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Exploring the link between innovation and digital trade exports: Cross-country firm-level evidence

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Abstract: This study examines the relationship between firm-level innovation and participation in digital trade exports, with particular attention to heterogeneity across firm sizes. Using cross-country firm-level data from the World Bank Enterprise Surveys covering 94 countries during 2022–2025, the analysis focuses on manufacturing firms. Innovation is measured using both input indicators (R&D investment) and output indicators (new products and improved processes). Probit and instrumental variable (IV) estimations are employed to address potential endogeneity, with sector–location average innovation used as an instrument. The results show that innovation significantly increases the likelihood of engaging in digital trade exports. Innovative firms are more likely to export digitally, even after controlling for endogeneity. However, the effect is heterogeneous: innovation has a strong positive impact for small and medium-sized enterprises (SMEs), while the effect is weaker or negative for large firms. Access to foreign technology, internet connectivity, and financial resources further shape digital export participation. Innovation plays a critical role in enabling firms to participate in digital trade, particularly among SMEs. The findings suggest that policies promoting R&D, digital infrastructure, and financial access, especially for SMEs, can foster more inclusive participation in global digital markets.

Keywords: *Innovation, Digital Trade, Export Participation, SMEs, Financial Constraints, R&D, Probit, Instrumental Variables.*

1. Introduction

The rapid rise of digital trade has clearly altered how global commerce works. It opens doors for firms, especially in manufacturing, to reach foreign customers through electronic channels that bypass many of the barriers of traditional exports. But digital trade isn't just "exports moved online." It often demands different kinds of capabilities: technological readiness, steady access to digital infrastructure, and, perhaps most importantly, a willingness to innovate [1, 2]. Innovation can help firms introduce new products, improve quality, and stand out in increasingly crowded digital markets [3, 4]. Still, how much innovation truly influences participation in digital exports remains uncertain. The answer likely depends on firm size and available resources.

Past research has linked innovation to export behavior for years [5, 6]. Yet, recent studies suggest that its effect may not be uniform. For smaller firms, innovation may carry more weight. SMEs, with their flexibility and quicker decision-making, often see greater benefits from adopting digital tools [7]. Larger firms, by contrast, may face diminishing returns. Structural rigidities or a focus on efficiency-driven changes rather than bold product innovation could blunt the benefits of R&D [8, 9].

Against this backdrop, our study examines how innovation relates to digital export participation, drawing on new cross-country firm-level data from the World Bank Enterprise Surveys (WBES). We look at manufacturing firms, the sector where trade theory is most tested, and consider both input innovation (R&D spending) and output innovation (new products or processes). To deal with the thorny

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problem of endogeneity, we use an instrumental variable approach based on sector-location averages, following Fisman and Love [10]. We also ask whether the innovation–export link appears different for SMEs compared with larger firms.

This work adds to the literature in several ways. First, while scholars have studied how innovation affects traditional exports, few have looked specifically at digital trade exports, a rapidly growing but distinct corner of global commerce. Digital exports require not only technical know-how but also new ways of organizing production and delivery, making them worth analyzing separately. Second, by using WBES data from 94 countries, we can compare firms across a wide range of institutional and economic environments, including developing and emerging economies that typically do not receive much attention in this field. Third, instead of relying solely on input measures of innovation such as R&D, we also include output measures, capturing whether firms are actually launching new products or processes. This provides a more comprehensive picture of how innovation functions in practice. Fourth, our instrumental variable approach, using sector-location averages, strengthens the causal interpretation, building on earlier work by Fisman and Love [10]. Finally, the study highlights that not all firms benefit equally: innovation appears to help SMEs far more than large firms, a result that complicates the common assumption that innovation benefits all firms equally.

The paper proceeds as follows. Section 2 reviews the theoretical background and sets out the main hypothesis. Section 3 describes the data, variables, and empirical strategy. Section 4 presents the main regression results. Section 5 explores robustness and heterogeneity. Section 6 concludes with the main insights and policy takeaways.

2. Theoretical Background and Hypothesis Development

2.1. Digital Trade Export

Digital trade exports refer to the cross-border delivery of goods and services made possible by digital technologies. This does not just cover electronically delivered products or standardized services; it also includes revenue streams from digital platforms like e-commerce marketplaces or software distribution systems. As global digital connectivity continues to expand, digital exports have become an important driver of trade growth, economic complexity, and firm competitiveness.

Recent research indicates that digital trade exports tend to be more geographically concentrated than traditional exports, while also experiencing significantly faster growth [11]. This growth is beginning to reshape the dynamics of global trade. Advances in robotics, cloud computing, 3D printing, and automated logistics reinforce this trend by increasing productivity and enabling firms to deliver more sophisticated, service-integrated products. These technologies also reduce transaction costs and facilitate digital supply chains, making exporting feasible even for firms in sectors that previously rarely considered international markets.

The spread of digital commerce is also changing labor markets and business performance in ways that aren't always straightforward. Some studies suggest digital exports may reduce wage gaps within firms by creating new export opportunities, particularly for smaller or less visible businesses. But at the same time, they may widen inequalities across sectors, since not all industries have equal access to infrastructure or digital know-how [12]. In China, for example, the rise of the digital economy has not only boosted exports but also made them more complex, even in traditionally low-tech sectors, thanks to spillovers of knowledge and market-driven innovation [13, 14].

Whether digital exports succeed or stall often depends on a mix of technology, economics, regulation, and firm strategy. On the technological side, internet access and the adoption of digital tools are essential. Firms that use digital technologies well usually export more intensively [15]. Better connectivity, easier access to global markets, and more transparent supply chains all help accelerate the move toward digital trade. One study even finds that the digital transformation of services led to a 5.82% increase in global service export growth [16].

Economic and institutional conditions are also significant. Countries with strong human capital, well-developed digital infrastructure, and efficient resource allocation are more likely to achieve higher

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levels of export sophistication [14, 17]. Regulation is another crucial aspect: open ICT markets, consistent rules for digital trade, and supportive legal frameworks can reduce transaction costs and facilitate involvement for smaller firms in low- and middle-income countries [18, 19].

At the firm level, strategy plays a significant role. Prior export experience, innovation capacity, and scale all influence how companies approach digital exports. Firms with existing international exposure often find it easier to adopt digital tools and transition into digital trade models [20]. The growth of cross-border e-commerce, especially within agreements like RCEP, has created new opportunities. Stronger transportation links, improved institutions, and enhanced financial infrastructure all contribute to lowering the fixed costs of entering digital markets.

Still, the road isn't smooth. Weak institutions, uneven digital access, and patchy regulatory environments remain significant barriers. The gains from digitalization are far from evenly distributed; they depend heavily on a firm's own capabilities and the local environment in which it operates [20]. For that reason, understanding the complex, multi-layered nature of digital export participation is essential if policymakers and businesses hope to design effective strategies.

2.2. Effects of Innovation on Digital Trade Export

Innovation plays a central role in helping firms transition into digital trade exports. It drives technological upgrades, enhances product offerings, and enables businesses to respond effectively to the evolving demands of international markets. This phenomenon is particularly evident among SMEs and manufacturing firms, where innovation often acts as the catalyst that allows them not only to enter but also to succeed in digital trade. Once firms begin innovating and exporting, these activities mutually reinforce each other, creating a cycle that enhances competitiveness over time. The discussion below examines the primary ways input innovation supports participation in digital exports.

A first point is technological innovation. Firms that invest in research and development (R&D) and adopt new technologies tend to be more engaged in exporting and expand their export volumes more quickly [21]. Product and process innovations, in particular, enable them to bring new or upgraded goods and services to market, an important step if they want to reach foreign consumers and keep pace in the digital economy [6].

There's a long-recognized complementarity between innovation and exporting: each feeds the other. Firms that innovate are usually better prepared to enter export markets. Meanwhile, exposure to global competition and knowledge flows often pushes exporters to keep innovating [6]. For SMEs, combining different types of innovation, whether in products, processes, or organizational practices, can be particularly powerful, making them more export-ready and improving their performance abroad [22]. This back-and-forth between innovation and exporting helps build capacity on both fronts over time.

Within this, product and process innovation stand out as especially influential. Product innovation, creating something new or making major improvements to existing goods, lets firms adapt to changing tastes, meet different regulatory or quality standards, and differentiate themselves in competitive markets. In the fast-moving world of digital trade, where customers expect rapid responses, this ability to customize and upgrade products can open niche opportunities and even allow firms to charge premium prices [22].

Process innovation takes a different but complementary path. By streamlining production, refining supply chains, or improving internal workflows, firms cut costs, reduce waste, and deliver consistent quality. These gains translate into stronger price competitiveness, something vital in international trade, especially in price-sensitive markets. Process innovation also supports scale and reliability, which matter greatly for digital exports that depend on timely delivery and efficient logistics [23].

What makes product and process innovation particularly powerful is how they reinforce each other. A firm that upgrades products while also improving efficiency can both raise value and lower costs, a dual advantage in crowded global markets. In digital trade, where speed, customization, and reliability all matter, this combination becomes even more important. It lowers barriers to entry, builds customer trust, and helps firms expand their international presence.

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Technological innovation is a key driver of export competitiveness, particularly in high-technology industries. Evidence from China indicates that innovation facilitates industrial upgrading and strengthens firms' positions in global markets by enabling the production of more technologically sophisticated goods [24]. At the regional level, the expansion of the digital economy, underpinned by technological innovation, has been shown to enhance urban export performance, with cities increasingly functioning as strategic nodes within global value chains and digital trade networks [25]. These findings highlight the spatial dimension of innovation, where digital infrastructure and innovation capacity at the city level reinforce export outcomes.

In short, product and process innovation provide firms with the flexibility and capacity needed to compete internationally. By adapting products to foreign markets, reducing costs, and leveraging technology, innovative firms are better positioned to participate in digital exports [3, 26]. Therefore, policies that promote both product and process innovation are likely to be crucial for enhancing digital trade participation.

Based on the above arguments, we propose the following hypothesis:

H_1: Innovation is positively associated with the probability of digital export participation.

3. Data Description

This study draws on cross-country data from the World Bank Enterprise Surveys (WBES)[1]. During the preprocessing stage, we dropped observations with missing values and dealt with outliers in continuous variables by winsorizing them at the 1st and 99th percentiles. To keep the analysis aligned with trade theory, we focus only on manufacturing firms. After applying these steps, the final sample includes approximately 7,207 firm-level observations across 94 countries, spanning the years 2022 to 2025[2]. It is worth noting that WBES only began collecting information on digital trade exports in the 2022 survey round, which sets the lower bound for our timeframe.

3.1. Dependent Variable: DTE

The main outcome variable, *DTE*, is coded as a binary indicator. It takes the value 1 if a firm reports exporting goods through electronic platforms and completing delivery via postal or courier services, and 0 otherwise. The dataset also includes firms that have not engaged in any kind of exporting, providing a useful contrast. As shown in Table 2, roughly 24% of the sampled firms are identified as participating in digital exports.

3.2. Independent Variable: Innovation

In this study, innovation is primarily measured through a firm's expenditure on research and development (R&D). This indicator reflects the firm's commitment to developing new products, improving existing processes, and enhancing technological capabilities. Firms are asked whether they have invested in R&D over the past three years, and this self-reported variable functions as an input-based measure of innovation, serving as a proxy for the internal efforts a firm dedicates to innovative activities, regardless of whether these efforts immediately yield results.

To test robustness and cover a broader view of innovation, we also use an output-based measure as an alternative specification. Output innovation points to the actual results of innovation efforts, for example, the launch of new or significantly improved products or services within a given period. By running models with both input and output measures, we can check whether the link between innovation and digital export participation holds consistently, while also accounting for the fact that effort and outcomes don't always line up perfectly.

[1]The data supporting the findings of this study are available from the corresponding author upon reasonable request.

[2]Table A1 in the Appendix shows that the share of observations varies across countries without the domination of a that from any single country.

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This two-pronged approach helps address concerns about measurement bias and provides a more comprehensive picture of how innovation influences a firm's likelihood of engaging in digital exports. As shown in Table 1, firms that participate in digital exports allocate a larger share of their resources to R&D compared with firms that do not.

Table 1.
Comparison between non-digital exporters and digital exporters.

	Non-digital exporters			Digital exporters			
Variable	**Mean**	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**	**t-test (p-value)**
Innovation	0.33	0	1	0.42	0	1	0.00

3.3. Control Variables

To account for firm-level differences that could influence digital export participation, this study includes a set of control variables drawn from earlier empirical work [1, 2, 27, 28]. These variables are chosen to capture critical aspects of firm characteristics that shape both digital readiness and the likelihood of engaging in international trade.

Productivity (measured as the log of revenue per employee) is a central control. More productive firms usually have an easier time absorbing the fixed costs of exporting and investing in digital infrastructure. As a result, higher productivity tends to be linked with stronger engagement in digital trade [29, 30].

Firm age reflects the number of years a company has been operating. Older firms may benefit from accumulated routines and institutional knowledge, which could support international expansion. At the same time, age may bring rigidity, making it harder to adapt to digital opportunities. The evidence here is mixed, suggesting the effect depends heavily on context [31].

Managerial experience is captured by the industry-specific tenure of the top manager. Leaders with longer experience may be better positioned to guide digital adoption and foreign market entry, given their familiarity with industry dynamics [32].

Joint stock status indicates whether a firm is publicly listed or structured as a joint stock company. These firms typically enjoy better access to capital, yet may also face tighter oversight and compliance requirements, which can slow their response to emerging digital trade opportunities [20].

Foreign technology adoption captures whether firms incorporate technologies developed abroad. Access to international tools and practices can accelerate digital transformation and strengthen competitiveness in global value chains, often linking directly to export growth [14].

Foreign ownership is included as well. International investors may bring in capital, managerial know-how, and cross-border networks. However, the effect is not uniform, depending on ownership structures and local institutional environments, foreign ownership can also create liabilities that complicate market navigation [33].

International certifications such as ISO standards signal compliance with global norms. These certifications reduce information asymmetries and build credibility with overseas partners, though they can be costly to obtain and maintain, an obstacle particularly for SMEs [20].

Internet access is a baseline requirement for digital trade. Reliable connectivity lowers transaction costs, supports market research, and enables firms to engage in e-commerce platforms and digital channels (Duan & Hu, 2024; Luu, 2023).

Finally, *financial constraints* are measured through a combination of self-reported credit obstacles and discouraged borrowing. Firms with limited financing often struggle to invest in innovation, digital infrastructure, and international expansion. A large body of research shows that credit frictions reduce both the probability of exporting and the intensity of exports [34, 35]. These barriers are especially binding in sectors like digital services or advanced manufacturing, where significant upfront investment is required.

By controlling for these factors, the analysis aims to better isolate the effect of financial constraints on digital export participation, rather than capturing differences driven by other firm-specific characteristics. A statistical description of all variables is presented in Table 2.

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Table 2.
Statistical summary.

	Count	Mean	Sd	Min.	Max.
DTE	7207	0.24	0.43	0.00	1.00
Innovation	7207	0.36	0.48	0.00	1.00
Financial constraints	7207	0.14	0.34	0.00	1.00
Productivity	7207	13.87	2.74	9.51	21.29
Firm age	7207	3.18	0.74	1.10	4.86
Managerial experience	7207	3.12	0.60	1.10	4.06
Joint stock status	7207	0.07	0.26	0.00	1.00
Foreign technology adoption	7207	0.24	0.43	0.00	1.00
Foreign ownership	7207	0.24	0.43	0.00	1.00
International certifications	7207	0.60	0.49	0.00	1.00
Internet access	7207	0.13	0.34	0.00	1.00
Alternative measures					
New product	7207	0.36	0.48	0.00	1.00
Improved process	7207	0.27	0.44	0.00	1.00

4. Model Specification

We adopt the approach used in recent studies on digital exports [1, 2] to construct the benchmark model as follows:

$$\Pr(DTE_{ijk}=1)=\Pr\left(\beta_0+\beta_1 Innovation_{ijk}+\beta_2 CONTROL_{ijk}+\upsilon_j+\gamma_k+\lambda_t+\varepsilon_{ijk}>0\right)$$
$$=\Phi\left(\beta_0+\beta_1 Innovation_{ijk}+\beta_2 CONTROL_{ijk}+\upsilon_j+\gamma_k+\lambda_t\right). \quad (1)$$

Subscripts i, j, k, and t denote firm, country, sector, and year, respectively. The terms υ_j, γ_k, and λ_t represent fixed effects at the country, sector, and year levels. The variable DTE_i indicates whether firm i engages in digital trade exports, while $Innovation_{ijk}$ measures the firm's investment in R&D activities. $CONTROL_{ijk}$ comprises a set of control variables. The error term ε_{ijk} is assumed to be normally distributed with a mean of zero and a variance of one. Since DTE_{ijk} is a binary variable, we estimate Equation (1) using a probit model. Pr denotes the probability, and Φ refers to the cumulative distribution function of the standard normal distribution. Coefficients are presented as marginal effects evaluated at the sample mean. To address unobserved heterogeneity, we incorporate fixed effects for country and sector (υ_j and γ_k). Year fixed effects (λ_t) are also included to control for global macroeconomic fluctuations over time. Standard errors are clustered at the country-sector-location level.

In our model, there is a potential simultaneity between firms' innovation activities and their digital export decisions, which may result in biased estimates. Specifically, participating in digital exports could, in turn, enhance a firm's innovation. To mitigate the endogeneity bias arising from this issue, we adopt the sector-location average method introduced by Fisman and Love [10]. More precisely, we decompose the financial constraint related to firm-level innovation ($Innovation_{ijk}$) in country j and location k into two separate components:

$$Innovation_{ijk}=INNOVATION_{ijk}+INNOVATION_{jk}. \quad (2)$$

In this framework, $INNOVATION_{ijk}$ represents the firm-specific component of innovation, whereas $INNOVATION_{jk}$ reflects the average innovation level among all firms within industry j at location k. The central assumption is that the sector-province-country average of innovation is uncorrelated with a firm's individual decision to engage in digital trade exports. Based on this premise, we use the average innovation at the sector-province-country level as an instrumental variable. Consequently, our model is estimated using an instrumental variable approach and is specified as follows.:

$$\Pr(DTE_i=1)=\Pr\left(\beta_0+\beta_1 INNOVATION_i^{IV}+\beta_2 CONTROL_i+\upsilon_j+\gamma_k+\lambda_t+\varepsilon_i>0\right)$$
$$=\Phi\left(\beta_0+\beta_1 INNOVATION_i^{IV}+\beta_2 CONTROL_i+\upsilon_j+\gamma_k+\lambda_t\right). \quad (3$$

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$INNOVATION_i^{IV}$ denotes the fitted value derived from the first-stage regression, in which firm-level innovation is regressed on the sector-province-location average of innovation, along with a set of control variables.

We start by analyzing the relationship between innovation and the decision to participate in digital trade exports, initially without accounting for potential endogeneity. We then address this concern by employing the sector-location average method. In addition, we re-estimate Equation (3) using sub-samples categorized by firm size to investigate how the impact of innovation on digital trade exports varies across firms of different sizes.

5. Empirical Results

5.1. Benchmark Results

Table 3 reports the baseline results, providing an initial overview of how firm innovation relates to digital trade export participation. In Column (1), we present estimates from the probit model, where the dependent variable is a binary indicator of whether or not a firm engages in digital exports.

The findings point to a clear pattern: the coefficient on innovation is positive and statistically significant. Firms that invest in innovation, captured here by R&D spending, are more likely to participate in digital trade. Put differently, innovation seems to act as a key enabler, helping firms overcome typical barriers to digital exports such as building the right technological infrastructure, meeting international standards, or adapting products for online delivery.

In terms of size, the marginal effect is approximately 14%.

This implies that, all else being equal, greater innovation activity is associated with a 14 percentage point higher probability of digital export participation. The effect is substantial, indicating that investment in innovation is not merely an incremental factor but a significant driver of competitiveness in digital markets.

Table 3.
Benchmark result without controlling the endogeneity problem.

	(1)
Variables	**DTE**
Innovation	0.14***
	(0.041)
Productivity	-0.06***
	(0.017)
Firm age	0.01
	(0.027)
Managerial experience	0.00
	(0.034)
Joint stock status	-0.10
	(0.075)
Financial constraints	-0.21***
	(0.063)
Foreign Tech	0.11**
	(0.046)
Foreign Ownership	-0.09**
	(0.046)
International certifications	-0.07
	(0.043)
Internet access	0.15***
	(0.055)
Constant	-0.72
	(1.063)
Observations	7,191

Note: Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1.

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In the next step of the analysis, we turn to the instrumental variable (IV) approach to address possible endogeneity. Table 4 reports the results, along with a set of diagnostic tests to check whether the chosen instruments are appropriate. The Hausman test for endogeneity yields a statistically significant χ^2 statistic when the innovation variable is included, suggesting that endogeneity is indeed present. The under-identification test, based on the LM statistic, also returns a significant χ^2 value, which confirms that the model is identified and that the instruments are relevant.

Finally, the Cragg-Donald Wald F-statistic exceeds the usual critical thresholds, indicating that the instruments are strong enough to correct for endogeneity.

Taken together, these diagnostics suggest that the instruments we use are both valid and robust, providing confidence in the IV estimates and in the strategy to reduce bias from endogeneity.

Table 4.
Endogeneity test.

Innovation (First stage model)	**Coefficient**
	Innovation
Hausman test of endogeneity (χ^2)	5.75 (0.016)
Kleibergen-Paap rk LM statistic (Under-identification test)	2633.96 (0.000)
Cragg-Donald Wald F-statistic (Weak identification test)	7464.10

Note: We portray endogeneity tests of *Innovation* on *DTE* from the specification using 2SLS. p-values are in brackets.

After addressing endogeneity, the regression results are presented in Table 5. The findings broadly mirror those in Table 3 in terms of direction and statistical significance, although the estimated size of the innovation effect is slightly smaller. Specifically, innovative firms are approximately 13% more likely to engage in digital trade exports. The positive and significant coefficient on the Innovation variable supports Hypothesis H1, which posits a positive relationship between innovation and firms' participation in digital trade. These results reinforce the idea that innovation is a central driver of digital exporting. At the same time, they also point to the need for closer attention to how other firm-level factors shape digital export behavior.

Turning to the control variables, the coefficient on *Productivity* is negative and statistically significant, consistent with the findings of Doan and Luong [2].

This suggests that more productive firms may actually be less inclined to use digital export channels. One plausible explanation is sectoral: highly productive firms often operate in industries such as advanced manufacturing, where traditional export mechanisms are already efficient and well-established [36]. For these firms, moving into digital channels could involve high adjustment costs and potential disruptions, making digital trade less attractive [37]. Another explanation is that the link between productivity and digital adoption may follow an inverted U-shape. As Suo et al. [38] note, once firms reach a certain level of digital maturity, additional investment may yield diminishing or even negative returns, discouraging further expansion into digital exports.

Financial constraints emerge as another major barrier. Firms facing financing difficulties are less likely to invest in the infrastructure and systems needed for digital trade, such as e-commerce platforms, cross-border logistics, or customer relationship management tools. Because digital export markets demand continuous product and service innovation, financially constrained firms often underinvest in R&D, limiting their ability to keep up with evolving international demand [39].

Compliance costs also matter: large platforms like Amazon or Alibaba impose demanding operational and financial standards, which liquidity-constrained firms may struggle to meet. Finally, because digital trade hinges on trust and reliability, firms without financial buffers may face delays,

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quality issues, or service disruptions, damaging their reputation and undermining customer retention [40, 41].

The results also highlight the importance of *foreign technology adoption*. Access to technologies developed abroad helps firms upgrade product sophistication, reduce communication and logistics costs, and integrate into global value chains. This pattern has been especially prominent in China [14], where foreign technologies have been linked to export upgrading [42].

Internet access shows a strong positive effect as well. Reliable access improves market intelligence, reduces transaction costs, and helps firms manage cross-border risks. The effect is particularly large during early adoption phases, when firms often experience sharp increases in export intensity [43, 44]. The role of *foreign ownership* is more complex. On one hand, it can provide access to capital, managerial know-how, and international networks that facilitate digital exports. On the other hand, foreign ownership sometimes introduces additional hurdles.

These include the "liability of foreignness," which makes it harder for firms to adapt to local regulatory or market conditions. For example, Jordaan [45] shows that foreign-owned firms suffered sharper sales declines during COVID-19, highlighting their vulnerability to local disruptions. Moreover, regulatory and trade restrictions, especially in digital services, can constrain foreign-owned firms. Jungmittag and Marschinski [46] point out that service trade restrictions often impede greenfield FDI, while Guo [47] documents how digital trade barriers reduce cross-border commerce.

Other firm-level factors, such as *age*, *managerial experience*, *joint stock status*, and *foreign certifications*, are commonly discussed in the literature as important for export capacity. Older firms may benefit from accumulated knowledge; experienced managers may make better strategic choices; joint stock firms may access capital more easily; and certifications may signal international compliance.

Yet, in this study, none of these variables shows a significant effect on digital export participation. This may suggest that their influence is highly context-specific or that digital trade introduces new dynamics (platform dependency, network effects, digital capabilities) that dilute the relevance of these traditional attributes.

In short, while these factors remain theoretically important, their insignificance here underscores the need for more nuanced research. Interaction effects or non-linear relationships may better explain when and how such characteristics shape participation in digital exports.

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Table 5.
Benchmark results by controlling the endogeneity problem.

	(1)	(2)
Variables	**DTE**	**Innovation**
Innovation	0.12**	
	(0.065)	
INNOVATION^{IV}		0.98***
		(0.003)
Productivity	-0.06***	0.01
	(0.017)	(0.004)
Firm age	0.01	0.00
	(0.027)	(0.006)
Managerial experience	0.00	0.00
	(0.035)	(0.007)
Joint stock status	-0.10	0.04**
	(0.076)	(0.016)
Financial constraints	-0.21***	-0.02
	(0.063)	(0.013)
Foreign Tech	0.11**	0.05***
	(0.046)	(0.009)
Foreign Ownership	-0.09**	-0.00
	(0.046)	(0.010)
International certifications	-0.07	0.06***
	(0.043)	(0.009)
Internet access	0.15***	0.04***
	(0.055)	(0.013)
Constant	-0.72	-0.16***
	(1.064)	(0.057)
Observations	7,191	7,191

Note: Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.2. Heterogeneity Analysis

In this section, we examine how innovation influences firms of different sizes by running regressions on sub-samples divided by firm size. This approach builds on both theory and prior evidence suggesting that organizational scale can shape the link between innovation and exporting. Following the WBES classification, firms with fewer than 99 employees are treated as SMEs, while those with 100 or more employees are considered large firms.

The results, shown in Table 6, reveal a striking divergence. Innovation has a strong and positive effect on digital export participation for SMEs, but for large firms, the effect turns negative. This split seems to reflect differences in firm characteristics, innovation strategies, and the way digitalization interacts with scale.

For SMEs, digitalization acts as a powerful equalizer. Online tools and platforms help them upgrade products and processes, streamline operations, and reach foreign customers with fewer physical or financial barriers [7]. Innovation and exporting also feed into each other for smaller firms: access to global markets exposes them to new knowledge and practices, which then fuel further innovation; at the same time, innovative products open up new market opportunities, reinforcing their export performance [6].

For large firms, by contrast, the benefits of innovation seem to fade. With mature processes and entrenched market positions, incremental improvements may add little to export growth [8]. Organizational inertia and internal complexity can also make it harder for innovation strategies to translate into real gains in digital trade [37].

Part of the story may lie in the types of innovation being pursued. Large firms often focus on cost-saving or process innovations that improve efficiency but do not necessarily boost product offerings or market reach. SMEs, meanwhile, are more inclined toward product-focused innovation, which tends to have a more direct and positive effect on export outcomes [8].

Overall, the evidence underscores that size matters in the innovation–export relationship. Policies to promote digital trade should take this into account: for SMEs, targeted support that encourages product innovation may be most effective, while for large firms, strategies that help realign innovation toward market expansion could generate better results.

Table 6.
Estimation results: Sub-sample by size.

	(1)	(2)	(4)	(5)
	SMEs		**Large-sized firms**	
Variables	**DTE**	**Innovation**	**DTE**	**Innovation**
Innovation	0.14**		-1.08*	
	(0.066)		(0.574)	
INNOVATION^{IV}		0.98***		1.10***
		(0.003)		(0.060)
Constant	-0.59	-0.22***	-1.40	-0.90***
	(1.060)	(0.072)	(2.085)	(0.280)
Observations	6,718	6,718	337	337

Note: Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
The same set of control variables is included.

5.3. Robustness Checks

Up to this point, our analysis has relied on R&D spending as a measure of input innovation—that is, the resources firms devote to developing new technologies, products, or processes. While useful, this proxy captures effort rather than outcome; it tells us about a firm's intent to innovate but not whether those efforts actually materialize.

To build a fuller picture of how innovation shapes digital export participation, we also consider output innovation, specifically, the introduction of new or significantly improved products and processes. Unlike inputs, output innovation reflects realized results that are visible in the marketplace and are more directly tied to economic value. In many cases, these outcomes provide a clearer signal of innovation success and responsiveness to market demands.

In digital trade, output innovation may be especially relevant. Launching new digitally enabled products or adopting production processes that improve customization, accelerate delivery, or integrate digital systems can directly strengthen export performance. Such innovations also suggest that a firm is ready to adapt to international standards and consumer expectations, both crucial in global digital markets.

By combining input and output measures, we capture not only the capacity and willingness to innovate but also the effectiveness of those efforts in enabling firms to participate in digital exports. This dual perspective provides a more nuanced understanding of the innovation–export link and enhances the robustness of our results.

In our sample, 36% of firms report having introduced new products, while 27% report adopting new processes. As shown in Table 7, the regression results based on these output measures align with the earlier findings in Table 5. Firms that introduced either new products or new processes are, on average, about 5% more likely to engage in digital exports than firms that did not. This consistency reinforces the conclusion that innovation outcomes, such as new products and processes, play a meaningful role in driving digital trade participation.

Table 7.
Alternative measure of innovation.

	(1)	(2)	(3)	(4)
Variables	**DTE**	**New product**	**DTE**	**Improved process**
New product	0.05**			
	(0.067)			
New product^{IV}		0.99***		
		(0.002)		
Improved process			0.06**	
			(0.072)	
Improved process^{IV}				0.98***
				(0.003)
Productivity	-0.06***	0.00	-0.06***	0.00
	(0.017)	(0.004)	(0.017)	(0.003)
Firm age	0.01	0.00	0.01	0.00
	(0.027)	(0.006)	(0.027)	(0.006)
Managerial experience	-0.00	-0.01	-0.00	0.01
	(0.035)	(0.007)	(0.034)	(0.007)
Joint stock status	-0.09	0.01	-0.09	0.02
	(0.075)	(0.015)	(0.075)	(0.015)
Financial constraints	-0.21***	-0.01	-0.22***	0.00
	(0.062)	(0.012)	(0.062)	(0.011)
Foreign Tech	0.11**	0.03***	0.11**	0.05***
	(0.046)	(0.009)	(0.046)	(0.009)
Foreign Ownership	-0.09**	-0.01	-0.09**	0.00
	(0.046)	(0.009)	(0.046)	(0.009)
International certifications	-0.06	0.03***	-0.06	0.03***
	(0.042)	(0.008)	(0.043)	(0.008)
Internet access	0.16***	0.03**	0.15***	0.04***
	(0.055)	(0.012)	(0.056)	(0.011)
Constant	-0.81	-0.02	-0.79	-0.13**
	(1.075)	(0.053)	(1.082)	(0.050)
Observations	7,191	7,191	7,191	7,191

Note: Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1.

6. Conclusion

This study examines how innovation shapes firms' participation in digital trade exports, drawing on cross-country evidence from the WBES. Focusing on manufacturing firms, where trade theory is most relevant, we consider both input innovation (R&D investment) and output innovation (the introduction of new products and processes). Across all specifications, the results point to the same conclusion: innovation significantly increases the likelihood that firms will engage in digital exports, and this holds even after accounting for potential endogeneity through instrumental variable estimation.

The sub-sample analysis adds an important layer of nuance. Innovation exerts a stronger positive effect on SMEs than on large firms. For smaller firms, innovation seems to act as a compensatory mechanism, helping them overcome resource gaps and break into digital markets. For larger firms, by contrast, the effect weakens and sometimes turns negative, likely reflecting diminishing returns, organizational inertia, or a tendency to prioritize cost-saving over product upgrading.

We also find that output innovation, especially product and process improvements, shows a clear positive association with digital export participation, reinforcing the robustness of the main findings. At the same time, firm-level attributes such as productivity, foreign ownership, and certification status produce mixed results, suggesting that context and firm-specific conditions matter greatly in shaping digital export strategies.

Taken together, the evidence highlights the importance of innovation policy in fostering more inclusive digital trade. Strengthening R&D capacity, supporting product development, and lowering

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barriers to entry on digital platforms could be particularly valuable for SMEs and for firms in developing economies. Looking forward, future research should investigate how the effects of innovation evolve and explore sector-specific pathways through which innovation enables digital export growth.

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The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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Appendix

Table A1.
List of countries.

No.	Countries (Year surveyed)	Percent	No.	Countries (Year surveyed)	Percent	No.	Economy	Percent
1	Armenia (2024)	0.4	33	Ghana (2023)	0.5	65	Poland (2025)	2.66
2	Azerbaijan (2024)	0.24	34	Greece (2023)	2.21	66	Portugal (2023)	3.05
3	Bahrain (2024)	0.25	35	Hong Kong SAR China (2023)	0.47	67	Romania (2023)	2.41
4	Barbados (2023)	0.35	36	Hungary (2023)	3.44	68	Rwanda (2023)	0.33
5	Belgium (2024)	1.39	37	Iceland (2024)	0.46	69	Samoa (2023)	0.11
6	Benin (2024)	0.17	38	Ireland (2024)	1.1	70	Senegal (2024)	0.5
7	Bhutan (2024)	0.22	39	Israel (2024)	0.33	71	Serbia (2024)	2.03
8	Bosnia and Herzegovina (2023)	0.89	40	Italy (2024)	4.66	72	Seychelles (2023)	0.03
9	Botswana (2023)	0.18	41	Jamaica (2024)	0.26	73	Sierra Leone (2023)	0.07
10	Bulgaria (2023)	2.53	42	Jordan (2024)	2.19	74	Singapore (2023)	0.58
11	Burkina Faso (2024)	0.21	43	Kazakhstan (2024)	1.36	75	Slovak Republic (2023)	1.42
12	Cambodia (2023)	1.15	44	Korea Republic (2024)	3.64	76	Slovenia (2024)	1.89
13	Cameroon (2024)	0.54	45	Kyrgyz Republic (2023)	0.51	77	South Sudan (2024)	0.01
14	Canada (2024)	1.83	46	Lao PDR (2024)	0.35	78	Spain (2024)	7.08
15	Central African Republic (2023)	0.12	47	Latvia (2024)	1.05	79	Sweden (2024)	2.51
16	Chad (2023)	0.03	48	Lesotho (2023)	0.14	80	Taiwan China (2024)	3.55
17	China (2024)	2.57	49	Malaysia (2024)	1.1	81	Tajikistan (2024)	0.14
18	Colombia (2023)	0.83	50	Mali (2024)	0.26	82	Tanzania (2023)	0.5
19	Congo (2024)	0.26	51	Malta (2024)	0.43	83	Togo (2023)	0.46
20	Costa Rica (2023)	0.51	52	Mauritius (2023)	0.68	84	Tonga (2024)	0.03
21	Croatia (2023)	1.4	53	Mexico (2023)	0.9	85	Trinidad and Tobago (2025)	0.04
22	Cyprus (2024)	0.6	54	Moldova (2024)	0.53	86	Tunisia (2024)	2.19

23	Czechia (2024)	1.73	55	Montenegro (2023)	0.42	87	Turkiye (2024)	1.46
24	Côte d'Ivoire (2023)	0.72	56	Morocco (2023)	1.42	88	Turkmenistan (2024)	0.33
25	DRC (2024)	0.18	57	Namibia (2024)	0.19	89	United Kingdom (2024)	1.23
26	Ecuador (2024)	0.42	58	Nepal (2023)	0.4	90	United States (2024)	3.64
27	El Salvador (2023)	1.22	59	New Zealand (2023)	0.64	91	Uruguay (2024)	0.53
28	Equatorial Guinea (2024)	0.03	60	North Macedonia (2023)	1.26	92	Uzbekistan (2024)	0.69
29	Estonia (2023)	1.6	61	Pakistan (2022)	1.75	93	Viet Nam (2023)	2.37
30	Eswatini (2024)	0.11	62	Papua New Guinea (2024)	0.04	94	West Bank and Gaza (2023)	0.61
31	Gambia (2023)	0.12	63	Paraguay (2023)	0.35			
32	Georgia (2023)	0.97	64	Philippines (2023)	0.74			

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