The Impact of Digital Transformation on International Trade: An Econometric Study of a Sample of Emerging Economies over the Period (2010-2024)

Bahi Ouafa [1*]
[1] Laboratory of Sustainable Economic Business Management El Oued University, (Algeria)

تأثير التحول الرقمي على التجارة الدولية:
دراسة قياسية لعينة من الاقتصادات الناشئة خلال الفترة (2010_2024)

باهي وفاء [1] *
[1] مخبر إدارة أعمال المؤسسات الاقتصادية المستدامة جامعة الوادي (الجزائر)

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Summary: This study aims to measure the impact of digital transformation on the volume of international trade for Brazil, Mexico, South Africa, Egypt, Morocco, India, Malaysia, Indonesia, Turkey, and Vietnam during the period (2010-2024), using the panel-corrected standard error method (PCSE), where the study used the international trade volume index as a dependent variable, and the indicators of the digital economy and technology as independent variables that express digital transformation, as well as digital infrastructure variables and other structural variables. The results of the PCSE model indicate that digital goods trade, internet use, and human capital are the essential factors driving trade openness in the emerging countries under study, while technical readiness and infrastructure alone remain insufficient without an institutional environment and strong human capital investment, and protectionist policies continue to be a clear constraint on trade expansion.
Keywords: International trade; panel data; technological transformation
Jel Classification Codes : F16 ; C33 ; O3

ملخص: تهدف هذه الدراسة الى قياس أثر التحول الرقمي على حجم التجارة الدولية لكل من البرازيل المكسيك جنوب افريقيا مصر المغرب الهند ماليزيا اندونيسيا تركيا الفيتنام للفترة (2010_2024) وذلك باستخدام طريقة الأخطاء المعيارية المصححة لبيانات البانل (PCSE) حيث استخدمت الدراسة مؤشر حجم التجارة الدولية كمتغير تابع ومؤشرات الاقتصاد الرقمي والتكنولوجيا كمتغيرات تفسيرية تعبر عن التحول الرقمي إضافة الى متغيرات البنية التحتية الرقمية ومتغيرات هيكلية أخرى, حيث أشارت نتائج نموذج PCSE إلى أن تجارة السلع الرقمية, استخدام الإنترنت, رأس المال البشري تمثل العوامل الجوهرية التي تدفع الانفتاح التجاري في الدول الناشئة محل الدراسة, بالمقابل تبقى الجاهزية التقنية والبنية التحتية وحدها غير كافية دون بيئة مؤسساتية واستثمار بشري قوي كما أن السياسات الحمائية ما تزال تشكل قيدًا واضحًا على توسع التجارة.
الكلمات المفتاح: تجارة دولية؛ بيانات بانل؛ تحول تكنولوجي
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* Corresponding author, e-mail: authorC@mail.com.

I- Introduction :

In the last two decades, the global economy has undergone a radical transformation due to the digital revolution and the development of information and communication technology (ICT), as international trade is no longer solely dependent on the exchange of physical goods and services, but has become increasingly dependent on digital platforms, electronically deliverable services, and online commerce. This transformation has contributed to the reshaping of production and consumption patterns and global value chains, making digital transformation a pivotal factor in enhancing the competitiveness and trade openness of countries.

In this context, the ability of countries to employ new technologies and develop their digital infrastructure has become one of the key determinants of their level of integration into the global economy, and emerging economies such as Brazil, India, and South Africa are emerging as a living laboratory for studying these transformations.

Accordingly, this study seeks to analyze the impact of digital transformation on the volume of international trade in a group of emerging markets with divergent digital experiences during the period (2010-2024), based on the methodology of economic measurement of the panel's data

1. The Problem of the Study:

Despite the efforts of emerging economies to expand their share of international trade and increase their integration into global value chains, there is a noticeable disparity in the volume of trade and the degrees of engagement in value chains, and it is assumed that this disparity is not only due to trade policies and the institutional environment, but also to the disparity in the capabilities of these economies in employing the digital economy and technology and linking them to human capital development policies.

Accordingly, the following research problem can be formulated :

To what extent will digital transformation affect the volume of international trade in a sample of emerging economies during the period of rapid technological transformation (2010–2024)

2. Sub-questions

1. What is the nature of the relationship between the development of digital goods and services trade and the volume of international trade?
2. Does the volume of digital services affect the volume of international trade?
3. What is the impact of the country's readiness for modern technologies on international trade?
4. To what extent does digital infrastructure influence:
    - Percentage of Internet users
    - Fixed broadband subscriptions on trade volume growth?

5. How does GDP per capita explain the differences in trade volume between countries?
6. How does investing in human capital affect the volume of international trade in the sample countries?
7. Do traditional trade barriers still be a barrier to the forces of digitalization and the volume of international trade?

Based on the problem and sub-questions, the following hypotheses can be formulated to test the relationship between digital transformation and the volume of international trade:

1. There is a direct relationship between the proportion of trade in ICT goods and the volume of international trade.
2. The increasing volume of digitally deliverable services is leading to an increase in the volume of international trade.
3. The high level of technological readiness leads to an increase in the volume of international trade.
4. Improved digital infrastructure – represented by high proportions of internet users and fixed broadband subscriptions – is positively impacting the volume of international trade.
5. High tariff rate leads to a decrease in the volume of international trade
6. Improving the level of human capital is positively correlated with the volume of international trade
7. The rise in GDP per capita contributes to boosting the volume of international trade as an indicator of a country's economic strength.

3. Study Methodology:

In order to answer the problem of the study and validate the hypotheses, we will adopt the analytical method and the standard experimental method to measure the relationship between the variables using various statistical tests**.**

II– Literature Review:

1. Dahdouh Selim Study 2025: Future Trends of Foreign Trade in Egypt in Light of Digital Transformation

This study aims to analyze the impact of digital transformation on the future of Egyptian foreign trade, and to anticipate future trends in light of the rapid technological developments, especially in the fields of digitalization. The study was based on the analysis of temporal data during the period (2005–2023), with the prediction of Egyptian exports and imports until 2030 using a model ARIMA

The impact of digital transformation on Egypt's foreign trade was measured using simple regression, correlation coefficient, and slope tests, the results showed that there is a strong direct relationship with statistical significance between digital transformation and exports, especially through the percentage of Internet users and the network readiness index. The forecasting model also showed that Egyptian exports will reach 104.3$ billion by 2030, thus achieving the declared national goal. Imports have also been shown to be positively affected by digitization, but to a lesser extent. The study also concluded that digital transformation has led to: significant growth in exports, enhanced efficiency of customs procedures through applications such as the Nafza platform, and enabling SMEs to access African and Asian markets. The study recommends the need to develop the digital legislative framework, raise the efficiency of technological infrastructure, increase spending on research and innovation, support small businesses in digital trade, and enhance institutional integration for the success of digital transformation in supporting foreign trade. (Dahdouh, 2025)

2. **Fathi El-Sayed and Bahi Mohamed Yassin 2025 Study: Measuring the Impact of Digital Transformation on BRICS^{+} Exports**

The study of the impact of digital transformation on exports in the BRICS+ countries is of particular importance in light of the global economic and digital transformations." To achieve this goal, the study examined the impact of digital transformation, as well as a set of other governing variables (GDP, exchange rate, foreign direct investment, trade openness, and inflation) on exports of goods and services using the Generalized Momentum Method GMM During the reference period of the study. The study concluded that the digital transformation showed a limited impact, as some of its indicators were not statistically significant, on the exports of goods and services to the BRICS+ bloc during the reference period of the study, as macroeconomic variables were the influential variables. The results of the study showed that the variables of exports slowed by one delay, GDP, exchange rate, and trade openness have a positive impact on the bloc's exports. The study recommends that the countries of the bloc should continue to work on improving macroeconomic indicators, in addition to exerting more efforts to improve digital infrastructure, promote innovation, and bridge the digital divides between them in order to optimally exploit digital potential to achieve a significant increase in exports. (Fathi Al-Sayed Youssef Abdel-Majeed, 2025)

3. **Study (Sina Mirzaye, Muhammud mohuiddin 2025): Digital Transformation in International Trade: Opportunities, Challenges and Policy Implications:**

The study aimed to answer the following problem: Do digital tools affect the volume and composition of cross-border trade? How do these effects differ according to the level of development of countries and the size of the company? The researchers conducted a systematic review of the literature that was consistent with PRISMA Covering the period 2010 to 2024, the results reveal three dominant technology clusters: (1) e-commerce platforms and cloud services, (2) IoT-powered supply chain solutions, and (3) emerging AI analytics. E-commerce and cloud

adoption are constantly increasing export intensity – doubling it for digitally mature SMEs – while AI applications are the fastest-growing branches of research, particularly in Eastern Asia and Northern Europe. However, the benefits are mixed: businesses in low-infrastructure environments face higher fixed digital costs, and cybersecurity and regulatory fragmentation remain widespread obstacles. By integrating the economics of trade with studies of development and the internationalization of SMEs, this review provides the first comprehensive framework linking national digital infrastructure and policy support to export performance at the company level. It explains that the effects of trade-enhancing digitalization depend on a strong broadband penetration, affordable cloud access, and harmonized data governance systems. (Sina Mirzaye, 2025)

4. **Study (Zheng Ye, Yongjia Tong 2022): The Impact of Digital Transformation of Foreign Trade Enterprises on Their Trade performance**

This study aimed to collect data from 27 foreign trade enterprises listed on the Shanghai and Shenzhen Stock Exchange (A) during the period from 2010 to 2020, and adopt the method of determining the full text of comprehensive financial reports of enterprises to measure the intensity of digital transformation. The result shows that the digital transformation of foreign trade enterprises has an important role to play in enhancing their key trade performance. In terms of how it works, digital transformation promotes the overall improvement of the core trade performance of organizations by improving the internal management of organizations and enhancing the mediating role of the innovation capacity of organizations. Finally, from the point of view of the government and institutions, some suggestions were made for foreign trade institutions to choose the path of digital transformation development. (Zheng Ye, 2022)

5. **Ahmedov (2020) Study: The Impact of the Digital Economy on International Trade:**

This study aimed to explore the role of digitalization and related technologies in international trade and the impact of changes in the structure and form of international trade, the researcher concluded that international trade is about to enter a new phase in the development of its organization and liberalization. This process requires the establishment of general rules for working in a digital environment and the use of digital technology. After the abolition of border barriers (border regimes), the reduction and abolition of tariffs, as well as the easing of many non-tariff restrictions on market activity related to the development of international production (border regimes), a host of new sciences emerged as a result of the regulation of trade relations in the transboundary virtual space (transboundary systems). The main areas of this regulation are the standards for combating cyberattacks, violations of intellectual property rights, certain rules aimed at preventing fraud on the Internet and e-commerce, and the freedom of movement, storage and use of data (Ahmedov, 2020)

III– Methods and Materials:

1. **Study sample:**

This study includes a group of emerging economies: Brazil, Mexico, South Africa, Egypt, Morocco, India, Malaysia, Indonesia, Turkey, and Vietnam, and represents a mix of Asia, Africa, and Latin America, and is classified as emerging markets according to the World Bank and the IMF. In addition, it is witnessing a boom in digital transformation (internet, e-commerce, innovation)

2. Study variables:

This study includes the dependent variable represented by the volume of international trade and eight explanatory variables, namely: the variables that express the digital transformation, represented by the percentage of digital goods trade in the total trade, international trade in digitally deliverable services, the readiness index for modern technologies, in addition to the variables that represent the digital infrastructure, represented by broadband internet subscriptions, the percentage of Internet users in the population, in addition to other structural variables represented in the customs tariff rate and the human capital index. and GDP per capita.

- **Share of ICT goods as % of total trade**: This indicator reflects the extent of the country's integration into the digital economy through the production and export of goods with high technological content, as through this approach, countries can increase their integration in global production chains, especially through backlinks, due to the high added value provided by the production of these goods.

- **International Trade in Digitally Deliverable Services:** The world has witnessed a significant expansion of cross-border services such as software, cloud services... This indicator reflects the extent to which the digital economy in the services sector contributes to the overall business activity of countries.

- **Frontier Technology Readiness Index:** This index reflects the country's ability to adopt advanced technological technologies such as artificial intelligence, the Internet of Things, Blockchain, nanotechnology, robotics, big data, and cloud computing, which are a key pillar in building the competitiveness of digital exports and improving production efficiency.

- **The proportion of the population of Internet users** and the number of broadband Internet subscriptions These indicators reflect the actual level of penetration of digital infrastructure and the extent to which societies use technology, as well as the extent to which national economies benefit from e-commerce opportunities and digital integration in international markets.

- **Human Capital Index:** Human capital consists of knowledge, skills, and health that people invest and accumulate throughout their lives, enabling them to realize their potential as productive members of society. Investing in people through nutrition, healthcare, quality education, jobs and skills helps develop human capital, which is key to ending extreme poverty and creating more inclusive societies. As noted in the World Development Report (WDR, 2019): The changing nature of work, the boundaries of skills are moving rapidly,

bringing opportunities and risks. There is growing evidence that unless countries strengthen their human capital, they will not be able to achieve sustainable and inclusive economic growth, will not have a workforce ready for the most skilled jobs of the future, and will not compete effectively in the global economy. The human element is at the core of the digital transformation process, because the educational competence and skills of workers are linked to their ability to absorb modern technologies and invest them in raising productivity and exports.

- **GDP per capita:** This indicator is related to national accounts, which are crucial for understanding and managing a country's economy. National accounts are the basis for estimating GDP and gross national income, which are the most commonly used indicators of economic performance, as high levels of income are expected to contribute to enhancing the technological and logistical capabilities that support trade (WDI, 2025).

- **Tariff rate:** This indicator reflects the degree of trade openness and protectionist policies, as they have a direct impact on the flow of goods and services across borders, as high tariffs usually constitute an obstacle to the expansion of foreign trade.

Table (Appendix 01) shows the definition of each indicator and its data source

3. Standard Methods and Tests:

STATA 17 software is relied on to perform standardized tests and select the appropriate model

The model adopted in this study will be estimated according to the following equation:

Trd = f (ICTg, dds, Ftri, NETbbnd, NETuser, Trate, HCI, GDPP)

Since the study variables are panel data, (Panel data), which are panel data whose first dimension is the cross-sections (10 countries), and the second dimension is the time series (the period 2010-2024). Since both the number of cross-sections (countries) and the length of the time series (years) are small, we will rely on the benchmark analysis of the panel, through Pooled regression model the option of differentiating between the panel's data models in their main forms, namely: Pooled Regression Model (PM) Fixed Effects Model (FEM), Random Effects Model (REM). (Baltagi, 2013)

Standard tests: The literature on the econometric analysis of the panel's data requires several tests and estimates, and they can be summarized as stated in this study as follows:

- Fisher's statistical test is used to compare the pooled model with the fixed effects model, where the null hypothesis indicates that the pooled model is best;
- Hausman test for the trade-off between the fixed effects model and the random effects model, where the null hypothesis suggests that the preferred model is random versus fixed effects;

- The Breusch and Pagan-Lagrangian test is a test for the trade-off between the random and pooled model, where the null hypothesis indicates that the aggregate model is better versus the random model;
- Wald Modified test for heteroskedasticity of fixed effects regression models, where the null hypothesis indicates the homogeneity of the variances of the fixed effects model;
- Born and Breitung (2016) HR-test for Autocorrelation
- The LM Pagan-Breusch test for residual independence of cross-sections, where the null hypothesis of residual independence indicates cross-sections of the panel model;
- Winsten–Prais estimation which is based on calculating the Corrected Panel Standard Error (PCSE) estimates for time series models of linear cross-sections where the parameters are estimated by either the OLS or Winsten–Prais regression. When calculating standard errors and contrast-heterogeneity estimates, it is assumed that the interference is, by default, heterogeneous and associated with synchronization across the panel;
- Kraay and Driscoll's estimation where it produces standard errors for coefficients estimated by pooled WLS/OLS effects regression, fixed effects, or random GLS regression. The error structure is also assumed to be heterogeneous, linked to each other with some slowdown, and even inter-group (panel);
- The FGLS estimation is suitable for linear models of panel data using feasible generalized least squares (FGLS). It allows estimation in the presence of an AR (1) within the panel, cross-sectional correlation and heterogeneity of variances across the panel. ;
- The Robust standard errors is commonly used to ensure correct statistical inference when some assumptions of the underlying regression model are violated. Provided that the residuals are distributed independently, the standard errors obtained by this estimator are consistent even if the residues are heterogeneous.

IV- Results and discussion :

1. Descriptive statistics of the model:

Appendix 2 shows, the table reflects clear differences between countries in terms of their ability to exploit digital transformation to support their international trade, where high levels of digitalization and technological readiness are associated with high trade volume and openness, while economies with high tariffs and weak digital connectivity suffer from limited trade performance.

While the descriptive statistics in Table 3 (Appendix 3) show that the selected sample is characterized by a wide variation in the variables of digitalization, trade openness and human development, which is suitable for conducting a panel analysis that measures the impact of digital transformation on international trade, as the table shows a difference between countries in the degree of their integration in global trade, where the values ranged between 22.77 and 186.67, while the descriptive statistics from the table showed that there is a significant difference in the level of digitization of the sector. Services between the countries under study, while the technological readiness index showed a relative convergence in the level of readiness to adopt modern technology among the sample countries, while the percentage of digital goods trade in the total trade reached about 8.64% as a general average, with a clear difference between countries (deviation = 11.55), which indicates the difference in the extent of the contribution of digital commerce to the national economy. The data also showed that the average fixed broadband subscriptions and internet users are a relative expansion in digital infrastructure despite the gaps between countries in terms of the tariff rate, which reached 7.95%, which is an average indicator that reflects relative trade openness in the sample. The Human Capital Index recorded an average of 0.56, which is an acceptable level for emerging countries, while the average GDP per capita reached about 6488$ With a wide

variation between countries (1347$ to 15473$), reflecting the diversity of economic structures and development levels within the sample.

2. Model estimation:

To determine the most appropriate model, two tests are relied upon, the first test to choose between the pooled model and the fixed effects model, which is the Fisher statistical test if. (F) the Fisher statistical test indicates the suitability of the pooled model of the data, it stops at this stage and the pooled model is considered the most appropriate, while if the Fisher statistic indicates the suitability of the fixed effects model over the pooled model, then the second test of the Hausman test is performed to determine the preference between the fixed effects model and the random effects model.(Hausman, 1978)

Estimating the Fixed Effects Model: We estimate the Fixed Effects model, and the results of the assessment are as follows:

It is clear from the outputs of Appendix 4 that the trade-off between the pooled model and the fixed effects model is based on the restricted Fisher statistical test (F), which indicates the rejection of the null hypothesis and the acceptance of the alternative hypothesis, i.e., the fixed effects model is the best. The next step is to estimate the random effects model

Estimation of the Random Effects Model:

After obtaining the results of the random-effects model, a Hausman test is required to compare the fixed effects model with the random-effects model. The next step is to make a trade-off between the random-effects model and the pooled model.

It is clear from the outputs of Table (5) that the null hypothesis is rejected and the alternative hypothesis is accepted, i.e., the random model is the best. The next step is to differentiate between the fixed effects model and the random effects model using the Hausman test.

Hausman test for the trade-off between the fixed effects model and the random effects model:

It is clear from the outputs of Appendix 6 that the null hypothesis is rejected and the alternative hypothesis is accepted, i.e., the fixed effects model is the best.

To ensure the quality of the fixed effects model, we perform diagnostic tests.

Model Diagnostic Tests: We will test the Born and Breitung (2016) HR-test for Autocorrelation, the Breusch-Pagan LM test of independence for cross-sectional independence, and the Modified Wald test for heterogeneity.

We note through the Appendix Table (7) The model does not suffer from the problem of self-correlation (autocorrelation) according to the results of the Born and Breitung (2016) HR-test. But it suffers from the problem of heterogeneity of the variances (heteroskedasticity) according to the test results Modified Wald test (Greene , 2000) , Appendix (8) The model also suffers from the lack of residual independence of the cross-sections (cross-sectional correlation) as shown by the test results Breusch-Pagan LM test of independence Appendix (9) This requires addressing standard problems in the model, and this is done using a number of standard approaches: estimation. (Driscoll & A. C. Kraay, 1998) feasible generalized least squares (FGLS) (Beck, Katz, 1995)estimate fe_robust, and Panel-corrected standard error (PCSE)It is an alternative to possible generalized least squares (FGLS)

Estimating the model according to the method PCSE and fe_robust and FGLS Fe_dris_kr ~ y: We note that the best model is **PCSE** (Appendix 11) It contains more significant

parameters, in addition to containing much fewer standard errors than other models, which is the standard he referred to (Beck, Katz, 1995) Appendix (10):

We can see from the outputs of the previous evaluation results:

- There is a direct significant relationship between the share of digital goods trade in the total trade and the international trade volume index, as the increase by one unit in the variable of the share of digital goods trade in the total trade increases in the volume of international trade by 2.77 units
- There is an inverse significant relationship between trade in deliverable digital services and the international trade volume index, as an increase of one unit in the index of trade in deliverable digital services reduces the volume of international trade by 0.0000856 units.
- The technological readiness index appeared positive but insignificant
- Broadband subscriptions index showed a positive but insignificant signal
- There is a direct significant relationship between the percentage of Internet users and the International Trade Volume Index, as the increase by one unit in the percentage of Internet users increases in the International Trade Volume Index by approximately 0.23 units.
- There is an inverse significant relationship between the tariff rate and the international trade volume index, as the increase by one unit in the tariff rate index decreases the trade volume index by 1.11 units
- There is a direct significant relationship between the Human Capital Index and the International Trade Volume Index, as the increase by one unit in the Human Capital Index increases the volume of international trade by 31,304 units.
- There is an inverse significant relationship between GDP per capita index and the trade volume index. The increase by one unit in GDP per capita index decreases in the trade volume index by 0.00327 units.

3. Analysis and interpretation of results:

The results showed a positive significant effect

between the trade of digital goods and the volume of international trade, and this suits the economic nature of these countries, especially Malaysia, India, Mexico and Vietnam, which have become major centers of assembly and manufacturing for electronics and information technology components, so increasing their exports and imports of these goods will lead to an increase in the volume of their trade, this result shows the success of their strategies in competing in global value chains, and this was proven by the study of production integration through backlinks, i.e. the inclusion of imported (foreign) intermediate products in local exports. It leads to a rise in its technological technology, especially if these parts or components are high-tech such as semiconductors that are used in high-tech devices and are difficult to produce at the local level, so the import of components from abroad increases the rise of local export technology. (Bahi, O., & Bahi, A. M. (2022))The Digital Services Trade Index (DDS) has a negative impact, suggesting that the growth of trade in digital services has not yet turned into a strong driver of overall trade in these

countries, and may parallel a transition from trade in goods to services rather than a general expansion of trade.

The Technology Readiness Index (FTRI), despite the positive trend, suggests that preparedness alone is not enough; it should translate into actual adoption of advanced technologies in the industrial and trade sectors. It may mean that technological readiness does not yet translate into actual business gains without supportive policies (infrastructure, investment, institutions).

As for the Internet Users Index, the results showed that it has a positive and significant impact, which indicates that the increase in the percentage of Internet users enhances trade, as every 1% increase in users increases the volume of trade by about 0.23 units, this reflects the impact of digital transformation in facilitating exchange, information and e-commerce, while the expansion of broadband subscriptions has not yet clearly affected trade, perhaps because the actual commercial use of the Internet is low despite the availability of infrastructure.

As for the tariff rate, as expected, every increase in the tariff rate by 1% leads to a decrease in the volume of trade by 1.11 units, and this explains that despite the attempts at digital transformation, the traditional trade policy is still dominant because many of the sample countries have protected sectors and regional trade agreements such as (USMCA for Mexico and ASEAN agreements for Malaysia and Indonesia) because the reduction of tariffs within these agreements is considered a key driver to increase trade exchange between them.

Human capital has a positive and strong impact (31,30), which explains why the sample countries over the past decade have focused on improving education and health, such as Turkey, India, Indonesia, Malaysia. It has invested in creating a more skilled workforce, which has enabled it to move from exporting raw materials to exporting higher value-added goods and services (upgrading in the links of global value chains, as a study has proved), which reflects positively on trade (Bahi, O., Makhzoumi, L., & Abdellaoui, A. (2021))The slight negative impact on GDP is consistent with the idea that countries with higher income levels may rely more on domestic production and services.

IIV- Conclusions and Policy Recommendations:

1. Conclusions:

The study aimed to measure the impact of digital transformation on international trade in a group of emerging economies, represented by (Brazil, India, Indonesia, Egypt, Morocco, Mexico, Malaysia, Turkey, South Africa, and Vietnam) during 2010–2024 The study relied on a model Regression Using Panel-Corrected Standard Errors of Panel Data (PCSE) This is to address the problems of residual association of cross-sections and heteroskedasticity, as the results showed:

- The existence of a positive significant effect between the trade of digital goods and the volume of international trade, which indicates that the increase in the exchange of digital goods has a positive effect on trade openness and integration into the global economy, thus increasing the volume of trade, and this proves the validity of the first hypothesis.

- There is a negative significant impact between trade in digitally deliverable services and the volume of international trade, which is contrary to theoretical expectations, and this result may be explained by the weak organizational and technical structure in the digital services sector in some countries, and perhaps to the transition from the trade of goods to the trade of services, and not to the expansion of the volume of trade as a whole, and this indicates that the second hypothesis did not receive empirical support in the case of the sample countries.

- The insignificance of the technological readiness index explains that technical readiness is not necessarily reflected in the actual trade performance, which indicates that the third hypothesis also did not receive empirical support in the sample countries.

- As for digital infrastructure, the Internet users index had a positive and significant impact, reflecting the positive role of Internet penetration in increasing the volume of trade exchange, while the fixed broadband subscriptions index was not of specialized significance, which partially proves the correctness of the fourth hypothesis.

- The existence of a negative and significant effect between the customs tariff index and the volume of international trade, and this is in line with economic theories, as customs restrictions constitute an obstacle to the flow of goods and services, whether physical or digital, and this proves the validity of the fifth hypothesis.

- The existence of a positive and strong significant impact between human capital and the volume of international trade, which explains that investing in the human element through education and skills development enhances the competitiveness of the economy and contributes to improving the efficiency of trade performance, and this proves the validity of the sixth hypothesis.

- There is a negative and significant effect between GDP per capita and the volume of international trade, which can be explained by the fact that some of the countries with higher incomes in the sample may depend on their domestic production and services, and this indicates that the seventh hypothesis has not received empirical support.

Based on these results, it is clear that the positive impact of digital transformation on international trade is not automatic, but depends on the level of technology employment in the economy and the type of indicator.

2. Recommendations:

From the results obtained, the following recommendations can be formulated for decision-makers in emerging countries:

- Invest in infrastructure to address the digital divide by investing in high-speed broadband networks and ensuring their access at affordable prices especially in remote areas.

- Develop human capital by reforming vocational education and training systems to keep pace with the requirements of the digital economy and the global labor market.

- Trade liberalization through the negotiation of regional and bilateral trade agreements that lower non-tariff barriers and facilitate the cross-border flow of digital goods and data.

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- Appendices:

Appendix (01) Study Variables and Data Sources

Variable symbol	Definition	source
Dependent variable		
Trd	**Trade volume**: It is the sum of exports and imports of goods and services. This indicator is expressed as a percentage of gross domestic product (GDP) which is the total income earned from the production of goods and services in an economic zone during an accounting period.	World Development Indicators | DataBank
Independent variables		
ICTg	**Percentage of digital goods trade in total trade** Trade in ICT goods is one of the ((ITU) I. T., 2025) Key Indicators developed by the Partnership in Measuring ICT for Development through a consultation process involving national statistical offices around the world. ((ITU), Partnership in Measuring ICT for Development, 2025)	IctGoodsShare
dds	**International trade in digitally deliverable services** Digitally deliverable services include those services that can be delivered remotely via computer networks. It is important to note that a digitally deliverable product does not mean that it is always delivered digitally when traded internationally. Thus, digitally deliverable trade will be greater than trade that is actually delivered digitally.	DigitallyDeliverableServices
Ftri	**Readiness for new technologies**: It includes technological capabilities related to physical investment, human capital, and technological effort, and covers national capacities for the use, adoption and adaptation of these technologies: • Use - technological knowledge. • Adoption • Adaptation -	FTRI
NETbbnd	**Fixed broadband subscriptions** refer to fixed subscriptions for high-speed public Internet access (TCP/IP connection), with downstream speeds equal to or greater than 256 kbit/s. This includes cable modems, fibre to the home/building and other fixed (wired) broadband, satellite broadband and fixed terrestrial wireless broadband.	World Development Indicators | DataBank=
NETuser	**Internet users**: They are individuals who have used the internet (from anywhere) in the last 3 months. The internet can be used via a computer, mobile phone, PDA, game machine, digital TV, etc.	World Development Indicators |

		DataBank=
Trate	**Simple Tariff Average:** The unweighted average of the rates effectively applied for all products subject to tariffs calculated for all traded goods	World Development Indicators | DataBank
HCI	**Human Capital: The** Capital Index calculates the contributions of health and education to worker productivity. The final index score ranges from zero to one and measures productivity as a future factor for the child born today relative to the standard of total health and full education.	World Development Indicators | DataBank
GDPP	**Gross Domestic Product (GDP)**: The total income earned from the production of goods and services in an economic zone during an accounting period.	World Development Indicators | DataBank

Source: Prepared by the researcher based on databases.

Appendix 02: Descriptive Statistics1

Variable		Mean	Std. dev.	Min	Max	Observations	
Trd	overall	71.0225	40.35265	22.77218	186.6758	N =	150
	between		41.13627	28.92251	150.2511	n =	10
	within		9.754045	34.74905	107.4472	T =	15
dds	overall	22347.22	47947.29	1654	292429	N =	150
	between		45804.26	2465.2	151953	n =	10
	within		19951	-50243.78	162823.2	T =	15
Ftri	overall	.6193333	.087237	.4	.8	N =	150
	between		.0773289	.5066667	.7133333	n =	10
	within		.046823	.4793333	.7126667	T =	15
ICTg	overall	8.6484	11.55046	.12	37.17	N =	150
	between		11.67799	.424	30.31133	n =	10
	within		3.138721	-11.79293	17.56707	T =	15
NETbbnd	overall	8.660074	6.382241	.883809	23.885	N =	150
	between		5.850735	1.597685	15.51708	n =	10
	within		3.117409	.9819403	17.58726	T =	15
NETuser	overall	56.584	22.56249	7.5	98	N =	150
	between		14.88148	28.88	78.58667	n =	10
	within		17.56177	23.05733	96.104	T =	15
Trate	overall	7.95225	5.296026	2.395	38.73	N =	150
	between		4.013466	4.405333	16.202	n =	10
	within		3.667898	-.72975	30.48025	T =	15
HCI	overall	.5647898	.0990671	.1264293	.6971657	N =	150
	between		.0933111	.3833864	.675324	n =	10
	within		.0438797	.3078327	.6923444	T =	15
GDPP	overall	6488.667	3780.383	1347.519	15473.29	N =	150
	between		3814.1	1878.614	11167.7	n =	10
	within		1053.948	3347.863	10794.26	T =	15

Source: STATA 17 Outputs

Appendix 03: Descriptive Statistics 2:

Summary statistics: Mean
Group variable: code (coden)

code	Trd	dds	Ftri	ICTg	NETbbnd	NETuser	Trate	HCI	GDPP
BRA	28.92251	19037.93	.7066667	.424	14.95781	65.74667	13.568	.550167	10215
EGY	39.01161	2465.2	.5066667	2.055333	5.970491	48.48	16.202	.4884369	3132.544
IDN	43.00992	9548	.5066667	3.318	2.769209	37.36667	5.817333	.5275333	3902.335
IND	46.17532	151953	.6733333	2.036	1.597685	28.88	9.85	.3833864	1878.614
MAR	78.08184	3935.4	.56	2.64	4.249951	69.17333	6.805333	.4978044	3414.462
MEX	72.69638	9805.533	.6466667	15.13867	14.57403	58.86	4.442167	.6053099	10767.33
MYS	136.8915	10856.33	.7133333	30.31133	9.939332	78.58667	5.680667	.6017736	10540.59
TUR	58.38694	7679.467	.6666667	1.292	15.51708	64.18667	4.405333	.642838	11167.7
VNM	150.2511	2540	.5733333	28.25133	14.57403	57.03333	5.716333	.675324	3072.242
ZAF	56.79781	5651.333	.64	1.017333	2.451127	57.52667	7.035333	.675324	6795.862
Total	71.0225	22347.22	.6193333	8.6484	8.660074	56.584	7.95225	.5647898	6488.667

Appendix 04 Estimation of the Fixed Effects Model:

```
Fixed-effects (within) regression               Number of obs      =       150
Group variable: code                            Number of groups   =        10

R-squared:                                      Obs per group:
     Within  = 0.4665                                         min =        15
     Between = 0.6360                                         avg =      15.0
     Overall = 0.0162                                         max =        15

                                                F(8,132)           =     14.43
corr(u_i, Xb) = 0.4317                          Prob > F           =    0.0000
```

Trd	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
ICTg	1.260803	.2184479	5.99	0.000	.8445161	1.677089
dds	.0000257	.0000456	0.56	0.573	-.0000644	.0001158
Ftri	7.369384	14.28196	0.52	0.607	-20.88179	35.62052
NETbbnd	2.152553	.3561937	6.04	0.000	1.447967	2.857139
NETuser	-.1577519	.0723425	-2.18	0.031	-.3008525	-.0146514
Trate	-.3653044	.1771196	-2.06	0.041	-.7158645	-.0147444
HCI	-23.54456	20.92233	-1.13	0.262	-64.93099	17.84186
GDPP	-.0007697	.0006178	-1.25	0.215	-.0019917	.0004523
_cons	66.46143	13.69841	4.85	0.000	39.36462	93.55824
sigma_u	27.988032					
sigma_e	7.5691185					
rho	.93148171	(fraction of variance due to u_i)				

Appendix 05 Breusch and Pagan Lagrangian test for the trade-off between random and aggregate model:

```
Breusch and Pagan Lagrangian multiplier test for random effects

        Trd[code,t] = Xb + u[code] + e[code,t]

        Estimated results:
                         |       Var       SD = sqrt(Var)
                ---------+------------------------------
                     Trd |   1628.336        40.35265
                       e |   57.29156        7.569119
                       u |   47.98085        6.926821

        Test: Var(u) = 0
                                  chibar2(01) =   146.89
                              Prob > chibar2 =   0.0000
```

Appendix 06: Hausman test for the trade-off between the fixed effects model and the random effects model:

	Coefficients (b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
ICTg	1.260803	2.133118	-.8723155	.096694
dds	.0000257	-.000059	.0000848	.0000259
Ftri	7.369384	-4.027351	11.39674	.
NETbbnd	2.152553	1.46559	.6869629	.
NETuser	-.1577519	-.0592062	-.0985458	.
Trate	-.3653044	-.4491083	.0838039	.
HCI	-23.54456	13.05358	-36.59814	9.478509
GDPP	-.0007697	-.0017931	.0010234	.000234

b = Consistent under H0 and Ha; obtained from xtreg.
B = Inconsistent under Ha, efficient under H0; obtained from xtreg.

```
Test of H0: Difference in coefficients not systematic

    chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B)
            =  42.48
Prob > chi2 = 0.0000
(V_b-V_B is not positive definite)
```

Appendix 07: Born and Breitung (2016) HR-test for Autocorrelation

```
Heteroskedasticity-robust Born and Breitung (2016) HR-test as postestimation
Panelvar: code
Timevar: year
```

Variable	HR-stat	p-value	N	maxT	balance?
Post Estimation	1.34	0.181	10	15	balanced

```
Notes: Under H0, HR ~ N(0,1)
   H0: No first-order serial correlation.
   Ha: Some first order serial correlation.
```

Appendix 08: Wald Modified Test for Heteroskedasticity:

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (10)   =          220.74
Prob > chi2 =           0.0000
```

Appendix 09: LM Pagan-Breusch Test for Residual Independence Across Cross-Sections

```
Breusch-Pagan LM test of independence: chi2(45) =   185.381, Pr = 0.0000
Based on 15 complete observations over panel units
```

Appendix 10: PCSE Model Estimation:

Linear regression, correlated panels corrected standard errors (PCSEs)

Group variable:	code	Number of obs	= 150
Time variable:	year	Number of groups	= 10
Panels:	correlated (balanced)	Obs per group:	
Autocorrelation:	no autocorrelation	min	= 15
		avg	= 15
		max	= 15
Estimated covariances	= 55	R-squared	= 0.8781
Estimated autocorrelations	= 0	Wald chi2(8)	= 7125.28
Estimated coefficients	= 9	Prob > chi2	= 0.0000

Trd	Coefficient	Panel-corrected std. err.	z	P>|z|	[95% conf.	interval]
ICTg	2.775312	.1130131	24.56	0.000	2.553811	2.996814
dds	-.0000856	.000027	-3.17	0.002	-.0001385	-.0000328
Ftri	36.85968	23.66387	1.56	0.119	-9.520651	83.24001
NETbbnd	.2527391	.1803452	1.40	0.161	-.100731	.6062092
NETuser	.2309107	.0877881	2.63	0.009	.0588492	.4029722
Trate	-1.110527	.2062113	-5.39	0.000	-1.514694	-.7063606
HCI	31.30424	7.162302	4.37	0.000	17.26639	45.3421
GDPP	-.0032784	.0005213	-6.29	0.000	-.0043002	-.0022566
_cons	23.27444	12.96904	1.79	0.073	-2.144402	48.69329

Appendix 11 **Estimation of the model according to the fe_robust, PCSE, FGLS and Fe_dris_kr~y methods**

	(1) Trd	(2) Trd	(3) Trd	(4) Trd
ICTg	1.261**	2.775***	2.161***	1.261***
	(3.51)	(24.56)	(14.60)	(6.79)
dds	0.0000257	-0.0000856**	-0.0000670***	0.0000257
	(0.57)	(-3.17)	(-7.59)	(0.57)
Ftri	7.369	36.86	5.236	7.369
	(0.70)	(1.56)	(1.41)	(0.68)
NETbbnd	2.153**	0.253	0.631***	2.153***
	(3.37)	(1.40)	(4.38)	(4.18)
NETuser	-0.158	0.231**	0.0549	-0.158
	(-1.07)	(2.63)	(1.38)	(-1.48)
Trate	-0.365	-1.111***	-0.237	-0.365
	(-2.24)	(-5.39)	(-1.71)	(-1.98)
HCI	-23.54	31.30***	39.51***	-23.54
	(-1.28)	(4.37)	(6.84)	(-1.52)
GDPP	-0.000770	-0.00328***	-0.00206***	-0.000770
	(-1.07)	(-6.29)	(-10.17)	(-1.47)

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