JOURNAL FOR SOCIAL SCIENCE STUDIES
An International Peer-Reviewed Open Access Journal

ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
Volume 4 • Issue 6 • October 2026

GREENER GROWTH OR HIDDEN PRESSURE? SERVICES-LED STRUCTURAL TRANSFORMATION AND ECOLOGICAL FOOTPRINTS IN DEVELOPING COUNTRIES

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DOI: https://doi.org/10.5281/zenodo.23662577

Keywords
Services-led structural transformation; ecological footprint; Environmental Kuznets Curve; system GMM; developing countries

Article History
Received: *25 June 2026*
Accepted: *16 September 2026*
Published: *26 October 2026*

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Abstract

This study examines whether services-led structural transformation alleviates or intensifies environmental pressure in developing countries, using ecological footprints on the production side as a comprehensive environmental indicator. Using panel data for 46 developing economies from 2002 to 2018 and applying the system Generalized Method of Moments (GMM) estimator, the study tests the Environmental Kuznets Curve (EKC) hypothesis across disaggregated service sectors, including trade services, transport services, business services, financial services, real estate service, government services, other services, and aggregate services. The results reveal strong heterogeneity across services subsectors. Trade, transport, business, financial, real estate, and government services exhibit an inverted U-shaped relationship with ecological footprints, validating the EKC hypothesis. Conversely, other services and aggregate services display a U-shaped relationship, suggesting renewed environmental pressure at advanced stages of service expansion. Renewable energy consistently mitigates ecological footprints, while GDP growth and foreign direct investment often intensify environmental stress. These findings highlight that services-led growth does not automatically guarantee environmental sustainability and must be complemented by clean energy transitions and strong institutional frameworks.

1. INTRODUCTION

Structural transformation refers to the long-run reallocation of economic activity as countries evolve, commonly related to shifts in output, employment, and productivity throughout key sectors of the economic system. Historically, this transition has been taken into consideration as a movement from agriculture to industry and, in the long run, to services (Kuznets 1971; Chenery and Syrquin 1975). In today's global economy, the most decisive changes are unfolding in the service sector itself. Services-led structural transformation does not mean an economic system becoming "more service-oriented"; rather, it reflects a profound reconfiguration of services as they grow, diversify, and redefine their role in national development (Rodrik 2016; McMillan and Rodrik 2011). Services-led structural transformation refers to a development process wherein a country's economic growth and structural change are commonly driven through the expansion of the services sector, rather than the traditional

ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
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shift from agriculture to manufacturing. Instead of analyzing transformation as a movement from one place to another, the modern task lies in understanding how services transform internally from simple, low-productivity activities to complex, information-intensive, and technology-enabled services (Hallward-Driemeier and Nayyar 2018). Many early discussions of structural transformation suggested that the enlargement of the services sector should reduce environmental stress because services are commonly much less energy- and resource-intensive than production and heavy industry (Bell 1973; Fuchs 1968). However, more recent research emphasizes that treating all services as environmentally friendly is misleading, as the services sector is highly heterogeneous and includes activities with markedly different environmental impacts (Giampietro et al. 2012; Lenzen et al. 2012).

Climate change isn't a natural phenomenon. The World Bank and the United Nations are aware that climate change is accelerating, with growing worldwide temperatures leading to more frequent and intense climate change, along with heatwaves, floods, and droughts, which affect whole populations. These institutions investigate that human activities, which include pollution and unbalanced consumption, are the primary drivers of these changes, underscoring the urgent need for resilient, sustainable development to mitigate, in addition to damage. The years 2015-2024 can be the warmest ten years on record; the lack of ice from glaciers, sea-level rise, and ocean heating are accelerating, and extreme weather is disrupting groups and economies internationally. Human economic activities have placed remarkable pressure on natural ecosystems, leading to a state of affairs where humanity consumes resources quicker than the planet can regenerate them. In line with the WWF Living Planet Report (2022), global consumption now requires the equivalent of one.75 Earths to preserve present-day life (WWF 2022). The ecological footprint, a composite indicator of resource consumption and waste absorption, is widely used to measure the environmental effect of human activities (Global Footprint Network 2022). The ecological footprint offers a complete indicator of human pressure on the surroundings by measuring the biologically productive land and water required to support the production of goods and services and the absorption of waste, particularly carbon emissions (Global Footprint Network 2022). Environmental degradation is an urgent problem because it impacts not only the economy but also public health (Raihan et al. 2022). Following the publication of Silent Spring (1962), Rachel Carson's book on the consequences of DDT on birds and biological diversity, environmental issues came to the forefront of public discourse, and as worries among conservation biologists grew, the first global conference on the human environment was convened in Stockholm in 1972.

In this study, environmental conditions are measured using ecological footprints on the production side. The ecological footprint reflects the degree of impact a person or a group has on the surrounding environment and may be expressed as the volume of resources consumed. The concept of the ecological footprint was introduced in 1990 to assess environmental effects related to human activities (Wackernagel and Rees 1996). The ecological footprint is a measure of the assets consumed and waste generated, and its assessment is related to the biologically effective place to be had, additionally called biocapacity. The ecological footprint measures ordinary demand, while biocapacity refers to the continuing supply. The figures of ecological footprint and biocapacity vary from year to year with reference to population, per capita consumption, production performance, and productivity. Along the same lines, components such as the carbon footprint and water footprint originated from the ecological footprint concept and have become widely used across the globe as climate change concerns have become a critical matter of policy attention (Nautiyal et al. 2019; Shree et al. 2015; Varun and

JOURNAL FOR SOCIAL SCIENCE STUDIES
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ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
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Chauhan 2014). Services-led structural transformation refers to the shift of an economic system from agriculture and manufacturing towards services, which often brings higher productivity and income growth (Herrendorf et al. 2014). As the services sector expands, it absorbs labor and capital from traditional sectors, changing production and consumption patterns. Many services are less energy-intensive than production, which can lessen direct domestic energy use and emissions (Jorgenson and Vu 2005). However, this shift often increases consumption of goods and imported services, potentially displacing environmental impacts rather than eliminating them (Dietzenbacher and Tukker 2014). The ecological footprint, which measures the total land and water required to support a population's consumption and take in its waste (Wackernagel and Rees 1996), might not decline proportionally, since service-oriented economies still depend on international supply chains for items and sources (Lenzen et al. 2004; Wiedmann et al. 2013). As a result, at the same time as services-led transformation can decouple GDP growth from local environmental degradation, it cannot reduce the global ecological footprint until combined with sustainable consumption practices (Jackson 2009). Policies promoting green services, digitalization, and efficiency can similarly help reduce ecological influences even as assisting structural transformation (UNEP 2011). In general, the shift to services can mitigate domestic environmental strain; however, it can also shift ecological burdens the world over if not managed sustainably. Therefore, it's essential to look at the relationship between services-led structural transformation and ecological footprints in developing countries, and to determine whether all varieties of services align with the Environmental Kuznets Curve hypothesis.

2. LITERATURE REVIEW

Contrary to the existing literature, there is a limited number of studies examining the impact of services-led structural transformation on ecological footprints. In 2012, Choudhary and Moran et al. conducted a critical analysis of the environmental Kuznets curve, contending that it oversimplifies complex socio-environmental issues by placing insufficient emphasis on income, the primary indicator of ecological change, while neglecting the influence of institutional effects, government, and historical contexts. Their review elucidates that the patterns of the EKC are not applicable in real-world scenarios. They emphasize the inclusion of more institutional and socio-environmental factors. Overall, this paper challenges the real-world applicability and regional validity of the EKC.

In this context, Ali and Gniniguè et al. (2022) examine the influence of the global value chain on structural transformation and environmental conditions across 41 African countries, employing the GMM system on a panel dataset spanning from 1990 to 2018. They elucidate that the global value chain enhances structural transformation, particularly through industrial growth, while simultaneously increasing CO_2 emissions per capita. In this study, the balance between economic prosperity and environmental sustainability is also shown by assessing environmental impact through carbon dioxide (CO2) emissions and structural change via manufacturing. The writers support the use of environmentally friendly industrial methods in Africa. In summary, this work highlights the need to connect sustainable development goals with growth pushed by GVCs. Between 1991 and 2016, Raza and Shah looked at the Environmental Kuznets Curve in relation to growth in CO2 emissions and environmental effects in the G7 countries. They used a lot of data from the G7 countries to see how these things are connected. What they discovered is that the Environmental Kuznets Curve is downward. This means that when people have

ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
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money, CO2 emissions go up. So, the G7 countries really need to focus on improvement. Using renewable energy is a good way to reduce CO2 emissions over the years. The study also showed that trade openness has a lot of outcomes. For example, the Environmental Kuznets Curve indicates that economic growth can lead to CO2 emissions, and the G7 countries need to apply renewable energy to reduce these emissions. Renewable energy fosters sustainability within the G7 nations, according to the study. Xiong et al. (2017) investigated the environmental Kuznets curve's applicability in China's Beijing-Tianjin-Hebei region through reading the vicinity's environmental circumstances and economic development. The authors determined that Beijing's economic growth and environmental situations do not follow the Kuznets curve's predictions, according to a panel dataset from 2004 to 2014. Without strong environmental governance, economic change alone is insufficient, according to the authors. In the end, the study confirms the EKC's limited applicability in the BTH region and highlights the importance of particularly designed policy interventions. Voumik et al. (2023) examined the environmental Kuznets curve in ten major Middle Eastern countries, including Saudi Arabia, Qatar, the United Arab Emirates, Iran, Israel, Jordan, Bahrain, Oman, Lebanon, and Egypt, from 1997 to 2019. The impact of trade, tourism, and education on CO_2 emissions is investigated in this study. economic boom does not continually enhance the environment; therefore, the findings conflict with the EKC hypothesis. However, sustainable development requires more tourism and renewable energy. Fossil fuels and trade liberalization, on the other hand, raise emissions. It's vital to recognize the conflict between educational institutions and environmental consciousness because education is also associated with increased CO2 emissions. The goal of this book is to promote the incorporation of environmentally sensitive issues into educational curricula. Between 1990 and 2022, Bashiri Dezfuli et al. (2024) investigated the environmental consequences of the transition from goods-based to service-based economies in 23 OECD countries. The authors utilize a panel data method with fixed and random effects models and a trend study primarily based on Baumol's cost sickness idea as econometric strategies. Their analysis demonstrates that transitioning to a provider-based economy reduces CO2 emissions, showing that services use much less energy than manufacturing goods and contribute to environmental protection. The research suggests that encouraging service-oriented economic structures may be a successful strategy for reducing carbon emissions and highlights the need to consider sectoral composition when creating environmental policies. The implications of their findings for future studies and policy are discussed by the writers, who also emphasize the need for continued investigation into the connection between economic structure and environmental outcomes. Yang et al. (2021) examine the effect of industrialization and globalization on the ecological footprints of the 10 nations with the highest healthcare expenditures from 1995 to 2018. The findings suggest that while industrialization and economic growth exacerbate environmental degradation, urbanization and globalization appreciably reduce it. Moreover, a bidirectional causal relationship is identified between industrialization and ecological footprints. Adebayo et al. (2022) investigated the results of structural trade on India's ecological footprint the usage of an innovative dynamic ARDL simulation approach. The empirical findings suggest that institutional structural change, as measured by service value added, reduces the ecological footprint in both the short and long term. Ibrahim et al. (2022) explored the relationship between natural resources, renewable energy, technology, green finance, and structural change represented by the services sector's contribution to GDP and CO2 emissions in the top 10 natural resource-rich nations from 1995 to

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2019. Their analysis of the link between structural change, as measured by the service sector's GDP contribution, and CO2 emissions reveals a significantly negative effect. This finding suggests that service-driven structural change has substantial potential to address environmental issues. Ibrahim et al. (2022) investigate the effects of structural change, natural resource dependence, environmental technology, and renewable energy on carbon emissions, ecological footprint, and PM2.5 air pollution in five leading carbon-emitting African countries: Algeria, Egypt, Morocco, Nigeria, and South Africa, over the period from 1990 to 2019. Structural change is represented by three indicators: total structural change (service value added to GDP), the production channel of structural change (service export), and the consumption channel of structural change (service import). The production channel of structural change mitigates environmental pollution in the long term, whereas its short-term effects are negligible. Both the consumption channel of structural change and total structural change enhance environmental quality in both the long and short term. Destek et al. (2021) examined the influence of structural transformations on environmental degradation, specifically in terms of CO_2 emissions and the ecological footprint, within Turkey from 1970 to 2017. The study reveals that industrialization, characterized by a positive impact in industrial value added, leads to an increase in both carbon emissions and the ecological footprint. Conversely, a negative impact on industrial value added, indicative of deindustrialization, results in a reduction of these environmental impacts in the short term. In the long term, industrialization continues to elevate carbon emissions and the ecological footprint, whereas deindustrialization decreases carbon emissions but does not significantly affect the ecological footprint. Furthermore, the adverse environmental impact of industrialization is found to be more substantial than the beneficial effect of deindustrialization. Cui et al. (2022) demonstrated that structural change (as indicated by economic complexity), increases the ecological footprint in 20 selected countries. Notably, existing studies do not address the transition from agriculture to the manufacturing and service sectors and focus solely on the consumption ecological footprint.

The present study, by contrast, examines the effects of disaggregated services led structural transformation on the production-side ecological footprint across a broader sample of developing countries. Based on the reviewed literature, we set the following hypotheses:

H1: Can services-led structural transformation reduce environmental degradation in developing countries?

H2: Do all services validate the Environmental Kuznets Curve hypothesis?

3. Empirical Model and DATA

3.1 Empirical Model

The theoretical basis of this relationship is derived from the Environmental Kuznets Curve (EKC) speculation, first officially discussed by Grossman and Krueger (1995). In line with this framework, environmental degradation to start with will initially increase with economic boom because of industrial expansion and higher resource use; however, after reaching a certain income threshold, environmental strain declines as economies undertake cleaner technology and shift towards less pollution-intensive sectors, including services. Building on this argument, numerous researchers emphasize that structural transformation affects environmental consequences through 3 mechanisms: scale, composition, and technique outcomes. The scale effect means that economic enlargement will increase energy use and environmental stress, while the composition effect shows that moving production from manufacturing toward services may additionally lessen environmental degradation owing to decreased material intensity. The technique effect captures improvements in technology and environmental

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regulation that accompany higher income levels. Research such as Alola (2019) and Shan et al. (2021) explains how these three effects jointly determine the environmental impact of economic growth and structural transformation within the EKC framework. Sahoo and Sethi (2022) show that the industrial sector raises ecological footprints, whereas the services sector contributes to environmental improvement in the long run through reduced direct emissions and resource use. Similarly, Doytch (2020) and Ashraf and Doytch (2023) highlight that structural shifts toward services can reduce environmental strain through efficiency gains and technological progress in upper-middle-income economies. In this paper, we test the relationship between eight disaggregated service categories and the production-side ecological footprint to examine whether they validate the Kuznets curve. The basic EKC equation used by Grossman and Krueger (1995) takes a quadratic functional form, in which environmental degradation is expressed as a function of income and income squared:

$E_{it} = \alpha + \beta 1 Yit + \beta 2 Yit^2 + \gamma Zit + \varepsilon_{it}$ [Eq. 1]

where Eit represents an environmental degradation indicator, Yit is income per capita (GDP per capita), Yit^2 captures the non-linear relationship between income and degradation, Zit is a vector of control variables (trade, time effects, country effects, and so on), α is the constant term, and εit is the error term. This paper further tests the EKC using services-led structural transformation. To statistically examine the relationship between services-led structural transformation and the environment in developing countries, we specify the following model:

$$\ln(EFP_{it}) = \partial_0 + \partial_1 \ln(EFP_{i,t-1}) + \partial_2 SER_{j\ i,(t-2)} + \partial_3 (SER_{j\ i,(t-2)})^2 + \partial_4 \ln GDPG_{i,t} + \partial_5 RegulatoryQuality_{it} + \partial_6 FDIIN_{it} + \partial_7 RenewableEnergy + \mu_i + \varepsilon_t$$ [Eq. 2]

In Equation 2, which is a log-linear specification, ln(EFP) represents the log of the ecological footprint of production. SER represents services-led structural transformation, and measures the eight service categories: trade, transport, business, financial, real estate, government, other services, and aggregate services. To capture the potential non-linear relationship, the squared term of each service variable is included alongside control variables — GDP growth, regulatory quality, FDI, and renewable energy. εit is the error term, ∂_0 is the constant term, and ∂_1 through ∂_7 represent the marginal effects of the independent variables on the dependent variable. In Equation 2, i denotes the country, and t denotes time; GDPG denotes GDP growth, and FDI denotes foreign direct investment.

3.2 Data

The dependent variable, the ecological footprint of production per capita, is collected from footprintnetwork.org and denoted EFP in the equations. The ecological footprint of production reflects the biologically productive land and water area required to produce the resources consumed and to absorb the waste generated by human activities, given prevailing technology and resource management practices (Wackernagel and Rees 1996). Services-led structural transformation is measured using the employment share of eight service categories, each calculated as the respective service sector's employment divided by total employment — for example, trade services equal the trade-services employment share divided by total employment in the sample of developing countries. The eight categories — trade, transport, business, financial, real estate, government, other, and aggregate services — are collected from the Economic Transformation Database (ETD). The remaining control variables — GDP growth (constant prices), regulatory quality (percentile rank), FDI net inflows (percentage of GDP), and renewable energy consumption (percentage of total final energy consumption) are collected from the World Development Indicators. Table 1 defines all variables, their measurement, and their sources. The dataset spans 2002 to 2018 for 46 developing countries; countries with excessive missing data

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were dropped from the original global sample, leaving a final panel of 46 developing countries. To address econometric issues, this study applies the system Generalized Method of Moments (system GMM) estimator developed by Manuel Arellano and Stephen Bond (1991) and further extended by Richard and Stephen Bond (1998). For 46 nations, Ulucak and Bilgili (2018) used system GMM to examine the link between economic development and ecological footprint. Using the GMM estimator system, the current study employs these techniques to obtain consistent, objective, and effective estimates while monitoring potential endogeneity and reverse causation between service sector activity and environmental quality. Table 1 in Appendix reports the descriptive statistics that summarize the underlying distribution of the data, and Table 2 in Appendix reports the unconditional pairwise correlations among all dependent and independent variables.

Table 1. Variable names, definitions, measurement, and sources.

Variables	Definition	Measurement	Source
EFP	Ecological footprint (production side)	Global hectares per capita	GFN
GDP growth	Annual percentage growth rate of real GDP at market prices, based on constant local currency	Change in the volume of output (real income)	WDI
Regulatory quality	Perceptions of a government's ability to formulate and implement sound policies and regulations that permit and promote private sector development	Estimate, percentile rank	WDI
FDI	Net inflows of foreign direct investment	Percent of GDP	WDI
Renewable energy	Renewable energy consumption	Percent of total final energy consumption	WDI
Aggregate services	Aggregate of the eight service categories relative to total employment	Aggregate of 8 services / total employment	ETD
Trade services	Wholesale and retail trade; repair of motor vehicles and motorcycles; accommodation and food service activities	Trade services / total employment	ETD
Transport services	Transportation and storage	Transport services / total employment	ETD
Business services	Information and communication; professional, scientific and technical activities; administrative and support service activities	Business services / total employment	ETD
Financial services	Financial and insurance activities	Financial services / total employment	ETD
Real estate services	Real estate activities	Real estate services / total employment	ETD
Government services	Public administration and defense; compulsory social security; education; human health and social work activities	Government services / total employment	ETD

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Variables	Definition	Measurement	Source
Other services	Arts, entertainment, and recreation; other service activities; activities of households as employers; activities of extraterritorial organizations and bodies	Other services / total employment	ETD

4. EMPIRICAL RESULTS

The results of services-led structural transformation and the ecological footprint of production for developing countries are presented in Table 2. The relationship between services-led structural transformation and the production ecological footprint is examined using the System GMM estimation technique. Column (1) presents aggregate services, measured as total services employment divided by total employment; Column (2) reports trade services; Column (3) reports transport services; Column (4) reports financial services; Column (5) reports business services; Column (6) reports other services; Column (7) reports government services; and Column (8) reports real estate services. All service-sector variables are constructed by dividing employment in the respective categories by total employment. The results indicate that aggregate services have a negative and statistically significant relationship with the production ecological footprint, while the squared term of aggregate services is positive. This means the ecological footprint initially declines as aggregate services expand but begins to rise again beyond a certain threshold — a U-shaped pattern that does not support the Environmental Kuznets Curve hypothesis for aggregate services.

Table 2. Services-led structural transformation and ecological footprints of production: system GMM.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	**Aggregate Services**	**Trade services**	**Transport services**	**Financial services**	**Business services**	**Other Services**	**Government services**	**Real-estate Services**
ln[EFP]t-1	-0.0141	1.0016***	1.0078***	0.9953***	0.0292	0.2520***	0.9988***	0.9593***
	[0.0946]	[0.0064]	[0.0111]	[0.0074]	[0.0569]	[0.0600]	[0.0077]	[0.0212]
GDP Growth	0.0024*	0.0082***	0.0087***	0.0110***	0.0035**	0.0092**	0.0119***	0.0080***
	[0.0012]	[0.0022]	[0.0027]	[0.0015]	[0.0014]	[0.0041]	[0.0021]	[0.0025]
Regulatory Quality	-0.2039**	-0.0153	-0.0250	-0.0179**	0.1035	0.1179	-0.0567**	0.0105
	[0.0980]	[0.0141]	[0.0161]	[0.0071]	[0.0970]	[0.1056]	[0.0249]	[0.0356]
FDI	0.0202***	0.0043*	0.0125***	-0.0025**	0.0072**	-0.0003	0.0009	0.0022*
	[0.0060]	[0.0024]	[0.0044]	[0.0011]	[0.0027]	[0.0045]	[0.0040]	[0.0013]
Renewable Energy	-0.0395***	-0.0002	-0.0001	-0.0007*	-0.0122**	-0.0221***	-0.0007	-0.0009***
	[0.0100]	[0.0003]	[0.0009]	[0.0004]	[0.0051]	[0.0029]	[0.0006]	[0.0003]
Aggregate services	-3.2772**							

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	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	**Aggregate Services**	**Trade services**	**Transport services**	**Financial services**	**Business services**	**Other Services**	**Government services**	**Real-estate Services**
	[1.4086]							
[Aggregate services]^2	3.5379**							
	[1.4935]							
Trade services		3.4016***						
		[0.9769]						
[Trade services]^2		-8.5012***						
		[2.8721]						
Transport services			8.7016***					
			[2.6445]					
[Transport services]^2			-85.3002***					
			[2.6445]					
Financial services				1.6477*				
				[0.8321]				
[Financial services]^2				-64.6021***				
				[12.9124]				
Business Services					18.8711***			
					[5.0100]			
[Business services]^2					-66.7010***			
					[24.5859]			
Other Services						-5.4121**		
						[2.5408]		
[Other services]^2						28.2214**		
						[11.7459]		

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	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	**Aggregate Services**	**Trade services**	**Transport services**	**Financial services**	**Business services**	**Other Services**	**Government services**	**Real-estate Services**
Government services							2.5171**	
							[1.1726]	
[Government services]^2							-8.9639**	
							[4.3618]	
Real estate services								15.1122***
								[4.1104]
[Real estate services]^2								-775.6623***
								[202.1769]
Observations	736	736	736	736	736	736	736	736
Number of countries	46	46	46	46	46	46	46	46
AR2 (p-val)	0.576	0.862	0.628	0.919	0.219	0.972	0.991	0.828
Hansen (p-val)	0.754	0.463	0.690	0.298	0.560	0.441	0.158	0.222
Instruments	46	46	46	46	46	46	46	46

Note: Results are estimated using the System GMM dynamic panel estimator developed by Arellano and Bond and extended by Blundell and Bond. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. AR(2) reports the Arellano-Bond test for second-order serial correlation in the differenced residuals. The Hansen test evaluates the overall validity of the instruments used in the System GMM estimation.

Trade-service-led structural transformation exhibits a positive and significant relationship with the production ecological footprint, while its squared term is negative and significant, confirming an inverted U-shaped relationship consistent with the EKC hypothesis: environmental pressure initially rises with trade-services expansion but declines beyond a certain level of development. Financial-services-led structural transformation shows the same pattern — a positive coefficient with a negative squared term — indicating that environmental degradation increases at early stages of financial-sector expansion but decreases thereafter, again supporting the EKC hypothesis. Business services-led structural transformation and its squared term are both negative, indicating an environmentally beneficial role that strengthens as the sector expands. Other services are significantly and negatively associated with the ecological footprint, while the squared term is positive, indicating that although growth in other services initially reduces environmental stress, the

ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
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footprint rises again beyond a certain stage of expansion. Government services exhibit an inverted U-shaped relationship, again confirming the EKC hypothesis, and real estate services show a positive relationship with a negative squared term, indicating that environmental pressure rises initially but declines after a higher level of sectoral development is reached. Overall, the environmental impacts of services-led structural transformation vary considerably across service categories, with some sectors supporting the EKC hypothesis and others not.

Some of the control variables, including GDP growth, have a positive and statistically significant relationship with the production ecological footprint, indicating that economic growth in developing nations is related to greater environmental pressure, probably to mirror improved industrial activity, energy consumption, and resource utilization. Regulatory exceptional suggests a negative relationship with the ecological footprint, implying that stronger institutional frameworks, powerful governance, and better environmental regulation help reduce ecological pressure through promoting more sustainable manufacturing practices. Foreign direct investment (FDI) is definitely associated with the ecological footprint, suggesting that overseas investment inflows may contribute to environmental degradation, potentially through the relocation of pollution-intensive industries to developing countries, consistent with the pollutants speculation. Renewable energy consumption, by contrast, suggests a positive and large relationship with the ecological footprint, indicating that greater use of renewable power sources reduces environmental harm through lowering dependence on fossil fuels and supporting cleaner manufacturing. The diagnostic tests confirm the validity of the system GMM estimation: the Arellano-Bond take a look at for 2nd-order serial correlation returns AR (2) p-values well above traditional thresholds across all specs, indicating the absence of second-order autocorrelation, and the Hansen test of over-identifying restrictions likewise confirms the validity of the instruments used, assisting the reliability of the estimated coefficients for empirical interpretation.

5. CONCLUSION

This study examines the relationship between services-led structural transformation and the ecological footprint of production in developing countries to assess whether the data support an Environmental Kuznets Curve. Using a panel of 46 developing countries over 2002-2018 and the System GMM estimator, this study contributes to the literature by examining the production-side ecological footprint and by disaggregating services into eight categories, since the relationship between different services and the ecological footprint is expected to differ across sectors in developing countries. Some services validate the EKC hypothesis, while others do not. Aggregate services and other services show a negative relationship with the ecological footprint alongside a positive squared term, meaning that the ecological footprint initially falls as these services expand but rises again after a certain point — a U-shaped pattern. In contrast, trade, transport, business, financial, real estate, and government services show a positive relationship with the ecological footprint alongside a negative squared term, consistent with an inverted U-shaped, EKC-validating pattern. We therefore conclude that services-led growth is not uniformly favorable for the environment: some service categories support the Environmental Kuznets Curve hypothesis, while others point to renewed environmental pressure at advanced stages of expansion, underscoring the need to pair services-led structural transformation with clean energy transitions and strong institutional frameworks.

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JOURNAL FOR SOCIAL SCIENCE STUDIES
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Appendix

Table 1. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
EFP	782	.403	.621	-1.079	1.768
GDP growth	782	5.234	3.037	-14.144	15.329
Regulatory quality	782	-.221	.677	-2.349	2.252
FDI	782	3.578	4.2	-2.5	38.94
Renewable energy	782	44.921	29.565	.5	95.6
Aggregate services	782	.421	.174	.095	.774
Trade services	782	.165	.057	.028	.308
Financial services	782	.01	.01	0	.053
Business services	782	.039	.035	.001	.17
Transport services	782	.04	.022	.003	.093
Government services	782	.097	.057	.021	.265
Real estate services	782	.003	.004	0	.027
Other services	782	.067	.043	.002	.214

Table 2. Matrix of correlations.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1 EFP	1.000												
2 GDP growth	-0.229	1.000											
3 Regulatory quality	0.532	-0.224	1.000										
4 FDI	0.150	0.134	0.350	1.000									
5 Renewable energy	-0.666	0.293	-0.515	-0.048	1.000								
6 Aggregate services	0.747	-0.396	0.632	0.098	-0.787	1.000							
7 Trade services	0.538	-0.305	0.447	-0.030	-0.641	0.752	1.000						
8 Financial services	0.556	-0.171	0.625	0.327	-0.613	0.687	0.489	1.000					
9 Business services	0.674	-0.303	0.684	0.279	-0.611	0.860	0.492	0.741	1.000				
10 Transport services	0.390	-0.215	0.361	0.008	-0.678	0.759	0.638	0.543	0.582	1.000			

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ISSN (Online): 3006-2071 | ISSN (Print): 3006-2063
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	1	2	3	4	5	6	7	8	9	10	11	12	13
11 Government services	0.629	-0.351	0.444	0.000	-0.700	0.778	0.364	0.462	0.643	0.472	1.000		
12 Real estate services	0.517	-0.091	0.610	0.425	-0.497	0.525	0.339	0.685	0.679	0.348	0.300	1.000	
13 Other services	0.554	-0.331	0.440	0.092	-0.381	0.727	0.366	0.351	0.633	0.463	0.448	0.299	1.000

Note: Column and row numbers correspond to: 1 EFP; 2 GDP growth; 3 Regulatory quality; 4 FDI; 5 Renewable energy; 6 Aggregate services; 7 Trade services; 8 Financial services; 9 Business services; 10 Transport services11 Government services; 12 Real estate services; 13 Other services

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