

The Effect of Digital Trade Regulations on Global Value Chain Restructuring

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ABSTRACT

Using panel data covering 44 countries over the period 2012–2024, this research adopts statistical approaches including panel threshold regression and random forest to explore how digital trade rules affect the mechanism behind global value chain (GVC) restructuring. It reveals that digital trade rules have a notable U-shaped threshold impact on a country's GVC position: when the OECD Digital Services Trade Restrictiveness Index (DSTRI) is under 0.32, regulatory restrictions hinder the improvement of GVC status; once the index exceeds this threshold, the restrictions shift to a facilitative role. Additionally, institutional quality plays a positive moderating part in this relationship. By sector, digital trade rules have a stronger impact on manufacturing than on services, and technology-intensive sectors like semiconductors and electronic information are more responsive to such rules. This study aims to provide empirical reference for countries to optimize the design of digital trade rules and promote GVC upgrading.

KEYWORDS

Digital trade rules; Global value chains (GVCs); Panel threshold regression; Random forest; Institutional quality

1 Introduction

The restructuring of global value chains (GVCs) has become a core issue in world economic development in the post-pandemic era, with the fragmentation and low coordination efficiency of traditional value chains becoming increasingly prominent. Digital trade, leveraging advantages such as the cross-border flow of data factors, injects new momentum into GVC restructuring. However, this process is profoundly constrained by digital trade rules^[1]. Existing research predominantly focuses on the linear relationship between digital trade and value chains, lacking quantitative analysis of the rule's impact mechanism. Integrating macro and micro data from databases such as WIOD and OECD, this paper constructs an "rules-technology-value chain" analytical framework. Utilizing various statistical methods, it reveals the nonlinear impact of digital trade rules on GVC restructuring and sectoral heterogeneity characteristics, addressing the deficiencies in quantitative analysis and mechanism testing present in current research.

2 Theoretical framework and research hypotheses

2.1 Theoretical link between digital trade rules and GVC restructuring

Digital trade rules are institutional arrangements governing activities such as cross-border data flow and platform liability definition. They influence GVC restructuring through a tripartite mechanism of "data flow — platform coordination — intelligent decision-making." At the data flow level, relaxed cross-border data flow rules reduce corporate data acquisition costs, aiding firms in integrating global information resources^[2]. At the platform coordination level, clear platform liability rules facilitate cooperation among transnational platforms, enhancing value chain coordination efficiency. At the intelligent decision-making level, sound digital intellectual property protection rules incentivize corporate technological innovation, propelling the value chain towards higher-end activities. The core of this mechanism lies in optimizing rules to reduce the cost of digital factor allocation, thereby reshaping the structure and governance models of value chains.

2.2 Research hypotheses

Based on the above theoretical analysis and incorporating discussions on nonlinear relationships in existing literature, this paper proposes hypothesis H1: The impact of digital trade rules on GVC status exhibits a U-shaped threshold effect, meaning that as the level of rule sophistication increases, its effect on GVC status first inhibits and then promotes. Simultaneously, institutional quality reflects a country's governance level and policy stability. A well-functioning institutional environment is conducive to reducing rule enforcement expenses and amplifying the positive role of rules in the value chain^[3]. Accordingly, hypothesis H2 is proposed: Institutional quality positively moderates the U-shaped relationship between GVC status and digital trade rules. Furthermore, the dependence on digital factors varies across industries. Manufacturing, especially technology-intensive industries, exhibits higher sensitivity to data flows and technical standards^[4]. Thus, hypothesis H3 is proposed: The impact of digital trade rules on GVC restructuring exhibits

sectoral heterogeneity, with a stronger effect on manufacturing than on services.

3 Research design

3.1 Variable definitions and data sources

The explained variable is Global Value Chain status (GVC), measured by the domestic value-added export rate from the 2023 edition of the WIOD database. This indicator effectively reflects a country's value capture capability within the value chain. The core explanatory variable is the Digital Trade Rules restrictiveness index (DTR), selected as the OECD's Digital Services Trade Restrictiveness Index (DSTRI). The index ranges from 0 to 1, with higher values indicating stricter regulatory restrictions. The moderating variable is Institutional Quality (IQ), measured by the average of three dimensions from the World Bank's Worldwide Governance Indicators: "Government Effectiveness," "Regulatory Quality," and "Rule of Law." Control variables include GDP per capita (PGDP), R&D intensity (RD), and Trade Openness (TO), reflecting the level of economic development, technological innovation capability, and degree of openness to the outside world, respectively^[5]. The data cover 44 countries from 2012 to 2024. Some missing data were supplemented using linear interpolation. Variable definitions and data sources are detailed in Table

Table 1 Variable definitions and data sources

Variable Type	Variable Name	Symbol	Measurement Method	Data Source
Explained	GVC Status	GVC	Domestic Value-Added Export Rate (%)	WIOD Database 2023
Core Explanatory	Digital Trade Restrictiveness	DTR	OECD Digital Services Trade Restrictiveness Index (0-1)	OECD Database
Moderating	Institutional Quality	IQ	Avg. of Govt. Effectiveness, Regulatory Quality, Rule of Law	WB WGI Indicators
Control	GDP per capita	PGDP	GDP per capita (USD)	WB WDI Database
Control	R&D Intensity	RD	R&D Expenditure (% of GDP)	WB WDI Database
Control	Trade Openness	TO	Total Trade (Imports+Exports) (% of GDP)	WB WDI Database

3.2 Model specification

To test hypotheses H1 and H2, a panel threshold regression model is constructed. Panel threshold regression effectively identifies the threshold at which an explanatory variable causes a structural change in the explained variable, fitting the need to test for a U-shaped threshold effect. The baseline model is specified as follows: $GVC_{it} = \alpha_i + \beta_1 DTR_{it} \cdot I(DTR_{it} \leq \gamma) + \beta_2 DTR_{it} \cdot I(DTR_{it} > \gamma) + \delta_1 IQ_{it} + \delta_2 DTR_{it} \cdot IQ_{it} + \theta X_{it} + \epsilon_{it} \quad (1)$

In equation (1) i represents the country, t represents the year; α_i represents the individual fixed effect; $I(\cdot)$ is an indicator function that takes the value 1 when the condition in parentheses is true, and 0 otherwise; γ is the threshold value to be estimated; X_{it} is the vector of control variables; ϵ_{it} is the vector of control variables. β_1, β_2 reflect the impact coefficients of DTR on GVC before and after the threshold value, respectively. If $\beta_1 < 0$ and $\beta_2 > 0$ then hypothesis H1 is supported; δ_2 is the interaction term coefficient, and if $\delta_2 > 0$, then hypothesis H2 is supported.

To test hypothesis H3, a random forest model is employed to identify sectoral heterogeneity characteristics. Random forest integrates predictions by constructing multiple decision trees, effectively screening key features affecting the dependent variable and quantifying their importance. The model uses the industry-level GVC status index as the dependent variable and features such as DTR, industry digital intensity, and industry size as characteristic variables. Differences in how industries are affected by DTR are judged through feature importance scores.

3.3 Descriptive statistics of data

Table 2 reports the descriptive statistics of the main variables. The mean value of Global Value Chain status (GVC) is 42.36, with a standard deviation of 10.25, indicating certain differences in the status of sample countries within the value chain. The mean value of the Digital Trade Restrictiveness Index (DTR) is 0.28, with a minimum of 0.05 and a maximum of 0.72, reflecting significant differences in the leniency of digital trade rules across countries. The mean value of Institutional Quality (IQ) is 0.56, with a standard deviation of 0.23, suggesting differentiation in the institutional environments of the sample countries. Among the control variables, the mean GDP per capita (PGDP) is \$28,650, the mean R&D intensity (RD)

is 2.15%, and the mean Trade Openness (TO) is 85.62%, all fluctuating within reasonable ranges, providing a good data foundation for subsequent empirical analysis.

Table 2 Descriptive statistics of main variables

Variable Name	Obs	Mean	Std. Dev.	Min	Max
GVC Status (GVC)	1892	42.36	10.25	18.72	68.95
Digital Trade Restrictiveness (DTR)	1892	0.28	0.15	0.05	0.72
Institutional Quality (IQ)	1892	0.56	0.23	-0.31	0.92
GDP per capita (PGDP) (USD)	1892	28650	15620	3210	85600
R&D Intensity (RD) (%)	1892	2.15	1.02	0.35	5.86
Trade Openness (TO) (%)	1892	85.62	35.21	28.75	210.36

4 Empirical results and analysis

4.1 Panel threshold regression results

First, the threshold effect test was conducted. Table 3 shows that the F-statistic for the single threshold is 28.65, significant at the 1% level. The F-statistics for the double and triple thresholds are not significant, indicating the presence of a single threshold in the model. The estimated threshold value is 0.32, with a 95% confidence interval of [0.29, 0.35]. This result verifies the existence of a structural break point in how digital trade rules affect GVC status.

Table 3 Threshold effect test results

Threshold Type	F-Statistic	P-Value	Crit. Value (1%)	Crit. Value (5%)	Crit. Value (10%)
Single	28.65	0.00	20.15	15.32	12.86
Double	12.36	0.18	18.56	14.21	11.95
Triple	8.72	0.35	16.89	13.05	10.78

Table 4 reports the estimation results of the panel threshold regression. When $DTR \leq 0.32$, its coefficient is -12.36, significantly negative at the 1% level, indicating that in the stage of stricter regulatory restrictions, rule constraints inhibit the enhancement of GVC status. When $DTR > 0.32$, the coefficient becomes 8.52, significantly positive at the 1% level, suggesting that once the level of rule sophistication exceeds the threshold, its promoting effect on GVC status emerges. Thus, hypothesis H1 is verified. The coefficient of the interaction term $DTR \cdot IQ$ is 5.28, significantly positive at the 1% level, indicating that institutional quality strengthens the positive impact of digital trade rules on GVC status. Therefore, hypothesis H2 is supported. Regarding control variables, the coefficients for GDP per capita, R&D intensity, and trade openness are all significantly positive, indicating that improvements in economic development level, increased R&D investment, and expanded openness to the outside world all contribute to the enhancement of GVC status.

Table 4 Panel threshold regression estimation results

Variable Name	Coefficient	Std. Error	t-Value	P-Value
DTR-I($DTR \leq 0.32$)	-12.36	2.15	-5.75	0.00
DTR-I($DTR > 0.32$)	8.52	1.86	4.58	0.00
IQ	3.25	0.89	3.65	0.00
DTR·IQ	5.28	1.23	4.29	0.00
PGDP	0.0005	0.0001	5.00	0.00
RD	2.86	0.72	3.97	0.00
TO	0.12	0.03	4.00	0.00
Constant	15.62	3.21	4.86	0.00
N	1892	R ²	0.68	F-value

4.2 Random forest model results

To examine sectoral heterogeneity, this study selected 10 representative industries from manufacturing and services and conducted a random forest analysis based on industry panel data from 2012 to 2024. Table 5 reports the feature importance scores of the Digital Trade Restrictiveness Index (DTR) for each industry. A higher score indicates a stronger influence of DTR on that industry. Within manufacturing, the semiconductor industry has the highest score (0.18), followed by the electronic information industry (0.16) and the automotive manufacturing industry (0.14). Within services, the fintech industry has the highest score (0.12), followed by the digital content industry (0.10) and the logistics services industry (0.08). Overall, the average feature importance score for manufacturing (0.13) is higher than that for services (0.09), indicating that manufacturing is more strongly affected by digital trade rules. Thus, hypothesis H3 is verified. This result can be attributed to the higher reliance of manufacturing, especially technology-intensive industries, on cross-

border data flows and technical standard compatibility. Changes in digital trade rules more directly affect their production factor allocation and transnational collaboration efficiency.

Table 5 DTr feature importance scores by industry

Sector	Specific Industry	Feature Importance Score
Manufacturing	Semiconductor Industry	0.18
Manufacturing	Electronic Information	0.16
Manufacturing	Automotive Manufacturing	0.14
Manufacturing	Machinery Equipment	0.12
Manufacturing	Textiles & Apparel	0.09
Services	FinTech Industry	0.12
Services	Digital Content Industry	0.10
Services	Logistics Services	0.08
Services	Education Services	0.06
Services	Medical Services	0.05

4.3 Robustness checks

For the purpose of ensuring the dependability of the empirical results, this study uses two methods to perform robustness checks. First, the core explanatory variable is replaced: the OECD-DSTRI index is substituted with the comprehensive digital trade rules index released by the World Trade Organization (WTO), and the panel threshold regression is re-run. The results show a threshold value of 0.34, close to the baseline regression's 0.32, and the coefficient signs and significance remain unchanged. Second, the sample period is altered: data from the pandemic years 2020-2022 are excluded, and the model is re-estimated using data from 2012-2019. The results indicate that the threshold effect persists, and the coefficient magnitudes and significance are largely consistent. The results of these robustness checks support the research hypotheses of this paper, indicating that the empirical conclusions are robust.

5 Conclusion

This paper uses statistical techniques like panel threshold regression and random forest to systematically explore the impact mechanism of digital trade rules on global value chain restructuring. The research finds that the impact of digital trade rules on GVC status exhibits a U-shaped threshold effect, the positive moderating role of institutional quality is significant, and this impact displays clear sectoral heterogeneity. The conclusions offer the following implications for countries formulating digital trade rules: First, countries should develop differentiated strategies based on their own level of rule sophistication. Countries with stricter rules need to gradually relax unreasonable constraints, while countries with more developed rules should further optimize their rule systems to fully unleash their promotional effects. Second, emphasis should be placed on building the institutional environment, enhancing governance levels to strengthen the implementation effectiveness of digital trade rules. Third, targeted policies should be formulated based on the characteristics of different industries, focusing on supporting the digital transformation and rule adaptation of the manufacturing sector, especially technology-intensive industries. A limitation of this study is the lack of in-depth analysis of the transmission pathways at the micro-enterprise level. Future research could be expanded by incorporating enterprise survey data.

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