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Research on the Impact of Digital Transformation on Enterprise Export Resilience

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Abstract: Using data from the 2015–2017 China Enterprise Database, China Customs Trade Barriers Data, and a Difference-in-Differences dataset, this study examines the impact of digital transformation on the export resilience of enterprises. Employing both Difference-in-Differences and fixed-effects panel methods, the analysis investigates how digitalization influences firms' ability to maintain and expand exports under varying market conditions. The results indicate that digital transformation significantly enhances export resilience, with particularly strong effects for state-owned enterprises, strategic emerging industries, and firms facing high competitive pressure. The study further explores the mechanisms through which digital transformation affects resilience, emphasizing the role of digital governance, regional science and technology cooperation, private-sector adoption, and the development of data asset markets. These findings provide evidence that digital transformation is a key driver of enterprise export performance and broader economic development.

Keywords: Digital transformation; Export resilience; Difference-in-differences model; Market reshaping effect; Economic effect

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1. Introduction

The global economic and trade landscape is undergoing profound adjustments. Unilateralism is prevalent, the risk of supply chain disruptions is increasing, and the impact of the COVID-19 pandemic is compounded. Export enterprises are facing huge vulnerability risks in their operations. The ability of enterprises to cope with complex and uncertain changes in the trade environment and maintain stable exports, namely "export resilience", is currently a hot topic in the field of international trade research [1]. The global trend of digital economy transformation has created opportunities for enterprises to break through and develop. By reconfiguring production processes, optimizing resource allocation, and reducing transaction costs, enterprises enhance their adaptability to the uncertain trade environment.

Research shows that the impact mechanism of enterprise digital upgrading on export resilience is mainly reflected in the reduction of production efficiency and operating costs. Based on data from listed manufacturing companies, Zhang *et al.* find that digital upgrading strengthens enterprise export resilience by enhancing total factor productivity and lowering operating costs, thereby enabling firms to better withstand shocks such as fluctuations in market demand and disruptions in the supply chain. Specifically, the adoption of industrial robot technology can increase the production flexibility of enterprises and quickly adjust the export product mix [1]. Digital supply chain management is based on real-time monitoring of inventory and logistics information, reducing the risk of enterprises missing delivery dates due to trade barriers.

Against the backdrop of global economic development transformation driven by digital technologies, big data, artificial intelligence, blockchain and other technologies are reshaping the international competitive landscape. According to the "Digital China Development Report" released by the National Data Bureau, the added value of China's core digital economy industries accounts for more than 10% of the GDP, with an industrial scale exceeding 12 trillion Chinese Yuan, and has become a core growth point of the national economy. However, the development of technological iteration and upgrading, along with the trend of complexity in China's international trade, and the coexistence of unilateralism, trade protectionism, and shrinking external demand, have become huge challenges hindering Chinese enterprises from participating in international competition. Against this backdrop, how to explore ways to enhance enterprises' ability to respond to external environmental risks through technological innovation has become a key issue that needs to be urgently addressed at present.

After the report of the 20th National Congress of the Communist Party of China respectively positioned and deployed the two goal orientations of enhancing the resilience of industrial and supply chains, developing digital trade and building a trade power at the national strategic level, the digital transformation of enterprises has brought about changes in production processes and innovations in business models through the penetration and integration of data elements. Improving the Pareto efficiency of supply chain resource allocation and the ability of enterprises to cope with market fluctuations at the micro level is reflected at the macro level as digital trading platforms breaking spatial limitations, reducing the transaction costs and risks of cross-border trade, and helping to cultivate export resilience. During the special period when the wave of anti-globalization sweeps across the world, exploring whether digital transformation can become a feasible path and key theoretical innovation for Chinese enterprises to cope with the impact of the international market and maintain the resilience of exports, while also having practical policy significance.

This paper conducts an empirical analysis of the effects and boundary conditions of digital transformation on the export resilience of enterprises by combining the difference-in-differences model and the panel fixed effects model. It is found that there are three channels for digital transformation to enhance the export resilience of enterprises: market mechanism reform, integration of management systems, and reduction of transaction costs. It also interprets the regulatory conditions affected by enterprise property rights, industry structure, market competition, etc., providing empirical evidence for local governments to carry out digital transformation.

2. Literature review

At the current stage of global value chain reshaping, cyclical trade frictions have evolved into long-term structural issues. The inhibitory effect of trade frictions on export trade has been studied empirical-effectively. Egger and Nelson's empirical research on the EU anti-dumping case shows that the average export volume of the involved

enterprises has decreased by 12% to 18%. China's microdata shows that the export volume of the involved enterprises to the United States has decreased by 19% to 24% within three years. Among them, technology-intensive industries have been more affected by export trade frictions. The obstruction of exports is due to both the increase in tariff barriers and non-tariff trade barriers such as supply chain and market access barriers [2].

Facing complex systemic pressures, enterprises often take a series of measures to enhance their ability to cope with such pressures. From the perspective of geographical dispersion, the response measures of enterprises are cross-border dispersion. Bown and Crowley found that the growth of exports transferred to third countries due to dumping duties imposed on exports to the United States has remained at 5–7%[2]. Shen also discovered a double transfer in this regard. One part was transferred to developing countries in the third world such as ASEAN and Africa, and the other part was the transfer of products in the form of parameter changes to avoid trade barriers. Chen *et al.* also found from the perspective of imports that the import substitution effect caused by China's implementation of anti-dumping duties benefited the trade of unrelated countries. The above conclusion provides new evidence for the global value chain reconfiguration caused by trade protectionism [3]. In order to achieve diversification of export products, multi-product export enterprises tend to reduce other products. Lu *et al.* found by using Chinese customs data that enterprises did indeed reduce other products during the trade friction period and concentrated resources on core products. The export concentration of core products increased by 23%, which was conducive to making corresponding adjustments when the total trade scale declined.

The academic community has not yet reached a consensus on the relationship between export diversification and resilience, and there are different opinions. Scholars of the risk transmission theory empirically tested the harmfulness of an overly diversified export structure based on urban panel data and found that when the external demand shock decreases, an overly diversified export structure will accelerate the shock transmission. The reason is that enterprises have difficulty forming a deep adaptability to specific markets. Scholars have demonstrated the positive effects of diversification strategies from various perspectives. Wang *et al.* empirically examined the connection between diversification and trade frictions at the urban level and found that a "related diversification" market structure with complementary economic structures can reduce the impact of trade frictions, with the impact elasticity coefficient decreasing by 0.31. Liu and Qi tracked manufacturing listed companies and found that under the active diversification strategy, the recovery speed of exports was 40% faster than that of the control group [4]. Existing research mainly focuses on spatial transfer strategies from the perspective of traditional geography. There is no relevant study on the issue of enterprises' re-response to shocks under digital transformation. The paths for digital technology to deal with tariff barriers, expand into new markets, and adjust the capacity of industrial Internet in the case of network disconnection urgently need the attention of relevant theoretical and empirical research [4].

At the same time, a large number of empirical analyses have shown that digital transformation can enhance the economic resilience of enterprises through the following approaches. In terms of improving production efficiency, with the wide application of industrial Internet, the total factor productivity of the manufacturing industry can increase by 12.7%, and the equipment utilization rate can rise by 18%. In terms of enhancing innovation capabilities, with the application of technologies such as artificial intelligence and big data analysis, the probability of successful innovation for enterprises has increased, and the cycle for converting patents into products has been shortened by 9 months [4]. The empirical analysis indicates that a 10-percentage-point increase in Internet broadband access is associated with a 4.2-percentage-point rise in the likelihood that enterprises engage in export trade. Furthermore, participation in cross-border e-commerce expands the number of foreign markets

accessible to small, medium, and micro enterprises by a factor of 3.1.

In terms of risk response, digital tools are context-dependent. Regarding market integration, some scholars have verified through enterprise transaction data on e-commerce platforms that online sales have broken market segmentation, reducing transaction costs between regions by 23% and ensuring the stable operation of the industrial chain during the COVID-19 pandemic [4]. In terms of capacity building, industrial Internet platforms have helped small and medium-sized enterprises shorten the digital transformation cycle from 24 months to 9 months through the output of resources and technical solutions, effectively solving the problem of "misallocation of capabilities and resources". In terms of crisis response, by analyzing the response to global public health events, it was found that e-commerce applications have maintained the employment retention rate in the retail industry at 85%. The risk of virus transmission has been reduced by 41% [5]. Wei *et al.* 'pioneering research on export resilience, taking the 2008 financial crisis as an exogenous shock, found that digital enterprises have the advantage of digital export, and their export recovery speed is 2.3 times that of traditional enterprises. This is mainly due to the elastic scheduling characteristics of digital supply chain systems. However, the research did not fully consider that the financial crisis is a demand-side shock. However, trade frictions have the characteristics of policy discrimination and targeted disruption of supply chains, and there is a lack of in-depth exploration on their unique impact [5].

The existing literature reveals notable gaps in both theoretical and empirical dimensions. Theoretically, current discussions of trade frictions largely focus on traditional response mechanisms and often neglect the transformative impact of digital technologies on trade practices. For example, the implementation of blockchain technology can increase the accuracy of certificates of origin by up to 80%, substantially reduce compliance costs, and enable the complete cross-border transfer of production capacity within 72 hours, a process that traditionally requires several months in conventional supply chains. In terms of empirical research, the existing literature on digital technology has mainly focused on the impact of the traditional economic environment on it.

Few studies have explored special policy shocks such as trade frictions, and the existing literature lacks micro-evidence at the enterprise level, thus failing to answer the following questions: Through what channels did digital technology reduce the decline in the export of the involved products? How did it promote trade transfer? How to deal with the product portfolio of enterprises under trade frictions?

The contributions of this paper are reflected in three main dimensions as follows:

(1) In terms of theoretical modeling, we construct a digital resilience triangular framework to explicate the intrinsic mechanisms linking data-driven decision-making, optimization of elastic supply chains, and the effects of reduced cross-border transaction costs. This framework provides a unified theoretical explanation for the cultivation of enterprise export resilience;

(2) In terms of empirical evidence, we develop an innovative counterfactual Difference-in-Differences model that leverages policy discrimination and chain-breaking characteristics of trade frictions to directly examine the buffering effects of digital technologies in specific contexts, such as tariff barriers and technological blockades;

(3) At the micro-policy level, drawing on the development of China's "Digital Silk Road," the paper analyzes how cross-border e-commerce comprehensive pilot zones can enhance export resilience under digital customs policies, cross-border payment systems, and other institutional frameworks, offering actionable micro-level policy insights to support the national strategy of building a "trade power."

3. Theoretical mechanism and hypothesis proposal

The theoretical contribution of this study lies in the systematic proposal of the "Digital Resilience Triangle" theoretical model, which multi-dimensionally reveals the inherent logical consistency of the promoting effect of digital transformation on the resilience of enterprise exports, making up for the deficiency of existing research in exploring from a single perspective. It is believed that the logic of its existence lies in the digital-driven decision-making mechanism (the optimization of supply chain resilience), and the digital-driven mechanism for reducing cross-border transaction costs (the restoration of enterprise export resilience). The organic coupling of the three provides the foundation for export enterprises to maintain and quickly restore their exports in response to external shocks such as trade frictions.

In the digital resilience framework, data-driven decision-making serves as the foundation of intelligence. The digital transformation of contemporary enterprises is a process of extensive collection, analysis, and effective utilization of multiple data sources. By leveraging digital tools and technological means such as the Internet of Things (IoT), big data, and artificial intelligence (AI), enterprises can achieve all-round real-time monitoring of the global market. By grasping market information such as changes in consumer habits, evolution of competitive landscapes, growth in emerging markets, and early warnings of supply chain risks, real-time data-driven decision-making platforms can enhance the spatial and temporal precision and expected accuracy of enterprises' strategic choices and layouts. Under the condition of restricted access to regional markets, enterprises with strong digital capabilities can, through data modeling, analysis and other means, evaluate alternative entry barriers, plan market exit strategies or adjust the composition of export products to avoid entry barriers [6].

As another key force in the digital resilience triangle, the supply chain resilience reorganization mechanism buffers the regional supply chain disruptions caused by trade frictions. Compared with the exogenous fragility of centralized chain-like supply chain organizations, the enterprise supply chain system of supply chain digital transformation is distributed, networked and flexible. Through digital tools such as industrial Internet platforms, cloud computing, and digital twin technology, cross-regional and even global capacity collaboration networks and resource sharing networks are formed. Specifically, when the supply from a regional factory is disrupted due to trade frictions or geopolitical factors, enterprises can quickly achieve flexible allocation of distributed production capacity nodes on digital platforms, as well as effective matching of qualified supplier resources within the platform. The multi-node elastic supply chain organization enhances the resilience of enterprises in responding to regional supply chain disruptions At the same time, it also ensures the stability of the supply of export products, enabling enterprises to maintain a basic export flow in a harsh external environment.

Research has found that digital technology has become an important support for enterprises to build digital resilience by reducing international transaction costs. In traditional trade, enterprises are confronted with high transaction costs such as documents, compliance, and settlement, long business cycles, and high difficulty in establishing trust [7]. Digital technologies represented by blockchain smart contracts, electronic customs systems, and digital payments can optimize these predicaments Smart contracts have reduced human intervention and contract disputes. Electronic documents and the "single window" have enhanced the efficiency of customs clearance. Digital payments have avoided risks related to exchange rates and settlement cycles. These technologies have reduced the transaction costs for enterprises to expand markets and adjust product structures, as well as the institutional costs for establishing trust with unfamiliar merchants. Empirical research shows that the reduction in transaction costs enables enterprises to have higher economic feasibility and market response speed when facing trade frictions to carry out transfer and product structure adjustment, thereby systematically enhancing the

resilience of export trade.

The Digital Resilience Triangle points out that the supply chain system is composed of complex interactions among data, resilient supply chains, and transaction cost reduction. From a mechanistic perspective, the Digital Resilience Triangle emphasizes data-based supply chain reconstruction, as well as the physical support provided by resilient supply chains for the execution of supply chain decisions and cost reduction. The gradually declining transaction costs provide support for the transfer of market data and the reconstruction of supply chains, thereby forming a dynamic digital resilience ecosystem with multi-factor interaction. This enables enterprises to demonstrate characteristics such as environmental adaptability, rapid response, and sustainable growth in the face of trade conflicts and other shocks. The Digital Resilience Triangle emphasizes the establishment of a theoretical framework for understanding the internal mechanisms by which digital trade transformation drives the resilience of enterprises' exports, and also provides a research perspective for academic research and management decision-making.

Based on this, the following hypotheses are proposed:

(1) Digital transformation will mitigate the impact of trade frictions on its exports. In the event of trade frictions, digital transformation has a smaller impact on a company's exports, while non-digital transformation has a greater impact on a company's exports;

(2) Digital transformation can not only reduce the adverse impact of trade frictions on the export of domestic products involved in cases, but also help enterprises achieve product transformation, shifting from involved products to non-involved ones.

4. Research design and data presentation

4.1. Model setting

This study needs to identify the causal effect of trade frictions on enterprises' exports. To alleviate potential endogeneity problems such as selection bias existing in model estimation, the difference-in-differences method was utilized. By matching the HS six-digit code product classification and the annual data of anti-dumping countries against China in the Chinese customs database and the global anti-dumping database system, the enterprise samples subject to anti-dumping measures are accurately identified. The enterprises subjected to anti-dumping measures will be taken as the treatment group and those not subjected to anti-dumping measures as the control group. The differences in the dynamic changes of exports between the treatment group and the control group under policy shocks will be examined to effectively control the common trends and other concurrent policy disturbances. To ensure that the sensitivity of the control group and the treatment group to anti-dumping shocks is comparable, a double matching strategy was adopted for sample selection in the following text.

The DID model is set as follows:

$$Export_{it}^{cj} = M_0 + \beta_1 Treat_i \times Post_t + nX_{it} + G_i + G_t + G^{c\times t} + G^{j\times t} + \varphi_{it}^{cj} \quad (1)$$

Given the substantial annual heterogeneity among enterprises affected by anti-dumping measures, we employ a staggered Difference-in-Differences approach for empirical analysis. Specifically, we define the treatment variables as follows: across the full sample, enterprises subject to an anti-dumping investigation are assigned a value of 1, while all others receive a value of 0. For the temporal dimension, a value of 1 is assigned to the year in

which an enterprise is affected by anti-dumping and to all subsequent years, with all other years coded as 0.

Among them, the variable represents the export volume of enterprise i in industry j of Province c in year T. Here, the subscripts c, j, i, and t respectively represent the region, industry, enterprise, and year. In the identification stage of anti-dumping impact, this study selected the anti-dumping cases initiated by major global economies against China from 2006 to 2013 as the research objects. Referring to the research methods of Chen et al., in order to capture the long-term effects of anti-dumping policies, five years before and after the impact were set as observation window periods. Based on a comprehensive consideration of multiple factors such as the impact time, observation period, and data availability, the period from 2015 to 2025 was finally determined as the sample research interval. Additionally, to verify the robustness of the research conclusions, The subsequent analysis also adopted the time points of the initial and final rulings of anti-dumping cases against China from 2006 to 2013 as the time points of policy impact for supplementary examination.

Based on the research design framework in the previous text, in order to make the matching effect of the control group enterprises more reasonable, this paper conducts two rounds of screening: The first round is precise matching based on HS codes, selecting enterprises that export goods under the same HS 4-digit code but other HS 6-digit codes but have not been subject to anti-dumping cases as control Group 1, which has been controlled in the benchmark regression; In the second round of the robustness test, the propensity score matching method was used to select samples with similar anti-dumping risk characteristics but not implemented as control Group 2. The specific construction is as follows.

Among the core explanatory variables, the variable that measures the heterogeneous impact of anti-dumping on the export behaviors of the involved enterprises and non-involved enterprises has a negative coefficient, indicating that the involved enterprises are inhibited by the anti-dumping policy on their exports. The enterprise-level factors controlled in the model include various possible factors that affect the export performance of enterprises: Enterprise scale (logarithm of assets), total factor productivity, enterprise survival years, proportion of processing trade exports, logarithm of subsidy amount; To alleviate the potential endogeneity problem in the model, the individual effect of enterprises, the time effect, the fixed effect of "province-year", and the fixed effect of "industry-year" are introduced. Considering the product heterogeneity of the implementation objects of anti-dumping measures, a clustering robust standard error at the industry level is set in the model to correct the potential correlation.

To analyze the transmission mechanism of digital transformation in alleviating the impact of trade frictions, this paper empirically tests the second hypothesis and quantitatively evaluates the improvement degree of digital transformation on the export resilience of enterprises. This paper constructs the following regression equation for empirical research.

$$Export_{it}^{cj} = M_1 + \eta_1 Post_t + k_1 Post_t \times FB_i + wX_{it} + G_i + G_t + G^{c\times t} + G^{j\times t} + \varphi_{it}^{cj} \qquad (2)$$

Based on Equation (1) as the basic model, the digital transformation variable construction of Equation (2) at the enterprise level was introduced. Whether the enterprise has joined the cross-border e-commerce platform is taken as the virtual variable at the enterprise level. The time is unchangeable, and the value is 0 or 1: If an enterprise has implemented digital transformation before being hit by anti-dumping, the value is 1; otherwise, it is 0.

To ensure the validity of the study, enterprises that have completed digital transformation have been excluded from the control group sample. Equation (2) is completely consistent with Equation (1) in terms of data selection

and other parameter Settings. The coefficient of the interaction term is the result that this paper focuses on. Its economic significance lies in measuring the differences in export changes between digital transformation enterprises and non-digital transformation enterprises under anti-dumping shocks, as well as the regulatory role of digital transformation. If it is positive, the decline in exports of enterprises undergoing digital transformation will be lower. This empirical result verifies the enhancing effect of digital transformation on the resilience of enterprises' exports.

4.2. Data sources

In this study, in the empirical part, we adopted cross-border e-commerce as a proxy indicator for digital transformation and anti-dumping as a substitute variable for trade frictions. Based on this, by connecting with four major databases, namely the Global Anti-Dumping Database, the China Customs Trade Database, the Alibaba China Station Enterprise Member Database, and the China Industrial Enterprise Database, A total of 413 anti-dumping cases initiated by major global economies against 1,010 HS six-digit code goods from 2006 to 2013 were selected as samples. In terms of data processing, first, based on the three variables of export year, destination country, and HS six-digit code goods, the GAD database and the CCTS database were one-to-one corresponding.

To obtain the export enterprises and their scales involved in anti-dumping cases each year, in the matching process, in order to distinguish e-commerce enterprises, this study used the enterprise member registration information provided by the ECD database, and matched and identified e-commerce enterprises and non-e-commerce enterprises with field information such as enterprise name, legal representative, and contact information, thereby identifying e-commerce enterprises from the enterprises involved in anti-dumping cases. The research also obtained control variables at the enterprise level and propensity score matching covariates through CIFD, where matching between databases was conducted using enterprise names and corresponding years.

5. Empirical results and analysis

5.1. Benchmark regression results

Table 1 shows the regression results using Equation (1). Columns (1) to (3) represent the regression results of the control groups with the selected "Control Group 1" enterprises as the control group. In Column (1), the regression coefficient of the variable is significantly negative, that is, compared with the non-anti-dumping subject enterprises, the anti-dumping subject has a significantly negative impact on the exports of the involved enterprises. In Column (2), the occurrence frequency of anti-dumping acts is considered, with the frequency of anti-dumping acts" 1 "as the main explanatory variable. The explanatory variable, the frequency of anti-dumping acts" 1 ", is still significantly negative. That is, being subject to anti-dumping measures has a negative impact on exports. The more frequently anti-dumping measures are imposed, the greater the negative impact on exports.

In Column (3), the explained variable is changed to whether the export enterprise will exit the market in the next year, that is: if the export enterprise exports the market in the current year, the export enterprise is not in the next year and is assigned a value of "1"; otherwise, it is assigned a value of "0". Column (3) shows that anti-dumping actions will increase the probability of export enterprises withdrawing in the next year. Columns (4) to (6) take the "Control Group 2" enterprises selected by the PSM method as the control group, and reach a conclusion basically consistent with Columns (1) to (3). Taking "Control Group 2" as the reference group, the imposition of anti-dumping measures will lead to an average reduction of 5.89% in the exports of the involved enterprises (Column (4)). The above results indicate that trade frictions have negatively impacted the exports of enterprises.

Table 1. Test of anti-dumping impact effects on export enterprises

Control group 1			**Control group 2 (selected by PSM method)**		
(1) Exit	(2) Exit	(3) Whether to quit	(4) Exit	(5) Exit	(6) Whether to quit
Whether to implement anti-dumping(inc)					
-0.0947***		0.0190***	-0.0589**		0.0129***
(0.0347)		(0.0034)	(0.0256)		(0.0029)
Frequency of implementing anti-dumping measures (inc1)					
	-0.0266***			-0.0112*	
	(0.0093)			(0.0059)	
Size					
0.6707***	0.6707***	-0.0069***	0.6140***	0.6139***	-0.0076***
(0.0345)	(0.0345)	(0.0015)	(0.0334)	(0.0334)	(0.0017)
Enterprise TFP					
0.0492***	0.0497***	-0.0004	0.0544***	0.0543***	-0.0029*
(0.0143)	(0.0143)	(0.0015)	(0.0140)	(0.0140)	(0.0016)
Age					
0.5976***	0.5958***	0.0338***	0.5671***	0.5661***	0.0050
(0.0517)	(0.0520)	(0.0051)	(0.0543)	(0.0544)	(0.0062)
Share of processing trade					
0.9999***	1.0004***	-0.0171***	0.9835***	0.9832***	-0.0113**
(0.1108)	(0.1105)	(0.0055)	(0.1081)	(0.1081)	(0.0046)
Enterprise subsidies (logarithmic)					
0.0258***	0.0257***	0.0000	0.0249***	0.0249***	-0.0005*
(0.0028)	(0.0028)	(0.0003)	(0.0033)	(0.0033)	(0.0003)
Enterprise fixed effect					
Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect					
Yes	Yes	Yes	Yes	Yes	Yes
The fixed effect of the industry in which the enterprise is located × years					
Yes	Yes	Yes	Yes	Yes	Yes
The fixed effect of the province where the enterprise is located for × years					
Yes	Yes	Yes	Yes	Yes	Yes
Clustering robust standard error (Industry)					
Yes	Yes	Yes	Yes	Yes	Yes
Observed value					
Yes	Yes	Yes	Yes	Yes	Yes
The adjusted R^2					
0.9248	0.9248	0.2826	0.9155	0.9154	0.2217

Note: * indicates a significance level of 10%, ** indicates a significance level of 5%, and *** indicates a significance level of 1%. The figures in parentheses are robust standard errors.

Table 2 examines the full moderating effect of enterprise digital transformation on export resilience under anti-dumping shock through the double-difference model. Columns (1) to (3) take "Control Group 1" as the benchmark group. The empirical results show that the larger negative coefficient of Column (1) indicates that the implementation of anti-dumping has led to a significant decrease in the export scale of the involved enterprises. A large cross-term coefficient indicates that digital transformation has a significant reducing effect on the negative impact of anti-dumping, resulting in a smaller decline in the exports of the involved enterprises. In Column (2), after adding the variable of the frequency of anti-dumping implementation, the core conclusion remains robust.

In Column (3), the explained variable is changed to "the probability of the enterprise exiting the export market in the next year". The larger positive cross-term and the larger negative term of indicate that digital transformation can effectively suppress the market exit probability of anti-dumping. The robustness test results of columns (4)–(6) "Control Group 2" constructed by the SPSSM method are highly consistent with the main regression conclusion. Furthermore, compared with enterprises that have not undergone digital transformation, the average export volume of enterprises that have undergone digital transformation after responding to anti-dumping lawsuits is 15.76% higher. The above evidence jointly supports the first hypothesis.

Table 2. Test of the anti-dumping impact response effect of enterprise digital transformation

Control group 1			**Control group 2 (selected by PSM method)**		
(1) Exit	(2) Exit	(3) Whether to quit	(4) Exit	(5) Exit	(6) Whether to quit
Whether to implement anti-dumping(inc)					
-0.1080***		0.0208***	-0.0692**		0.0147***
(0.0351)		(0.0036)	(0.0269)		(0.0031)
inc×EB					
0.2119***		-0.0299***	0.1576**		-0.0275***
(0.0611)		(0.0053)	(0.0578)		(0.0044)
Frequency of implementing anti-dumping measures(inc1)					
	-0.0339***			-0.0138**	
	(0.0093)			(0.0062)	
inc1×EB					
	0.0881***			0.0345***	
	(0.0247)			(0.0120)	
Size					
0.6700***	0.6703***	-0.0068***	0.6133***	0.6133***	-0.0075***
(0.0346)	(0.0347)	(0.0015)	(0.0335)	(0.0335)	(0.0017)
Enterprise TFP					
0.0494***	0.0499***	-0.0005	0.0543***	0.0542***	-0.0029*
(0.0142)	(0.0143)	(0.0015)	(0.0140)	(0.0140)	(0.0016)
Age					
0.5970***	0.5946***	0.0339***	0.5673***	0.5661***	0.0050
(0.0518)	(0.0521)	(0.0051)	(0.0539)	(0.0540)	(0.0062)

Table 2 (Continued)

Control group 1			Control group 2 (selected by PSM method)		
Share of processing trade					
0.9997***	1.0006***	-0.0170***	0.9831***	0.9829***	-0.0113**
(0.1110)	(0.1105)	(0.0055)	(0.1081)	(0.1081)	(0.0046)
Enterprise subsidies (logarithmic)					
0.0257***	0.0257***	0.0000	0.0249***	0.0249***	-0.0005*
(0.0028)	(0.0028)	(0.0003)	(0.0033)	(0.0033)	(0.0003)
Enterprise fixed effect					
Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect					
Yes	Yes	Yes	Yes	Yes	Yes
The fixed effect of the industry in which the enterprise is located × years					
Yes	Yes	Yes	Yes	Yes	Yes
The fixed effect of the province where the enterprise is located for × years					
Yes	Yes	Yes	Yes	Yes	Yes
Clustering robust standard error (Industry)					
0.9248	0.9248	0.2826	0.9155	0.9154	0.2217
Observed value					
108464	108464	108464	152259	152259	152259
The adjusted R^2					
0.9248	0.9248	0.2828	0.9155	0.9155	0.2219

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

5.2. Placebo test

Placebo test I involves constructing counterfactual samples to evaluate the causal effect of digital transformation on mitigating the impacts of anti-dumping measures. Counterfactual treatment groups of "digitally transformed" enterprises were generated randomly, and the resulting effects were tested. The underlying logic is that if the improvements in export performance observed in the benchmark regression genuinely arise from digital transformation, then random assignment should not produce significant treatment effects. Conversely, if the estimated effects vanished under random allocation, this provides evidence for the robustness of the benchmark results and indicates that the original findings were not driven by spurious or incidental factors.

To further validate the benchmark results, a second placebo test was conducted, involving double randomization of both virtual anti-dumping enterprises and virtual digital enterprises. Policy shocks were simulated annually over the period 2006 to 2013. For each iteration, the same number of virtual anti-dumping enterprises as observed in the real sample were randomly selected. From these virtual anti-dumping enterprises, a number of virtual treatment group enterprises equal to the number of real digitally transformed enterprises were randomly chosen. This random sampling procedure was repeated 500 times. Kernel density estimation of the

resulting regression coefficients closely mirrors the distribution observed in the benchmark results (**Figure 1**). The concordance of the two placebo tests reinforces the robustness of the benchmark findings and supports their statistical significance.

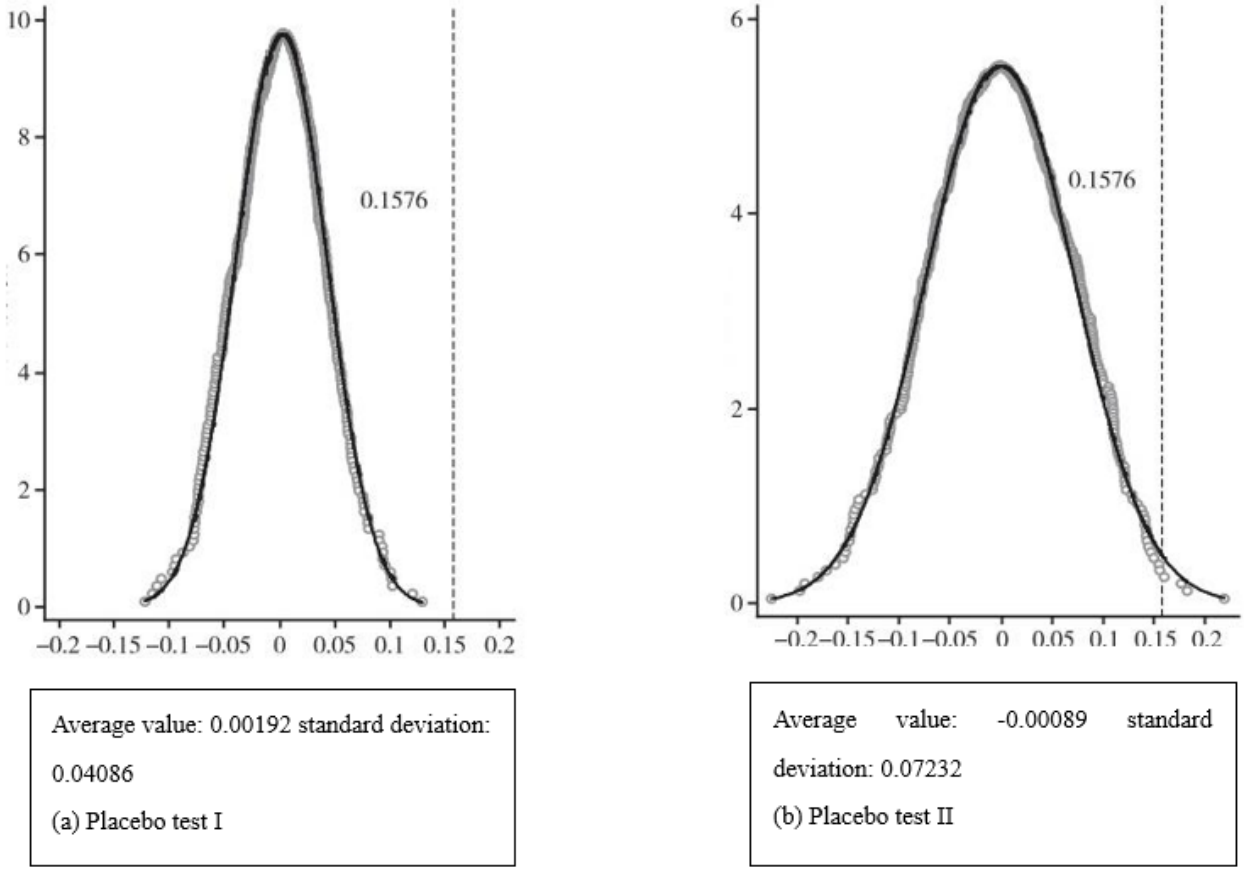

Figure 1. Placebo test.

5.3. Robustness test

For the sake of caution, the study took into account the phased characteristics of anti-dumping investigations and analyzed the effects of different ruling stages and different tax rates. Anti-dumping usually includes a standardized process of three stages: initiation-preliminary ruling-final ruling. Therefore, the measurement model was introduced with the preliminary ruling result and the preliminary ruling tax rate, as well as the final ruling result and the final ruling tax rate as explanatory variables respectively. At the same time, comprehensively analyze the policy effects of anti-dumping case initiation, preliminary ruling and final ruling, and test the research hypotheses from multiple aspects.

In this study, propensity score matching was conducted using multiple approaches as outlined:

(1) Control group enterprises were selected with a matching ratio of approximately 1:2, which enhanced the comparability between the treatment and control groups;

(2) To address potential instability arising from traditional phased matching, a "covariance mean matching" approach was employed, allowing treatment group enterprises to identify more robust and stable control group counterparts.

Based on the scientific control consideration of samples, this paper constitutes "Control Group 2" according to the propensity score matching principle. Its specific composition is based on enterprises with the probability characteristics of responding to the investigation, but ultimately not being investigated. Compared with the potential timing mismatch and sample self-selection problems of "representative period matching" and "mixed matching", this paper first adopts period-by-period matching. That is, within the policy year, the involved enterprises will be matched with the corresponding non-involved enterprises. The deficiency lies in the fact that the non-involved control samples of the involved enterprises matched in the current period have the potential to become involved enterprises in future years, and the same enterprise may also be matched multiple times, leading to statistical errors in sample duplicate matching.

To address the above research predicaments, in the process of conducting period-by-period matching in this paper, the following data processing strategies are adopted: All enterprise samples that have undergone anti-dumping investigations within the 2006–2013 window are excluded from the candidate samples of the PSM control group. For duplicate matching results, only the first matching result is retained. Considering the inherent limitations of the period-by-period matching method, In the robustness test, referring to the research of scholars such as Jia, the covariate mean matching strategy was adopted to select the control group. In the specific matching process, referring to the research of Blonigen and Park, a Logit model was adopted to estimate the probability of enterprises being involved in cases by considering covariates such as product characteristics and business attributes of enterprises. The propensity score was obtained based on the estimation results of the model, and the nearest neighbor matching method was used to finally determine the control group enterprise sample at 1:5.

6. Conclusions and suggestions

In the current era where the global economic and trade situation is turbulent and trade protectionism is prevalent, the negative impact of trade frictions on China's export trade has the potential to be superimposed and magnified. It is extremely necessary to explore whether the digital transformation of enterprises can become an important way for enterprises to enhance the resilience of exports in response to external shocks, which is a research topic of macroeconomic stability significance [8]. Based on the theoretical framework of expanding multi-factory exports of enterprises, this paper innovatively introduces digital parameters to systematically analyze how the digital transformation of enterprises can play a role in mitigating the process and transmission path of the impact of trade frictions. In the empirical design, the participation rate of cross-border e-commerce platforms is selected as the representative variable to measure the level of digital transformation of enterprises. The number of anti-dumping cases against China was adopted as the proxy variable to measure trade frictions, and quantitative tests were conducted on the three-dimensional matching samples of the China Customs Import and Export Database, the global anti-dumping database and the China Industrial Enterprise Database from 2015 to 2025.

6.1. Research conclusion

In summary, trade frictions have a negative impact on export enterprises. The average export scale of the involved enterprises has decreased by 5.9%, and they are more likely to exit the international market. Digital transformation has enhanced the risk response level and export resilience of enterprises. Empirical evidence shows that digital transformation has increased the average export scale of the involved enterprises by 15.8% compared with that of non-involved enterprises. This is because digital transformation can enhance an enterprise's risk response

level and export resilience. This article reveals that digital transformation can counteract the negative impact of trade frictions on the involved products, and guide enterprises to adjust their export product structure strategies, exporting the involved products to other international markets and increasing the export share of non-involved products. From a mechanistic perspective, it explains the role of digital transformation in enhancing the export resilience of enterprises by reducing the marginal cost of product exports and the fixed costs of developing and researching new export markets. This is the inherent logic of digital transformation in improving the export resilience of enterprises.

6.2. Policy recommendations

The corresponding research results obtained have very important practical significance for reducing enterprises' economic costs and maintaining the stability of exports. From the perspective of research conclusions, this paper puts forward the following policy implications. Existing research suggests that new forms of digital economy and digital technologies hold a certain strategic position in the face of external economic shocks and can serve as an important approach for enterprises to cope with risks and reduce the impact of trade frictions [9]. Although this paper focuses on cross-border e-commerce, a specific form of digital transformation, the research conclusions can provide references for policy measures from a broader perspective. In response to the current highly uncertain external economic situation, decision-making departments need to fully consider the strategic position of various digital transformation paths, vigorously guide enterprises to adopt digital marketing and sales methods, including cross-border e-commerce platform sales and big data application and other new forms of foreign trade. At the policy level, it is necessary to explore the construction of a trade friction response system under the background of the digital economy. Systematically promote the digital transformation of enterprises, provide precise relief to relevant enterprises that have long been affected by trade frictions, and effectively reduce the losses of enterprises [10].

Furthermore, this paper finds that the digital transformation of enterprises can mitigate the negative impact of trade frictions through multiple channels, and its role needs to be brought into play through the construction of supporting mechanisms. Empirical tests have shown that digital transformation and upgrading can directly weaken the impact of exogenous shocks and also enhance export resilience by promoting product structure adjustment and layout structure adjustment. Among them, the improvement of the business environment, trade liberalization and opening up to the outside world are important fundamental guarantees. Accelerating high-standard free trade negotiations with major economies will provide an important institutional guarantee for external risk prevention with digital transformation as the key point.

The continuous and in-depth application of digital technology is of great significance. It can reduce trade costs and facilitate trade exports. High trade costs are the most significant factor restricting trade liberalization. However, digital transformation has demonstrated remarkable advantages in reducing trade costs for enterprises. We should promote the innovative application of digital technology and give full play to its beneficial role in cost reduction. Against the backdrop of anti-globalization development, The strategic value of the application of digital technology in breaking through trade barriers has become even more prominent. For enterprise entities with relatively weak international competitiveness, it is necessary to strengthen policy guidance and support to encourage them to accelerate digital technology transformation, enhance the trade performance of small and medium-sized enterprises through digital empowerment, and achieve coordinated development among enterprises.

Disclosure statement

The author declares no conflict of interest.

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