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Article

Estimating the Extensive Margin of Exports in the Chinese Market: The Impact of Digital Trade Facilitation on Export Diversification

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Abstract

This study investigates the causal relationship between digital trade facilitation (DTF) and export diversification, as measured by the extensive margin (EM) of exports in the Chinese market. Findings from a preceding textual analysis of regional trade agreements (RTAs) indicate that high-income countries tend to exhibit better trade performance by engaging in deeper RTAs that have more comprehensive coverage of DTF provisions. Based on our analysis using various gravity regression models, we assert that the implementation of DTF significantly enhances the extensive margin of exports. Our analysis of mediating effects confirms that e-commerce expansion plays a crucial role in amplifying the positive impact of DTF on export diversification within the Chinese market. Furthermore, our findings indicate that the development of DTF and e-commerce is not solely limited by economic size and technology level. Consequently, we strongly encourage small and medium-sized enterprises (SMEs) in developing countries to proactively enhance their DTF capabilities to effectively utilize their RTA network.

Keywords

Digital trade facilitation, Export diversification, Extensive margin of exports, e-commerce, China

Introduction

Enhancing trade facilitation is crucial for promoting easier trade and complementing the discriminatory aspects of regional trade agreements (RTAs). By reducing trade costs and expanding market access, improved trade facilitation not only increases trade volume but also

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enables a broader range of products to be traded, particularly benefiting smaller firms seeking to enter new markets abroad. Extensive research has demonstrated the significant contribution of trade facilitation in ensuring that trade benefits all participants in the interconnected global economy (OECD, 2018). Specifically, studies have highlighted the positive impact of trade facilitation on the extensive margin of exports, which represents export diversification by facilitating the entry of new exporters into the global market, leading to lower prices and a more diverse array of products for consumers (Berthou & Fontagné, 2008; Dennis & Shepherd, 2011; Feenstra & Ma, 2014; Hendy & Zaki, 2021; Persson, 2013). Export diversification resulting from these efforts plays a significant role in driving sustainable economic development, particularly in developing countries (Dennis and Shepard, 2011; Eicher and Kuenzel, 2016 ; Hesse, 2009; Mora and Olabisi, 2023).

In recent years, the adoption of digital tools has gained momentum in trade facilitation measures to meet the evolving requirements of digitalized trade activities. Referred to as digital trade facilitation (DTF), this approach differs from general trade facilitation (GTF).[1] The extensive margin (EM) of exports, which captures the expansion of new products or trading partners, serves as a crucial indicator for an open economy's economic development through active participation in external trade.

This study presents empirical experiments exploring the relationship between DTF and the extensive margin of exports, utilizing various econometric estimation models. We employ firm-level panel data extracted from 96 sectors of 76 exporting countries operating in the Chinese market. To assess the potential influence of DTF on export diversification, we rely on biannual data from the United Nations Trade Facilitation Network (UNTF) survey report, which measures DTF levels between 2015 and 2019.[2]

Distinguishing itself from existing research, this study not only defines DTF and establishes its connection with the extensive margin of exports but also examines the implementation status of DTF through textual analysis, analyzing 334 effective RTAs as of January 2022 to derive relevant policy implications. Additionally, recognizing the strong correlation between emerging digital trade and DTF, and the significant role of e-commerce within the digital trade framework, we further investigate the mediating effect of e-commerce on the relationship between DTF and export diversification.

To address potential biases associated with the commonly used indicator of the extensive margin of exports (i.e., the number of exporting firms), which may overestimate export diversification due to larger countries having more exporting firms within the same sectors across different periods (Persson, 2013), we adopt Hummels and Klenow's (2005) index. This index measures the worldwide export of goods by the investing exporting country relative to the total worldwide export of all goods. To account for sample selection bias, we employ the Heckman sample selection (Heckit) model, alongside widely used estimation techniques such as ordinary least squares (OLS), fixed effects (FE), instrumental variables (IV), and Poisson pseudo-maximum likelihood (PPML). Furthermore, we conduct robustness checks by employing alternative measurements of export diversification and exploring alternative model specifications.

China has been chosen as a representative foreign market for exporters worldwide due to its prominent role as a global manufacturing hub and a significant marketplace where both final and intermediate goods hold equal importance. Enhancing trade diversification in China mitigates the risks associated with dependence on specific markets or products and capitalizes on China's competitive advantage, allowing the country to leverage its diverse industries and strategic position within global supply chains. Furthermore, when compared to the extensive margin of trade, China's intensive margin of trade, which measures trade volume, has already experienced a period of rapid growth and is currently stagnant. Taking these factors into consideration, our

analysis will primarily focus on variations within the extensive margin.[3]

The structure of this paper is as follows. In Section 2, we review previous studies examining the relationship between trade facilitation, encompassing both general and digital aspects, and the extensive margin of exports. Moreover, we qualitatively evaluate the findings obtained from a textual analysis, investigating the status of DTF provisions within currently effective RTAs. Section 3 outlines the models and data utilized in our empirical analysis, providing regression results accompanied by robustness checks. In Section 4, we present additional empirical evidence regarding the mediating effect of e-commerce, serving as a proxy for digital trade. Finally, Section 5 concludes the study, summarizing the key findings and implications.

Trade Facilitation and Extensive Margin of Exports

General and Digital Trade Facilitation

Distinguishing between GTF and DTF lies in the mechanisms through which they enhance trade activities. GTF encompasses a wide range of policies, procedures, and measures aimed at reducing trade barriers and increasing efficiency, predictability, and cost-effectiveness. It includes actions such as simplifying customs procedures, standardizing regulations, lowering tariffs and non-tariff barriers, and improving trade-related infrastructure. In contrast, DTF specifically focuses on utilizing digital technologies and electronic means to facilitate and enhance international trade processes. This involves digitizing trade documents, implementing electronic data interchange (EDI) systems, developing single window systems for customs clearance, and adopting advanced technologies like blockchain to improve supply chain transparency and traceability. DTF emphasizes electronic signatures, applications, and transactions, earning it the moniker of 'paperless trade facilitation' in contrast to the paper-based approach of GTF. Both GTF and DTF generate cost-reduction effects, making it crucial to investigate the causal relationship between DTF and the extensive margin, particularly in the current era of digitalization.[4]

DTF measures have increasingly been incorporated into RTAs and have been explicitly addressed in the text of these agreements (UNESCAP, 2019). The utilization of emerging data and advancements in information and communication technology (ICT) support the implementation of DTF provisions in RTAs (Lewis, 2009). As global tariff and non-tariff protections have decreased due to multilateral liberalization efforts under the General Agreement on Tariffs and Trade (GATT)/World Trade Organization (WTO) and the proliferation of RTAs, DTF becomes a desirable policy alternative for maximizing welfare gains from easier trade. However, despite DTF's potential to generate substantial cost reductions comparable to or even surpassing those of GTF (Duval et al., 2018; UNESCAP, 2017), there is a scarcity of studies examining the trade effects of DTF, highlighting the need for further research in this area.

Existing Studies

Numerous studies have emphasized the role of the extensive margin in fostering export-led economic growth by reducing trade costs through improved trade facilitation. Building upon the heterogeneous firm model of trade trade (Chaney, 2008; Melitz, 2003), Feenstra (1994) argued that export diversification is crucial for realizing welfare gains in trade. Broda and Weinstein (2006) further demonstrated that the increased number of export varieties in the U.S. market contributes significantly to overall welfare gains. In line with this, Kehoe and Ruhl (2013) discovered that goods with the least trading activity prior to liberalization experienced the largest

increase in value (from a 10 percent share to 40 percent) following trade openness, highlighting the importance of the extensive margin compared to the intensive margin.

Chaney (2008) discussed how a reduction in trade costs is a prominent pathway to achieving greater export diversification. Drawing on import data from developing countries to the EU, Persson (2013) demonstrated that a 1 percent decline in trade costs resulting from trade facilitation leads to a 0.7 percent increase in the variety of differentiated products and a 0.4 percent increase in the variety of homogeneous products. Similarly, using EU data on imports from 118 developing countries, Dennis and Shepherd (2011) found that a 10 percent reduction in export, transport, and market entry costs corresponds to a 1 percent, 3 percent, and 4 percent increase in export diversification, respectively.

In addition to examining the overall trade effects, several studies have explored the firm- or sector-level impact of trade facilitation. Berthou et al. (2008) analyzed French firm-level exporting data in 2010 and utilized the Poisson estimator to demonstrate that an increase in the OECD trade facilitation index (TFI) positively affects the extensive margin for French exporters, particularly for small and medium-sized exporters. Wang and Li (2015) studied US export data in 2011 and found that trade facilitation significantly contributes to export diversification. Liu and Duan (2019) observed a similar trend, showing that trade facilitation leads to a significant increase in the extensive margin of exports among APEC member nations from 2007 to 2014. Hendy and Zaki (2021) collected firm-level data from Egypt spanning the period 2005 to 2016 and found that trade facilitation, through the reduction of time required for trade or costs for customs procedures, promotes an expansion of the extensive margin of exports.

While these studies suggest a positive relationship between trade facilitation and export diversification, empirical investigations specifically focused on DTF are limited. UNESCAP (2017), using the results of the Global Survey of Facilitation and Paperless Trade Facilitation Implementation (formerly the UNTF survey report), confirmed that DTF outperforms GTF in terms of reducing trade costs. Duval et al. (2018) also demonstrated that the full implementation of cross-border paperless trade provisions listed in the UNTF survey report leads to significant cost reductions. Ismail (2020) obtained similar results by employing a synthetic digital trade index based on data from 2003 to 2017 for 20 Asian countries. However, these studies did not specifically investigate the impact of DTF on the extensive margin of exports.

Characteristics of Trade Facilitation Implementation: Textual Analysis

The DTF-related policies examined in the UNTF survey, which serves as the source of DTF measurement in this study, contribute to the implementation of corresponding provisions proposed in RTAs. To assess the status of DTF implementation in comparison to GTF, we conduct a textual analysis by examining the provisions of RTAs.

Since the provisions of RTAs for trade facilitation are closely associated with the depth of the agreements, we incorporate an RTA depth index as a reference indicator in this textual analysis. Thus, we investigate the depth of the RTA provisions (*Depth*)[5], *GTF measures*, and *DTF measures*. Drawing on the work of Dür et al. (2014), we recalibrate the criteria for determining the depth score of specific RTAs. For identifying GTF regulations, we refer to Breinlich et al. (2021), who utilized a machine learning method combined with the iceberg lasso[6] to identify more influential agreements for increasing trade volume. From their findings, we select four clauses under the 'Trade Facilitation and Customs' category.[7] However, we only include three of them to maintain consistency with our research question, as the last two clauses provide detailed explanations of simplification related to customs clearance, which can be consolidated into a single index. To represent DTF, we use the subgroup of 'Cross-Border Paperless Trade' from

the UNTF survey report, with some adjustments. Table 1 presents an overview of the standards adopted in the textual analysis.

A total of 334 RTAs have been selected from the WTO RTA database as of January 2022 to assess the status of DTF, excluding those that are no longer in effect. These RTAs are classified based on the established criteria, and a point is assigned to countries participating in an RTA if they meet at least one of the standards outlined in Table 1. While this manual text analysis approach may have some inherent inaccuracies, it has been widely used in early studies on textual analysis of corporate disclosure documents (Li, 2011). Given the small sample size and the non-decisive impact of the analytical results in this study, the method demonstrates a certain degree of credibility. To address the wide range and ambiguity of the assigned values for each country, the outcome values are log-normalized to ensure comparability.

Table 2 presents the average values of the three criteria by income level. As anticipated, the level of economic development, as indicated by per capita GDP, influences the status of RTAs. High-income countries are more actively involved in deeper RTAs that comprehensively cover both GTF and DTF. Interestingly, the average DTF value for low-income countries (1.11) is slightly higher than that of GTF (1.00), which is unlike other income groups where DTF is lower than GTF. The DTF gaps between low- or lower-middle-income countries and high-income countries are also smaller compared to the gaps in RTA depth and GTF. This suggests that the

Table 1. Calibrating RTA scores

	Depth	*GTF measures*	*DTF measures*
Texts considered to be a standard	More than a partial scope agreement	Customs harmonization and legality	Customs IT techniques adoption
	Substantive provision of services	Customs regulation	Paperless trading: a) laws and regulations for electronic transactions b) paperless collection of payment from a documentary letter of credit c) electronic exchange of Sanitary & Phyto-Sanitary Certificate d) electronic exchange of Certification of Origin e) electronic exchange of Customs Declaration (single window) f) recognized certification authority
	Substantive provision on investments	Customs simplification	
	Substantive provision on public procurement		
	Substantive provision on competition		
	Substantive provision on intellectual property rights		
Maximum Score	*5*	*3*	*2*

Notes: GTF-General trade facilitation; DTF-Digital trade facilitation; RTA-Regional trade agreements
Sources: Dür et al. (2014), Breinlich et al. (2021), and UNESCAP (2017).

Table 2. Depth, GTF, and DTF by income group

Income Group	Depth	GTF	DTF
All	0.60	0.63	0.60
Low Income	0.07	0.10	0.11
Low-Middle Income	0.29	0.33	0.32
Upper-Middle Income	0.47	0.49	0.45
High Income	1.12	1.16	1.11
Distance to Frontier (Deviation)			
Low Income	-1.05	-1.06	-1.00
Low-Middle Income	-0.83	-0.83	-0.79
Upper-Middle Income	-0.65	-0.67	-0.66
High Income	0.00	0.00	0.00
Pearson Correlation Coefficients with per capita GDP for All (p-value)	0.6192 (2.6E-18)	0.5599 (1.4E-14)	0.4892 (5.2E-11)

Notes: Income group according to the World Bank's classification based on per capita GDP. As classified in UNESCAP (2022), GTF (general trade facilitation) includes the WTO's Trade Facilitation Agreement (TFA) measures with sub-groups of transparency, formalities, institutional arrangement and cooperation, and transit facilitation; and DTF (digital trade facilitation) covers two sub-groups, paperless trade and cross-border paperless trade.

Sources: Author's compilation of 334 RTAs notified to the WTO as of January 2022.

relatively new aspect of DTF is less differentiated among income groups. The Pearson correlation coefficients of the three indicators with per capita GDP in Table 2 support the weaker relationship between DTF and economic development status. Additionally, we observe that countries with relatively high DTF values participate in RTAs with lower depth of GTF values. This implies that the adoption of digital customs administration is not solely determined by the economic status of member states or the depth of trade agreements.

This observation can be interpreted as positive evidence for developing countries and their small and medium-sized enterprises (SMEs) to bridge the gap with developed countries by actively participating in deeper RTAs. SMEs, in particular, rely on DTF to facilitate their export activities and prefer to engage in the export market under the general rules of RTAs. Given the challenges faced by SMEs, such as limited economies of scale and global competitiveness, they are particularly vulnerable to tariff barriers. DTF, through its digitalization efforts (UNESCAP, 2019), plays a crucial role in reducing customs barriers and provides SMEs with a valuable tool to overcome these challenges. The inclusion of trade facilitation provisions in RTAs can offer significant certainty and support to potential exporters, leading to employment growth, export diversification, and overall welfare gains.

In general, the development of DTF is increasingly independent of market size, income level, and the previous levels of GTF development. This trend opens up opportunities for SMEs in developing countries to catch up and thrive in international trade.

Digital Trade Facilitation and Extensive Margin of Exports in the Chinese Market: Gravity Regression Model Analysis

Model Specification

Based on the distorted gravity model analysis of exports by Chaney (2008), the impact of reduced trade costs on trade flows can be divided into two distinct margins: the intensive margin, which reflects changes in the size of exports from existing exporters, and the extensive margin, which represents changes in the number of new entrants. Building on the theoretical framework and gravity model applications in Shepherd (2007), Chaney (2008), Felbermayr and Kohler (2010), Martincus et al. (2010), Feenstra and Ma (2014), Wang and Li (2015), and Liu and Duan (2019), we adopt Chaney's (2008) theoretical framework for our modified gravity model analysis at the sectoral level. This framework suggests that the implementation of DTF reduces trade costs and promotes export diversification.

To estimate the model, we employ the standard ordinary least squares (OLS) method and fixed effects (FE) model as the baseline estimation. Additionally, we use the instrumental variable (IV) method to address potential endogeneity issues. Moreover, we observe that many exporting countries trade with China across a limited range of products, resulting in a significant number of zero values at the sectoral level. Consequently, the decision to export specific products to China is influenced by non-random practical considerations. To mitigate bias arising from this issue, we employ the Heckman sample selection (Heckit) model, which addresses endogenous sample selection concerns caused by heterogeneous firms.

OLS and FE Models

The OLS model is constructed as follows.

$$EM_{ijst} = c_1 + \beta_1 lnGDPPC_{it} + \beta_2 (lnGDPPC_{it})^2 + \beta_3 lnDTF_{it} + \beta_4 ln(tariff_{ijt} + 1) + \beta_5 lndist_{ij} + \beta_6 conti_{ij} + \beta_7 lang_{ij} + \beta_8 RTA_{ij} + \epsilon_{ijst} \quad (1)$$

Table 3 describes the variables used in the analysis. The dependent variable, EM, represents the extensive margin of exports at the sectoral level and takes values between 0 and 1. To measure EM, we employ the methodology proposed by Hummels and Klenow (2005).[8] Building upon Feenstra's (1994) index, they introduced a cross-exporter perspective and developed a new index that captures the extensive margin of exporters. The calculation of the index is as follows:

$$EM_{ijs} = \frac{\sum_{s \in S_{ijs}} P_{kjs} x_{kjs}}{\sum_{s \in S} P_{kjs} x_{kjs}} \quad (2)$$

In this context, EM_{ijs} represents the extensive margin of sector s exports from country i to country j (China), S_{ijs} represents the subset of products in sector s that are exported from country i to country j, while s represents the set of all products in sector s that are exported to j. The s refers to specific products included in the subset s. The country or region denoted as k serves as the reference entity, which in this case is the entire world. The p_{kjs} and x_{kjs} represent the average global price and quantities, respectively, of products sector s that are exported to country j.

Table 3. Description of variables

Dependent variable	
EM_{ijst}	The extensive margin of s sector exported from country i to country j (China) in year *t*.
Policy variable	
$lnDTF_{it}$	Degree of digital trade facilitation implementation of country i in year *t*.
Control variables	
$lnGDPPC_{it}$ $(lnGDPPC_{it})^2$	GDP per capita of country i in year *t* and its quadratic form
$ln(tariff_{ijt}+1)$	Applied Tariff rate imposed on country i by importing country j (China) in year *t*.
$lndist_{ij}$	The distance between the most populated city of country i and that of country j (China).
$conti_{ij}$	Dummy equals 1 if country i and country j (China) are contiguous.
$lang_{ij}$	Dummy equals 1 if country i and country j (China) share a common language spoken by at least 90% of their population.
RTA_{ij}	Dummy equals 1 if country i and country j (China) are engaged in a regional trade agreement of any type. It is a time-invariant variable because there has been no change in the number of China's effective RTAs from 2015 until 2019 (our sample period).

Table 3 displays selected variables from our modified gravity model specification. In line with standard gravity model practices, we included GDP per capita, tariff rate, distance, contiguity, common language, and participation in an RTA as control variables. The GDP per capita (GDPPC) is an indicator of a country's market size, and its quadratic term captures the U-shaped relationship between the extensive margin and the level of economic development (Imbs and Wacziarg, 2003). To ensure appropriate scaling and mitigate the impact of heteroskedasticity on regression results, we apply a logarithmic transformation to the GDPPC, DTF, tariff rate, and distance (dist) variables. The multilateral resistance factor includes various components such as the distance between trading partners, contiguous conditions (conti), language usage conditions (lang), and the presence of regional trade agreements (RTA).[9] ε is the error term. In the fixed effects (FE) model estimation, we incorporate fixed effects for importer-exporter pairs, sectors, and times to control for unobserved heterogeneity.

IV Model

When there is a significant initial diversification in exports between exporters and China, the implementation of a DTF mechanism becomes more likely to accommodate large-scale trade flows. However, this reversed causal link, where the dependent variable influences the policy variable, creates an endogeneity issue and reduces the reliability of the OLS regression results. To address this problem, we employ the IV method, using the Control of Corruption Indicator (CCI) provided by the World Bank as an instrumental variable for DTF.

The Control of Corruption Indicator (CCI) is one of the six World Governance Indicators (WGI) that assess governance quality in terms of corruption perception. A higher index indicates a lower perceived level of corruption (Kaufmann et al., 2011). The control of corruption reflects

the level of governance security. Given that e-transfer and data flows' openness can pose risks to digital security, which is crucial in the digitalization era, a governance structure subject to rigorous oversight is more likely to develop DTF (Adomako et al., 2021; Martincus et al., 2010). We assume that the Control of Corruption Indicator (CCI) has no direct relationship with export diversification, thus meeting the theoretical requirements to be considered an instrumental variable.

To incorporate the IV into the baseline model, we employ the two-stage least squares (2SLS) estimation. The first stage of the estimation is outlined as follows:

$$lnDTF = c_2 + \sigma_1 lnGDPPC_{it} + \sigma_2 (lnGDPPC_{it})^2 + \sigma_3 ln(tariff_{ijt} + 1) + \sigma_4 lncci_{it} + \sigma_5 lndist_{ij} + \sigma_6 conti_{ij} + \sigma_7 lang_{ij} + \sigma_8 RTA_{ij} + \epsilon_{it} \quad (3)$$

The second stage of the estimation proceeds as follows:

$$EM_{ijst} = c_3 + \phi_1 lnGDPPC_{it} + \phi_2 (lnGDPPC_{it})^2 + \phi_3 lnDTF_{it} + \phi_4 ln(tariff_{ijt} + 1) + \phi_5 lndist_{ij} + \phi_6 conti_{ij} + \phi_7 lang_{ij} + \phi_8 RTA_{ij} + \epsilon_{ijst} \quad (4)$$

Heckit Model

In the Heckit model, the first step involves utilizing probit regression, while the second step involves employing OLS regression. The model can be represented as follows:

$$P_{ijst} = c_4 + \alpha_1 lnGDPPC_{it} + \alpha_2 (lnGDPPC_{it})^2 + \alpha_3 lnDTF_{it} + \alpha_4 ln(tariff_{ijt} + 1) + \alpha_5 lndist_{ij} + \alpha_6 conti_{ij} + \alpha_7 lang_{ij} + \alpha_8 RTA_{ij} + \alpha_9 consulates_{ijt} + \epsilon_{ijst} \quad (5)$$

The dependent variable P_{ijst} represents the probability of country i exporting to j (China) with a positive value of the extensive margin in sector s in a given year. To ensure identification in the Heckit model, an exclusion restriction is required. This exclusion restriction should influence the dependent variable in the first step without being correlated with it in the second step. In this study, we consider the $consulates_{ijt}$ dummy variable as the exclusion restriction.

The $consulates_{ijt}$ dummy variable takes a value of 1 if the exporting country has established at least one trade-related consulate with China, based on the official list of foreign consulates recorded by China's Ministry of Commerce. These consulates are recognized as export promotion agencies that facilitate countries in establishing economic partnerships with others (Martincus et al., 2010, 2011). The presence of consulates signifies a stable trade and business relationship between the exporting country and China, which initially motivates the country to export to China. Moreover, countries with consulates in China perceive fewer risks and costs associated with exporting decisions due to the political and economic ties between the two countries (Ahmed & Brennan, 2019; Hornby et al., 2002; Segura-Cayuela & Vilarrubia, 2008).

However, in terms of the measurement of the extensive margin, there is little evidence to suggest that the formation of close contacts through consulates can precisely determine the categories of export products at the sector level during trade negotiations. In other words, the value of $consulates_{ijt}$ is uncorrelated with that of the extensive margin represented by EM_{ijst}.

Hence, the $consulate_{sijt}$ dummy variable can be treated as an exclusion restriction in the Heckit estimation.

The OLS model in the second step can be represented as follows:

$$EM_{ijst} = c_5 + \gamma_1 lnGDPPC_{it} + \gamma_2 (lnGDPPC_{it})^2 + \gamma_3 lnDTF_{it} + \gamma_4 ln(tariff_{ijt} + 1) + \gamma_5 lndist_{ij} + \gamma_6 conti_{ij} + \gamma_7 lang_{ij} + \gamma_8 RTA_{ij} + \lambda + \epsilon_{ijst} \quad (6)$$

where λ represents the inverse Mills ratio (imr) derived in the first step. To facilitate comparison with previous studies, the estimation initially employs the PPML model before conducting the Heckit model estimation.

Data

The dataset used in this study covers 96 sectors across 76 countries, spanning the years 2015 to 2019 with a two-year interval. Sector-level product data is utilized to analyze the extensive margin of exports. To examine the current trend in the extensive margin, trade value and quantity data of exported products are extracted from the UN Comtrade database at the six-digit HS (Harmonized System) sector level. These data are further aggregated into two-digit HS data, which are suitable for sector-level studies.

Figures 1 and 2 provide a comparison of the number of export sectors with positive trade values among exporters. The average number of export sectors per exporter is computed, and the exporters are divided into two comparative economic groups. The lines displayed across all the columns represent the simple average value within each group. It is observed that developed countries export a wider variety of goods to the Chinese market compared to developing countries. The average number of export product lines for developed countries is nearly double that of developing countries, with a value of 88 versus 46, respectively. In developing countries,

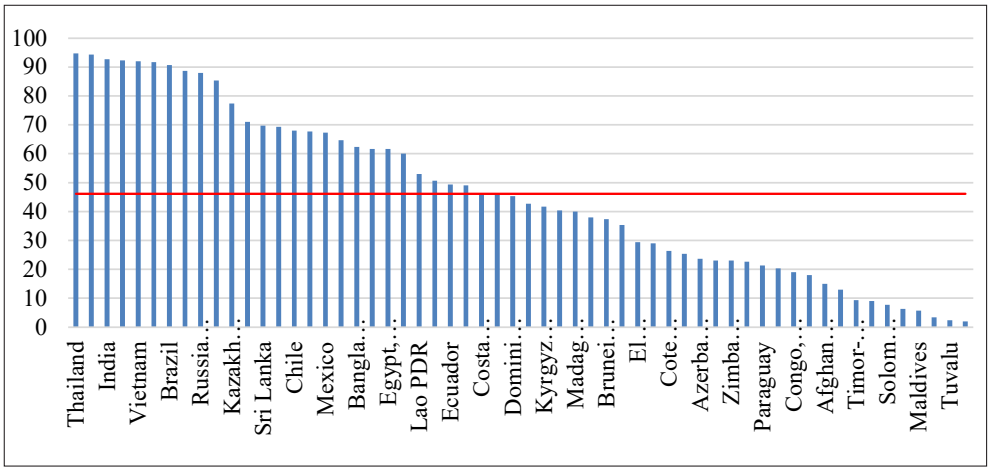

Figure 1. Average number of export sectors in developing countries
Source: UN, UN COMTRADE Database.

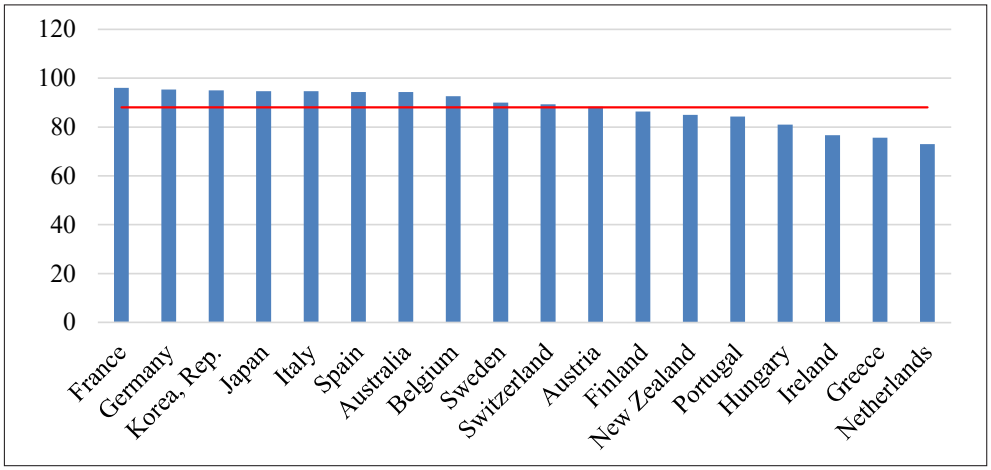

Figure 2. Average number of exporting sectors in developed country
Source: UN, UN COMTRADE Database.

Table 4. Data sources

Variables	*Data sources*
EM_{ijst}	UN Comtrade 96 sectors with HS six-digit products from 76 countries
DTF_{it}	UN Global Survey on Trade Facilitation and Paperless Trade Implementation: 2015-2019; the average of "cross-border trade facilitation" and "paperless trade facilitation"
$GDPPC_{it}$	The World Bank's World Development Indicator (WDI) database
$tariff_{it}$	World Integrated Trade Solution (WITS)
$dist_{ij}/conti_{ij}/lang_{ij}/RTA_{ij}$	Centre d'Etudes Prospectives et d'Informations Internationales (CEPII)
$consulates_{ijt}$	China's Ministry of Commerce (MOFCOM)
cci_{it}	The World Bank's Worldwide Governance Indicators (WGI) database

the extensive margin exhibits significant diversification. For example, Thailand has exports in 95 sectors, while Micronesia only has exports in 2 sectors. Although this disparity may be influenced by various factors, the data indicate that less developed countries demonstrate greater variations in the import variety from China compared to developed countries.

Table 4 provides information on the data sources used in the study, while Table 5 presents the descriptive statistics of the variables.

Statistical Observation

Before estimating the causal relationship between DTF and EM, we analyze the raw data used in the regression to examine the linkages between them. Table 6 presents the summary statistics of trade facilitation indices obtained from the UNTF survey reports, along with the calibrated EM

Table 5. Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
EM	21,888	0.275	0.361	0	1
DTF	21,888	43.149	24.837	0	91.665
tariff+1	21,888	1.114	.232	1	12.45
GDPPC	21,888	14,751	18,852	467	86,119
dist	21,888	7,642	4,163	956	19,080
lang	21,888	0.026	0.16	0	1
conti	21,888	0.158	0.365	0	1
RTA	21,888	0.263	0.44	0	1
consulates	21,888	0.579	0.494	0	1
cci	21,888	0.003	1.027	-1.546	2.276

Table 6. Trade facilitation and extensive margin: summary statistics

	Overall TF (OTF)	General TF (GTF)	Digital TF (DTF)	Extensive Margin of Export (EM)
All	55.90	65.30	42.60	0.27
Low Income	29.12	39.00	16.98	0.05
Low-Middle Income	41.47	53.79	26.26	0.15
Upper-Middle Income	55.61	63.94	42.71	0.21
High Income	73.78	81.57	61.63	0.49
Average	49.99	59.57	36.89	0.22
Standard Deviation	19.20	17.88	19.63	0.19

computed as a simple average across 97 sectors.

Consistent with the findings from the textual analysis of RTAs, several observations emerge. Firstly, the level of economic development, as measured by per capita GDP in 2019, exhibits a positive correlation with both trade facilitation implementation and EM. Secondly, it is observed that GTF is more prevalent than DTF. Thirdly, the standard deviation of DTF is slightly higher than that of GTF, indicating the presence of a digital divide between lower-income and higher-income countries.

Figure 3 illustrates the bilateral relationship between DTF (or GTF) and EM, encompassing the three years of data used in this study as a whole. The figure supports the existence of positive linkages between trade facilitation and EM. It is worth noting that EM demonstrates slightly higher sensitivity to GTF compared to DTF. Although these observations provide valuable insights, it is important to acknowledge that they are limited by the lack of appropriate control for other important variables. Hence, more systematically conducted gravity regression analyses are necessary to further explore these relationships.

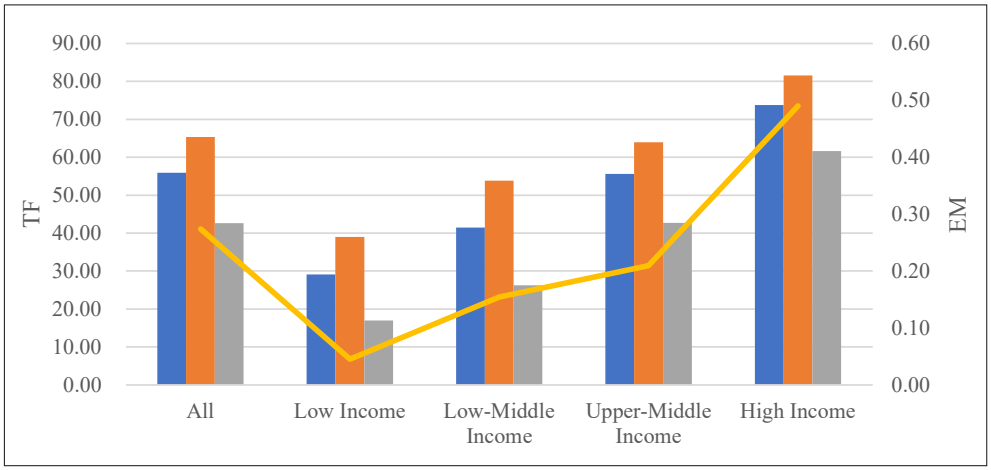

Figure 3. Trade facilitation (TF) and extensive margin (EM): Average of 2015, 2017, and 2019

Results

Table 7 presents the regression results obtained from five main regression models conducted systematically. In columns (1) and (2), the results of the OLS and FE model estimations are reported, respectively. The FE regression introduces importer-exporter pair fixed effects, sector-fixed effects, and time-fixed effects. The IV method, including the three types of fixed effects, is presented in column (3). The estimates using the PPML model are reported in column (4). Finally, column (5) presents the estimates from the Heckit model, incorporating the three fixed effects in the second step.

Consistent with our hypothesis, the OLS estimate indicates that the implementation of DTF has a positive impact on export diversification. Referring to the estimate in column (1), a 1 percent rise in DTF results in a growth of 0.000748 points in export diversification, translating to a 0.27% increase in the average EM, as indicated in Table 5.[10] The estimates derived from IV and FE identification methods in columns (2) and (3) show comparable results, albeit at relatively lower levels. According to these estimates, a 1 percent increase in DTF is expected to raise export diversification by 0.000149 (0.05% of the average EM) and 0.000333 points (0.12% of the average EM), respectively, using the IV and FE approaches. The PPML estimates presented in column (4) are reasonably positive (0.001974 points which increase EM by 0.72%), supporting the hypothesis that DTF has a positive impact on export diversification. The results obtained from the Heckit model estimation in column (5) do not significantly differ from the PPML estimates. The Heckit estimates suggest that a 1 percent increase in DTF expands export diversification by 0.000411 points which increases the EM by 0.15%.

The analysis of other control variables reveals results consistent with our expectations. An increase in the tariff rate and distance has a negative effect on export diversification, while other country-specific characteristics show positive effects. The inverted signs observed between GDPPC and GDPPC2 suggest a U-shaped relationship between GDP per capita and export diversification. The significance of the inverse Mills ratios (imr) in the Heckit model confirms the validity of using the Heckit model. The positive sign indicates that the omitted factor not included in the probit model has a positive effect on the extensive margin.

Trade facilitation emerges as the most plausible mechanism through which governance quality influences export decisions. Governments with robust review mechanisms can safeguard digital systems against cybersecurity threats. Furthermore, efficient governments can establish citizen-friendly e-government systems that implement DTF-related policies. In practical terms, single windows (SWs) have become the most widely adopted approach for implementing DTF. However, according to the World Bank (2014), the establishment of SWs requires long-term investment and substantial technical assistance. In this context, only experienced e-governments are capable of managing SWs and promoting DTF. Hence, we anticipate that countries with a high Control of Corruption Indicator (CCI) indicating high-quality governments, are more likely to be pioneers in DTF deployment, resulting in higher DTF scores during the initial stages of DTF development. Consequently, the selection of the Control of Corruption Indicator (CCI) as an instrument is statistically and conceptually justified. The results of the first stage of regression also support the expected effects, indicating that greater DTF implementation is associated with a higher Control of Corruption Indicator (CCI) index. However, we acknowledge that DTF may not be the exclusive channel through which the Control of Corruption Indicator (CCI) can impact the extensive margin. Nevertheless, based on the conducted tests, DTF can be considered a viable alternative and positioned as the second-best choice.[11]

The estimate obtained from the IV method is relatively higher compared to the FE regression. This can be explained by the concept of the local average treatment effect. In certain countries, the process of customs clearance may still be cumbersome despite relatively low levels of corruption. Additionally, some countries may have high DTF levels due to advanced foreign trade practices or the establishment of efficient e-government systems, even if their government quality is not particularly high. The IV estimation may not fully capture the dynamics of the aforementioned types of countries. However, it applies to countries that adhere to the logic of a low corruption coefficient, resulting in high DTF levels. The positive effect of 0.000333 (0.12% of the average EM) is specifically targeted towards these countries, where DTF is relatively high.

Robustness

Four robustness checks were conducted to further examine the validity of the results. Firstly, we added Property Rights (PR)[12] as another instrumental variable to test the sensitivity of the IV estimation. Property rights play a vital role in shaping the institutional environment that influences DTF. In countries where property rights are well protected, businesses may be more inclined to participate in DTF due to the increased security it provides for their digital assets and transactions. As a result, there appears to be a plausible correlation between property rights and DTF. However, it's important to note that property rights indirectly affect the extensive margin of trade by influencing DTF rather than having a direct impact. The regression results in column (1) of Table 8 indicate that DTF still has a positive effect on export diversification when both Property Rights (PR) and Control of Corruption Indicator (CCI) are used as instrumental variables. Additionally, the F-test (854.698) confirms the absence of weak instrumental variables, and the over-identification test (p-value of the Hansen J statistic=0.5040) rules out the endogeneity of the instruments. Secondly, we rerun the regression by including the sector-year fixed effect only. The result in column (2) of Panel A in Table 9 shows a similar result to the previous estimates in Table 7. Thirdly, to address the bias caused by unobserved firm heterogeneity, we incorporated an estimated latent variable, $\hat{z}_{ijs} = \Phi^{-1}(\hat{\rho}_{ijs})$, where $\Phi(\cdot)$ represents the cumulative distribution function of the unit-normal distribution and $\hat{\rho}_{ijs}$ is the probability of sector s in country i exporting to country j. The Heckit model with the standard correction for sample selection,

$\hat{\eta}_{ijs} = \phi(\hat{z}_{ijs})/\Phi(\hat{z}_{ijs})$, was employed. The results in Column (3) of Panel A in Table 9 show that this corrected Heckit model generates similar results to the previous Heckit estimates in Table 7.

Fourthly, we replaced the measurement of export margins with the number of sectors with positive export values. Although only country-level investigations were conducted due to data

Table 7. Correlation (ROA)

	(1)	(2)	(3)	(4)	(5)	
	OLS	FE	IV	PPML	Heckit	
					First	Second
lnDTF	0.0748***	0.0149***	0.0333***	0.1974***		0.0411***
	(0.0023)	(0.0040)	(0.0092)	(0.0338)		(0.0110)
ln(tariff+1)	-0.1002***	-0.1044***	-0.0825***	-0.5233***	-1.4254***	-0.2890**
	(0.0125)	(0.0238)	(0.0148)	(0.1222)	(0.1326)	(0.1165)
lnGDPPC	-0.2217***	-0.0337	-0.1252	1.2813***	-1.7930***	0.4927***
	(0.0185)	(0.0760)	(0.0794)	(0.3667)	(0.2733)	(0.1220)
$lnGDPPC^2$	0.0184***	0.0063	0.0134**	-0.0619***	0.1451***	-0.0210***
	(0.0011)	(0.0049)	(0.0053)	(0.0205)	(0.0156)	(0.0073)
lndist	-0.0928***				-0.3885***	
	(0.0042)				(0.0581)	
RTA	0.0680***				1.1571***	
	(0.0059)				(0.0728)	
lang	0.0531***				0.3342	
	(0.0162)				(0.2558)	
conti	0.0337***				0.2052**	
	(0.0070)				(0.0961)	
consulates					1.2636***	
					(0.0637)	
imr						0.2162*
						(0.1246)
cons	1.3064***	0.0186		-8.0242***	7.3677***	-2.4940***
	(0.0870)	(0.2886)		(1.6518)	(1.2691)	(0.5960)
Country-pair FE	No	Yes	Yes	Yes	No	Yes
Time FE	No	Yes	Yes	Yes	No	Yes
Sector FE	No	Yes	Yes	Yes	No	Yes
K-P Wald rk F-test	F = 356.764					
N	21888	21888	21888	21888	21888	12800
R^2	0.3116	0.6111				0.5264
$Adjusted\ R^2$	0.3114	0.6080				0.5197
$Pseudo\ R^2$				0.6457		

Robust standard errors are in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 8. Robustness checks

Panel A. Property rightsas an additional IV, sector-year FE, and heckit model with correction

	(1)	(2)	(3)
	IV	Sector-year FE	Heckit model with correction
lnDTF	0.0862***	0.0767***	0.0400***
	(0.0116)	(0.0034)	(0.0110)
ln(tariff+1)	-0.0784***	-0.0938***	-0.3431***
	(0. 0165)	(0.0193)	(0.9420)
lnGDPPC	0.0575*	-0.2237***	0.4400***
	(0.0827)	(0.0322)	(1.8608)
$lnGDPPC^2$	-0.0012*	0.0185***	-0.3542***
	(0.0053)	(0.0020)	(0.9598)
lndist		-0.0931***	
		(0.0074)	
RTA		0.0675***	
		(0.0086)	
lang		0.0529***	
		(0.0178)	
conti		0.0336***	
		(0.0095)	
z_{ijs}_hat			2.4316***
			(6.6344)
z_{ijs}_hat^2			-0.3282**
			(0.4420)
z_{ijs}_hat^3			-0.1310**
			(0.0340)
eta_hat			0.2687*
			(0.4033)
cons		1.3132***	-1.3257***
		(0.1682)	(3.5539)
Country-pair FE	Yes	No	Yes
Time FE	Yes	No	Yes
Sector FE	Yes	No	Yes
Sector-year FE	No	Yes	No
K-P Wald rk F-test	F = 854.698		
Hansen J statistic	P = 0.5040		
N	20736	21888	12800
R^2		0.4253	0.5274
$Adjusted\ R^2$		0.4174	0.5206

Robust standard errors are in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Panel B. Different measurements of EM

	(1)	(2)
	FE	PPML
lnDTF	5.0299**	0.1225**
	(1.9402)	(0.0398)
ln(tariff+1)	-3.6716**	-0.0705*
	(1.4792)	(0.0387)
lnGDPPC	-22.7292**	-0.4638*
	(25.3768)	(0.5814)
$lnGDPPC^2$	1.4854**	0.0249*
	(1.7092)	(0.0358)
lndist		
RTA		
lang		
conti		
cons	128.1212	5.9853**
	(91.4888)	(2.3302)
Country-pair FE	Yes	Yes
Time FE	Yes	Yes
Sector FE	No	No
N	219	219
R^2	0.9396	
$Adjusted\ R^2$	0.9059	
$Pseudo\ R^2$		0.7171

Robust standard errors are in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

availability, this robustness check aimed to demonstrate the consistency of the results regardless of the EM measurement. The PPML method was used instead of the Heckit model to account for the counting nature of the extensive margin. The regression results of this fourth robustness check are presented in Panel B of Table 8. Columns (1) and (2) report the results of the FE and PPML estimations, respectively. The positive effect of DTF on the alternative measure of EM remains evident.

In summary, the robustness checks, including alternative instrumental variables and fixed effect, the incorporation of sample selection correction, and the use of an alternative measure of EM, provide further support for the results obtained in the previous regressions. Overall, an increase in DTF is associated with an increase in export diversification to a certain extent.

Mediating Effect Analysis for Policy Implications

DTF and E-commerce

We conducted a test to examine whether the development of digital trade can amplify the positive contribution of DTF to export diversification. In today's digital era, digital trade, particularly e-commerce, has gained significant prominence and has become a driving force behind economic growth, particularly in developing countries. China, for instance, has experienced remarkable growth in cross-border e-commerce revenue, even amidst the economic challenges posed by the COVID-19 pandemic. China is recognized as the world's largest B2C digital market, controlling approximately 26 percent of the global digital trade market (CCG, 2021). Other countries, such as Thailand and Peru, have also implemented initiatives and laws to support SMEs in adopting and leveraging digital trade. In the developing world, the initial adoption of e-commerce has led to increased trade volumes and welfare gains in various industries (Smeets, 2021).

The emergence of e-commerce has led to a reduction in production and trade costs, enhancing business efficiency and reducing barriers to entry into the global market. As a result, more participants, particularly SMEs, are encouraged to export a diverse range of products. In countries with well-developed digital trade mechanisms, DTF can be easily and affordably integrated into this transmission chain, thereby exerting a more significant impact on export diversification. Since DTF and digital trade share a common digital dividend, we hypothesize that countries with a relatively mature digital trade sector can leverage it as a foundation to facilitate the establishment of DTF systems. This forms the central premise of our study on the mediating effect. E-commerce can serve as a crucial channel for less-developed countries and SMEs to enhance their DTF systems, ultimately leading to an enrichment of export varieties.

Model and Data

To empirically test our hypothesis, we introduce an interaction term that combines DTF with the UNCTAD B2C E-commerce Index (ECI), which captures the relationship between domestic and cross-border digital trade. The ECI incorporates various indicators, which are listed in Table 9. In addition to the ECI, we also consider the ICT Development Index (IDI) and the Digital Economy and Social Index (DESI) as alternative measures of e-commerce. However, we find that the ECI is more suitable for our analysis as it focuses on the interactive nature of ICT and the digital economy, making it more inclusive and appropriate. While the DESI provides a comprehensive framework for assessing national e-commerce development, it is primarily tailored to the European Union and may not be easily adaptable to other economic regions. Thus, we assume that the ECI outperforms other indicators in terms of representing the global level of digital trade.

$$\begin{aligned} EM_{ijst} = c_5 &+ \pi_1 lnGDDPC_{it} + \pi_2 (lnGDPPC_{it})^2 + \pi_3 lnDTF + \pi_4 lnECI_{it} \\ &+ \pi_5 (lnDTF_{it} \cdot lnECI_{it}) + \pi_6 ln(tariff_{ijt} + 1) + \pi_7 lndist_{ij} + \pi_8 conti_{ij} \\ &+ \pi_9 lang_{ij} + \pi_{10} RTA_{ij} + e_c + e_s + e_t + \epsilon_{ijst} \end{aligned} \tag{7}$$

where e_c, e_s and e_t are country-pair fixed effect, sector-fixed effect, and time-fixed effect, respectively. Other variables are consistent with previous settings, except for the interaction term $lnDTF_{it} \cdot lnECI_{it}$. The settings of the Heckit model are the same with the addition of an interaction term in both steps.

Table 9. Measuring digital trade level

ECI	IDI	DESI
Account ownership at a financial institution or with a mobile-money-service provider as the percentage of the population aged over 15	ICT access: for example, the percentage of households with Internet	Human capital
Individuals using the Internet as the percentage of the total population	ICT use: for example, the percentage of individuals using the Internet	Connectivity
Postal Reliability Index	ICT skills: for example, the proportion of individuals with ICT skills	Integration of digital technology
Secure Internet servers as per one million people		Digital public services

Sources:

1) UNCTAD, 2019, *B2C E-commerce Index, 2019*, p. 1.

2) ITU, 2017, *Measuring the Information Society Report 2017–Volume 1*, p. 27.

3) EU, 2021, *Digital Economy and Society Index (DESI) 2021: DESI methodological note*, p. 4.

Results

The empirical findings are displayed in Table 10, where different regression models are reported. Columns (1) and (2) present the results of the OLS and FE regressions respectively, using the same model specifications as in the previous analysis. Columns (3) and (4) present the results of the Heckit regression model. In all three models, both DTF and ECI exhibit positive effects on the extensive margin when the interaction term is introduced. Furthermore, the interaction term has a positive impact on export diversification from the OLS estimation to the second step of the Heckit estimation.

Consistent with previous regressions, the remaining variables demonstrate similar patterns. The U-shaped relationship between GDP per capita and the extensive margin persists, and the signs of the estimates for other country-specific characteristics align with the previous regression results.

Policy Implications

To support the effectiveness of the DTF system coupled with e-commerce in less developed countries with smaller economic sizes and lower ICT development, we have created two 3D graphs displayed in Figure 4. The z-axis represents the GDPPC and the IDI respectively. Using data from 116 countries between 2016 and 2018, including GDP per capita, ECI, DTF, and IDI, we examine the relationship between DTF and ECI with GDPPC and ICT.

These figures demonstrate that the development level of DTF and digital trade is not solely determined by economic size or ICT level. In both graphs, countries with relatively lower ICT indices or GDPPC values exhibit higher levels of e-commerce and DTF. These countries are depicted as upward-sloping pits beneath the surface, indicating their progress along the GDPPC or ICT axis. As the surfaces in both graphs rise along the z-axis, the overall trend leans towards higher technological progress and larger market sizes, which foster the expansion of e-commerce.

Table 10. DTF, E-Commerce, and EM

	(1)	(2)	(3)	
	OLS	FE	Heckit	
			First	Second
lnDTF	0.1502***	0.1666***		0.1645***
	(25.5301)	(23.3959)		(16.6518)
lnECI	0.1342***	0.1586***	0.5275***	0.0952***
	(20.4078)	(24.8434)	(7.2402)	(6.1460)
lnDTF×lnECI	0.1221***	0.1369***	0.0405	0.0994***
	(16.6050)	(24.6944)	(0.6127)	(9.2007)
ln(tariff+1)	-0.1355***	-0.1228***	-1.0822***	0.0332
	(-7.3606)	(-5.1185)	(-6.5665)	(0.5809)
lnGDPPC	-0.1895***	-0.2151***	-1.3408***	-0.1554**
	(-9.2849)	(-6.5567)	(-4.8075)	(-3.0272)
$lnGDPPC^2$	0.0140***	0.0148***	0.1106***	0.0103***
	(11.8559)	(7.4240)	(6.9347)	(3.6654)
lndist	-0.1247***	-0.1246***	-0.7359***	-0.0956***
	(-26.8820)	(-14.5275)	(-11.6216)	(-10.2688)
RTA	0.0578***	0.0536***	1.0051***	0.0017
	(9.6080)	(6.1458)	(13.5342)	(0.1661)
lang	0.0772***	0.0847***	-0.0593	0.0905***
	(4.9772)	(4.4857)	(-0.2412)	(5.0495)
conti	0.0037	0.0081	-0.3098**	0.0188
	(0.4920)	(0.7915)	(-3.1729)	(1.4943)
consulates			0.8277***	
			(12.3646)	
cons	1.0563***	1.1045***	7.7405***	1.0591***
	(10.9689)	(6.2703)	(5.8772)	(4.0287)
imr				-0.0931***
				(-4.9346)
Country-pair FE	No	Yes	No	Yes
Time FE	No	Yes	No	Yes
Sector FE	No	Yes	No	Yes
N	18720	18720	18720	12198
R^2	0.3277	0.4595		0.3897
$Adjusted\ R^2$	0.3274	0.4564		0.3843

Robust standard errors are in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

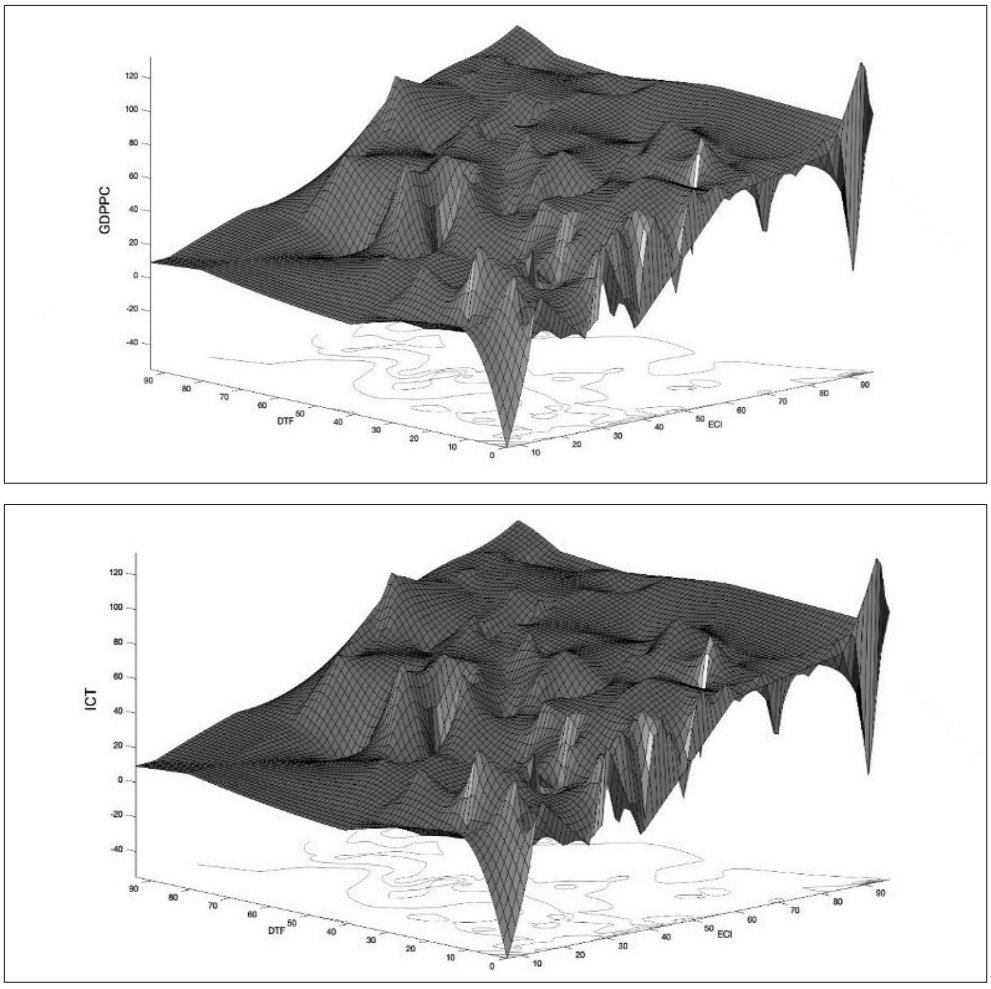

Figure 4. Trilateral relationships: GDPPC or ICT, DTF, and ECI

However, the graphs also reveal a non-linear surface, indicating that some lower and middle-income countries have successfully pursued their paths toward expanding digital trade and DTF.

From the findings, two implications can be drawn. Firstly, the construction of a DTF system can benefit from leveraging a relatively mature digital trade mechanism. This can provide practical experience in areas such as digital logistics deployment, payment system integration, and governance settings. By doing so, it reduces the opportunity costs involved in establishing the DTF system. In this context, e-commerce serves as a mediator, amplifying its impact on export diversification. Moreover, this information suggests that the potential of DTF is not limited to countries with technological advantages and significant trade volumes. Similar to the development process of e-commerce, the establishment of DTF is a composite process that can rely on the construction of domestic digital trade systems. In this regard, developing countries can enhance the effectiveness of DTF by leveraging existing e-commerce systems. This, in turn, stimulates more participation from SMEs in the global market and contributes to increased export diversification on a global scale.

In summary, the flourishing of digital trade reinforces the positive effects of DTF on the extensive margin of exports. As the development of DTF and e-commerce is not solely determined by market size and technical capabilities, developing countries can foster SME engagement in the international market by implementing DTF within the framework of e-commerce development.

Concluding Remarks

This study provides empirical evidence supporting the positive relationship between DTF and export diversification, focusing on the Chinese market. Through a comprehensive analysis of 334 currently effective RTAs worldwide, we found that the adoption of digital customs administration is not solely determined by the economic status of member states or the depth of trade agreements.

Utilizing a rigorous gravity regression model and EM data from 96 sectors of 76 countries exporting to China, our analysis demonstrates that the implementation of DTF has a significant positive impact on the extensive margin of exports. This not only benefits China as an importer but also generates welfare gains for exporters to the Chinese market. Furthermore, our mediating effect analysis reveals that the expansion of digital trade, when interacting with the level of e-commerce, further amplifies the positive effect of DTF on export diversification in the Chinese market.

Importantly, our findings suggest that the development of DTF and e-commerce is not solely determined by economic size or ICT level. This highlights the importance of actively promoting the enhancement of DTF systems by SMEs in developing countries. By doing so, these countries can better leverage trade cooperation within the framework of RTAs and expand e-commerce coverage.

The policy implications derived from this study indicate that DTF can serve as a cooperative pathway for trading countries to achieve mutual benefits. It alleviates the pressure of catching up for comparative advantage and offers opportunities for bilateral commerce. However, it is crucial to address issues related to cybersecurity, data security, and cross-border trade policies at the national level, as they are closely linked to the development of DTF. Mutual understanding and the pursuit of common goals without provoking conflicts are essential for successful DTF implementation, which ultimately leads to welfare gains resulting from the extensive margin of trade.

While our analysis provides robust evidence supporting the positive relationship between DTF and export diversification, particularly within the Chinese market, there remain areas that warrant further exploration. For instance, future studies could investigate the long-term impacts of DTF on different sectors and regions, examine the interplay between DTF and other trade policies, and explore the role of specific e-commerce platforms in enhancing trade outcomes. These areas of inquiry will help build a more comprehensive understanding of DTF's role in global trade dynamics.

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Notes

1. According to the classification by UNESCAP (2022), trade facilitation encompasses four main measures: (1) general trade facilitation, which includes the measures outlined in the World Trade Organization's Trade Facilitation Agreement (TFA) and consists of sub-groups such as transparency, formalities, institutional arrangements and cooperation, as well as transit facilitation; (2) digital trade facilitation, which encompasses two sub-groups: paperless trade and cross-border paperless trade; (3) sustainable trade facilitation, which focuses on trade facilitation measures for small and medium-sized enterprises (SMEs), agriculture, and women; and (4) other trade facilitation measures.
2. In 2019, this survey was renamed as the UN Global Survey on Digital and Sustainable Trade Facilitation. The survey results provide valuable insights into the current state of DTF policies and contribute to the credibility of our empirical findings to a certain extent.
3. We investigated the impact of DTF on the intensive margin (IM) of exports in comparison to the extensive margin (EM) by utilizing OLS and FE regressions at the 3 digit HS (Harmonized System) classification level. The regression analyses demonstrated that there is no significant causal relationship between DTF and the IM of exports but a significantly positive impact of DTF on the EM of exports. These findings suggest that DTF primarily influences the EM, supporting our decision to focus primarily on analyzing the EM of exports in the Chinese market.See Appendix Table 1 for a detailed presentation of the results.
4. According to the systematic analysis in Gradillas and Thomas (2023), there are seven distinct categories differentiating 'digitization' and 'digitalization'. The former term refers to information processing and digital technology development, while the latter term points out the digital adoption and usage in infrastructures deployment and policy constructions. Therefore, in this paper, we consistently use 'digitalization' to illustrate digital adoption in the trade policy.
5. For the gains from deep trade agreements by investigating RTA provisions, see Matto et al. (2020). For the RTA depth indexation, see Dür et al. (2014).
6. According to Breinlich et al. (2021), the "iceberg lasso" method processes by applying a specialized algorithm that incorporates elements from both the plug-in lasso and cross-validation techniques, optimizing for scenarios where true causal variables are highly correlated with numerous other variables. This method aims to balance the stringent variable selection of the plug-in lasso with the flexibility of cross-validation, improving model performance and variable selection accuracy in small-to-moderate sample sizes.
7. The four clauses include the following provisions: (1) Does the agreement require customs harmonization and a common legal framework? (2) Does the agreement regulate customs and other duties collection? (3) Do trade facilitation provisions simplify requirements for proof of origin? (4) Does trade facilitation provisions simplify procedures to issue proof of origin?
8. Hummels and Klenow (2005) define the extensive margin as a measure of the number of categories i exports to j relative to the total number of categories k available for export. When all categories are

considered equally important, the extensive margin can be calculated as the fraction of categories in which *i* exports to *j*.

9. The tariff rate represents an applied tariff, whereas RTA is a dummy variable indicating the existence of a regional trade agreement between countries. These variables are independent of one another.
10. Persson (2013) reported that the number of exported differentiated and homogeneous products would rise by 0.6% and 0.3%, respectively, if the number of days needed to export a good declined by 1%.
11. The CCI as an instrument variable does not exhibit significant issues of weak IV, as indicated by the F-test reported in Table 7, which is well above the threshold of 10. Regarding the exogeneity test, we assert that corruption control does not directly affect the number of exported production lines.
12. One from the Index of Economic Freedom published by The Heritage Foundation- https://www.heritage.org/index/visualize. 4 countries ("Nauru", "Palau", "Tuvalu", "Myanmar") are excluded from the sample due to the limits in the PR data.

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Appendix

Table 11. Estimated Effects of DTF on IM and EM

	IM		EM	
	(1)	(2)	(3)	(4)
	OLS	FE	OLS	FE
lnDTF	0.0050***	-0.0004	0.0763***	0.0282***
	(0.0007)	(0.0011)	(0.0019)	(0.0025)
ln(tariff+1)	-0.0058**	0.0016	-0.1168***	-0.0171
	(0.0026)	(0.0074)	(0.0107)	(0.0231)
$lnGDPPC$	-0.0011	-0.0030	-0.2666***	0.1804**
	(0.0067)	(0.0285)	(0.0156)	(0.0739)
$lnGDPPC^2$	0.0002	0.0004	0.0209***	-0.0081*
	(0.0004)	(0.0020)	(0.0009)	(0.0047)
lndist	-0.0151***		-0.0891***	
	(0.0034)		(0.0036)	
RTA	0.0094**		0.0535***	
	(0.0041)		(0.0049)	
lang	-0.0159***		0.0532***	
	(0.0042)		(0.0139)	
conti	-0.0086**		0.0322***	
	(0.0034)		(0.0059)	
cons	0.1174**	0.0072	1.4574***	-0.7804***
	(0.0468)	(0.1064)	(0.0728)	(0.2842)
Country-pair FE	No	Yes	No	Yes
Time FE	No	Yes	No	Yes
Sector FE	No	Yes	No	Yes
N	33516	33516	33516	33516
R^2	0.3126	0. 2350	0.2977	0.5223
$Adjusted\ R^2$	0.3049	0.1910	0.2975	0.5189

IM and EM were measured by 3-digit HS classification.
Robust standard errors are in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$