

Services Trade Liberalization, Digitalization, and Green Growth: Nonlinear Effects on Sustainable Competitiveness

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Abstract

This study examines the nonlinear relationship between services trade liberalization and green growth in BRICS economies. Because direct measures of services trade liberalization are limited for the study period, ICT service exports are used as an outcome-based proxy for international services-trade integration. Using linear and nonlinear panel quantile autoregressive distributed lag (QARDL) models, the study estimates both short-run and long-run effects. The linear results indicate that services trade supports green growth in BRICS economies, mainly in the long run and at higher quantiles. The nonlinear results show that positive shocks to services trade promote green growth, whereas negative shocks weaken it. Green investment, human capital, and R&D expenditure generally contribute positively to green growth, although their effects vary across quantiles. These findings suggest that policies supporting services trade liberalization, digital service exports, green investment, human-capital development, and R&D activity can strengthen green growth and sustainable competitiveness in BRICS economies.

Keywords: Services trade liberalization, ICT service exports, green growth, BRICS, QARDL, sustainable competitiveness

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1 INTRODUCTION

The concept of green growth has become increasingly important in policy debates on sustainable economic transformation. The World Bank and the OECD have promoted green growth as a development strategy that combines economic expansion with environmental protection and more efficient use of natural resources (World Bank, 2012; OECD, 2011; Smulders et al., 2014). The Global Green Growth Institute was also established to support countries in designing and implementing green-growth strategies (O'Donnell, 2012). Green growth was initially associated mainly with climate-change mitigation, but it now covers a

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broader set of environmental concerns, including biodiversity, water, soil, fisheries, and ecosystem services (Antal & van den Bergh, 2016). It rests on the premise that economic activity can be increasingly decoupled from resource use and CO₂ emissions through structural change, technological progress, and cleaner production systems (Hickel & Kallis, 2020; Adamowicz, 2022).

The expansion of green-growth policy has coincided with the rising importance of the services sector and services trade. Trade-openness research increasingly examines whether services trade can improve productivity, resource efficiency, technological diffusion, and environmental performance (Hakimi & Hamdi, 2016). Services frequently add value to manufactured goods and global value chains; therefore, restrictions on services trade can reduce competitiveness across entire supply chains (Laget et al., 2020). Services trade liberalization is thus relevant not only for economic growth, but also for sustainable competitiveness, because open and efficient services markets can support productivity gains, digitalization, and cleaner modes of production (McMillan et al., 2014; Tiep et al., 2021).

This study examines the effect of service trade liberalization on green growth in BRICS economies. Although BRICS countries have made progress in services trade, they continue to face restrictions and structural barriers in several service sectors. Inefficient distribution, transport, telecommunications, storage, and financial services can raise input costs and weaken export competitiveness, thereby limiting the contribution of services trade to sustainable growth (Khatun, 2019). Service trade liberalization may support green growth through several channels. First, it can increase productivity by improving resource allocation, competition, scale economies, capital accumulation, innovation, and technological progress (Li et al., 2021). Second, it can strengthen global-value-chain participation and increase economies' capacity to absorb external shocks (Dou et al., 2021). Third, more efficient services can reduce transaction costs and facilitate the diffusion of cleaner technologies and knowledge (Chauffour & Hoekman, 2013).

The empirical measurement of services trade liberalization requires caution. Direct liberalization indicators are often limited by data availability, sector coverage, and cross-country comparability. Earlier research has therefore used sectoral services-trade indicators, including telecommunications, financial services, transport, communication, and distribution services, to capture openness and reform in services markets (El Khoury & Savvides, 2006;

Hoekman et al., 2007; Eschenbach & Hoekman, 2006; Mattoo et al., 2001; Konan & Maskus, 2006). Following this outcome-based logic, the present study uses ICT service exports as a proxy for the international integration of services trade, particularly digitally enabled services trade. This operational choice is consistent with the title's focus on services trade liberalization, while acknowledging that the variable captures realized services-trade openness rather than a direct statutory liberalization index.

Recent evidence shows that services trade and services reform can support economic performance. Arnold et al. (2011) find that services liberalization improves firm performance in the Czech Republic, while Arnold et al. (2012) report that reforms in transport, telecommunications, and banking services contributed to manufacturing performance in India. Nevertheless, the link between services trade and green growth remains underexplored, especially in BRICS economies, where large markets, natural resources, digital capability, and environmental pressures coexist.

BRICS economies are particularly important in the services trade and green-growth literature because they combine rapid structural transformation with substantial environmental challenges. These economies also increasingly rely on digital trade, ICT services, green investment, and technological upgrading to improve competitiveness and environmental performance (Chen et al., 2023; Li et al., 2022; Zhang & Choi, 2025). However, the nonlinear and asymmetric effects of services trade on green growth in BRICS economies remain insufficiently understood.

This study contributes to the literature in two main ways. First, it examines the relationship between services trade and green growth in BRICS economies using both linear and nonlinear panel QARDL models. Second, it evaluates whether positive and negative changes in services trade have asymmetric effects across different quantiles of green growth. This approach provides a more nuanced understanding of how services trade, green investment, human capital, and R&D expenditure contribute to sustainable competitiveness in BRICS economies.

The remainder of the paper is organized as follows. Section 2 presents the model and methods used to examine the linear and nonlinear effects of services trade on green growth. Section 3 describes the data, variables, and descriptive statistics. Section 4 reports and discusses the empirical results, including the linear and nonlinear QARDL estimates and asymmetry tests.

Section 5 concludes the study by summarizing the main findings, policy implications, limitations, and future research directions.

2 MODEL AND METHODS

Service trade liberalization can support green growth by facilitating access to cleaner technologies, reducing service-sector barriers, and promoting cross-border knowledge flows, investment, and digital service exports (Murshed et al., 2021). It can also stimulate innovation and productivity by increasing competition among service providers and encouraging the adoption of efficient and environmentally friendly technologies and practices (Ding et al., 2025). This study employs the panel quantile autoregressive distributed lag (QARDL) framework introduced by Cho et al. (2015) to examine heterogeneous short-run and long-run effects across the conditional distribution of green growth. The QARDL approach is suitable because it allows coefficients to vary across quantiles and can accommodate non-stationary variables, nonlinearities, and structural heterogeneity (Godil et al., 2021; Wang et al., 2024).

The baseline long-run relationship is specified as follows:

$$GG_{it} = \alpha_i + \beta_1 ST_{it} + \beta_2 GI_{it} + \beta_3 HC_{it} + \beta_4 RD_{it} + \varepsilon_{it} \quad (1)$$

In Specification (1), GG denotes green growth, ST denotes services trade liberalization proxied by ICT service exports, GI denotes green investment proxied by renewable energy production, HC denotes human capital, RD denotes R&D expenditure, and ε denotes the residual term. The subscripts i and t represent country and time, respectively. The lag orders are selected according to the model specification and data properties.

The linear panel QARDL error-correction specification is expressed as follows:

$$\Delta GG_{it} = \mu_i(\tau) + \rho_i(\tau) ECM_{i,t-1}(\tau) + SR_{it}(\tau) + \varepsilon_{it}(\tau) \quad (2a)$$

$$ECM_{i,t-1}(\tau) = GG_{i,t-1} - \theta_1(\tau) ST_{i,t-1} - \theta_2(\tau) GI_{i,t-1} - \theta_3(\tau) HC_{i,t-1} - \theta_4(\tau) RD_{i,t-1} \quad (2b)$$

In Equations (2a) and (2b), $0 < \tau < 1$ denotes the quantile. The coefficient $\rho_i(\tau)$ is the error-correction parameter and is expected to be negative and statistically significant when adjustment toward the long-run equilibrium exists. The term $SR_{it}(\tau)$ collects the quantile-specific short-run coefficients of the lagged first differences of GG, ST, GI, HC, and RD. This structure allows

the effects of services trade and the control variables to differ across low, middle, and high levels of green growth.

Because linear models may conceal asymmetric responses, the study further applies a nonlinear QARDL specification. Following Shin et al. (2014), services trade is decomposed into positive and negative partial-sum components as follows:

$$ST^+_{it} = \sum_{s=1}^t \Delta ST^+_{is} = \sum_{s=1}^t \max(\Delta ST_{is}, 0) \quad (3a)$$

$$ST^-_{it} = \sum_{s=1}^t \Delta ST^-_{is} = \sum_{s=1}^t \min(\Delta ST_{is}, 0) \quad (3b)$$

The positive component captures increases in services trade, whereas the negative component captures decreases in services trade. This decomposition allows the analysis to test whether increases and decreases in services trade affect green growth differently.

The nonlinear long-run model is specified as follows:

$$GG_{it} = \alpha_i + \beta_1 ST^+_{it} + \beta_2 ST^-_{it} + \beta_3 GI_{it} + \beta_4 HC_{it} + \beta_5 RD_{it} + \varepsilon_{it} \quad (4)$$

The nonlinear panel QARDL error-correction specification is written as follows:

$$\Delta GG_{it} = \mu_i(\tau) + \rho_i(\tau) NECM_{i,t-1}(\tau) + NSR_{it}(\tau) + \varepsilon_{it}(\tau) \quad (5a)$$

$$NECM_{i,t-1}(\tau) = GG_{i,t-1} - \theta_1 ST^+_{i,t-1} - \theta_2 ST^-_{i,t-1} - \theta_3 GI_{i,t-1} - \theta_4 HC_{i,t-1} - \theta_5 RD_{i,t-1} \quad (5b)$$

The term $NSR_{it}(\tau)$ collects the short-run lagged first differences of GG , ST^+ , ST^- , GI , HC , and RD . Thus, the nonlinear QARDL model distinguishes between short-run and long-run responses to positive and negative services-trade shocks across the green-growth distribution.

The short-run coefficients capture immediate effects on green growth, whereas the long-run coefficients capture persistent relationships among services trade, green investment, human capital, R&D expenditure, and green growth. Wald tests are used to examine whether the positive and negative components of services trade differ significantly in the long run and short run:

$$H_0^{LR}: \theta_1^+(\tau) = \theta_1^-(\tau) \quad (6a)$$

$$H_0^{SR}: \pi_j^+(\tau) = \pi_j^-(\tau) \quad (6b)$$

Rejection of these null hypotheses indicates asymmetric effects in the corresponding time horizon.

3 DATA AND DESCRIPTIVE ANALYSIS

This study examines the impact of services trade liberalization on green growth in BRICS economies from 1995Q1 to 2020Q4. Data are drawn primarily from the World Development Indicators (WDI). Because several source variables are originally reported annually, they were converted to quarterly frequency using quadratic match-sum interpolation before estimation. The dependent variable is green growth (GG), measured as pollution-adjusted GDP growth (%). The main explanatory variable is services trade (ST), measured by ICT service exports as a percentage of total service exports. Although ICT service exports do not directly measure statutory liberalization, they serve as an outcome-based proxy for openness and international integration in digitally enabled services trade. Following related green-growth studies (Sohail et al., 2022), green investment (GI) is proxied by total renewable energy production, which reflects green-energy capacity. Human capital (HC) is measured using the logarithm of secondary school enrollment. R&D expenditure (RD) is measured as R&D expenditure as a percentage of GDP and transformed for quarterly estimation. Table 1 reports the definitions and descriptive statistics.

Tab. 1 – Definitions and descriptive statistics. Source: authors' calculations

Variables	Definitions	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.
GG	Pollution-adjusted GDP growth (%)	5.16	4.98	13.13	-4.73	3.03	-0.46	3.57	25.68	0.000
ST	ICT service exports (% of service exports, BoP)	12.44	4.43	52.08	0.30	16.46	1.44	3.30	82.79	0.000
GI	Renewable energy production (quad Btu)	3.59	3.13	21.61	0.11	4.05	2.60	10.47	177.4	0.000
HC	ln secondary school enrollment (% gross)	4.40	4.51	4.700	3.76	0.24	-1.08	3.09	101.9	0.000
RD	Transformed R&D expenditure (% of GDP)	1.46	0.96	66.55	-5.07	5.77	3.21	124.60	348.1	0.000

Figure 1 presents the Q-Q plots used to assess the distributional characteristics of the variables.

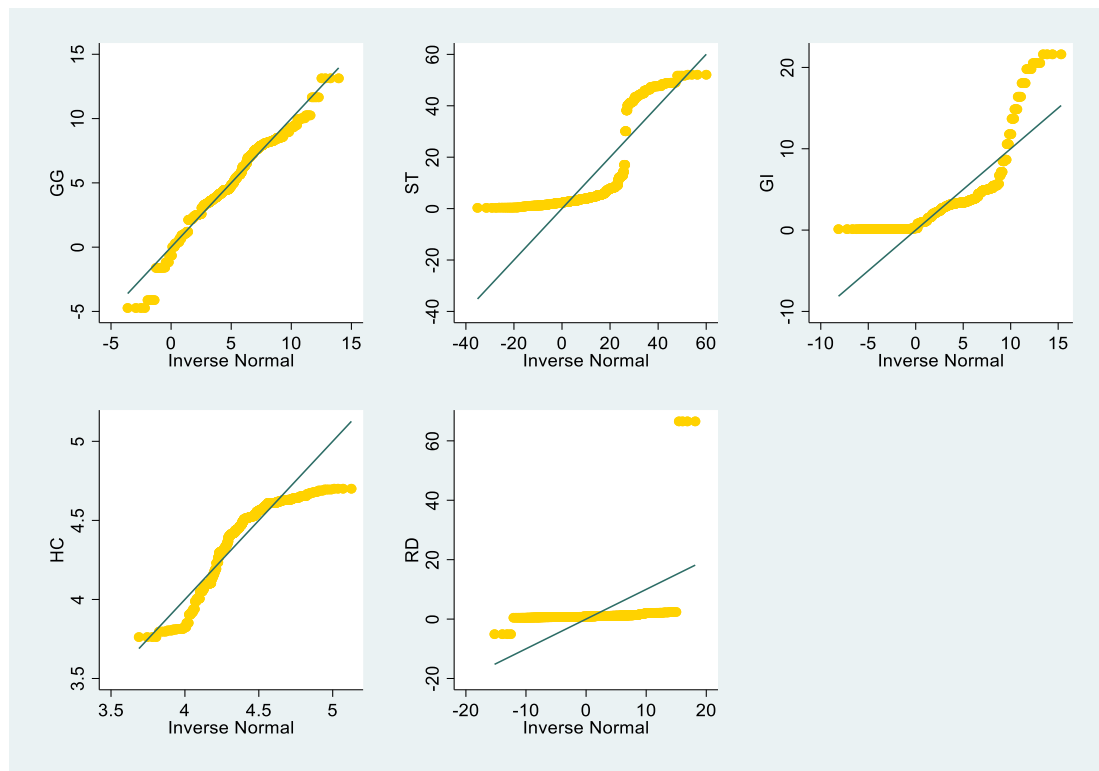


Fig. 1 – Q-Q plots for normality. Source: authors' calculations

4 EMPIRICAL RESULTS AND DISCUSSION

Before QARDL estimation, the unit-root properties of the data are examined using LLC and IPS tests. Table 2 shows that RD is stationary at level, whereas GG, ST, GI, and HC become stationary after first differencing. The mixed order of integration supports the use of the QARDL estimation technique, provided that none of the variables is integrated of order two. Table 3 reports the long-run and short-run estimates of the linear panel QARDL model, while Table 4 reports the nonlinear panel QARDL estimates.

Tab. 2 – Results of unit root tests. Source: authors' calculations

	LLC				IPS		
	I(0)	I(1)	Decision		I(0)	I(1)	Decision
GG	-0.123	-1.986**	I(1)		-0.985	-3.895***	I(1)
ST	-1.023	-3.652***	I(1)		-1.365	-4.652***	I(1)
GI	-1.035	-2.987***	I(1)		-0.134	-5.265***	I(1)

	LLC			IPS		
HC	-0.582	-2.891***	I(1)	-0.251	-4.356***	I(1)
RD	-1.634*		I(0)	-1.826**		I(0)

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 3 presents the linear panel QARDL estimates. The ECM term is negative and statistically significant across quantiles, confirming adjustment toward the long-run equilibrium. The long-run effect of ST on GG is positive and statistically significant from the 0.60 to 0.95 quantiles, indicating that services trade contributes to green growth mainly at higher levels of the green-growth distribution. In contrast, the ST-GG relationship is insignificant from the 0.05 to 0.50 quantiles. GI has a positive and significant relationship with GG across all quantiles. HC is positive and significant from the 0.30 to 0.95 quantiles, while RD is positive and significant from the 0.50 to 0.95 quantiles. These results indicate that services trade, green investment, human capital, and R&D expenditure support green growth, but their effects vary across quantiles.

Table 4 reports the nonlinear panel QARDL estimates. The ECM terms are negative and statistically significant, again confirming the presence of a long-run relationship among the variables. Positive shocks to ST have a significant positive effect on GG from the 0.40 to 0.95 quantiles, suggesting that increases in services trade promote green growth at the middle and upper quantiles. The negative component of ST is also significant from the 0.40 to 0.95 quantiles. Because this component captures decreases in services trade, the result indicates that reductions in services trade are associated with lower green growth. Thus, services trade affects green growth asymmetrically in BRICS economies.

The positive association between services trade and green growth can be explained through productivity, composition, and technology channels. Trade liberalization may initially increase economic activity and energy demand, but over time it can improve production efficiency, support cleaner technologies, and shift activity toward less pollution-intensive sectors (Antal & van den Bergh, 2016; Zhang et al., 2021; Shah et al., 2022). In this context, services trade can help reduce the environmental burden of economic expansion by supporting more efficient and knowledge-intensive activities.

Compared with energy-intensive manufacturing, the service sector is generally more compatible with energy savings and digital dematerialization (Song et al., 2019; Lange et al., 2020). ICT service exports are especially relevant because digital services can replace some material-intensive activities with information-based processes. Online transactions, digital communication, teleconferencing, and e-commerce can reduce time, material use, and transaction costs (Usman et al., 2021). Such changes may support green growth when they are accompanied by cleaner energy systems, digital infrastructure, and appropriate environmental policy (Zheng et al., 2023; Can et al., 2022). Carbon-market mechanisms may also help offset macroeconomic losses through technological advancement and environmental innovation (Ji & Wang, 2026).

The control variables also provide important insights. Green investment and human capital are positively associated with green growth across most quantiles, suggesting that renewable-energy capacity and education contribute to sustainable development in BRICS economies. R&D expenditure is positive and significant mainly at higher quantiles, indicating that research activity becomes more effective where green-growth performance is already stronger. In the short run, positive shocks to ST enhance GG, whereas negative shocks to ST weaken GG, reinforcing the importance of maintaining stable and open services-trade conditions.

Tab. 3 – Estimates of the panel QARDL model. Source: authors' calculations

	ECM	Constant	Long Run estimates				Short Run estimates					
	$\rho(\tau)$	$C(\tau)$	$\beta_{ST}(\tau)$	$\beta_{GI}(\tau)$	$\beta_{HC}(\tau)$	$\beta_{RD}(\tau)$	$\pi_{0ST}(\tau)$	$\pi_{1ST}(\tau)$	$\pi_{0GI}(\tau)$	$\pi_{1GI}(\tau)$	$\pi_{HC}(\tau)$	$\pi_{RD}(\tau)$
0.05	-0.673***	4.942	0.035	0.393***	1.602	0.061	0.017	0.043	0.531	0.292	0.545***	0.010
	(-7.824)	(1.283)	(0.803)	(8.372)	(1.412)	(1.317)	(0.413)	(1.057)	(1.193)	(0.240)	(8.035)	(1.606)
0.10	-0.675***	6.475	0.018	0.372***	1.773	0.050	0.012	0.072	0.550	0.318	0.578***	0.007
	(-9.489)	(1.206)	(0.350)	(6.672)	(1.262)	(1.211)	(0.246)	(1.458)	(1.152)	(0.757)	(5.006)	(1.359)
0.20	-0.674***	5.855	0.021	0.286***	1.126	0.036	0.002	0.062	0.434	0.195	0.626***	0.004
	(-5.400)	(1.401)	(0.541)	(5.890)	(1.254)	(1.450)	(0.026)	(1.022)	(1.557)	(1.029)	(4.341)	(1.524)
0.30	-0.674***	7.571*	0.032	0.269***	1.326*	0.023	0.009	0.072	0.497	0.259	0.648***	0.003
	(-6.540)	(1.971)	(1.123)	(7.281)	(1.700)	(0.501)	(0.125)	(0.977)	(1.623)	(1.147)	(3.662)	(0.795)
0.40	-0.715***	12.57***	0.009	0.299***	2.488***	0.011	0.070	0.131	0.535	0.299	0.711***	0.001
	(-4.426)	(5.855)	(0.487)	(11.39)	(5.284)	(1.344)	(0.752)	(1.400)	(1.063)	(1.589)	(3.536)	(0.286)
0.50	-0.763***	16.58***	0.007	0.292***	4.242***	0.021***	0.004	0.071	0.624	0.410	0.807***	0.008
	(-4.465)	(11.53)	(1.217)	(11.43)	(10.05)	(2.707)	(0.823)	(0.417)	(1.489)	(1.587)	(3.476)	(1.256)
0.60	-0.758***	19.24***	0.005*	0.227***	3.405***	0.033***	0.011	0.076	0.593	0.399	0.850***	0.011
	(-6.081)	(11.07)	(1.699)	(12.02)	(9.217)	(5.101)	(1.175)	(0.505)	(1.266)	(1.206)	(3.333)	(1.571)
0.70	-0.804***	20.87***	0.008*	0.217***	3.689***	0.039***	0.049	0.035	0.389	0.219	0.983***	0.020
	(-3.370)	(15.18)	(1.842)	(11.65)	(12.47)	(6.901)	(1.370)	(0.269)	(1.256)	(1.611)	(2.836)	(1.132)
0.80	-0.845***	22.18***	0.012**	0.341***	3.916***	0.043***	0.107**	0.001	0.438*	0.296	1.064***	0.026
	(-7.280)	(14.21)	(2.092)	(3.179)	(12.41)	(6.750)	(2.443)	(0.023)	(1.686)	(1.152)	(2.912)	(1.287)
0.90	-0.770***	23.74***	0.016***	0.511***	4.244***	0.045***	0.027**	0.025	0.030**	0.020	1.808**	0.073
	(-4.827)	(16.22)	(3.356)	(5.486)	(14.27)	(8.859)	(2.011)	(0.691)	(2.156)	(0.106)	(2.514)	(1.140)
0.95	-0.662***	21.59***	0.029**	0.497***	5.326***	0.054***	0.014**	0.031	0.017**	0.024	1.912**	0.079
	(-8.520)	(5.280)	(2.296)	(4.712)	(4.758)	(6.404)	(2.200)	(1.129)	(2.125)	(0.179)	(2.184)	(1.391)

Note: The t-statistic is shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Tab. 4 – Estimates of the panel nonlinear QARDL model. Source: authors' calculations

	ECM	Constant	Long Run estimates					Short Run estimates						
	$\rho(\tau)$	$C(\tau)$	$\beta^*_{st}(\tau)$	$\beta_{-st}(\tau)$	$\beta_{GI}(\tau)$	$\beta_{HC}(\tau)$	$\beta_{RD}(\tau)$	$\pi^*_{st}(\tau)$	$\pi_{-st}(\tau)$	$\pi 0_{GI}(\tau)$	$\pi 1_{GI}(\tau)$	$\pi_{HC}(\tau)$	$\pi 0_{RD}(\tau)$	$\pi 1_{RD}(\tau)$
0.05	-0.669***	7.655***	0.020	0.138	0.460***	3.458***	0.083	0.145	0.230	0.350	0.023	0.563***	0.010	0.025
	(-3.442)	(4.869)	(0.448)	(1.122)	(8.800)	(5.299)	(1.545)	(1.093)	(1.181)	(1.152)	(0.198)	(6.220)	(1.640)	(0.649)
0.10	-0.679***	6.268***	0.091	0.036	0.328***	3.282***	0.050	0.132	0.210	0.362	0.049	0.595***	0.007	0.005
	(-2.705)	(6.801)	(1.228)	(0.082)	(6.923)	(6.862)	(1.618)	(1.472)	(1.370)	(1.228)	(0.324)	(3.945)	(0.821)	(0.540)

	ECM	Constant	Long Run estimates					Short Run estimates						
0.20	-0.705**	5.149***	0.118	0.025	0.236***	3.014***	0.016	0.130**	0.253	0.430	0.124	0.578***	0.013	0.004
	(-2.059)	(4.745)	(1.542)	(0.829)	(6.822)	(4.177)	(1.418)	(2.117)	(1.568)	(1.383)	(0.821)	(4.817)	(1.566)	(0.003)
0.30	-0.646***	7.249***	0.131	0.012	0.309***	2.590***	0.009	0.102***	0.229	0.553	0.277	0.622***	0.009	0.004
	(-3.604)	(6.454)	(0.017)	(0.733)	(6.469)	(5.839)	(1.211)	(2.844)	(1.625)	(1.552)	(1.195)	(5.184)	(1.029)	(0.006)
0.40	-0.638***	7.729***	0.124**	0.008*	0.326***	2.089***	0.005	0.135***	0.262**	0.577	0.300	0.707***	0.005	0.003
	(-3.827)	(11.14)	(2.563)	(1.789)	(9.724)	(9.823)	(0.015)	(3.294)	(2.098)	(1.653)	(1.429)	(5.357)	(0.478)	(0.006)
0.50	-0.692***	8.825***	0.107**	0.172**	0.309***	2.473***	0.013*	0.157***	0.288**	0.454*	0.178	0.793***	0.004	0.003
	(-4.107)	(12.95)	(2.449)	(2.387)	(11.99)	(11.09)	(1.752)	(3.042)	(2.357)	(1.888)	(1.369)	(5.778)	(0.024)	(0.004)
0.60	-0.688***	9.725***	0.095*	0.217**	0.238***	2.859***	0.030***	0.201***	0.356**	0.329**	0.152	0.882***	0.005	0.002
	(-4.447)	(11.52)	(1.907)	(2.546)	(13.03)	(9.248)	(4.585)	(2.795)	(2.496)	(2.065)	(0.442)	(4.287)	(0.737)	(0.002)
0.70	-0.714***	10.38***	0.083*	0.237*	0.223***	3.350***	0.037***	0.188**	0.337***	0.267**	0.115	0.970***	0.011	0.004
	(-4.810)	(10.86)	(1.850)	(1.902)	(11.57)	(8.442)	(6.695)	(2.159)	(2.931)	(2.421)	(0.138)	(3.877)	(1.544)	(0.001)
0.80	-0.619***	12.30***	0.066*	0.255*	0.342***	3.768***	0.041***	0.294***	0.544***	0.255**	0.100	1.061***	0.007	0.007
	(-4.936)	(9.324)	(1.943)	(1.8100)	(2.972)	(7.376)	(6.744)	(8.199)	(3.363)	(2.145)	(0.003)	(3.402)	(1.015)	(1.036)
0.90	-0.526***	14.48***	0.114**	0.270**	0.364***	3.959***	0.048***	0.058**	0.093***	0.113*	0.097	1.933***	0.004	0.074
	(-5.128)	(10.46)	(2.216)	(2.037)	(4.328)	(8.594)	(9.190)	(2.460)	(3.945)	(1.956)	(0.680)	(3.351)	(0.289)	(1.572)
0.95	-0.473***	15.22***	0.182***	0.313***	0.433***	4.160***	0.050***	0.045***	0.052**	0.085*	0.085	2.067**	0.004	0.083
	(-5.421)	(12.98)	(3.815)	(3.493)	(4.961)	(10.14)	(10.74)	(3.017)	(2.115)	(1.752)	(0.032)	(2.348)	(0.386)	(1.488)

Note: The t-statistic is shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 5 reports the Wald-test results for the positive and negative components of ST in the long run and short run. The long-run results reject the null hypothesis of symmetry across all quantiles, confirming that services trade has asymmetric long-run effects on green growth. In the short run, asymmetry is confirmed from the 0.40 to 0.95 quantiles. These results indicate that green growth responds differently to increases and decreases in services trade, particularly at the middle and upper quantiles (Zheng et al., 2023).

Tab. 5 – Wald test for long-run and short-run asymmetry. Source: authors' calculations

	H0: Long-run symmetry	H0: Short-run symmetry
0.05	9.145***	2.123

	H0: Long-run symmetry	H0: Short-run symmetry
0.10	8.022***	2.325
0.20	7.752***	2.732
0.30	8.698***	3.355
0.40	9.659***	3.897*
0.50	12.32***	4.698**
0.60	15.31***	5.654***
0.70	14.65***	6.985***
0.80	10.23***	7.332***
0.90	9.658***	8.658***
0.95	8.698***	9.659***

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

5 CONCLUSION AND IMPLICATIONS

This study examines the relationship between services trade and green growth in BRICS economies. The analysis applies linear and nonlinear panel QARDL models to capture both short-run and long-run effects and to distinguish between positive and negative services-trade shocks. Before estimation, LLC and IPS tests confirm that the variables have mixed orders of integration, supporting the use of the QARDL framework. The linear results show that services trade contributes positively to green growth, especially at higher quantiles. The nonlinear results indicate that positive shocks to services trade promote green growth, whereas negative shocks weaken it. Green investment, human capital, and R&D expenditure also support green growth, although their effects differ across quantiles.

These findings provide several policy implications. First, policymakers should treat positive and negative changes in services trade separately because their effects on green growth are asymmetric. Second, BRICS economies should continue to liberalize and strengthen digitally enabled services trade, particularly ICT services, because digitalization and dematerialization can help reduce the environmental intensity of economic activity. Third, green investment, human-capital development, and R&D expenditure should be prioritized as complementary channels that enhance the green-growth benefits of services trade. Finally, policies promoting

services trade should be aligned with sustainable-development goals so that trade openness supports green productivity, environmental upgrading, and sustainable competitiveness.

This study has several limitations. First, ICT service exports are used as an outcome-based proxy for services-trade liberalization because direct liberalization indices are limited for the study period. Future research could use direct services-trade restrictiveness indices or sector-specific liberalization measures when available. Second, the study focuses on BRICS economies, so the results may not be generalizable to all emerging or developing economies. Third, the analysis uses aggregate data and does not capture sector-level heterogeneity. Future studies may examine individual service sectors, digital infrastructure, environmental policy stringency, institutional quality, or country-specific heterogeneity to further explain the services trade-green growth nexus.

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