

Degree of Global Value Chain Embeddedness and ICT Services Export Performance: The Mediating Role of Productivity

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Abstract. In the context of globalization and rapid technological development, the deep embedding of ICT services in global value chains is of great significance to international trade and export growth. This study constructs a theoretical model and empirically analyzes the impact of GVC embeddedness on the export performance of ICT service industry by using the panel data of 56 countries and regions in the world from 2007 to 2021 and the regression method of fixed-effects model, focusing on the mediating role of production efficiency. The study shows that the degree of GVC embeddedness has a significant positive impact on the export performance of ICT services, and production efficiency plays a mediating role, i.e., the participation of GVCs enhances production efficiency, which in turn promotes the growth of export performance. Heterogeneity tests show that both developed and developing countries benefit from GVC embeddedness, but with different degrees of impact. Based on the findings of the study, policy recommendations are provided for countries to enhance the export performance of ICT services in GVCs, including developing countries' integration into and upgrading of the value chain, developed countries' consolidation of their advantages and innovative cooperation, and countries should encourage technological innovation, strengthen education and training, guide the flow of foreign investment, support the regulation of service industries and formulate targeted policies.

Keywords: Global Value Chains, ICT Services, Export Performance, Productive Efficiency, Mediating Role.

1. Introduction

Against the backdrop of globalisation and rapid technological advancement, global value chains have become pivotal drivers of modern economic growth and international trade. For developing countries and emerging market economies in particular, deep integration into global value chains not only enhances industrial competitiveness internationally but also accelerates domestic industrial upgrading and economic modernisation through technology diffusion and knowledge spillover effects [1]. Among numerous industries, the information and communications technology (ICT) services sector, being both technology-intensive and innovation-driven, has seen its deep integration into global value chains emerge as a key factor propelling international trade and export growth [2].

However, despite extensive attention to the impact of global value chains on export performance, numerous unresolved questions remain regarding their specific mechanisms and pathways of influence. Particularly within the specialised ICT services sector, a systematic theoretical framework and empirical research are lacking on how the degree of global value chain integration influences export performance through other mediating factors. Existing literature predominantly focuses on analyses of manufacturing or entire industries, with relatively scarce research on ICT services. Notably, there is a lack of in-depth exploration of the mediating role of production efficiency in this process.

This study aims to address this research gap by examining how the degree of GVC embedding influences export performance in ICT services through the mediating effect of production efficiency. We propose that deep participation in global value chains enhances production efficiency within ICT services. This improved efficiency, in turn, significantly boosts firms' competitiveness in global markets, thereby stimulating export growth. To this end, this paper constructs a theoretical model incorporating GVC embeddedness, production efficiency, and ICT services export performance. It

empirically analyses the impact mechanism of global value chains on ICT services export performance and tests the mediating role of production efficiency in this process.

2. Literature Review

2.1. GVC Embeddedness and Export Performance

The theory of global value chains elucidates how different nations and regions participate in global markets through division of labour and cooperation within transnational production networks. The degree of GVC embeddedness refers to the depth of a nation or region's participation within global value chains, typically measured by exports of intermediate goods, cooperation among multinational corporations, or involvement in upstream and downstream activities of industrial chains. In recent years, researchers have increasingly recognised the impact of GVC embeddedness on national export performance.

For instance, deep GVC integration enhances developing countries' competitiveness in global markets, thereby stimulating export growth [3]. Such studies emphasise that higher GVC embedding enables nations to capture greater value-added within global value chains, consequently improving export performance. Differing positions within global value chains influence export structures and product value-added across nations, with GVC impacts being particularly pronounced in high-technology sectors such as ICT services [4].

2.2. The Mediating Role of Productivity

Production efficiency, as a crucial economic variable, has been highlighted in numerous studies on export performance in recent years and is frequently regarded as a potential mediating variable. It reflects the degree of optimisation in resource utilisation and production processes within a nation or region. Research indicates that higher production efficiency enhances the cost competitiveness of exporting firms, thereby improving their export performance.

For instance, export performance in China's manufacturing sector and found that productivity played a significant mediating role between Global Value Chain (GVC) integration and export growth [5]. The study indicated that deeper participation in GVCs enhances domestic firms' productivity through technology transfer and knowledge spillover effects, thereby driving improvements in export performance. Similarly, in examining East Asian service exports, emphasised that productivity gains exert a crucial influence on export performance, with this effect being particularly pronounced within the context of global value chains [6].

2.3. ICT Services and Export Performance

The ICT (Information and Communications Technology) services sector constitutes a vital component of contemporary globalisation and digital transformation, exerting a particularly pronounced influence on global value chains. Beyond facilitating knowledge spillovers and technological advancement, ICT services enhance national export performance by delivering innovative, high-value-added solutions.

The role of ICT services within global value chains, noting that rapid advancements and applications in information technology have made this sector a vital driver of export growth for emerging economies [7]. Against this backdrop, ICT services not only directly enhance corporate productivity but also stimulate export expansion in other industries through technological innovation. With the development of digital technologies and e-commerce, the export competitiveness of ICT services has markedly increased globally [8].

Furthermore, international evidence indicates that the development of ICT services relies not only on technological innovation and capital investment but is also influenced by educational attainment and scientific and technological expenditure. Educational enrolment rates and workforce quality in specific regions directly correlate with technological innovation and knowledge accumulation within

ICT services, while scientific and technological expenditure contributes to enhancing the sector's overall technological sophistication and productivity [9].

Recent research has progressively illuminated the impact of global value chain (GVC) embeddedness on ICT services export performance, with the importance of production efficiency as a mediating variable gaining widespread recognition. Particularly in technology-intensive sectors such as ICT services, both production efficiency and GVC embeddedness exert significant influence on export performance.

3. Theoretical Mechanism Analysis

3.1. The Direct Mechanism of Global Value Chain Embeddedness on the Export Performance of ICT Services

Resource Integration and Optimisation: When an ICT service sector within a nation or region becomes deeply embedded within global value chains, it gains broader access to worldwide production factors such as advanced technologies, specialised talent, and high-quality capital. By participating in global division of labour, enterprises can concentrate limited resources on their most competitive segments according to comparative advantage, thereby achieving optimal resource allocation. This enhances production efficiency and product quality, ultimately strengthening the international competitiveness of export goods and boosting export performance.

Technology Spillovers and Innovation-Driven Development: Leading enterprises within global value chains typically possess advanced technologies and management expertise. ICT service enterprises in developing countries or regions can absorb and learn advanced technical knowledge and management models through technology spillover effects when collaborating with or competing against these leading firms. This dissemination of technology and knowledge helps drive technological and managerial innovation among local enterprises, improving production efficiency and product value-added. Consequently, they better meet international market demands, expand export scale, and enhance export performance [10][11].

Market Expansion and Economies of Scale: Embedding within global value chains enables ICT service enterprises to transcend domestic market constraints and access broader international markets. As market share expands, enterprises can achieve economies of scale, reducing unit production costs and enhancing operational efficiency [12]. Concurrently, competitive pressures in international markets compel enterprises to continually elevate their production and management standards, thereby strengthening their global competitiveness and fostering sustained growth in export performance.

3.2. The Mediating Mechanism of Production Efficiency

3.2.1. The Impact of Global Value Chain Embeddedness on Production Efficiency

Industrial Synergy: Global value chain integration fosters the coordinated development of ICT services alongside other related industries. For instance, convergence with manufacturing enables ICT services to better address enterprises' digital transformation needs, while substantial demand from manufacturers drives ICT service providers to continually optimise service processes, enhance service quality and boost productivity. Through inter-industry collaboration, resource sharing and complementary strengths are achieved, elevating the entire industrial chain's efficiency.

Knowledge Sharing and Learning: Within global value chains, enterprises engage in more frequent exchanges and collaborations, accelerating the dissemination of knowledge and information. ICT service providers can access advanced production technologies, management expertise, and market intelligence from worldwide sources. Through internal assimilation and innovative application, these resources are transformed into enhanced operational efficiency. This knowledge-sharing and learning mechanism elevates enterprises' production organisation and management capabilities, thereby boosting productivity.

3.2.2. The Impact of Production Efficiency on Export Performance in the ICT Services Sector

Cost advantage: Enhanced production efficiency enables enterprises to produce more and better goods or services with the same inputs, or to reduce production costs while maintaining output levels. In international market competition, lower production costs grant enterprises a pricing advantage, thereby boosting product competitiveness, expanding export market share, and improving export performance.

Quality and Innovation Enhancement: Highly efficient production processes assist enterprises in ensuring consistent product or service quality while accelerating the transformation of new technologies and innovations into tangible offerings for market deployment. High-quality and innovative ICT service products garner greater recognition and favour in international markets, aiding enterprises in establishing strong brand images, elevating customer satisfaction and loyalty, and consequently driving improved export performance.

4. Model Specifications

Based on panel data from 56 countries and regions worldwide spanning 2007–2021, this study employs a fixed-effects model regression method to empirically analyse the impact of GVC embeddedness on ICT service product exports. The selected sample comprises 33 developed economies and regions—including the United States, Germany, the United Kingdom, France, Denmark, Austria, Singapore, Canada, Sweden, and Hong Kong, China—alongside 23 developing economies and regions such as China, India, Thailand, Malaysia, Kazakhstan, and the Philippines. The final econometric regression model is formulated as follows:

$$\text{EXP}_{i,t} = \beta_0 + \beta_1 \text{GVC_par}_{i,t} + \beta_2 \ln \text{Efficiency}_{i,t} + \beta_3 \text{growth}_{i,t} + \beta_4 \text{FDI}_{i,t} + \beta_5 \text{laborf}_{i,t} + \beta_6 \text{service}_{i,t} + \beta_7 \ln \text{Enrollment}_{i,t} + \beta_8 \text{tech}_{i,t} + \mu_i + \gamma_t + \epsilon_{i,t}$$

Here, i denotes the country, t denotes the year, β_0 represents the intercept term, μ_i denotes the unobservable country-specific effect, γ_t denotes the time effect, and $\epsilon_{i,t}$ denotes the disturbance term that varies with the individual and over time.

5. Model Assumptions

5.1. The Direct Impact of Global Value Chain Embeddedness on ICT Services Export Performance

Hypothesis 1: The greater the degree of global value chain integration within the ICT services sector, the stronger its export performance.

Deep integration into global value chains may yield increased international market opportunities, technological spillover effects, and optimised resource allocation, thereby directly enhancing the export performance of the ICT services sector.

5.2. The Direct Impact of Production Efficiency on Export Performance in the ICT Services Sector

Hypothesis 2: The higher the production efficiency of ICT services, the better their export performance.

Enhanced production efficiency implies reduced unit costs, improved product quality and accelerated delivery speeds. These factors collectively bolster the competitiveness of ICT services in international markets, thereby elevating their export performance.

5.3. The mediating role of production efficiency in the degree of integration into global value chains and the export performance of ICT services

Hypothesis 3: Global value chain integration indirectly enhances the export performance of ICT services by boosting production efficiency.

Embedding within global value chains may facilitate technological upgrading, management optimisation, and improved resource allocation. These factors collectively elevate production efficiency, thereby strengthening the export performance of ICT services through enhanced productivity.

5.4. The Impact of Control Variables on the Export Performance of the ICT Services Sector

Hypothesis 4: Control variables including foreign direct investment, trade openness, internet penetration rate, tertiary enrolment rate, and government education expenditure as a percentage of GDP exert a significant positive influence on ICT services export performance.

Foreign direct investment may provide capital and technological support, trade openness facilitates expanded international market access, increased internet users enhance information circulation efficiency, while higher education enrolment rates and government education expenditure may elevate human resource quality and innovation capacity. These factors collectively influence the ICT services sector, thereby promoting improvements in its export performance.

6. Variable Specification

6.1. Dependent Variable

Exports of ICT services products (EXP) denote the value of ICT services exports from 56 sample countries and regions between 2007 and 2021. The United Nations Conference on Trade and Development (UNCTAD) categorises the ICT industry into ICT services and ICT manufacturing. ICT services encompass telecommunications services, software services, cloud computing services, and internet services. The export value of these four categories of ICT services products constitutes the dependent variable in this study.

6.2. Independent Variable

The GVC Embeddedness Index (GVC_{par}) measures the participation level of the ICT industry in Global Value Chains (GVCs) across 56 sample countries and regions from 2007 to 2021. It employs the ‘GVC Participation Index (GVC_{participation index})’ proposed by Koopman et al. (2010), defined as the proportion of the sum of exported intermediate value added and the foreign value added incorporated therein.

$$\text{GVC_participation}_{ir} = \frac{\text{IV}_{ir}}{\text{E}_{ir}} + \frac{\text{FV}_{ir}}{\text{E}_{ir}}$$

Where *i* denotes industry, *r* denotes country, *IV_{ir}* represents the indirect value added exports of country *r*'s industry *i*—that is, the value added of country *r*'s industry *i*'s intermediate exports, which are directly imported and processed by country *A* before being re-exported to country *B*. *FV_{ir}* denotes the value added of foreign intermediate goods utilised by country *r*'s industry *i* during production. *E_{ir}* represents the total exports of country *r*'s industry *i*.

6.3. Control Variables

Based on relevant literature, the following representative indicators were selected as control variables. (1) Foreign Direct Investment (FDI): This may influence technology introduction, market expansion, and enhanced export capacity within the ICT services sector. (2) Education Enrolment Rate: This reflects a nation's human resource quality; higher educational attainment implies a greater pool of skilled talent, which aids in elevating the technical proficiency and innovation capabilities of the ICT services sector, thereby strengthening its export competitiveness. (3) Technology Investment

(tech): Measures a nation's commitment to scientific and technological innovation, directly influencing technological advancement and export capacity within the ICT services sector. (4) GDP Growth Rate (growth): Reflects the overall expansion of a national economy. Economic growth typically accompanies increased consumption and investment demand, thereby boosting market demand and export opportunities for ICT services. (5) Proportion of Service Sector Employment (labourf): Measures the service sector's share within the national economy and labour allocation patterns. Rapid service sector development and optimised labour allocation enhance the ICT service industry's production efficiency and export competitiveness. (6) Service Sector Level (service): Expressed as the value added generated per service sector employee.

6.4. Mediating Variable

Selecting production efficiency (lnEfficiency) as an intermediary variable, measured by the average gross domestic product generated per employed person. This serves as the bridge linking the degree of global value chain integration to export performance. An increase in the degree of global value chain integration may indirectly promote the enhancement of ICT services export performance by raising production efficiency.

Table 1. Variable Specifications

Variable Category	Variable Name	Variable Symbol	Variable Definition	Data Source
Dependent Variable	Export Performance	EXP	ICT services exports as a proportion of total services exports	World Bank
Independent variable	Global Value Chain Embeddedness	GVC_par	GVC embeddedness index	TIVA database
Control Variables	Foreign Direct Investment	FDI	Foreign Direct Investment (as a percentage of GDP)	World Bank
	Education enrolment rate	lnEnrollment	Gross enrolment ratio	World Bank
	Technology input	tech	Research and development expenditure (as a percentage of GDP)	World Bank
	GDP growth rate	growth	GDP growth rate	World Bank
	Proportion of service sector employment	laborf	Percentage of total employment accounted for by service sector workers	World Bank
	Service sector level	service	Value added generated per service sector worker	World Bank
Mediating Variable	Production efficiency	lnEfficiency	Average gross domestic product generated per employed worker	World Bank

The data primarily originates from the TIVA database, the World Bank, and other sources. For specific data definitions and sources, please refer to the Table 1.

7. Empirical Analysis

7.1. Descriptive Analysis

The mean value for export performance (EXP) reached 10.035, yet the standard deviation stood at 10.022 – nearly equal to the mean. This indicates substantial variation in export performance across the sample. The minimum value was a mere 0.634, while the maximum reached 58.044. This substantial dispersion reflects markedly divergent export market performances among ICT service enterprises, suggesting some may excel exceptionally while others face significant market challenges.

The mean for Global Value Chain Embeddedness (GVC_par) stands at 0.322, indicating a generally moderate level of integration within global value chains for the sample enterprises. Its standard deviation of 0.160 reveals considerable variation in enterprises' positions within these chains. Such divergence may stem from multiple factors including international competitiveness, technological capabilities, and market strategies.

Regarding control variables, foreign direct investment (FDI) exhibits an exceptionally high standard deviation (24.858) and a substantial range between minimum and maximum values (-

117.375 to 279.361). This likely reflects considerable disparities among countries or regions in attracting foreign capital, alongside varying degrees of FDI influence across different ICT service enterprises. The mean and standard deviation of the logarithm of enrolment rates (lnEnrollment) and technological investment (tech) indicate that sample enterprises also exhibit certain disparities in educational resources and technological investment, which may exert differing effects on their export performance. The results are shown in Table 2.

Table 2. Descriptive Statistics

	N	Mean	SD	Min	Max
EXP	648	10.035	10.022	.634	58.044
GVC par	648	.322	0.160	.083	1.038
FDI	648	7.555	24.858	-117.375	279.361
lnEnrollment	648	101.638	6.000	70.244	146.541
tech	648	1.493	0.986	.054	4.93
growth	648	2.312	4.093	-14.839	24.475
laborf	648	15.947	1.690	12.269	20.476
service	648	10.531	0.903	7.651	12.407

7.2. Multicollinearity Test

According to conventional criteria for collinearity testing, a VIF value exceeding 10 typically indicates significant collinearity concerns among variables. However, the current test results demonstrate that the VIF values for each variable are substantially below this critical threshold. This finding strongly suggests that within the established model framework, no severe collinearity risks exist between the variables. This characteristic provides robust support for the model's validity and stability. It establishes a reliable foundation for subsequent in-depth exploration of the mechanisms through which each variable influences export performance, as well as the intricate interplay between them. This approach effectively mitigates model bias and erroneous inferences arising from multicollinearity, thereby ensuring greater scientific rigour and credibility in the research findings. The results are shown in Table 3.

Table 3. Multicollinearity Test

	EXP	GVC_par	FDI	lnEnrollment	tech	growth	laborf	service	Vif
EXP	1								-
GVC_par	0.063	1							2.03
FDI	0.004	0.211***	1						1.09
lnEnrollment	0.020	-0.156***	0.017	1					1.04
tech	0.112***	-0.074*	-0.126***	0.049	1				1.90
growth	0.091**	0.157***	0.038	0.056	-0.136***	1			1.17
laborf	0.070*	-0.661***	-0.216***	0.155***	0.057	0.104***	1		2.05
service	0.051	0.237***	0.069*	0.006	0.623***	-0.198***	-0.296***	1	2.11
*** p<0.01, ** p<0.05, * p<0.1									

7.3. Hausmann Test

For panel data, random effects regression and fixed effects regression are the two primary approaches. To determine the final model selected for this paper, the Hausman test was employed to discern whether random effects regression or fixed effects regression should be used. The results are presented in Table 4, where the p-value is 0.0000, significantly less than 0.05. This indicates that the Hausman test rejects the null hypothesis for the random effects model, thereby confirming that the fixed effects model should be adopted.

Table 4. Hausmann Test

Inspection Type	Chi2 (7)	P value
Hausmann Test	72.54	0.0000

7.4. Baseline Regression

In all seven models, the coefficient of global value chain embeddedness (GVC_par) on export performance (EXP) remained statistically significant. In the initial model m1, which included only GVC_par, the coefficient was 8.023 (robust standard error 3.487), significant at the 5% level. As additional control variables were progressively incorporated, the coefficient fluctuated—for instance, in model m7 it became 10.937 (robust standard error 3.404)—yet consistently remained statistically significant at the 1% level. This indicates a relatively stable and positive correlation between the degree of global value chain (GVC) integration and export performance. It suggests that, across varying variable contexts, a higher level of a country or region's integration into global value chains is often associated with superior export performance, highlighting the significant role this variable plays in enhancing export outcomes.

Following the introduction of the foreign direct investment (FDI) variable in model M2, its coefficient remained negative across all models and generally significant at the 10% level. The coefficient values stabilised between approximately -0.010 and -0.011, with a robust standard error of around 0.006. This indicates that, within the current research sample and model specifications, increased foreign direct investment may exert a certain inhibitory effect on export performance. This could stem from short-term negative impacts of foreign capital inflows on local industrial structures and market competition, or from resource misallocation, thereby hindering export performance enhancement.

Upon incorporating the education enrolment rate variable (lnEnrollment) into model m3, its coefficient exhibited variations across some models. However, in model m7, it reached 0.086 (robust standard error of 0.040) and proved statistically significant at the 5% level. This indicates that higher educational enrolment rates generally exert a positive driving force on export performance. A higher enrolment rate implies a more abundant reserve of high-quality human resources, which can help enhance industrial productivity and product quality, thereby positively influencing export performance. However, its effect exhibits some volatility across different models, suggesting that its impact may be influenced by interactions with other variables.

The coefficient of the technological investment (tech) variable exhibits considerable instability, with varying degrees of significance across different models. For instance, in model m4, the coefficient stands at 0.130 (robust standard error of 0.597), whereas subsequent models show fluctuating coefficients, some failing to attain statistical significance. This reflects the complex nature of technology investment's impact on export performance, potentially constrained by factors such as current conversion efficiency and integration with industry. Its positive driving effect on export performance has not been consistently and stably demonstrated, necessitating deeper analysis of its operational mechanisms and enabling conditions.

The GDP growth rate variable (growth) yielded coefficients that were not highly significant across all models, fluctuating between 0.015 and 0.038, with robust standard errors around 0.042. This indicates that within the current analytical framework, the direct impact of GDP growth rate on export performance is not particularly pronounced. It is possible that the effects of economic environment changes brought about by GDP growth on export performance are masked by the influence of other variables, or that a more complex non-linear relationship exists between them.

The coefficient for the proportion of service sector employment (laborf) is negative upon inclusion in the model and reaches 10% significance in certain models (e.g., m6, m7), with values of -6.741 (robust standard error 3.693) and -5.948 (robust standard error 3.464). This suggests that an increase in the share of service sector employment may be detrimental to export performance enhancement. It may reflect that the current excessive absorption of labour by the service sector could lead to relatively insufficient labour input in other industries, thereby exerting a certain negative impact on the development and performance of export industries.

In the final model m7, the service level coefficient was 11.060 (robust standard error 1.832) and significant at the 1% level, indicating that enhanced service sector development exerts a strong positive influence on export performance. A high-level service sector can provide export industries

with superior and efficient supporting services, such as logistics and financial support, thereby enhancing the competitiveness of export products and improving export performance.

Judging by R^2 and adjusted R^2 , the fit of the model improves as control variables are progressively added. the model's goodness of fit improved. For instance, model m1 had an R^2 of 0.941 and an adjusted R^2 of 0.934, whereas model m7 achieved an R^2 of 0.946 and an adjusted R^2 of 0.939. This demonstrates that progressively incorporating more appropriate control variables effectively explains variations in export performance, thereby continuously optimising the model's fit to the data. The results are shown in Table 5.

Table 5. Baseline Regression

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	EXP	EXP	EXP	EXP	EXP	EXP	EXP
GVC_par	8.023** (3.487)	7.217** (3.367)	7.458** (3.339)	7.414** (3.354)	6.536* (3.408)	5.894* (3.496)	10.937*** (3.404)
FDI		-0.010* (0.006)	-0.011* (0.006)	-0.010* (0.006)	-0.011* (0.006)	-0.011* (0.006)	-0.010* (0.005)
lnEnrollment			0.047 (0.038)	0.047 (0.038)	0.043 (0.038)	0.048 (0.037)	0.086** (0.040)
tech				0.130 (0.597)	0.148 (0.597)	0.041 (0.582)	-0.011 (0.547)
growth					0.038 (0.042)	0.024 (0.042)	0.015 (0.042)
laborf						-6.741* (3.693)	-5.948* (3.464)
service							11.060*** (1.832)
_cons	7.450*** (1.123)	7.788*** (1.089)	2.965 (3.915)	2.755 (3.831)	3.372 (3.895)	110.748* (60.637)	-23.766 (65.250)
Country (Region)	Control	Control	Control	Control	Control	Control	Control
Time	Control	Control	Control	Control	Control	Control	Control
N	648	648	648	648	648	648	648
R2	0.941	0.942	0.942	0.942	0.942	0.942	0.946
Adj.R2	0.934	0.935	0.935	0.935	0.935	0.935	0.939

Note: The figures in brackets denote robust standard errors. *, **, and *** denote significance levels of 10%, 5%, and 1% respectively.

7.5. Mediation Effect Test

Direct impact: In Model 1, the coefficient of GVC_par on export performance (EXP) is 10.937 (significant at the 1% level). This reflects the initial direct impact of global value chain embeddedness on export performance: higher embeddedness correlates with better export performance when controlling for no mediating variables. This aligns with findings from the baseline regression, reaffirming the stable positive relationship between the two.

Indirect effect (mediated by production efficiency): In Model 2, the coefficient of GVC_par on production efficiency (lnEfficiency) is 4.031 (significant at the 1% level), indicating that the degree of global value chain integration significantly and positively influences production efficiency. This implies that a higher degree of integration contributes to enhanced production efficiency. In Model 3, when both GVC_par and production efficiency (lnEfficiency) are included to explain export performance, the coefficient for GVC_par becomes 8.449 (significant at the 5% significance level), a decrease compared to Model 1. Meanwhile, the coefficient for production efficiency (lnEfficiency) itself is 0.617 (significant at the 1% significance level). This indicates that production efficiency partially mediates the relationship between GVC embeddedness and export performance. Specifically, GVC embeddedness exerts a direct effect on export performance while also exerting an indirect positive influence through the mediating variable of enhanced production efficiency. The results are shown in Table 6.

Table 6. Mediation Effect Test

	(1)	(2)	(3)
	EXP	lnEfficiency	EXP
GVC_par	10.937*** (3.404)	4.031*** (1.397)	8.449** (3.542)
lnEfficiency			0.617*** (0.216)
FDI	-0.010* (0.005)	-0.000 (0.002)	-0.009 (0.006)
lnEnrollment	0.086** (0.040)	0.006 (0.006)	0.082** (0.040)
tech	-0.011 (0.547)	-0.330** (0.148)	0.193 (0.544)
growth	0.015 (0.042)	0.035*** (0.013)	-0.007 (0.041)
laborf	-5.948* (3.464)	-1.352 (0.937)	-5.113 (3.407)
service	11.060*** (1.832)	6.182*** (0.789)	7.245*** (2.326)
_cons	-23.766 (65.250)	-36.097** (17.966)	-1.492 (66.991)
Country (Region)	Control	Control	Control
Time	Control	Control	Control
N	648	648	648
R2	0.946	0.991	0.947
Adj.R2	0.939	0.990	0.940

7.6. Heterogeneity Test

Table 7. Heterogeneity Test

	Developed Countries	Developing Countries
	EXP	EXP
GVC_par	9.271** (3.632)	10.569* (6.051)
FDI	-0.010* (0.005)	-0.009 (0.017)
lnEnrollment	-0.001 (0.049)	0.123** (0.053)
tech	0.158 (0.534)	-1.953* (1.142)
growth	-0.032 (0.055)	0.043 (0.071)
laborf	-2.477 (3.814)	-7.055* (3.663)
service	22.944*** (2.916)	8.402*** (2.828)
_cons	-208.008*** (68.906)	33.381 (72.223)
Country (Region)	Control	Control
Time	Control	Control
N	420	228
R2	0.943	0.957
Adj.R2	0.935	0.948

The 56 sample countries and regions were divided into two groups: 33 developed countries and regions, and 23 developing countries and regions. Within the developed countries (regions) sample, the coefficient for Global Value Chain Participation (GVC_par) was significantly positive (9.271**) and statistically highly significant ($P < 0.05$). This finding indicates that for developed countries

(regions), increased participation in global value chains exerts a significant positive effect on ICT services exports. This suggests developed countries and regions prioritise deepening their involvement in global value chains and enhancing the development level of their service sectors.

In the developing country sample, the coefficient for GVC_{par} was also significantly positive (10.569*), though its statistical significance was marginally lower than in the developed country (region) model ($P < 0.1$). This indicates that for developing countries, increased participation in global value chains also exerts a significant positive effect on ICT service exports. However, the statistical significance of this effect is somewhat weaker, potentially because developing countries remain in the early stages of integration or face greater external challenges. The results are shown in Table 7.

8. Conclusions and Policy Implications

This study constructs a theoretical model linking global value chain (GVC) embeddedness, production efficiency, and ICT services export performance to explore the impact mechanism of GVC embeddedness on ICT services export performance. It focuses on analysing the mediating role of production efficiency in this process. Empirical analysis indicates that deep participation in GVCs significantly enhances production efficiency in the ICT services sector, while improved production efficiency further stimulates growth in corporate export performance. The following conclusions are drawn from this paper:

First, developing countries should actively pursue opportunities for deep integration into global value chains. This can be achieved by formulating preferential policies to attract foreign investment, strengthening infrastructure development, and other measures to reduce the costs of enterprise participation in GVCs, thereby enhancing their involvement within these chains [13]. Concurrently, emphasis should be placed on ascending from mid-to-low value-added segments towards higher-value-added segments within the GVCs. Increased investment in high-value-added activities such as R&D, design, and brand marketing is essential to elevate their position within the global division of labour, thereby securing greater trade benefits and enhancing export performance potential [14]. Developed economies should consolidate their dominant positions in high-value-added segments of the GVCs, strengthen innovation cooperation and knowledge sharing with other nations, and further expand their global market share. Concurrently, attention should be paid to the dynamic changes in the GVCs, with timely strategic adjustments made to address competitive challenges from emerging economies and maintain stable growth in export performance.

Secondly, governments should encourage enterprises to increase investment in technological innovation, establish robust science and technology innovation systems, and provide policy support such as R&D subsidies and tax incentives to facilitate the conversion of scientific achievements into tangible productive capacity. By enhancing production efficiency and strengthening the core competitiveness of ICT services, the intermediary role of productivity in linking global value chain integration with export performance can be better leveraged [15].

Thirdly, nations should strengthen education and training systems to enhance workforce quality and skill levels, providing enterprises with high-calibre human resources capable of adapting to new technologies and emerging industries. Developing countries, in particular, must increase educational investment to boost enrolment rates and educational quality, cultivating more professionals with innovative capabilities and international perspectives to provide robust talent support for ICT service sector development.

Fourthly, countries should rationally guide the flow of foreign direct investment (FDI) according to their stage of economic development and industrial structure characteristics, avoiding excessive concentration in specific sectors that could lead to industrial imbalances or crowding-out effects on local enterprises. FDI should be encouraged towards high-value-added and strategically significant sectors such as high-tech industries and emerging services, thereby promoting industrial restructuring and upgrading while enhancing the overall export competitiveness of the economy.

Fifthly, countries should strengthen support and regulation of domestic service industries to drive internal restructuring and upgrading [16]. Developing nations should focus on enhancing service specialisation and quality, fostering synergies between services and other sectors, and amplifying the positive contribution of services to export performance. Developed economies should maintain their innovation edge in services, explore new business models and formats, and cultivate a more favourable environment for ICT service exports.

Sixth, given the heterogeneity among nations at different developmental stages regarding global value chain integration and the impact of controlling variables, countries should formulate targeted policy measures. Developing nations should prioritise addressing technical bottlenecks and talent shortages encountered during global value chain upgrading, strengthen infrastructure development and institutional innovation, and enhance policy flexibility and adaptability [17]. Developed nations, meanwhile, should monitor shifts in the global economic landscape and emerging technological trends, enhancing forward-looking policy research and formulation to maintain their leading positions in global trade and technological innovation. Concurrently, countries should strengthen policy coordination and cooperation to jointly address global challenges and foster the healthy, sustainable development of global ICT services trade.

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