

Digital Governance and Carbon Impact: Threshold Dynamics in Emission Reductions for High-Income Economies

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Understanding the carbon impact of e-government is essential for addressing climate change in the digital age. This study investigates the nonlinear effects of e-government and its core components on carbon emissions over the period 2003–2020 for a panel of 54 high-income countries. Using the Panel Smooth Transition Regression (PSTR) approach, the results identify statistically significant threshold effects, indicating that the environmental impact of digital governance varies across regimes. Specifically, e-government exerts a positive effect on carbon emissions below the estimated threshold, while beyond the threshold level, further improvements lead to a measurable reduction in emissions, confirming a nonlinear adjustment process. The estimated thresholds are systematically lower in major oil-producing countries, implying that relatively modest improvements in digital governance generate larger marginal emission-reduction effects in these economies. Robustness checks using GMM and fixed-effects estimations confirm the magnitude, direction, and statistical significance of the main results. These findings suggest that surpassing identified digital governance thresholds is critical for policymakers seeking to leverage e-government as an effective tool for environmental sustainability in developed economies.

Keywords: Carbon emission, E-government, High-income countries, PSTR, Top oil-producing countries

Table S1 — Robustness results using different estimation methods

	Model 1 EGDI	Model 2 OSI	Model 3 TII	Model 4 HCI
GMM model				
L.CO2	0.101*** (0.009)	—	—	—
EGDI	0.004** (0.002)	—	—	—
EGDI	-0.122** (0.036)	—	—	—
OSI	—	0.003** (0.001)	—	—
OSI ²	—	-0.120*** (0.010)	—	—
TII	—	—	0.002* (0.001)	—
TII ²	—	—	-0.132** (0.079)	—
HCI	—	—	—	0.003* (0.001)
HCI ²	—	—	—	-0.100*** (0.003)
Constant	0.010* (0.001)	0.111* (0.041)	0.014** (0.132)	0.044* (0.031)
Control variables: yes				
AR(1)	0.144	0.175	0.137	0.162
AR(2)	0.524	0.421	0.494	0.531
Hansen p value	0.201	0.214	0.210	0.221
Fixed effects model				
EGDI	0.011* (0.056)	—	—	—
EGDI ²	-0.102*** (0.046)	—	—	—
OSI	—	0.022* (0.013)	—	—
OSI ²	—	-0.100*** (0.001)	—	—
TII	—	—	0.002 (0.136)	—

TII ²	—		−0.122** (0.064)	—
HCI	—		—	−0.034* (0.025)
HCI ²	—		—	−0.094*** (0.002)
Constant	0.011** (0.006)	0.010* (0.009)	0.016* (0.011)	0.010* (0.008)
Control variables: yes				
R ²	0.64	0.60	0.61	0.62
Countries	54	54	54	54

Note: Models 1 to 4 include EGDI, OSI, TII and HCI as dependent variables; Hansen: test the null hypothesis of the appropriate set of instruments; AR1: Test for first-order serial correlation; AR2: Test for second-order serial correlation; *, **, and *** denote significance levels at 10, 5, and 1%, respectively

Table S2 — Robustness results using additional control variables

	Model 1 EGDI	Model 2 OSI	Model 3 TII	Model 4 HCI
EGDI	0.007* (0.003)	—	—	—
EGDI* g (.)	−0.010** (0.004)	—	—	—
OSI	—	0.001* (0.002)	—	—
OSI* g (.)	—	−0.022** (0.011)	—	—
TII	—	—	0.006* (0.004)	—
TII*g(.)	—	—	−0.102* (0.044)	—
HCI	—	—	—	0.011** (0.005)
HCI*g(.)	—	—	—	−0.031** (0.003)
Control variables				
FD	0.010 (0.320)	0.096* (0.026)	0.013* (0.009)	−0.088 (0.303)
FDI	0.019 (0.100)	0.023* (0.011)	0.033* (0.011)	0.036* (0.020)
TO	0.109* (0.014)	0.122 (0.231)	0.112* (0.060)	0.155** (0.009)
GDP	0.100* (0.111)	−0.099 (0.206)	0.112* (0.051)	0.102* (0.077)
ENERG	−0.041* (0.013)	−0.074* (0.036)	−0.025* (0.021)	−0.036** (0.001)
POP	0.022* (0.005)	0.008 (0.120)	0.013* (0.009)	0.012** (0.009)
URB	0.106** (0.022)	0.101** (0.034)	0.100* (0.077)	0.104*** (0.019)
GOV	−0.102** (0.066)	−0.111*** (0.006)	−0.103** (0.036)	−0.097*** (0.024)
REG	−0.030** (0.015)	−0.035* (0.013)	0.012* (0.010)	−0.028* (0.022)
Transition parameters				
EGDI(c _{1,1})	0.57 (0.022)	—	—	—
EGDI(γ)	24.10 (0.466)	—	—	—
OSI(c _{1,1})	—	0.52 (0.033)	—	—
OSI(γ)	—	18.43 (0.560)	—	—
TII(c _{1,1})	—	—	0.49 (0.033)	—
TII(γ)	—	—	22.39 (0.769)	—
HCI(c _{1,1})	—	—	—	0.67 (0.055)
HCI(γ)	—	—	—	27.11 (0.622)
Countries	54	54	54	54

Note: Models 1 to 4 include EGDI, OSI, TII and HCI as transition variables; c_{1,1} and γ represent the estimated location parameter and estimated slope parameter; ENER, URB, GOV and REG are additional control variables; *, **, and *** denote significance levels at 10, 5, and 1%, respectively