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Research Article

The Impact of Digital Trade on Sustainable Development: An Empirical Study of BRICS Countries During the Period (2010–2023)

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ABSTRACT

This study seeks to rigorously examine the impact of digital trade on sustainable development across the BRICS countries (Brazil, Russia, India, China, and South Africa) over the period 2010–2023. It specifically addresses the three core dimensions of sustainability: the economic (Gross Domestic Product), the social (Human Development Index), and the environmental (carbon dioxide emissions). The analysis is conducted using panel data econometric techniques, including fixed effects, random effects, and pooled regression models.

The empirical findings indicate that digital service exports have a positive and statistically significant effect on economic growth (coefficient: 0.087) and contribute to the reduction of carbon emissions (coefficient: -0.0049). However, they exhibit a negative impact on human development (coefficient: -0.0028), likely due to the concentration of resources in technology-intensive sectors at the expense of broader social investments. In contrast, digital service imports are found to enhance human development (coefficient: 0.0026) but simultaneously lead to an increase in emissions (coefficient: 0.0027), reflecting the energy-intensive nature of the supporting infrastructure. Moreover, the results underscore the pivotal role of technological readiness (coefficient: 0.455) as a determinant of improved quality of life.

The study underscores the importance of adopting integrated policy frameworks that can maximize the developmental benefits of digital trade while mitigating its environmental and social trade-offs.

Keywords: Digital Trade, Sustainable Development, BRICS Countries, Panel Data Analysis.

Introduction:

In recent decades, the global economic structure has been undergoing a remarkable transformation, driven by the rise of digital trade as a central force redefining the mechanisms of production, marketing, and consumption. Governments are increasingly directing investments toward the development of technological infrastructure—such as 5G networks and cloud computing systems—to support the expansion of digital exchange in goods and services. This phenomenon is no longer limited to the exchange of goods via electronic platforms, but also encompasses advanced digital services such as artificial intelligence, blockchain technologies, and electronic payments, which facilitate cross-border capital flows.

This transformation is largely attributed to rapid technological advancements, which have significantly reduced transaction costs and expanded access to global markets, particularly for small and medium-sized enterprises. However, this digital revolution also presents fundamental challenges, such as disparities in digital infrastructure among countries and varying regulatory capacities to keep pace with technological progress.

Research Problem:

This study seeks to assess the impact of digital trade on sustainable development within the BRICS countries. Accordingly, it aims to answer the following research question:

To what extent does digital trade contribute to achieving sustainable development in the BRICS countries?

Research Hypotheses:

To address the research problem, the study is guided by the following hypotheses:

- Exports of digital services are significantly and positively associated with GDP, human development, and carbon dioxide emissions.
- Imports of digital services are significantly and negatively associated with GDP, human development, and carbon dioxide emissions.

Scope of the Study:

The **spatial scope** of the study is limited to the BRICS countries (Brazil, China, India, Russia, and South Africa), which exhibit diverse economic and social structures, making them ideal for a multidimensional analysis of the impacts of digital trade. These are also rapidly growing economies that collectively account for a significant share of the global economy and face common challenges in achieving sustainable development. The **temporal scope** of the study spans the period from 2010 to 2023, based on the availability of relevant data for the study variables.

Significance of the Study:

The significance of this study lies in its assessment of the interplay between technological growth and the economic, social, and environmental dimensions of development. Given the diversity of BRICS experiences—from China's manufacturing-based economy to Russia's resource-driven model—the study offers generalizable insights applicable to other countries, particularly in Africa and Latin America, seeking to integrate digitalization with sustainability.

Objective of the Study:

The primary objective of this study is to measure the impact of digital trade on the three pillars of sustainable development—economic, social, and environmental—in the BRICS countries.

Research Methodology:

To achieve the study's objectives, a **descriptive approach** is employed to review definitions of digital trade and its relationship with sustainable development. Additionally, an **analytical approach** is applied through empirical analysis to identify and quantify the relationship between the study variables, using econometric tools and statistical analysis methods.

Previous Studies:

1. **Wang Kai & Kazeem Alasinrin Babatunde (2023):**

Titled *"Sustainable Trade: Evolution and Trends in Digital Trade Research in China"*, this study aimed to review the body of research on digital trade in China, emphasizing its role as a catalyst for sustainable trade development. The authors utilized the **Citespace** software for bibliometric data analysis and visualization. A total of 1,311 articles were collected from the **China Knowledge Network**, with a focused analysis of 424 peer-reviewed documents from journals indexed in CSSCI and EI. The study examined keyword trends and temporal evolution by segmenting the period from 2009 to 2022. The findings revealed that digital trade serves as a major driver for modernizing China's trade systems. However, its sustainable development requires enhanced academic collaboration, the establishment of international legal frameworks, and comprehensive consideration of social and environmental aspects.

2. **Maria Vásquez Callo-Müller & Kholofelo Kugler (2023):**

Titled *"Digital Trade, Development, and Inequality"*, this study explored the intersection between digital trade, development, and inequality. It specifically focused on the ability of developing and least-developed countries to participate in shaping digital trade governance frameworks. The study critically analyzed discussions and negotiations within the **World Trade Organization** and preferential trade agreements, utilizing data from the **TAPED** database, case studies, and reports from international organizations. The findings suggest that while digital trade offers promising opportunities for development, realizing its full potential depends on:

- Enhancing meaningful participation of developing countries in rule-making,
- Striking a balance between digital trade liberalization and the protection of national interests (e.g., revenue and data governance),

- Promoting international cooperation to bridge the digital divide and ensure equitable distribution of technological benefits.

3. Anita Pariyar et al. (2024):

The study, titled *"The Effects of Digital Trade on Environmental Quality in Developing Countries"*, aimed to investigate the role of digital trade (DT) in reducing carbon emissions and improving environmental quality in developing nations. It focused on mechanisms such as industrial modernization, green technologies, and economic scale. The analysis was based on **panel data** for five developing countries (China, India, Bangladesh, Brazil, and Turkey) over the period 2004–2023. The results indicated that digital trade can serve as an effective tool for achieving carbon neutrality goals in developing contexts. However, its success is contingent upon the implementation of supportive policies targeting infrastructure and innovation, while accounting for diverse regional conditions.

First: Definition of Digital Trade

There is no consensus in the literature on a precise definition of digital trade. Therefore, this study adopts definitions provided by leading international organizations (Saad Jermoune, 2025):

- **OECD (Organisation for Economic Co-operation and Development):** Digital trade is defined as "all commercial activities that rely on or are facilitated by digital technologies, including the exchange of goods and services, cross-border data transfers, and the use of digital platforms to manage business operations."
- **UNCTAD (United Nations Conference on Trade and Development):** Digital trade includes "online commercial transactions, whether involving physical goods or digital services (such as software or digital content), in addition to the technological infrastructure supporting these processes, such as electronic payment systems and cloud platforms."
- **WTO (World Trade Organization):** Digital trade is described as "not limited to online goods exchange, but also includes international data flows, cross-border digital services, and the regulatory frameworks governing the digital economy."

Second: The Relationship Between Digital Trade and Sustainable Development

Digital trade contributes—both directly and indirectly—to achieving the Sustainable Development Goals (SDGs) through various mechanisms, as highlighted in the following studies:

- **Carbon Emissions Reduction (SDG 13):** Digital trade fosters industrial modernization and adoption of green technologies, thus reducing carbon intensity.*(Pariyar, Guo, Pan & Dastgeer, 2024)*
- **Economic Inclusion (SDGs 1, 5, 8, 10):** It promotes the participation of marginalized groups—such as women and youth—in the economy through freelancing platforms and e-commerce. *(Beer & Ncube, 2024)*
- **Food Security (SDG 2):** Digital technologies support smart agriculture by leveraging data analytics to improve crop productivity and reduce waste.
(de Beer, Oguamanam & Ubalijoro, 2023)
- **Clean Technology Transfer (SDGs 7, 13):** Trade agreements facilitate the transfer of clean technologies; however, intellectual property rights may hinder this process unless regulated equitably. *(Rimmer, 2018)*
- **Challenges and the Digital Divide:** Developing countries face a lack of digital infrastructure, which hampers their ability to harness the full benefits of digital trade. *(UNCTAD, 2021)*

Hence, while digital trade serves as a key driver for sustainable development, its success depends on:

- Policies ensuring equitable access to data and technology,
- Enhanced digital infrastructure in developing countries,
- A balanced approach to intellectual property rights that considers developmental needs.

Third: Methodology and Tools Used

1. Study Variables:

Based on a review of previous studies, survey results, and data availability, the following indicators were selected:

- **Independent Variable (Digital Trade):**

Represented by trade in digitally deliverable services using the following indicators:

- **Exports of digitally deliverable services (ESD):** as a percentage of total services trade,
- **Imports of digitally deliverable services (ISD):** as a percentage of total services trade,
- **Frontier Technology Readiness Index (FTRI):** to assess technological readiness.

- **Dependent Variable (Sustainable Development):** Each of the three dimensions of sustainable development is represented by:

- **Economic Dimension:** Gross Domestic Product (GDP),
- **Social Dimension:** Human Development Index (HDI),
- **Environmental Dimension:** Carbon intensity per unit of GDP (CO_2 emissions/GDP).

2. Study Sample: The study sample includes BRICS countries—Brazil, India, China, Russia, and South Africa—selected based on data availability for the study variables between 2010 and 2023.

3. Analytical Methods and Tests:

3.1. Estimation of the Model Using Static Panel Models

To measure the impact of digital trade on sustainable development, we estimated static panel models, including the three types: pooled regression, fixed effects, and random effects models. In this analysis, we utilized the Wallace and Hussain test. Our analysis is based on a balanced dataset that combines both cross-sectional and time-series data, consisting of five (N = 5) BRICS countries: Brazil, India, China, Russia, and South Africa, over the time period from 2010 to 2023, yielding 13 time observations (T = 13) for each variable used in the model, resulting in a total sample size of 65 observations (N × T = 65). This approach facilitates better estimation results and allows for conducting various statistical tests for different hypotheses, with all three models estimated using the statistical software EViews 13.

3.2. Tests for Model Specification:

To identify the most appropriate model for panel data, specification tests are employed. There are three main types of longitudinal models, leading to the question: What is the most suitable model for a given study's data? To address this question, we conduct the following tests:

- **Lagrange Multiplier Test:**This test, proposed by Breusch and Pagan (1980**)**, follows a chi-squared distribution with one degree of freedom and is based on the Lagrange multiplier related to the errors resulting from the ordinary least squares method. The hypotheses are as follows:

$$LM = \frac{nT}{2(T-1)}\left(\frac{\sum_{i=1}^{n}\left(\sum_{t=1}^{T}\hat{u}_{it}\right)^2}{\sum_{i=1}^{n}\sum_{t=1}^{T}\hat{u}_{it}^2}-1\right)^2 \mapsto \chi_1^2$$

- **H0:** Null hypothesis: The pooled regression model is the appropriate model.
- **H1:** Alternative hypothesis: The fixed effects or random effects model is appropriate.

The test is assessed as follows: If the calculated LM value exceeds the chi-squared critical value, we reject the null hypothesis and accept the alternative hypothesis. Additionally, we can evaluate this using the Mackinnon statistic; if the P-value is less than the significance level of 5%, we reject the null hypothesis.

- **Model 1: Dependent Variable GDP**According to Table (1) in the appendices, the statistical value is greater than 0.05; thus, we accept the null hypothesis and reject the alternative hypothesis regarding the presence of fixed or random effects. Therefore, the appropriate model is the pooled regression model for the dependent variable GDP.
- **Model 2: Dependent Variable HDI**According to Table (2**)** in the appendices, the statistical value is greater than 0.05; hence, we accept the null hypothesis and reject the alternative hypothesis concerning the presence of fixed or random effects. Therefore, the suitable model is the pooled regression model for the dependent variable HDI.
- **Model 3: Dependent Variable CO_2**According to Table (3) in the appendices, the statistical value is less than 0.05; thus, we reject the null hypothesis and accept the alternative hypothesis regarding the presence of fixed or random effects. Here, we proceed to the Hausman test to choose between the fixed and random effects models.
- **Hausman Test:**To differentiate between fixed and random effects, we will utilize the Hausman test. When considering individual effects in the model, we examine the nature of this effect, determining whether it is random or a fixed effects model. Although standard analysis indicates that fixed effects are more suitable for cross-sectional data across countries, it is necessary to confirm this using the Hausman test:
  - **H0:** Null hypothesis: The random effects model is appropriate.
  - **H1:** Alternative hypothesis: The fixed effects model is appropriate.

After conducting the Hausman test for the third model with the dependent variable CO_2, we obtained the results shown in Table (4) in the appendices. The table results indicate that the statistical value exceeds the tabulated value; therefore, we reject the null hypothesis and accept the alternative hypothesis. Consequently, the suitable model is the fixed effects model for the dependent variable CO_2.

3.3. Estimated Models

After conducting the study analysis tests, the outputs from the above tables yield the following estimated models (Tables (5), (6), and (7) are available in the appendices):

Model 1: For the dependent variable GDP$GDP\ it = 8.6259 + 0.0871ESD - 0.2467ISD$

- **Model 2:** For the dependent variable HDI$\mathrm{HDI\ it} = 0.462726 - 0.002801\mathrm{ESD} + 0.002607\mathrm{ISD} + 0.455161\mathrm{FTRI}$
- **Model 3:** For the dependent variable $CO_2$$CO2\ it = 0.499632 - 0.049ESD + 0.002699ISD$

Fourth: Discussion of Results

Model 1: For the Dependent Variable GDP

1. **Overview of the Statistical Model:**

○ **Analysis Method:** The **Panel Least Squares** regression model was employed to study the impact of digital service exports and imports (ESD and ISD) on the GDP of BRICS countries during the period 2010–2023.

○ **Statistical Significance:** All variables (ESD and ISD) and the constant term show high statistical significance (Prob < 0.01), confirming the reliability of the results.

○ **Model Strength:** The coefficient of determination ($R^2 = 0.40$) indicates that 40% of the variance in GDP is explained by the included variables, which is a reasonable rate in economic studies, especially given the existence of external factors not included (such as government policies and global crises).

2. **Interpretation of Coefficients According to Economic Theories:**

A. Impact of Digital Service Exports (ESD)

○ **Positive Coefficient (0.087):** This indicates that a 1% increase in digital service exports leads to an approximate 0.087% growth in GDP, which aligns with the export-led growth theory that posits that exports stimulate productivity, innovation, and job creation.

○ **Interpretation in the Context of BRICS Countries:**

▪ Countries like India and China possess strong technological sectors (such as software and e-commerce), making their digital exports a key driver of growth.

▪ The results reflect the role of technology in enhancing the competitive advantage of these countries on a global scale.

B. Impact of Digital Service Imports (ISD)

○ **Negative Coefficient (-0.246):** This suggests that a 1% increase in digital service imports reduces GDP by approximately 0.246%, which can be explained through the dependency theory, where imports may lead to:

▪ **Depletion of foreign currency.**

▪ **Impediments to the development of local industries** (if countries rely on foreign solutions rather than investing in internal innovation).

○ **Interpretation in the Context of BRICS Countries:**

▪ Digital imports may reflect reliance on advanced technologies from other countries (such as the United States or the European Union), increasing costs and limiting domestic production.

▪ **Example:** Importing artificial intelligence systems or cloud computing services from foreign companies.

C. Constant (C = 8.625):

○ This represents the baseline value of GDP in the absence of the effects of the included variables and reflects the fixed factors not accounted for in the model (such as natural resources and traditional infrastructure).

3. Additional Analysis of BRICS Countries:

A. Common Factors:

- **Investment in Digital Infrastructure:** China and India are heavily investing in technological infrastructure (such as 5G networks and data centers), which enhances their capacity for digital exports.
- **Supportive Policies:** Innovation-promoting policies (such as "Made in China 2025") increase the contribution of the digital sector to economic growth.

B. Differences Among Countries:

- **India:** Considered a hub for exporting IT services, which may explain the stronger positive impact of ESD compared to South Africa or Brazil.
- **Russia:** Its high digital imports in areas such as cybersecurity may increase the economic burden.

4. Challenges and Considerations:

- **Technological Gap:** Despite growth, BRICS countries exhibit disparities in their digital capabilities (e.g., China is technologically advanced compared to Brazil).
- **External Factors:**

○ The impact of the COVID-19 pandemic (2020–2022) increased the demand for digital services.

○ Geopolitical tensions (such as the Russia-Ukraine war) may affect digital trade flows.

The results reflect a varied role of digital trade in the economies of BRICS, where digital exports are seen as a growth driver, while digital imports may pose challenges if not managed with effective policies. These findings necessitate the strengthening of the institutional and technological framework to achieve a balance between leveraging digital globalization and protecting the local economy.

Model 2: For the Dependent Variable HDI

1. **Overview of the Statistical Model:**

○ **Analysis Method:** The **Panel Least Squares** regression model was utilized to study the impact of digital service exports (ESD), digital service imports (ISD), and the Frontier Technology Readiness Index (FTRI) on the Human Development Index (HDI) of BRICS countries during the period 2010–2023.

○ **Statistical Significance:** All variables (ESD, ISD, FTRI) and the constant term are highly statistically significant (Prob < 0.01), confirming the reliability of the results.

○ **Model Strength:** The coefficient of determination ($R^2 = 0.803$) indicates that 80.3% of the variance in HDI is explained by the included variables, reflecting a high efficiency in explaining the relationship between technology and human development.

2. **Interpretation of Coefficients According to Economic Theories:**

A. Impact of Digital Service Exports (ESD)

○ **Negative Coefficient (-0.0028):** This suggests that a 1% increase in digital service exports reduces the HDI by approximately 0.0028 points, a result that may seem contradictory to expectations. This can be explained by:

▪ **Theory of Concentration on High-Profit Sectors:** Digital exports may direct resources toward specialized technological sectors (such as software) without sufficient investment in education or public health, limiting their impact on human development.

▪ **Social Disparity:** The benefits of digital exports may be concentrated among specific groups (such as skilled labor), without achieving inclusivity in improving the quality of life for lower-income classes.

B. Impact of Digital Service Imports (ISD)

○ **Positive Coefficient (0.0026):** This indicates that a 1% increase in digital imports raises the HDI by approximately 0.0026 points, aligning with the technology transfer theory, where imports introduce advanced technological solutions (such as educational platforms and smart health systems) that enhance essential services.

▪ **Example:** Importing artificial intelligence systems for hospital management in India enhances healthcare efficiency.

C. Impact of the Frontier Technology Readiness Index (FTRI):

○ **Large Positive Coefficient (0.455):** This confirms that improving technology readiness by one point raises the HDI by approximately 0.455 points, consistent with modernization theory, which posits that:

▪ Digital infrastructure (such as high-speed internet) increases access to education and healthcare.

▪ Investment in innovation boosts productivity and supports the financing of social services.

D. Constant (C = 0.4627):

○ This represents the baseline value of HDI in the absence of the effects of the included variables and reflects fixed factors such as culture or social policies not accounted for in the model.

3. Additional Analysis of BRICS Countries:

A. Common Factors:

- **China:** Its high investments in FTRI (such as the "Digital Silk Road" initiative) explain the strong impact of technology on its HDI.
- **India:** Its reliance on digital imports (ISD) in the education and health sectors, such as platforms like Byju's, has contributed to improving development indicators.
- **Brazil and South Africa:** Their weaker digital infrastructure compared to China may limit the impact of FTRI, highlighting the need for supportive policies.

B. Differences Among Countries:

- **Russia:** It may experience a negative impact from ESD due to its digital exports being concentrated in cybersecurity sectors that do not directly contribute to human development.
- **South Africa:** Sharp social disparities may weaken the impact of technology on HDI, despite improvements in digital imports.

4. Challenges and Considerations:

- **Autocorrelation:** The Durbin-Watson statistic (0.739) indicates a potential positive autocorrelation, necessitating the use of more advanced models (such as random effects models).
- **Interaction Among Variables:** Digital imports (ISD) may interact with FTRI to enhance their effect on HDI (e.g., importing advanced technology that supports local infrastructure).

The results show that technology readiness (FTRI) is the strongest driver of human development in BRICS countries, while digital exports need equitable distribution policies to ensure shared benefits. Digital imports, despite their positive impact, should be managed carefully to avoid excessive reliance on foreign solutions. These findings underscore the importance of integrating technology with social policies to achieve inclusive development.

Model 3: For the Dependent Variable CO_2

1. **Overview of the Statistical Model:**

○ **Analysis Method:** The **Panel Least Squares** regression model with fixed effects across countries was used to study the impact of digital service exports (ESD) and imports (ISD) on carbon dioxide (CO_2) emissions in BRICS countries during the period 2010–2023.

○ **Statistical Significance:** All variables show high statistical significance (Prob < 0.01), confirming the reliability of the results.

○ **Model Strength:** The coefficient of determination ($R^2 = 0.96$) indicates that 96% of the variance in CO_2 emissions is explained by the included variables, which is a strong indicator of model efficiency.

2. **Interpretation of Coefficients According to Economic Theories:**

A. Impact of Digital Service Exports (ESD)

○ **Negative Coefficient (-0.0049):** The results indicate that a 1% increase in digital service exports reduces CO_2 emissions by approximately 0.0049%, consistent with the structural transformation theory, where digital services replace traditional, energy-intensive industries (such as manufacturing), thereby reducing carbon footprints.

▪ **Example:** China's shift toward exporting high-tech services instead of polluting heavy industries.

B. Impact of Digital Imports (ISD):

○ **Positive Coefficient (0.0027):** An increase of 1% in digital service imports raises CO_2 emissions by approximately 0.0027%. This can be explained by:

▪ **Technology Dependency Theory:** Countries may rely on imported digital solutions that require intensive infrastructure (such as data centers) consuming unclean energy.

▪ **Economic Growth Effect:** Digital imports may lead to increased overall economic activity, raising energy demand (especially if dependent on fossil fuels).

C. Constant (C = 0.4996):

○ This represents the baseline emissions in the absence of the effects of the included variables and reflects fixed factors such as:

▪ The reliance of BRICS countries on fossil fuels (such as coal in China and India, oil in Russia).

▪ Traditional industrial and agricultural activities (such as deforestation in Brazil).

3. Additional Analysis of BRICS Countries:

A. Common Factors:

- **China and India:** Both countries are gradually transitioning toward a digital economy, which reduces CO_2 emissions from traditional industries. However, they still rely on coal for electricity generation, which limits the negative impact of ESD.
- **Russia:** Its economy depends on oil and gas exports, resulting in high CO_2 emissions despite the limited impact of ESD and ISD.

B. Differences Among Countries:

- **Brazil:** Agricultural practices and deforestation (not included in the model) may explain the high emissions despite the negative impact of ESD.
- **South Africa:** The country relies on coal for 80% of its electricity generation, weakening the impact of digital services in reducing emissions.

4. Challenges and Considerations:

- **Autocorrelation:** The low Durbin-Watson statistic (0.488) indicates the presence of positive autocorrelation, necessitating the use of more advanced models.
- **Unmeasured External Factors:**

○ Renewable energy policies (such as solar energy projects in India).

○ The impact of the COVID-19 pandemic (2020–2022), which temporarily reduced economic activity.

The results demonstrate a dual role of digital trade in CO_2 emissions among BRICS countries: while digital exports contribute to emissions reduction through structural transformation, digital imports may increase emissions due to reliance on energy-intensive technologies. These findings underscore the need for integrated policies that connect technology with environmental sustainability, taking into account the structural differences among BRICS economies.

Conclusion:

In the context of rapid digital transformation, this study investigates the impact of digital trade on sustainable development in BRICS countries (Brazil, Russia, India, China, and South Africa) during the period 2010–2023. The study utilized panel data analysis to measure the relationship between digital service exports and imports and the three indicators of sustainable development: economic growth (GDP), human development (HDI), and environmental sustainability (CO_2). The aim was to determine the extent to which digital trade contributes to balancing economic, social, and environmental dimensions.

Results of Hypothesis Testing

1. **Impact of Digital Trade on GDP:**

○ **Digital Service Exports (ESD):** Positive and statistically significant effect (coefficient: 0.087), as it contributes to enhancing GDP by stimulating productivity and innovation.

○ **Digital Service Imports (ISD):** Negative effect (coefficient: -0.246), attributed to reliance on foreign solutions and the depletion of hard currency.

2. **Impact of Digital Trade on Human Development (HDI):**

○ **Digital Service Exports (ESD):** Slight negative effect (coefficient: -0.0028), due to the concentration of resources in specialized technological sectors without sufficient investment in social services.

○ **Digital Service Imports (ISD):** Positive effect (coefficient: 0.0026), through technology transfer to improve health and education.
○ **Technology Readiness (FTRI):** The strongest effect (coefficient: 0.455), as digital infrastructure enhances quality of life.
3. **Impact of Digital Trade on Carbon Emissions (CO_2):**
○ **Digital Service Exports (ESD):** Reduces emissions (coefficient: -0.0049) by replacing polluting industries with digital sectors.
○ **Digital Service Imports (ISD):** Increases emissions (coefficient: 0.0027) due to reliance on energy-intensive infrastructure.

Practical Implications

- **BRICS Economies:** China and India benefit from digital service exports in boosting GDP, while countries like South Africa face structural gaps that limit benefits.
- **Human Development:** Frontier technology (such as internet infrastructure) is the primary driver of improving HDI, but digital service exports may deepen social inequalities.
- **Environmental Impact:** The transition to a digital economy reduces emissions in China and India, but reliance on fossil fuels limits this effect.

Key Recommendations

1. **Enhance Integrated Policies:** Integrate digital trade into national strategies to balance economic growth with social justice, and encourage investment in renewable energy to support digital infrastructure (such as green data centers).
2. **Bridge the Digital Divide:** Direct investments toward rural areas and marginalized groups to ensure inclusive development, and enhance cooperation among BRICS countries to share technological expertise (e.g., digital Silk Road projects).
3. **Manage Digital Imports:** Implement controls to balance technological imports with the development of local industries, and activate data protection policies to enhance trust in imported digital services.
4. **Strengthen Institutional Frameworks:** Develop legislation that ensures intellectual property rights while considering developmental needs, and establish monitoring platforms to measure the environmental impact of digital trade and adjust policies accordingly.

Digital trade in BRICS countries serves as a driver of development; however, its success hinges on smart policies that link technological innovation with social justice and environmental sustainability. Achieving this integration requires international cooperation and strategic investment in both infrastructure and human capital.

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Appendices

Table (1): Breusch-Pagan Lagrange Multiplier Test for the Dependent Variable GDP

Test Value	P-VALUE
LM Breusch-Pagan	0.599865

Source: Prepared by the researchers based on EViews 13 results

Table (2): Breusch-Pagan Lagrange Multiplier Test for the Dependent Variable HDI

Test Value	P-VALUE
LM Breusch-Pagan	1.3873655

Source: Prepared by the researchers based on EViews 13 results

Table (3): Breusch-Pagan Lagrange Multiplier Test for the Dependent Variable CO_2

Test Value	P-VALUE
LM Breusch-Pagan	254.882

Source: Prepared by the researchers based on EViews 13 results

Table (4): Hausman Test for the Third Model with the Dependent Variable CO_2

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f	Prob
Cross-section random	2.435727	2	0.2959

Source: Prepared by the researchers based on EViews 13 results

Table (5): Pooled Model for the Dependent Variable GDP

Dependent Variable: GDP
Method: Panel Least Squares
Date: 02/20/25 Time: 13:54
Sample: 2010 2023
Periods included: 14
Cross-sections included: 5
Total panel (balanced) observations: 70

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ESD	0.087130	0.023078	3.775404	0.0003
ISD	-0.246708	0.038949	-6.334158	0.0000
C	8.625863	1.644810	5.244290	0.0000

R-squared	0.400222	Mean dependent var	3.523614
Adjusted R-squared	0.382318	S.D. dependent var	3.729978
S.E. of regression	2.931493	Akaike info criterion	5.030812
Sum squared resid	575.7745	Schwarz criterion	5.127176
Log likelihood	-173.0784	Hannan-Quinn criter.	5.069089
F-statistic	22.35396	Durbin-Watson stat	1.590439
Prob(F-statistic)	0.000000		

| **Source:** EViews 13 Outputs |

Table (6): Pooled Model for the Dependent Variable HDI

Dependent Variable: HDI
Method: Panel Least Squares
Date: 02/20/25 Time: 14:12
Sample: 2010 2023
Periods included: 14
Cross-sections included: 5
Total panel (balanced) observations: 70

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ESD	-0.002801	0.000247	-11.35663	0.0000
ISD	0.002607	0.000423	6.159694	0.0000
FTRI	0.455161	0.041717	10.91076	0.0000
C	0.462726	0.036711	12.60464	0.0000

R-squared	0.803432	Mean dependent var	0.730857
Adjusted R-squared	0.794497	S.D. dependent var	0.068887
S.E. of regression	0.031228	Akaike info criterion	-4.039539
Sum squared resid	0.064364	Schwarz criterion	-3.911053
Log likelihood	145.3839	Hannan-Quinn criter.	-3.988503
F-statistic	89.92039	Durbin-Watson stat	0.739586
Prob(F-statistic)	0.000000		

| **Source:** EViews 13 Outputs |

Table (7): Fixed Model for the Dependent Variable CO_2

Dependent Variable: CO2
Method: Panel Least Squares
Date: 02/20/25 Time: 13:19
Sample: 2010 2023
Periods included: 14
Cross-sections included: 5
Total panel (balanced) observations: 70

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ESD	-0.004900	0.000702	-6.978435	0.0000
ISD	0.002699	0.000911	2.962983	0.0043
C	0.499632	0.027595	18.10618	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.960156	Mean dependent var	0.360832
Adjusted R-squared	0.956362	S.D. dependent var	0.167716
S.E. of regression	0.035036	Akaike info criterion	-3.770269
Sum squared resid	0.077332	Schwarz criterion	-3.545420
Log likelihood	138.9594	Hannan-Quinn criter.	-3.680956
F-statistic	253.0297	Durbin-Watson stat	0.488639
Prob(F-statistic)	0.000000		

| **Source:** EViews 13 Outputs |