_i [Y_{i,t-1} - \theta' X_{i,t-1}] + \sum \lambda_{ij} \Delta Y_{i,t-j} + \sum \delta_{ij} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it},$$

where Y is $\ln(\text{Stock})$, X contains CPU, inflation, $\ln(\text{FX})$ and VIX, θ contains the long-run coefficients and ϕ_i is the country-specific speed of adjustment. A valid equilibrium-correction mechanism normally requires $\phi_i < 0$ and statistical significance. PMG constrains θ to be common across countries but allows short-run coefficients and adjustment speeds to differ.

Information-criterion comparisons favour approximately ARDL(2,1) for the core country-CPU model. An extended model including $\ln(\text{Brent})$ and GPR is estimated with a more parsimonious ARDL(1,1) structure.

Mean Group estimates are used as a heterogeneity comparison. A conventional Hausman comparison is treated cautiously because the estimated covariance-difference matrix is not positive definite in this four-country panel.

4.4 Robustness strategy

Three specifications are emphasized. Model A is the core country-CPU PMG model with inflation, $\ln(\text{FX})$ and VIX. Model B adds $\ln(\text{Brent})$ and GPR. Model C replaces country CPU with global CPU and uses the full January 2015-December 2025 panel. Country and global CPU are not automatically entered together because they represent related uncertainty constructs and may create unnecessary collinearity.

5. Empirical Results

5.1 Descriptive statistics

Variable	N	Mean	SD	Min	Max
ln Stock Market	360	5.244	0.483	4.390	6.200
Monthly stock return (%)	360	0.728	4.370	-32.839	14.811
Country CPU	360	2.171	1.669	0.000	9.675
Inflation YoY (%)	360	4.079	2.444	-0.815	12.132
ln FX	360	2.673	1.071	1.314	4.501
VIX	360	19.952	6.831	12.524	57.737
ln Brent	360	4.249	0.293	2.911	4.810
GPR	360	114.177	40.848	58.421	318.955

The balanced sample displays substantial variation in both stock returns and transition-risk indicators. Monthly stock returns range from -32.84% to 14.81%, reflecting episodes of severe market stress. VIF values are approximately 1.15-2.06, indicating no serious multicollinearity among the principal regressors.

5.2 Cross-sectional dependence and integration

Variable	CD statistic	p-value	Inference
ln Stock Market	16.91	<0.001	Cross-sectional dependence
Country CPU	4.03	<0.001	Cross-sectional dependence
Inflation	5.43	<0.001	Cross-sectional dependence
ln FX	13.58	<0.001	Cross-sectional dependence

Cross-sectional independence is strongly rejected for the main country-varying variables. VIX, Brent and GPR are common global series and therefore naturally induce shared time variation. This finding supports second-generation unit-root procedures and motivates cross-sectionally augmented robustness analysis.

Variable	Level assessment	First-difference assessment	Working order
ln Stock Market	Borderline in balanced sample; more persistent in 2015-2025	Stationary	Predominantly I(1)
Country CPU	Stationary	Stationary	I(0)
Inflation	Persistent/non-stationary in balanced sample	Stationary	I(1) / persistent
ln FX	Non-stationary	Stationary	I(1)
VIX	Stationary	-	I(0)
ln Brent	Persistent	Stationary	Approximately I(1)
GPR	Stationary	-	I(0)
Global CPU	Stationary	-	I(0)

The mixture of I(0) and I(1) variables is consistent with ARDL modelling, and no core variable is classified as I(2). Because the stock-market level is less decisively non-stationary in the shorter balanced sample, the long-run results are interpreted conservatively and are supplemented with adjustment and robustness evidence.

5.3 Baseline PMG-ARDL results

Regressor	Long-run coefficient	p-value	Short-run coefficient	p-value
Country CPU	0.0590	0.271	0.0012	0.535
Inflation	-0.0168	0.421	-0.0064	0.012**
ln FX	0.5895	0.015**	-0.8192	<0.001***
VIX	-0.0113	0.078*	-0.00378	<0.001***

Country-specific CPU is statistically insignificant in both the long run and short run. H1 and H2 are therefore not supported by the baseline model. The long-run ln(FX) coefficient is positive and significant, while VIX is marginally negative at the 10% level. In the short run, inflation, exchange-rate changes and changes in VIX are statistically significant and negative. These results indicate that conventional macro-financial conditions have more consistent immediate relationships with emerging equity markets than country-specific climate-policy uncertainty.

The short-run CPU coefficient is also insignificant when examined by country: Brazil $p \approx 0.60$, China $p \approx 0.41$, India $p \approx 0.32$ and South Africa $p \approx 0.51$. Thus, the pooled null result is not masking an individually significant short-run CPU coefficient in one of the four markets.

5.4 Error-correction and long-run adjustment

Country	ECT coefficient	p-value	Interpretation
Brazil	-0.0979	0.010**	Significant convergence; about 9.8% monthly adjustment

China	-0.0546	0.111	Correct sign, statistically weak
India	-0.0048	0.752	Near-zero adjustment
South Africa	+0.0073	0.685	No convergence; wrong sign

The adjustment evidence is heterogeneous. Brazil exhibits a negative and significant error-correction coefficient, while China has the expected sign but lacks conventional significance. India shows almost no adjustment and South Africa has a small positive coefficient. H3 is therefore not supported as a uniform panel-wide proposition. The results are more accurately described as evidence of heterogeneous equilibrium adjustment concentrated in selected markets rather than strong common cointegration across all four countries.

5.5 Extended model with Brent and geopolitical risk

Regressor	Long-run coefficient	p-value	Short-run coefficient	p-value
Country CPU	0.0987	0.497	0.0010	0.595
Inflation	-0.0536	0.445	-0.0076	0.012**
ln FX	0.2985	0.684	-0.8762	<0.001***
VIX	-0.0293	0.254	-0.00326	<0.001***
ln Brent	-0.3338	0.537	0.0468	0.017**
GPR	-0.00156	0.575	-0.00003	0.611

Adding energy-market and geopolitical controls does not change the central CPU conclusion. Country CPU remains insignificant in both horizons. Inflation, exchange-rate changes and VIX retain significant negative short-run coefficients, while the short-run change in Brent is positive and significant. GPR is insignificant. The stability of the CPU null result across the core and extended models increases confidence that it is not simply an omitted-Brent or omitted-GPR artifact.

5.6 Global CPU robustness

Regressor	Long-run coefficient	p-value
Global CPU	0.000683	0.059*
Inflation	-0.0267	0.045**
ln FX	-1.1502	0.014**
VIX	-0.00178	0.546

Replacing national CPU with global CPU permits use of the complete 2015-2025 panel (N=528). Global CPU is marginally significant at the 10% level in the long run, but its short-run coefficient remains insignificant ($p \approx 0.144$). This provides limited evidence that broad global climate-policy signals may be more relevant to longer-run emerging-market valuation than isolated national CPU variation. The result is suggestive rather than conclusive because it does not reach the 5% significance level and global CPU is common across countries.

5.7 PMG-MG comparison and residual diagnostics

Mean Group long-run CPU estimates are heterogeneous: approximately +0.042 for Brazil, +0.053 for China, +0.026 for India and -0.388 for South Africa. This variation raises a substantive question about PMG's homogeneous long-run-slope restriction. A conventional Hausman covariance-difference matrix is not positive definite in the small four-country sample; accordingly, no mechanically forced Hausman decision is reported.

Residual serial correlation is generally limited. Ljung-Box tests do not indicate significant autocorrelation through 12 lags for Brazil, China or India, although South Africa shows evidence at lag 12 ($p \approx 0.041$). More importantly, residual cross-sectional dependence remains significant ($CD \approx 3.40$, $p < 0.001$). The baseline PMG results should therefore be regarded as the principal Panel ARDL estimates but not the final word on common-factor robustness.

6. Discussion

The most important empirical result is the absence of a statistically significant average relationship between country-specific climate policy uncertainty and stock-market performance. This finding is robust across the baseline and extended PMG specifications and across country-specific short-run coefficients. The result does not imply that climate transition risk is irrelevant to financial markets. Instead, it suggests that broad national equity indices may diversify or aggregate transition exposures in ways that weaken a uniform CPU signal.

The stronger short-run effects of inflation, exchange rates and VIX are economically plausible. Emerging equity markets are highly exposed to domestic price conditions, currency movements and global risk sentiment. These channels operate quickly and broadly across listed firms. Climate policy uncertainty, by contrast, may be more sector-specific, may affect investment over longer horizons, or may be transmitted more directly through energy, carbon-intensive and transition-sensitive assets than through a broad market index.

The difference between national CPU and global CPU is also informative. National CPU is insignificant, whereas global CPU is marginally related to stock-market levels in the long-run robustness model. One interpretation is that investors in emerging markets respond more to synchronized global transition-policy signals than to domestic climate-policy uncertainty alone. However, this interpretation must remain cautious because global CPU is a common factor and the coefficient is only significant at the 10% level.

The error-correction results further qualify the long-run story. Significant adjustment is concentrated in Brazil, with weaker evidence for China and none for India or South Africa. This heterogeneity is consistent with differences in market structure, investor composition, exchange-rate regimes, sector weights and transition-policy exposure. It also indicates that a single homogeneous long-run coefficient may be an approximation rather than a structural law across emerging economies.

These findings provide a natural bridge to a more focused thesis on climate transition risk in Indian crude oil futures. Broad equity indices aggregate firms with very different exposures to decarbonisation. Crude oil futures are directly linked to fossil-fuel demand, energy-transition expectations and carbon-market developments. A subsequent market-specific study can therefore investigate whether transition risk appears more clearly through returns, asymmetric volatility and dynamic hedging relationships than through broad equity-market averages.

7. Implications

7.1 Implications for investors

The results caution against treating national CPU as a standalone tactical signal for broad emerging-market equity allocation. Exchange-rate conditions and global risk sentiment exhibit more reliable short-run associations in this sample. Climate-policy information may be more useful when combined with sectoral exposure, carbon intensity or asset-specific transition sensitivity.

7.2 Implications for policymakers

The absence of a uniform negative CPU coefficient should not be interpreted as evidence that climate policy has no financial consequences. Rather, the effect may depend on policy credibility, sector composition and the interaction between domestic policy and global transition developments. Predictable policy design may still reduce adjustment costs even when broad equity indices do not display a statistically uniform response.

7.3 Implications for research

The study highlights the importance of genuine country-specific transition-risk measurement, transparent treatment of structural missingness and explicit testing for cross-sectional dependence. It also demonstrates why long-run Panel ARDL conclusions should not be inferred solely from statistically significant pooled coefficients; country-specific error correction and common-factor dependence must be considered.

8. Limitations and Robustness Priorities

Several limitations remain. First, the cross-sectional dimension is small ($N=4$), which limits the reliability of some asymptotic panel procedures and the conventional PMG-MG Hausman comparison. Second, the balanced country-CPU sample begins only in July 2018 because South African CPU is unavailable earlier. Third, broad stock-market indices may dilute sector-specific transition exposure. Fourth, significant residual cross-sectional dependence indicates that observed global controls do not absorb all common factors. Fifth, the analysis is associative and does not establish causal effects. Sixth, the stock-market level is less decisively non-stationary in the shorter balanced sample than over the full 2015-2025 period, so long-run inference should remain conservative.

Before journal submission, the most important robustness extension is a cross-sectionally augmented dynamic specification such as CS-ARDL or a common-correlated-effects estimator, together with a formally bootstrapped Westerlund error-correction cointegration table where software and sample dimensions permit. These tests would directly address the common-factor dependence documented in the current analysis. Sector-level or energy-intensive equity portfolios would provide an additional substantive robustness check.

9. Conclusion

This study examines climate transition risk and stock-market dynamics in Brazil, China, India and South Africa using a validated monthly panel from 2015 to 2025. The principal country-specific CPU model uses a balanced July 2018-December 2025 sample because South African national CPU is unavailable before July 2018. Panel diagnostics reveal strong cross-sectional dependence and a mixture of $I(0)$ and $I(1)$ variables, supporting an ARDL framework while requiring caution about common global shocks.

The baseline PMG-ARDL estimates do not show a statistically significant country-specific CPU effect in either the long run or short run. By contrast, inflation, exchange-rate movements and VIX exhibit stronger short-run relationships with stock-market performance. Error-correction behaviour is heterogeneous, with significant convergence for Brazil but weak or absent adjustment elsewhere. Adding Brent and geopolitical risk leaves the CPU conclusion unchanged. A full-sample global-CPU model provides only marginal evidence of a positive long-run relationship.

The findings therefore reject a simple narrative in which higher domestic climate-policy uncertainty uniformly depresses emerging stock markets. Instead, transition-risk transmission appears heterogeneous and potentially more global than domestic at the level of broad equity indices. This conclusion motivates further analysis using cross-sectionally augmented estimators and more transition-sensitive assets. It also provides a coherent foundation for subsequent research on Indian crude oil futures, where climate transition risk may operate more directly through returns, volatility and dynamic hedging relationships.

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Appendix A. Sample and Missing-Data Structure

Country	Master sample	Country availability CPU	Balanced CPU sample
Brazil	2015-01 to 2025-12 (132)	2015-01 to 2025-12	2018-07 to 2025-12 (90)
China	2015-01 to 2025-12 (132)	2015-01 to 2025-12	2018-07 to 2025-12 (90)
India	2015-01 to 2025-12 (132)	2015-01 to 2025-12	2018-07 to 2025-12 (90)
South Africa	2015-01 to 2025-12 (132)	2018-07 to 2025-12	2018-07 to 2025-12 (90)

Total master panel: 528 country-month observations. Balanced national-CPU estimation panel: 360 observations. The 42 South African CPU observations before July 2018 are structural source gaps and are intentionally left unavailable.

Appendix B. Statistical Significance

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. Statistical significance is interpreted as sampling evidence and not as proof of causality. Coefficient magnitude, model assumptions, cross-sectional dependence, sample coverage and data provenance should be considered jointly.

Appendix C. Recommended Pre-Submission Extension

Because residual cross-sectional dependence remains statistically significant, the preferred pre-submission extension is a cross-sectionally augmented ARDL/common-correlated-effects robustness analysis and a formal Westerlund error-correction cointegration test with appropriate resampling. The current PMG estimates should be retained as the baseline Panel ARDL evidence and compared transparently with those robustness results rather than replaced selectively.