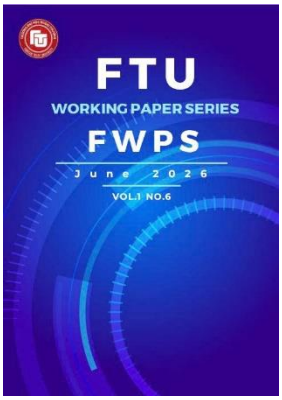

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VAI TRÒ TRUNG GIAN CỦA ỨNG DỤNG SỐ TRONG MỐI QUAN HỆ GIỮA DỊCH VỤ PHÂN PHỐI KỸ THUẬT SỐ VÀ HIỆU QUẢ XUẤT KHẨU: BẰNG CHỨNG CẤP QUỐC GIA TỪ 143 NỀN KINH TẾ MỚI NỔI VÀ ĐANG PHÁT TRIỂN

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Tóm tắt

Nghiên cứu phân tích tác động của dịch vụ phân phối kỹ thuật số (Digitally Delivered Services) đến hiệu quả xuất khẩu tại 143 nền kinh tế mới nổi và đang phát triển giai đoạn 2014-2023, đồng thời kiểm định vai trò trung gian của mức độ ứng dụng số (Digital Adoption). Nghiên cứu sử dụng khung phân tích dựa trên mô hình lực hấp dẫn kết hợp với mô hình phương trình cấu trúc (SEM) trên dữ liệu bảng nhằm đánh giá đồng thời tác động trực tiếp và gián tiếp giữa các biến. Kết quả

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cho thấy dịch vụ phân phối kỹ thuật số có ảnh hưởng tích cực đến hiệu quả xuất khẩu và thúc đẩy mức độ ứng dụng số, đồng thời ứng dụng số cũng đóng vai trò trung gian một phần trong mối quan hệ này. Kết quả nghiên cứu nhấn mạnh rằng lợi ích từ thương mại số phụ thuộc đáng kể vào mức độ sẵn sàng số và năng lực hấp thụ công nghệ của nền kinh tế.

Từ khóa: *dịch vụ phân phối kỹ thuật số, hiệu quả xuất khẩu, mô hình lực hấp dẫn, ứng dụng số*

THE MEDIATING ROLE OF DIGITAL ADOPTION IN THE RELATIONSHIP BETWEEN DIGITALLY DELIVERED SERVICES AND EXPORT PERFORMANCE: EVIDENCE FROM 143 EMERGING AND DEVELOPING ECONOMIES

Abstract

This study examines the impact of digitally delivered services (DDS) on export performance in 143 emerging and developing economies during the period 2014-2023 while testing the mediating role of digital adoption. An extended gravity model estimated using Structural Equation Model (SEM) is applied to panel data to evaluate both direct and indirect relationships among the variables. The results show that digitally delivered services have a positive and statistically significant effect on export performance and also promote digital adoption. In turn, digital adoption positively influences export performance and partially mediates the relationship between DDS and export outcomes. These findings suggest that the benefits of digital trade depend strongly on the level of digital readiness and technological absorption capacity of national economies.

Keywords: *digital adoption, digitally delivered services, emerging and developing economies, export performance, gravity model*

1. Introduction

Digitally delivered services (DDS), defined as services supplied across borders through computer networks without requiring physical proximity between supplier and consumer (WTO, 2023a), have become a defining feature of contemporary international trade. According to the World Trade Organization (2023), global exports of DDS reached nearly US$4 trillion in 2022, almost four times their 2005 level, demonstrating both exceptional growth and resilience during

the COVID-19 pandemic. This development highlights the growing importance of digital connectivity and cross-border data flows in shaping global trade patterns.

For many emerging and developing economies, DDS presents both opportunities and structural challenges. While DDS can reduce transaction costs and expand access to international markets by enabling remote service provision (Freund & Weinhold, 2002; López González & Jouanjean, 2017), its benefits are unevenly distributed and remain concentrated in digitally advanced economies (UNCTAD, 2021). The ability to translate digital trade opportunities into improved export performance critically depends on the level of digital adoption, including infrastructure readiness, digital skills, and institutional capacity (Roy & Sauvé, 2023).

However, while most existing studies focus primarily on the direct relationship between DDS and export performance, the mediating role of digital adoption through which DDS influence export performance has not been adequately addressed in prior research. Therefore, this study aims to address the following research question: *Do digitally delivered services affect export performance only directly, or also indirectly through the mediating role of digital adoption?* By investigating both channels, the study provides empirical evidence relevant to digital transformation strategies and export-oriented development.

2. Literature review

2.1. The direct impact of digitally delivered services on export performance

Digitally delivered services are defined as international service transactions delivered remotely over computer networks (WTO, 2023a). Early empirical studies emphasized the role of digital infrastructure in facilitating export growth. Freund and Weinhold (2002) found that a 10% increase in web servers is associated with a 0.2 percentage-point increase in export growth, arguing that the Internet reduces fixed market entry costs.

More recent research focuses particularly on digitally delivered services. Abeliansky et al. (2020) found that improvements in telecommunications infrastructure reduce trade barriers and promote exports of digital services such as finance and telecommunications more effectively than traditional services. Lopes and Ferreira (2022) concluded that countries with higher digital readiness tend to achieve larger service trade surpluses and greater resilience to shocks. At the sectoral level, Lanz and Maurer (2015) highlighted the role of digital services as intermediate inputs that increase export value added. Similarly, Loungani et al. (2017) documented that exports

of digitally deliverable services have grown faster than traditional services requiring physical presence. Leogrande et al. (2022) noted stronger effects in knowledge-intensive sectors, while Banga (2019) warned of value concentration on large digital platforms, potentially limiting competitiveness in developing economies.

2.2. The indirect impact of digitally delivered services on export performance

2.2.1. Digitally delivered services as a driver of digital adoption

Most studies view digital adoption as a prerequisite for participation in digital trade, as digital infrastructure and technological capabilities enable economies to engage in digital service exports (Di et al., 2022; Zhang & Wang, 2022).

However, emerging evidence suggests that the relationship may also work in the opposite direction, where the expansion of DDS stimulates technological upgrading and digital capability formation. Using firm-level data, Qiu, Yu, and McCollough (2023) find that participation in digital service trade significantly promotes technological innovation in manufacturing firms. At the macro level, Shepherd (2022) argues that liberalization of DDS can generate spillover effects across industries through global value chain linkages, which are often associated with technological and functional upgrading.

Similarly, López González and Jouanjean (2017) show that digital technologies, reflected in indicators such as digital connectivity and cross-border data flows, facilitate global value chains by reducing coordination costs and enabling the transfer of managerial and technological knowledge. Roy and Sauvé (2023) also highlight the role of digital connectivity in lowering trade costs for digitally deliverable services.

Although empirical evidence remains limited, these studies suggest that beyond the commonly discussed direction from digital adoption to digital trade, the expansion of DDS may also encourage technological spillovers and incentives for further digital adoption.

2.2.2. The impact of digital adoption on export performance

A large body of research indicates that digital adoption improves export outcomes through several mechanisms. At the firm level, digital technologies such as internet use, websites, ICT systems, and digital payments increase the likelihood of export participation and influence export intensity (Reddy & Sasidharan, 2024; Hagsten & Kotnik, 2016).

Other studies emphasize productivity improvements and market expansion as key channels. Castellani et al. (2022) and Pattanyak (2025) show that greater digital investment enhances firm

productivity and expands international market reach. Recent research also highlights capability upgrading as an important mechanism, as digital technologies strengthen firms' digital trade capabilities and support upgrading within global value chains (Oh & Hwang, 2025; Chen et al., 2025).

At the country level, empirical evidence is more limited but generally supports similar conclusions. Choi (2010) finds that internet diffusion significantly increases service trade, while Freund and Weinhold (2004) and Clarke and Wallsten (2006) show that internet development reduces information and communication costs in international trade. However, the effects of digital connectivity vary across economies: digital connectivity tends to play a larger role in developing countries by easing information constraints and improving market access, while its marginal impact is smaller in developed economies where digital infrastructure is already widespread (Mirzaye & Mohiuddin, 2025).

2.2.3. The indirect impact of digitally delivered services through digital adoption

Prior studies suggest that DDS and digital adoption are both associated with export performance through different mechanisms. Participation in digitally delivered trade may generate technological spillovers and upgrading dynamics by exposing firms and economies to digital technologies and global value chain linkages (Qiu, Yu & McCollough, 2023; Shepherd, 2022).

At the same time, extensive evidence shows that digital adoption enhances export performance by improving productivity, reducing trade costs, and strengthening firms' capabilities in international markets (Reddy & Sasidharan, 2024; Castellani et al., 2022; Oh & Hwang, 2025).

Taken together, although studies examining these relationships simultaneously remain limited, the existing literature suggests a potential indirect linkage in which digital adoption acts as a transmission channel connecting DDS and export outcomes.

2.3. Research gap

Despite growing research on digitalization and trade, the relationship between digitally delivered services, digital adoption, and export performance remains insufficiently integrated. Existing studies often examine these factors separately, focusing either on the direct trade effects of digital services or the productivity gains from digital technologies. Moreover, most evidence is based on firm-level data or developed economies, leaving country-level dynamics in emerging and developing economies underexplored. In particular, limited attention has been given to the mediating role of digital adoption in linking digitally delivered services to export outcomes. This

study addresses this gap by modeling digital adoption as a mediating variable within an extended gravity framework for emerging and developing economies.

3. Theoretical framework

3.1. Foundational theories

3.1.1. Gravity model of trade

The gravity model is a popular theoretical framework for analyzing global trade flows, initiated by Jan Tinbergen (1962). Based on Newton's law of universal gravitation, the gravity model posits that bilateral trade flows increase with economic size and decrease with trade costs. In its simplest form, this relationship can be expressed as:

$$T_{ij} = A\frac{Y_i \, x \, Y_j}{D_{ij}}$$

A significant turning point came from the research of Anderson and van Wincoop (2003) when they introduced the concept of multilateral trade resistance. This theoretical framework emphasizes that bilateral trade is not only affected by direct barriers between two countries, but also depends on the relative level of barriers they face with all other partners globally. Therefore, reducing trade costs plays a core role in helping businesses penetrate international markets and optimize export performance.

3.1.2. Heterogenous-firm trade theory

The heterogeneous-firm trade theory developed by Marc J. Melitz (2003) provides a microeconomic foundation for understanding firms' participation in international trade and the role of trade costs in export performance. Unlike traditional trade theories such as the Ricardian model and Heckscher-Ohlin model, which assume identical firms within an industry, Melitz shows that firms differ significantly in productivity. Because exporting involves fixed costs, only more productive firms can enter export markets. When trade costs decline, more firms begin exporting (extensive margin) and existing exporters expand their export volumes (intensive margin). In modern trade, digital technologies and DDS further facilitate information access and cross-border coordination.

3.1.3. Endogenous growth theory

Endogenous growth theory emphasizes the role of technological progress and knowledge accumulation as key drivers of long-term economic growth. According to Paul Romer (1990),

knowledge and technology exhibit characteristics of increasing returns and positive spillovers, meaning that the creation and diffusion of knowledge can generate long-lasting improvements in productivity.

In the context of the digital economy, digital technologies and DDS represent important channels for technological diffusion and knowledge transmission across countries. These interactions stimulate learning processes and encourage domestic firms to adopt new technologies.

3.2. Conceptual framework and hypothesis development

3.2.1. Direct impact of digitally delivered services on export performance

Within the structural gravity framework, DDS may enhance export performance by reducing trade costs. Delivered through digital networks, DDS reduces coordination costs and facilitates access to international markets. Empirical studies show that improvements in Internet infrastructure and digital connectivity are associated with higher exports (Freund & Weinhold, 2002; Choi, 2010; Nath & Liu, 2017).

From the perspective of heterogeneous-firm trade theory, reductions in fixed export costs allow more firms to enter foreign markets and expand the extensive margin of trade (Melitz, 2003). As a result, DDS functions as a trade-cost-reducing factor that directly strengthens export performance.

Based on the above arguments, the following hypothesis is proposed:

H1: Digitally Delivered Services (DDS) have a positive and statistically significant effect on Export Performance (EP)

3.2.2. Digitally delivered services and export performance: The mediating role of digital adoption

Beyond direct cost reduction, DDS may influence export performance indirectly through digital adoption. From the perspective of endogenous growth theory (Romer, 1990), exposure to technology-intensive activities generates knowledge spillovers and incentives for upgrading. Participation in DDS exposes economies to international digital standards and technologically embedded practices.

Empirical evidence supports this upgrading mechanism. Qiu, Yu, and McCollough (2023) find that digital service trade positively affects technological innovation. Shepherd (2022) highlights spillovers through global value chain linkages, while studies on digital trade also emphasize the role of digital connectivity and infrastructure in facilitating knowledge diffusion and technological capability building (López González & Jouanjean, 2017; Roy & Sauvé, 2023). At the same time,

participation in digitally delivered trade often requires technological upgrading and adequate digital infrastructure (WTO, 2023b; UNCTAD, 2021).

Based on this mechanism, the following hypothesis is proposed:

H2: Digitally Delivered Services (DDS) have a positive and statistically significant effect on Digital Adoption Index (DAI).

The positive relationship between digital adoption and export performance can be explained by the gravity model of trade. According to Anderson & van Wincoop (2003), digital technologies such as internet connectivity and ICT systems reduce trade costs by lowering information frictions, communication barriers, and coordination costs in international transactions. Lower trade costs facilitate firms' access to foreign markets and increase cross-border trade flows. This mechanism is also consistent with the heterogeneous-firm trade theory proposed by Melitz (2003), which suggests that improvements in productivity allow more firms to overcome substantial fixed export costs and enter international markets. Empirical studies support these mechanisms, showing that firms adopting digital technologies are more likely to participate in export markets and achieve higher export intensity (Reddy & Sasidharan, 2024; Castellani et al., 2022).

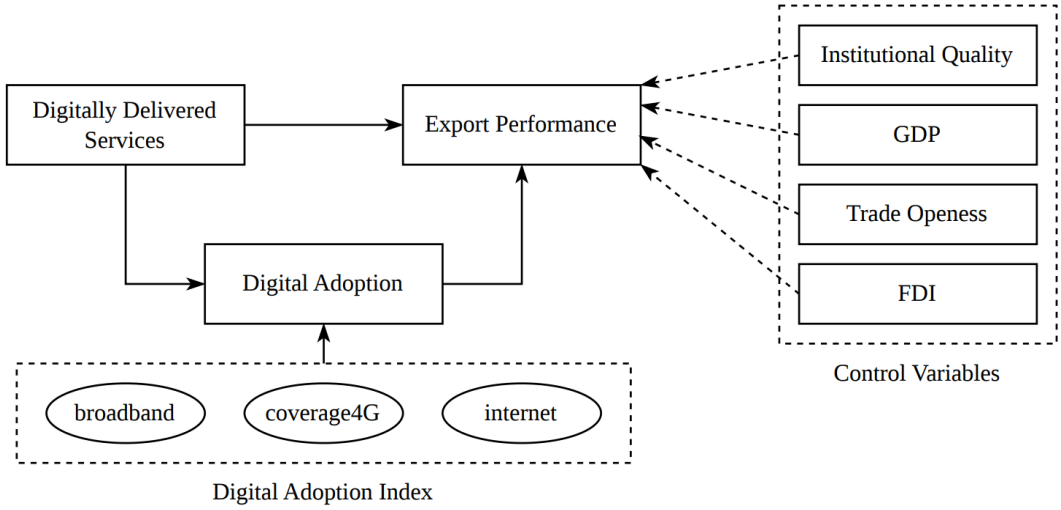
H3: Digital Adoption Index (DAI) has a positive and statistically significant effect on Export Performance (EP).

Taken together, these findings suggest a two-stage structural mechanism. Expansion of DDS increases demand for broadband infrastructure, data-processing capacity, and digital security, thereby stimulating digital adoption. Enhanced digital adoption, in turn, improves export performance by reducing coordination costs, strengthening connectivity, and facilitating integration into global digital value chains.

Within this integrated framework, digital adoption operates as a mediating variable linking DDS and export performance. DDS may therefore affect export outcomes not only through direct trade-cost reduction but also through structural improvements in national digital capacity.

H4: Digital Adoption Index (DAI) plays a mediating role in the relationship between DDS and EP.

3.2.3. Conceptual framework



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4. Research methodology and model

4.1. Research model

To rigorously test both direct and mediating effects, this study employs a structural model that integrates the Extended Structural Gravity Model formalized by Baier and Bergstrand (2001) with the chain mediation framework explicitly proposed by Qiu et al. (2023). The empirical strategy relies on two interconnected system equations estimated via Partial Least Squares Structural Equation Modeling (PLS-SEM), which allows for the simultaneous evaluation of complex causal pathways.

The study employs two interconnected model blocks estimated via Partial Least Squares Structural Equation Modeling (PLS-SEM):

A. Mediation Model

$$DAI_{i,t} = \gamma_0 + \gamma_1 DDS_{i,t} + \Gamma' Z_{i,t} + \mu_i + \lambda_t + \nu_{i,t}$$

Where:

- $DAI_{i,t}$: Level of digital adoption of country i at time t
- $DDS_{i,t}$: Digitally delivered services
- $Z_{i,t}$: Vector of macroeconomic control variables (GDP, institutional quality, FDI, trade openness)

- μ_i, λ_t: Country and year fixed effects
- $\nu_{i,t}$: Stochastic error term

B. Outcome Model

$$EP_{i,t} = \beta_0 + \beta_1 DDS_{i,t} + \beta_2 DAI_{i,t} + B'X_{i,t} + \phi_i + \tau_t + \epsilon_{i,t}$$

Where:

- $EP_{i,t}$: Export Performance of country i at time t.
- β_1 : Coefficient capturing the direct effect of DDS on EP
- β_2 : Coefficient capturing the direct effect of DAI on EP
- $X_{i,t}$: Vector of identical macroeconomic control variables.
- ϕ_i, τ_t: Country and year fixed effects

4.2. Research data

The dataset covers 143 developing economies from 2014-2023. Export Performance (EP) is obtained from UNCTAD and CEPII, while Digitally Delivered Services (DDS) are sourced from the WTO. The mediating variable, Digital Adoption Index (DAI), is constructed using PCA/SEM based on three indicators from the World Bank and ITU, including internet usage, broadband subscriptions, and 4G coverage. Control variables include GDP (World Bank) and Institutional Quality, measured using PCA from six governance indicators in the Worldwide Governance Indicators.

Table 1. List of variables and sources

Variable	Description	Expected Sign	Supporting Literature (Sources)
Dependent Variable			
EP	**Export Performance**: Total export value of the developing economies.	N/A	Anderson & van Wincoop (2003); Melitz (2003); Yotov et al. (2016)
Independent Variable			

DDS	**Digitally Delivered Services**: Export value of services delivered digitally across borders.	**(+)**	Meltzer (2014); González & Ferrier (2016); UNCTAD (2015)
Mediating Variable			
DAI	**Digital Adoption Index**: A latent construct reflecting the level of digital technology penetration, measured by: *internet*: Internet users (% of population); *broadband*: Fixed broadband subscriptions; *coverage 4G*: Population covered by at least a 4G mobile network	**(+)**	Freund & Weinhold (2004); Clarke & Wallsten (2006); Choi (2010); Li et al. (2020)
Control Variables			
gdp_o	**Economic Size (GDP)**: Gross Domestic Product of the origin (exporting) country.	**(+)**	Tinbergen (1962); Anderson & van Wincoop (2003); Baier & Bergstrand (2001)
inst_o	**Institutional Quality**: A composite index (via PCA) of six governance dimensions (e.g., rule of law, regulatory quality) from WGI.	**(+)**	Anderson & Marcouiller (2002); Levchenko (2007); Kaufmann, Kraay, & Mastruzzi (2010)
ln_FDI	**Foreign Direct Investment**: The natural logarithm of net FDI inflows. Captures the capital, technology, and market access brought by foreign firms.	**(+)**	Helpman, Melitz, & Yeaple (2004); Harding & Javorcik (2012)
Trade	**Trade Openness:** The sum of exports and imports of goods and services measured as a share of GDP. Reflects the country's integration into the global market.	**(+)**	Frankel & Romer (1999); Alcalá & Ciccone (2004)

Source: Compiled by Author

The FDI variable is log-transformed to reduce skewness and scale differences and to allow coefficient interpretation in percentage terms. In contrast, trade openness and institutional quality

are measured as ratios or standardized indices with relatively stable scales, so they are retained in their original form.

4.3. Research methodology

This study employs Partial Least Squares Structural Equation Modeling (PLS-SEM) to examine the relationships among variables. PLS-SEM is particularly appropriate for this research rather than traditional panel regression or CB-SEM for several reasons. First, Digital Adoption Index is a latent construct measured by multiple indicators; PLS-SEM enables simultaneous estimation of measurement and structural models while accounting for measurement error, which traditional regression cannot address. Second, compared with CB-SEM, PLS-SEM requires fewer distributional assumptions and is more suitable for non-normal, heterogeneous cross-country macroeconomic data. Third, PLS-SEM is particularly appropriate for variance explanation, prediction-oriented research, and the estimation of mediating effects within a single framework.

To construct the Digital Adoption Index (DAI), this study integrates Principal Component Analysis (PCA) within the PLS-SEM algorithm. Unlike simple averaging, which assumes equal weights and risks multicollinearity among interdependent digital indicators, this PCA-based approach extracts the first principal component to maximize explained variance. This data-driven transformation objectively weights the three infrastructural variables (internet usage, broadband subscriptions, and 4G coverage), yielding a robust, unidimensional continuous latent score for the structural model.

Reliability is assessed using Cronbach's Alpha and Composite Reliability, while convergent validity is evaluated using AVE. Discriminant validity is examined using the Heterotrait-Monotrait ratio (HTMT). Multicollinearity is tested using the Variance Inflation Factor (VIF), and outliers are screened to ensure the robustness of the model.

5. Result

5.1. Descriptive statistics

Table 2. Descriptive Statistics

Name	Mean	Median	Standard deviation	Excess kurtosis	Skewness	Cramér-von Mises p-value
DDS	3805.615	233.275	17349.791	95.889	9.126	0.000
internet	48.890	53.001	28.605	-1.182	-0.131	0.000
broadband	8.661	4.099	10.052	1.045	1.243	0.000
coverage4G	55.146	65.000	37.955	-1.494	-0.285	0.000

gdp_o	24999402 4659.290	24534663 636.178	126852264 9687.056	134.729	11.101	0.000
inst_o	-0.003	0.035	0.999	-0.313	-0.160	0.002
EP	64707123 881.730	70738597 41.000	256595584 553.342	113.101	9.849	0.000
Trade	67.765	62.841	46.294	2.497	0.906	0.000
FDI	- 21979803 31.065	- 34566154 9.170	110136930 97.996	111.133	-2.995	0.000
ln_FDI	-14.015	-20.354	14.333	1.527	1.743	0.000

Source: Authors' calculations using SmartPLS software

The mean value of DDS is 3805.615 (SD = 17349.791), indicating substantial disparities in digital service development across countries. EP has a mean value of 64707123881.730, reflecting significant differences in export capacity among economies. The components of DAI - Internet usage, fixed broadband subscriptions, and 4G coverage - show an upward trend over time, consistent with ongoing global digital transformation.

5.2. Measurement model assessment

The measurement model is evaluated to test the reliability and validity of the latent construct DAI. All factor loadings exceed the recommended threshold of 0.70, ranging from 0.727 to 1.00, indicating that the observed variables adequately reflect the latent structure.

Table 3. Reliability and Convergent Validity Testing

	Cronbach's alpha	**Composite reliability (rho_a)**	**Composite reliability (rho_c)**	**Average variance extracted (AVE)**
DAI	0.819	0.874	0.889	0.727

Source: Authors' calculations using SmartPLS software

Internal consistency reliability is confirmed with a Cronbach's Alpha of 0.819, exceeding the acceptable threshold of 0.70. Composite Reliability (CR) reaches 0.874, indicating high consistency among measurement indicators. The Average Variance Extracted (AVE) is 0.727, greater than the recommended 0.50 threshold, confirming convergent validity.

Table 4. Discriminant Validity Testing (HTMT)

	DAI	**DDS**	**EP**	**Trade**	**gdp_o**	**inst_o**	**ln_FDI**
DAI							

DDS	0.192						
EP	0.270	0.777					
Trade	0.117	0.078	0.063				
gdp_o	0.198	0.765	0.976	0.097			
inst_o	0.423	0.084	0.068	0.198	0.021		
ln_FDI	0.102	0.038	0.000	0.038	0.002	0.128	

Source: Authors' calculations using SmartPLS software

Discriminant validity is assessed using the Heterotrait-Monotrait ratio (HTMT). Although the HTMT value between GDP and EP is relatively high, this is acceptable since GDP is a control variable rather than a core latent construct. VIF results remain within acceptable thresholds, indicating no serious multicollinearity issues.

Table 5. Multicollinearity Testing (VIF)

	VIF
DDS	1.000
EP	1.000
Trade	1.000
broadband	1.815
coverage4G	1.748
gdp_o	1.000
inst_o	1.000

Source: Authors' calculations using SmartPLS software

5.3. Model fit assessment

Overall model fit is assessed using PLS-SEM indices. The SRMR is 0.048, below the 0.08 threshold, indicating acceptable model error, while the NFI of 0.928 suggests a good fit between the theoretical model and observed data. The R^2 values show the model's explanatory power, with DAI at $R^2 = 0.033$ and EP at $R^2 = 0.946$, indicating strong explanatory capacity according to SEM standards.

Regarding the high R^2 of export performance (0.946), such values are not uncommon in cross-country macroeconomic studies, where structural variables (development level, trade integration, institutional quality) explain substantial variation in economic outcomes. In PLS-SEM, a high R^2 reflects strong explanatory power rather than overfitting. The robustness of the results is further

supported by statistically significant paths, theoretically consistent signs, and bootstrapping procedures, indicating stable and reliable estimates.

5.4. Structural model and hypothesis testing

The structural model is estimated using bootstrapping with 5,000 resamples to test statistical significance.

Table 6. Structural Model Results

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
DAI -> EP	0.061	0.063	0.012	5.229	0.000
DDS -> DAI	0.188	0.191	0.032	5.879	0.000
DDS -> EP	0.065	0.070	0.022	2.953	0.003
gdp_o -> EP	0.916	0.910	0.023	39.859	0.000
inst_o -> EP	0.017	0.017	0.006	2.859	0.004
ln_FDI -> EP	0.013	0.014	0.006	2.207	0.027
Trade -> EP	0.022	0.023	0.007	3.123	0.002

Source: Authors' calculations using SmartPLS software.

The results show that DDS positively affects EP ($\beta = 0.065$, $p < 0.05$) and DAI ($\beta = 0.188$, $p < 0.05$), supporting H1 and H2. DAI also positively influences EP ($\beta = 0.061$, $p < 0.05$), confirming H3. Among the control variables, GDP shows the strongest positive effect on EP($\beta = 0.916$, $p < 0.05$), followed by Institutional Quality ($\beta = 0.017$, $p < 0.05$), FDI ($\beta = 0.013$), and Trade Openness ($\beta = 0.022$), all of which are statistically significant.

5.5. Mediation analysis

Bootstrapping results show that the indirect effect of DDS on EP through DAI is $\beta = 0.010$, with the 95% bootstrap confidence interval excluding zero. This confirms a statistically significant mediation effect and supports Hypothesis H4. The finding suggests that DDS improves EP not only directly but also indirectly by increasing the level of DAI in emerging and developing economies. In other words, the diffusion of digital infrastructure and technologies enhances firms' ability to participate in international markets and strengthens export performance.

Table 7. Effect Size and Predictive Relevance

	DAI	DDS	EP	Trade	gdp_o	inst_o	ln_FDI
DAI			0.042				

DDS	0.034		0.011				
EP							
Trade			0.006				
gdp_o			6.654				
inst_o			0.004				
ln_FDI			0.005				

Source: Authors' calculations using SmartPLS software.

Table 7 presents the effect size (f^2) of each exogenous construct and the predictive relevance of the model. The results show that DDS has a small but meaningful effect on both DAI and EP, with f^2 values of 0.034 and 0.011, respectively. According to conventional benchmarks, these correspond to small effect sizes, indicating that DDS contributes incrementally to explaining the variance of the endogenous variables. Such modest effects are expected in macro-level cross-country analyses, where export performance is influenced by multiple structural factors.

The mediating role of DAI highlights digital transformation as a transmission mechanism linking DDS to export outcomes. Although the indirect effect size is relatively small, its statistical significance indicates that improvements in digital connectivity and technology diffusion strengthen the capacity of firms and economies to leverage digital services for export expansion.

Regarding the control variables, GDP shows the largest effect size ($f^2 = 6.654$), suggesting that economic scale remains a key determinant of EP. This is consistent with international trade theory, which emphasizes the importance of production capacity and market size for export competitiveness. Trade openness, institutional quality, and FDI also have positive but smaller effect sizes, indicating that their marginal contribution becomes more limited once broader macroeconomic factors are considered.

Overall, despite the relatively small f^2 values for several predictors, the path coefficients remain statistically significant ($p < 0.05$) and align with theoretical expectations. This suggests that the model captures meaningful relationships among DDS, DAI and EP while controlling for key macroeconomic factors. The results therefore provide empirical support for the role of digital transformation in shaping export dynamics in emerging and developing economies.

6. Discussion

6.1. Theoretical contributions

The results show that digitally delivered services (DDS) have a positive and significant effect on export performance, and partially transmitted through digital adoption. This suggests that the export benefits of DDS arise not only from reduced transaction costs but also from improvements in domestic digital capabilities.

The findings are consistent with Schumpeter's view that technological innovation reshapes production and markets, and with Solow's growth model, which highlights the role of technological progress in long-term growth. In this context, digital adoption acts as the mechanism through which digital technologies translate into productivity and export competitiveness.

The significance of GDP and institutional quality also supports North's institutional theory, indicating that effective institutions reduce uncertainty and transaction costs, allowing technology to generate economic gains.

From an academic perspective, the study contributes national-level empirical evidence for developing economies by integrating DDS, DAI, and EP within a unified framework. The use of SEM enables direct testing of mediation effects, clarifying transmission mechanisms rather than focusing solely on direct impacts. The findings suggest that digital trade policies should be accompanied by infrastructure investment and digital capability enhancement to maximize export performance.

6.2. Policy recommendations for Vietnam

The empirical findings reveal a significant divergence between the direct and indirect channels through which DDS affect export performance. Specifically, the direct impact of DDS on exports ($\beta = 0.065$) substantially outweighs the indirect effect mediated by domestic digital adoption ($\beta = 0.012$). This disparity indicates that digital trade directly increases exports, while its technological spillovers remain limited. Consequently, to achieve the National Digital Transformation Program's target of the digital economy contributing 30% of GDP by 2030, Vietnam's policy interventions must move beyond merely facilitating digital trade. Policymakers must prioritize targeted strategies that alleviate these structural bottlenecks, fostering deeper domestic digital integration and enhancing the technological absorptive capacity of local enterprises.

To capitalize on the direct trade effect ($\beta = 0.065$), where the reduction of trade costs generates substantial export gains, it is imperative for Vietnam to systematically alleviate behind-the-border

regulatory frictions. Policymakers should accelerate the country's integration into regional digital frameworks, notably the ASEAN Digital Economy Framework Agreement (DEFA), and establish streamlined mechanisms for cross-border data flows. Furthermore, providing transparent regulatory guidelines for navigating data localization mandates, such as the Personal Data Protection Decree (PDPD), is crucial. Clarifying these regulatory environments will significantly reduce compliance costs, thereby enhancing the capacity of domestic small and medium-sized enterprises (SMEs) to actively participate in the export of digitally delivered services.

The limited magnitude of the indirect mediation effect suggests a notable deficiency in the national "absorptive capacity." Consequently, the economic gains derived from digital trade appear to be concentrated within specific technological hubs rather than being widely dispersed across the broader economy. To optimize this transmission mechanism, policy interventions must bridge the physical infrastructure divide by facilitating targeted investments in the deployment of 5G networks and high-capacity data centers, particularly within rural and secondary economic zones. Concurrently, a strategic realignment of the national education framework is essential. Prioritizing STEM (Science, Technology, Engineering, and Mathematics) disciplines and artificial intelligence (AI) literacy will cultivate a workforce equipped to effectively absorb, adapt, and innovate upon the technological spillovers generated by international digital trade.

The empirical results regarding the control variables provide critical foundational insights for policy formulation. The modest impact of Foreign Direct Investment (FDI) ($\beta = 0.013$) reflects Vietnam’s ongoing structural challenge, often characterized by a "dual economy" where multinational enterprises operate with limited backward linkages to domestic firms. To address this fragmentation, Vietnam's FDI strategy must transition from prioritizing sheer volume to emphasizing the quality and spillover potential of incoming investments. Rather than mandating technology transfers, policymakers should strategically align investment incentives with voluntary technology sharing, local workforce upskilling, and the integration of domestic firms into global digital value chains. Furthermore, the positive coefficient for Institutional Quality ($\beta = 0.017$) underscores the fundamental role of regulatory efficacy. Strengthening the enforcement of intellectual property rights and accelerating the deployment of e-government administrative portals are critical prerequisites. These measures will cultivate a transparent and secure business environment, fostering the international trust necessary to expand digital service exports.

7. Conclusion and limitations

This study examines the impact of digitally delivered services (DDS) on export performance across 143 emerging and developing economies from 2014 to 2023, while testing the mediating role of digital adoption. The results show that DDS positively affect export performance, and digital adoption partially mediates this relationship. This suggests that the benefits of digital trade depend on an economy's digital readiness and its capacity to absorb technological advancements.

Academically, this study contributes to the literature by developing an integrated analytical framework that combines the gravity theory of trade with a mediation mechanism at the country level using structural equation modeling (SEM). From a policy perspective, the findings highlight that promoting digitally delivered services should be accompanied by investments in digital infrastructure, digital skills, and institutional quality to maximize export performance.

However, several limitations remain. The Digital Adoption Index mainly captures infrastructure and connectivity and may not fully reflect firm-level innovation capabilities. In addition, country-level data may mask heterogeneity across industries and firms, and potential endogeneity issues may persist. Future research could address these limitations by using micro-level data or applying more robust econometric techniques to further examine the underlying mechanisms.

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